SUBJECT

Description of the APL Programming Language Elements, Statements, Functions, and System Commands

SOFTWARE SUPPORTED

APL D00 on CP-6 Operating System Release D00.

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Preface

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<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-2</td>
<td>Value of a Variable versus its Name</td>
</tr>
<tr>
<td>4-2</td>
<td>Default Output</td>
</tr>
<tr>
<td>4-3</td>
<td>Errors and Breaks</td>
</tr>
<tr>
<td>5-1</td>
<td>Section 5 APL Primitive Functions</td>
</tr>
<tr>
<td>5-2</td>
<td>Scalar Functions</td>
</tr>
<tr>
<td>5-3</td>
<td>Arithmetic Functions:</td>
</tr>
<tr>
<td>5-4</td>
<td>+ Function (Conjugate, Addition)</td>
</tr>
<tr>
<td>5-4</td>
<td>- Function (Negate, Subtraction)</td>
</tr>
<tr>
<td>5-5</td>
<td>* Function (Signum, Multiplication)</td>
</tr>
<tr>
<td>5-6</td>
<td>÷ Function (Reciprocal, Division)</td>
</tr>
<tr>
<td>5-7</td>
<td></td>
</tr>
<tr>
<td>5-8</td>
<td>⌊ Function (Natural Logarithm, Logarithm)</td>
</tr>
<tr>
<td>5-8</td>
<td>⌈ Function (Ceiling, Maximum)</td>
</tr>
<tr>
<td>5-9</td>
<td>⌊ Function (Floor, Minimum)</td>
</tr>
<tr>
<td>5-10</td>
<td></td>
</tr>
<tr>
<td>5-11</td>
<td>O Function (Pi Times, Circular)</td>
</tr>
<tr>
<td>5-12</td>
<td>↑ Function (Factorial, Binomial)</td>
</tr>
<tr>
<td>5-13</td>
<td>Relational Functions:</td>
</tr>
<tr>
<td>5-13</td>
<td>&lt; Function (Less Than)</td>
</tr>
<tr>
<td>5-13</td>
<td>≤ Function (Less Than or Equal)</td>
</tr>
<tr>
<td>5-13</td>
<td>= Function (Equal)</td>
</tr>
<tr>
<td>5-14</td>
<td>≥ Function (Greater Than or Equal)</td>
</tr>
<tr>
<td>5-15</td>
<td>&gt; Function (Greater Than)</td>
</tr>
<tr>
<td>5-15</td>
<td># Function (Not Equal)</td>
</tr>
<tr>
<td>5-16</td>
<td>Logical Functions:</td>
</tr>
<tr>
<td>5-16</td>
<td>^ Function (And, LCM)</td>
</tr>
<tr>
<td>5-16</td>
<td>v Function (Or, GCD)</td>
</tr>
<tr>
<td>5-17</td>
<td>◀ Function (Nand)</td>
</tr>
<tr>
<td>5-17</td>
<td>◁ Function (Nor)</td>
</tr>
<tr>
<td>5-18</td>
<td>~ Function (Not)</td>
</tr>
<tr>
<td>5-19</td>
<td>Mixed Functions:</td>
</tr>
<tr>
<td>5-19</td>
<td>? Function (Roll, Deal)</td>
</tr>
<tr>
<td>5-19</td>
<td>≷ Function (Index Generator, Index Of)</td>
</tr>
<tr>
<td>5-20</td>
<td>≦ Function (Enclose)</td>
</tr>
<tr>
<td>5-21</td>
<td>≧ Function (Disclose, Pick)</td>
</tr>
<tr>
<td>5-21</td>
<td>≉ Function (Depth, Equivalence)</td>
</tr>
<tr>
<td>5-22</td>
<td>≈ Function (Ravel, Catenation, Lamination)</td>
</tr>
<tr>
<td>5-23</td>
<td>ρ Function (Shape, Reshape)</td>
</tr>
<tr>
<td>5-26</td>
<td>Φ Function (Reversal, Rotation)</td>
</tr>
<tr>
<td>5-26</td>
<td>ρ Function (Traversals, Reshape)</td>
</tr>
<tr>
<td>5-27</td>
<td>▲ Function (Grade-up)</td>
</tr>
<tr>
<td>5-31</td>
<td>◄ Function (Grade-Down)</td>
</tr>
<tr>
<td>5-33</td>
<td>▼ Function (Base Value, Decode)</td>
</tr>
<tr>
<td>5-34</td>
<td>▶ Function (Representation, Encode)</td>
</tr>
<tr>
<td>5-35</td>
<td>◆ Function (Format)</td>
</tr>
<tr>
<td>5-37</td>
<td>◀ Function (First, Take)</td>
</tr>
<tr>
<td>5-39</td>
<td>◁ Function (Drop)</td>
</tr>
<tr>
<td>5-40</td>
<td>≡ Function (Type, Membership)</td>
</tr>
<tr>
<td>5-40</td>
<td>≢ Function (Execute)</td>
</tr>
<tr>
<td>5-41</td>
<td>≢ Function (Matrix Inverse, Matrix Divide)</td>
</tr>
<tr>
<td>5-43</td>
<td>Operators:</td>
</tr>
<tr>
<td>5-45</td>
<td>Reduct d/ Operator</td>
</tr>
<tr>
<td>5-45</td>
<td>Compression A\ Operator (Replicate)</td>
</tr>
<tr>
<td>5-47</td>
<td>Scan d\ Operator</td>
</tr>
<tr>
<td>5-48</td>
<td>Expansion A\ Operator</td>
</tr>
<tr>
<td>5-49</td>
<td>Inner Product f.g Operator</td>
</tr>
<tr>
<td>5-50</td>
<td>Outer Product o.d Operator</td>
</tr>
<tr>
<td>5-53</td>
<td>Each Operator</td>
</tr>
<tr>
<td>5-53</td>
<td>Section 6 APL Statements:</td>
</tr>
<tr>
<td>6-1</td>
<td>Comment Statements</td>
</tr>
<tr>
<td>6-1</td>
<td>Branch Statements</td>
</tr>
<tr>
<td>6-2</td>
<td>Statement Labels</td>
</tr>
<tr>
<td>6-4</td>
<td>Assignment and Non-assignment Statements</td>
</tr>
<tr>
<td>6-5</td>
<td>Compound Statements</td>
</tr>
<tr>
<td>7-1</td>
<td>Section 7 Defined Functions</td>
</tr>
<tr>
<td>7-1</td>
<td>User-Defined Functions</td>
</tr>
</tbody>
</table>
CONTENTS (cont)

OPRN  Communicating with Computer Center Operator ........................................... 8-30
ORIGIN Setting Index Origin ...................................................................................... 8-31
PCOPY Copying from Saved Workspace ......................................................................... 8-31
LOAD, JCOPY, and QPCOPY Quiet Commands ................................................................ 8-32
QUIT Leaving APL ........................................................................................................ 8-32
REPORT Selecting the Function Stop Display ............................................................. 8-33
SALVAGE Copying from Saved Workspace ................................................................... 8-33
SAVE Saving a Workspace ............................................................................................ 8-34
SEAL Saving a Sealed Workspace ................................................................................ 8-35
SET Changing Assignments of Input/Output Streams ................................................... 8-35
SI Controlling the State Indicator ................................................................................ 8-36
SIC Clearing the State Indicator .................................................................................. 8-36
SIL Listing the State Indicator Lines ............................................................................ 8-37
SINL Listing the State Indicator .................................................................................. 8-37
STEP Single Step Execution ......................................................................................... 8-38
TERMINAL Specifying Input/Output Device .................................................................. 8-39
VARS Listing Global Variable Names .......................................................................... 8-40
WIDTH Setting Line Width ........................................................................................... 8-40
WSID Identifying the Active Workspace ........................................................................ 8-41

Section 9 Report Formatting .......................................................................................... 9-1
Format Specifications....................................................................................................... 9-1
Format Specifications versus Data Types ....................................................................... 9-2
Format Statement (Left Argument) ................................................................................ 9-2
Format Data List (Right Argument) .............................................................................. 9-2
Operation of DFHT ......................................................................................................... 9-3
Formatting Scalar Arguments ....................................................................................... 9-3
Formatting Vector Arguments ...................................................................................... 9-3
Formatting a Vector on One Line .................................................................................. 9-4
Formatting Matrix Arguments ...................................................................................... 9-4
Picture Format .............................................................................................................. 9-5
Forms of Output Values ............................................................................................... 9-5
Format Qualifier and Affixture Codes .......................................................................... 9-6
Format Symbol Substitution ......................................................................................... 9-7
Format Result ................................................................................................................ 9-7
Format Error Reports .................................................................................................... 9-7
Formatting Aids ............................................................................................................. 9-8
DFCE Function (Skip to New Output Page) .................................................................. 9-8
DFLS Function (Number of Lines Remaining) .............................................................. 9-8
DFHR Function (Set Page Heading) ............................................................................. 9-9
DFPC Function (Set Line Spacing) .............................................................................. 9-9
DFL Function (Translate Text) ..................................................................................... 9-10

Section 10 Execution Stops ............................................................................................ 10-1
Normal Stop ................................................................................................................... 10-1
Execution Break ............................................................................................................ 10-1
Stop For User Input ....................................................................................................... 10-2
Stop Control Vector ....................................................................................................... 10-2
Error Stop ...................................................................................................................... 10-3
Sidetracking On Errors And Breaks ............................................................................ 10-4
DSH Function (Set/Query Sidetrack Matrix) .................................................................. 10-7
Dynamics of Sidetracking ............................................................................................... 10-8
Considerations in Gaining a Sidetrack ......................................................................... 10-9
Aids for Sidetrack Users ............................................................................................... 10-10
DERN Function (Error Number) ................................................................................... 10-10
DERF Function (Error Function) .................................................................................. 10-10
DERM Function (Error Message) .................................................................................. 10-10
DERL Function (Error Line) ....................................................................................... 10-11
DERP Function (Error Position) ................................................................................... 10-11
DERX Function (I/O Error) ........................................................................................... 10-11
DERF Function (Error Help) ....................................................................................... 10-11
DERF Function (Error Simulation) ................................................................................ 10-11

Section 11 System Functions and Variables ................................................................... 11-1
DCT Variable (Comparison Tolerance) ......................................................................... 11-1
DFX Variable (Index Origin) ........................................................................................ 11-1
DLX Variable (Latent Expression) ................................................................................ 11-1
DPW Variable (Platen Width) ....................................................................................... 11-1
DPS Variable (Positioning and Spacing) ........................................................................ 11-1
<table>
<thead>
<tr>
<th>Variable/Function</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP Variable</td>
<td>Print Precision</td>
<td>11-3</td>
</tr>
<tr>
<td>RL Variable</td>
<td>Random Link</td>
<td>11-3</td>
</tr>
<tr>
<td>DP Variable</td>
<td>Session Parameter</td>
<td>11-3</td>
</tr>
<tr>
<td>SA Variable</td>
<td>Stop Action</td>
<td>11-3</td>
</tr>
<tr>
<td>System Functions</td>
<td>11-3</td>
<td></td>
</tr>
<tr>
<td>Workspace Management Functions</td>
<td>11-3</td>
<td></td>
</tr>
<tr>
<td>Namelist and Canonical Representations</td>
<td>11-4</td>
<td></td>
</tr>
<tr>
<td>System Functions for Function Definition</td>
<td>11-4</td>
<td></td>
</tr>
<tr>
<td>OLVK Function</td>
<td>Lock Function</td>
<td>11-4</td>
</tr>
<tr>
<td>CST Function</td>
<td>Set/Query Stop</td>
<td>11-5</td>
</tr>
<tr>
<td>CTTR Function</td>
<td>Set/Query Trace</td>
<td>11-5</td>
</tr>
<tr>
<td>Workspace Management System Functions</td>
<td>11-6</td>
<td></td>
</tr>
<tr>
<td>OAV Function</td>
<td>Atomic Vector</td>
<td>11-6</td>
</tr>
<tr>
<td>DPU Function</td>
<td>CPU Time Used</td>
<td>11-7</td>
</tr>
<tr>
<td>CVT Function</td>
<td>Convert</td>
<td>11-7</td>
</tr>
<tr>
<td>DD Function</td>
<td>Delay</td>
<td>11-8</td>
</tr>
<tr>
<td>CX Function</td>
<td>Expunge</td>
<td>11-9</td>
</tr>
<tr>
<td>DFX Function</td>
<td>Expunge Globals</td>
<td>11-9</td>
</tr>
<tr>
<td>OLI Function</td>
<td>Fix Input</td>
<td>11-9</td>
</tr>
<tr>
<td>OGR Function</td>
<td>Return Group Members</td>
<td>11-10</td>
</tr>
<tr>
<td>IBEX Function</td>
<td>IBEX Expunge</td>
<td>11-11</td>
</tr>
<tr>
<td>IBLST Function</td>
<td>Set/Query IBEX Variable</td>
<td>11-11</td>
</tr>
<tr>
<td>IBNL Function</td>
<td>IBEX Namelist</td>
<td>11-12</td>
</tr>
<tr>
<td>DLOC Function</td>
<td>Identifier Location</td>
<td>11-12</td>
</tr>
<tr>
<td>DCF Function</td>
<td>Line Chain</td>
<td>11-13</td>
</tr>
<tr>
<td>DGT Function</td>
<td>Logon Time</td>
<td>11-14</td>
</tr>
<tr>
<td>DWC Function</td>
<td>Name Classification</td>
<td>11-14</td>
</tr>
<tr>
<td>DWC Function</td>
<td>Name Correspondence of Global</td>
<td>11-15</td>
</tr>
<tr>
<td>DLL Function</td>
<td>Namelist</td>
<td>11-15</td>
</tr>
<tr>
<td>OVL Function</td>
<td>Online</td>
<td>11-16</td>
</tr>
<tr>
<td>OOVH Function</td>
<td>Overhead Time</td>
<td>11-17</td>
</tr>
<tr>
<td>DFM Function</td>
<td>Room</td>
<td>11-17</td>
</tr>
<tr>
<td>DRC Function</td>
<td>Global Room</td>
<td>11-18</td>
</tr>
<tr>
<td>DST Function</td>
<td>Session Time</td>
<td>11-18</td>
</tr>
<tr>
<td>DST Function</td>
<td>State Indicator</td>
<td>11-19</td>
</tr>
<tr>
<td>DITEID Function</td>
<td>Site ID</td>
<td>11-20</td>
</tr>
<tr>
<td>DITENAME Function</td>
<td>Site Name</td>
<td>11-20</td>
</tr>
<tr>
<td>DSTEPC Function</td>
<td>Step Condition Codes</td>
<td>11-20</td>
</tr>
<tr>
<td>SYSID Function</td>
<td>Sysid</td>
<td>11-21</td>
</tr>
<tr>
<td>DTS Function</td>
<td>Time Stamp</td>
<td>11-21</td>
</tr>
<tr>
<td>DTT Function</td>
<td>Terminal Type</td>
<td>11-22</td>
</tr>
<tr>
<td>DUA Function</td>
<td>User Account</td>
<td>11-22</td>
</tr>
<tr>
<td>DUL Function</td>
<td>User Load</td>
<td>11-23</td>
</tr>
<tr>
<td>DWI Function</td>
<td>Verify Input</td>
<td>11-23</td>
</tr>
<tr>
<td>DIVERSION Function</td>
<td>Version</td>
<td>11-24</td>
</tr>
<tr>
<td>DWA Function</td>
<td>Workspace Available</td>
<td>11-24</td>
</tr>
<tr>
<td>DWS ID Function</td>
<td>Workspace Identifier</td>
<td>11-25</td>
</tr>
<tr>
<td>DSC Function</td>
<td>Shared Variable Controls</td>
<td>11-25</td>
</tr>
<tr>
<td>DSW Function</td>
<td>Shared Variable Offer</td>
<td>11-26</td>
</tr>
<tr>
<td>DSVQ Function</td>
<td>Shared Variable Query</td>
<td>11-27</td>
</tr>
<tr>
<td>DSVR Function</td>
<td>Shared Variable Retract</td>
<td>11-28</td>
</tr>
<tr>
<td>DSVS Function</td>
<td>Shared Variable State</td>
<td>11-29</td>
</tr>
<tr>
<td>DSVW Function</td>
<td>Shared Variable Process Name</td>
<td>11-30</td>
</tr>
<tr>
<td>DSC Function</td>
<td>State Change</td>
<td>11-30</td>
</tr>
<tr>
<td>Text Editing System Functions</td>
<td>11-31</td>
<td></td>
</tr>
<tr>
<td>DTIX Function</td>
<td>Text Index</td>
<td>11-31</td>
</tr>
<tr>
<td>DTEX Function</td>
<td>Text Lexemes</td>
<td>11-32</td>
</tr>
<tr>
<td>DSSS Function</td>
<td>Substring Search</td>
<td>11-33</td>
</tr>
<tr>
<td>DSSR Function</td>
<td>String Search and Replace</td>
<td>11-34</td>
</tr>
<tr>
<td>DSRP Function</td>
<td>Substring Replace</td>
<td>11-35</td>
</tr>
<tr>
<td>DSCP Function</td>
<td>String Compare</td>
<td>11-36</td>
</tr>
<tr>
<td>Terminal I/O System Functions</td>
<td>11-37</td>
<td></td>
</tr>
<tr>
<td>DTM Function</td>
<td>Terminal Input</td>
<td>11-37</td>
</tr>
<tr>
<td>DPAM Function</td>
<td>Terminal Attributes</td>
<td>11-38</td>
</tr>
<tr>
<td>DTIME Function</td>
<td>Terminal Timeout</td>
<td>11-39</td>
</tr>
</tbody>
</table>
## CONTENTS (cont)

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECHO Function</td>
<td>Terminal Echo</td>
<td>11-39</td>
</tr>
<tr>
<td>TSOZ Function</td>
<td>Terminal Mnemonic Translation</td>
<td>11-39</td>
</tr>
<tr>
<td>WINDOW Function</td>
<td>Terminal Windows</td>
<td>11-40</td>
</tr>
<tr>
<td>Section 12: CP-6 APL File I/O.</td>
<td>File Information Functions.</td>
<td>12-1</td>
</tr>
<tr>
<td>.FNUNS Function</td>
<td>Numbers of Open Files.</td>
<td>12-3</td>
</tr>
<tr>
<td>.FNAMS Function</td>
<td>Names of Open Files.</td>
<td>12-3</td>
</tr>
<tr>
<td>.FID Function</td>
<td>File Identifier</td>
<td>12-4</td>
</tr>
<tr>
<td>Opening, Closing, and Deleting Files.</td>
<td>.OPEN Function (Open File).</td>
<td>12-4</td>
</tr>
<tr>
<td>.CLOSE Function (Closing and Renaming Files).</td>
<td>.ERASE Function (Close and Delete File).</td>
<td>12-6</td>
</tr>
<tr>
<td>.CLEAR Function (Close All Open Files).</td>
<td>Reading and Writing Records.</td>
<td>12-7</td>
</tr>
<tr>
<td>.APPEND Function</td>
<td>Append Record to File.</td>
<td>12-8</td>
</tr>
<tr>
<td>.READ Function (Read a Record).</td>
<td>.WRITE Function (Write or Replace a Record).</td>
<td>12-9</td>
</tr>
<tr>
<td>.FDROP Function</td>
<td>Delete Record from File.</td>
<td>12-10</td>
</tr>
<tr>
<td>.FRDCI Function</td>
<td>Return Component Information.</td>
<td>12-11</td>
</tr>
<tr>
<td>File Access Controls.</td>
<td>.FENQ Function (Hold a Record).</td>
<td>12-12</td>
</tr>
<tr>
<td>.FDSEQ Function (Release Record or File).</td>
<td>Coordinating Shared Files.</td>
<td>12-13</td>
</tr>
<tr>
<td>File Status Functions.</td>
<td>.FOPEN Function (Return File Access Matrix).</td>
<td>12-14</td>
</tr>
<tr>
<td>.FRSTAC Function (Store File Access Controls).</td>
<td>Reading and Writing Records.</td>
<td>12-15</td>
</tr>
<tr>
<td>.FENQ Function (Hold a Record).</td>
<td>File Name Functions.</td>
<td>12-16</td>
</tr>
<tr>
<td>.FSIZE Function (File Size).</td>
<td>.FKEYNT Function (Set Key Interval).</td>
<td>12-16</td>
</tr>
<tr>
<td>.FKV Function (Return Key Values).</td>
<td>.FKL Function (Return File Keys).</td>
<td>12-16</td>
</tr>
<tr>
<td>.FK3 Function (Return File Flags).</td>
<td>.FKL Function (Return File Names).</td>
<td>12-18</td>
</tr>
<tr>
<td>Library or Account Information.</td>
<td>.FENQ Function (Hold a Record).</td>
<td>12-19</td>
</tr>
<tr>
<td>.FPARAM Function (Return File Management Account).</td>
<td>.FLIB Function (Return File Names).</td>
<td>12-18</td>
</tr>
<tr>
<td>Record Field Descriptions.</td>
<td>.FENQ Function (Hold a Record).</td>
<td>12-20</td>
</tr>
<tr>
<td>.FLDS Function (Return Record Fields).</td>
<td>Alternate Indexed Files.</td>
<td>12-21</td>
</tr>
<tr>
<td>Specialized File Options.</td>
<td>.FENQ Function (Hold a Record).</td>
<td>12-22</td>
</tr>
<tr>
<td>Section 13 CP-6 APL I-D-S/II System Functions.</td>
<td>.FENQ Function (Hold a Record).</td>
<td>12-23</td>
</tr>
<tr>
<td>Subschema Information Functions.</td>
<td>.FENQ Function (Hold a Record).</td>
<td>13-1</td>
</tr>
<tr>
<td>.DBNAMES Function (List Subschema Names).</td>
<td>.DDBYPES Function (Subschema Name Types).</td>
<td>13-2</td>
</tr>
<tr>
<td>.DDBYPES Function (Subschema Name Types).</td>
<td>I-D-S/II Function Arguments.</td>
<td>13-3</td>
</tr>
<tr>
<td>.NAME Function (Analyze Subschema Names).</td>
<td>.DOWNER Function (Set Owner).</td>
<td>13-4</td>
</tr>
<tr>
<td>.DNMEMBER Function (Set Member).</td>
<td>.DINFORM Function (Database Register).</td>
<td>13-5</td>
</tr>
<tr>
<td>Accessing Data.</td>
<td>.FENQ Function (Hold a Record).</td>
<td>13-6</td>
</tr>
<tr>
<td>.FDROP Function (Delete Record from File).</td>
<td>Standard I-D-S/II Functions.</td>
<td>13-7</td>
</tr>
<tr>
<td>.FENQ Function (Hold a Record).</td>
<td>I-D-S/II Function Arguments.</td>
<td>13-7</td>
</tr>
<tr>
<td>.FENQ Function (Hold a Record).</td>
<td>Section 14 Packages.</td>
<td>13-9</td>
</tr>
<tr>
<td>.FENQ Function (Hold a Record).</td>
<td>.DUSE Function (Use Procedures).</td>
<td>13-9</td>
</tr>
<tr>
<td>Package System Functions.</td>
<td>.DUSE Function (Use Procedures).</td>
<td>14-1</td>
</tr>
<tr>
<td>.DPACK Function (Package Create).</td>
<td>.DUSE Function (Use Procedures).</td>
<td>14-2</td>
</tr>
<tr>
<td>.DPNC Function (Package Name Correspondence).</td>
<td>.DUSE Function (Use Procedures).</td>
<td>14-3</td>
</tr>
<tr>
<td>.DPVAL Function (Package Value).</td>
<td>.DUSE Function (Use Procedures).</td>
<td>14-4</td>
</tr>
<tr>
<td>.DPDEF Function (Protected Package Definition).</td>
<td>.DUSE Function (Use Procedures).</td>
<td>14-6</td>
</tr>
</tbody>
</table>

viii Table of Contents CE38-04
Section 15 CP-6 APL Graphics

Graphics Output Functions

- CP-6X Function (Package Expunge) .... 14-7
- CPLOCK Function (Package Lock) .... 14-7

Graphics Segment Functions

- CGRSEGCOPEN Function (Create a Retained Segment) .... 15-10
- CGRSEGCLOSE Function (Close Retained Segment) .... 15-10
- CGRSEGDEL Function (Delete Retained Segment) .... 15-10
- CGRSEGREN Function (Renew Retained Segment) .... 15-10
- CGRSEGSURFS Function (Inquire Segment Surfaces) .... 15-13
- CGRSEGS Function (Inquire Retained Segment Names) .... 15-14
- CGRSECCURR Function (Inquire Open Segment) .... 15-15
- CGRTSEG Function (Create Temporary Segment) .... 15-15
- CGRTSEC Function (Close Temporary Segment) .... 15-15
- CGRTSEC Function (Inquire Open Temporary Segment) .... 15-15
- CGRSEGVISIBILITY Function (Segment Visiblility) .... 15-17
- CGRSEGHIGHLIGHT Function (Segment Highlight) .... 15-18
- GVISIBILITY Variable (Set/Inquire Visiblility) .... 15-19
- GHI L T HIGHLIGHT Variable (Set/Inquire Highlighting) .... 15-19

Graphics Attribute Variables

- CGRMARKER Variable (Marker Symbol) .... 15-20
- CGRPINS Variable (Polygon Interior Style) .... 15-20
- CGRPES Variable (Polygon Edge Style) .... 15-20
- CGLN Variable (Line Width) .... 15-20
- CGLI Variable (Line Index) .... 15-20
- CGLS Variable (Line Style) .... 15-20
- CGPEN Variable (Pen) .... 15-20
- CRFONT Variable (Font) .... 15-20
- CRTEXTI Variable (Text Index) .... 15-20
- CRCHSIZE Variable (Character Size) .... 15-20
- CRCHPLANES Variable (Character Plane) .... 15-20
- CRCHUP Variable (Character Up) .... 15-20
- CRCHPATH Variable (Character Path) .... 15-20
- CRCHSPACE Variable (Character Space) .... 15-20
- CRCHJUST Variable (Character Justification) .... 15-20
- CRCHPREC Variable (Character Precision) .... 15-20
- CRFILL Variable (Fill Index) .... 15-20
- C RVERTEX Variable (Vertex Indices) .... 15-20

Graphics Viewing Variables

- CRWINDOW Variable (Window) .... 15-20
- CRUP Variable (View Up) .... 15-20
- CRSSPACE Variable (NDC Space) .... 15-20
- CVIEWPORT Variable (Viewport) .... 15-20
- CVREFPT Variable (View Reference Point) .... 15-20
- CVPLNORM Variable (View Plane Normal) .... 15-20
- CVPLNDIS Variable (View Plane Distance) .... 15-20
- CVDEPHT Variable (View Depth) .... 15-20
- CPROJECTION Variable (Projection Type) .... 15-20

Window Clipping Variables

- CCLIP Variable (Window Clipping) .... 15-20
- CRFCCLIP Variable (Front Plane Clipping) .... 15-20
- CRBCCLIP Variable (Back Plane Clipping) .... 15-20
- CCRCOORD Variable (Coordinate System Type) .... 15-20
- CCRWORLD Variable (World Transformation) .... 15-20

Graphics Control Functions and Variables

- CEINIT Function (Initialize APL Graphics) .... 15-20
- CERDONE Function (Terminate APL Graphics) .... 15-20
Section 16 Blind I/O

Using Blind I/O
Blind I/O on a Device
Accessing Files with Blind I/O
Blind I/O System Functions
  QBIN Function (Set and Query Binary Mode)
  BSIZE Function (Read Size)
  BVFC Function (Set and Query VFC)
  BTRANS Function (Set and Query Transparency)
  BINES Function (Lines Remaining)
  BKEY Function (Return Key)
  BPRECORD Function (Position Record)
  BFIRE Function (Position File)
  BREW Function (Rewind)
  BWRITE Function (Rewrite Record)
  BSEED Function (Encryption Seed)
  BREAD Function (Re-Read Mode)
  BRS Function (Record Size)
  BRR Function (Key Returned)
  BCLOSE Function (Close Blind I/O Channel)
  BFACE Function (Skip to New Page)
  BDELREC Function (Delete Record)
  BUNSET Function (Unset DCB)
Forms Mode
  Field Definition Matrix
    Field Definition Matrix Columns
    BFIFD Function (Field Definition)
    BMMFLD Function (Modify Field)
    BDAFLD Function (Delete Field)
    BRRFLD Function (Record Field)
    BEXPFLD Function (Expunge Field)

Appendix A CP-6 APL Parameters

Arithmetic Limits
Array Limits
System Variables
Implementation Defined System Variables
Defined Functions
APL Input and Output
Miscellaneous Limits
File System
Trigonometric and Hyperbolic Algorithms
Numeric Algorithms
  Semi Numeric Algorithms
  Pseudo-random Number Generation
  Deal Function
CP-6 Dependent Algorithms
Array Representation
Consistent Extensions to the ISO APL Standard
Nested Arrays
**CONTENTS (cont)**

| Table E-1. | Scalar Monadic Functions | E-1 |
| Table E-2. | Scalar Dyadic Functions | E-1 |
| Table E-3. | Relational and Logical Functions | E-2 |
| Table E-4. | Mixed Functions | E-3 |
| Table E-5. | Operators | E-4 |
| Table E-6. | System Variables | E-4 |
| Table E-7. | Special Symbols | E-5 |
| Table E-8. | Function Header Syntax | E-6 |
| Table E-9. | Directive Summary | E-6 |
| Table E-10. | Defined Function Controls | E-6 |
| Table E-11. | Error Numbers | E-7 |
| Table E-12. | Error Control Functions | E-7 |
| Table E-13. | CP-6 APL System Functions | E-8 |
| Table E-14. | Shared Variable System Functions | E-8 |
| Table E-15. | File I/O Example Names | E-9 |
| Table E-16. | File Functions | E-9 |
| Table E-17. | File I/O Open Options | E-10 |
| Table E-18. | Text Editing Functions | E-10 |
| Table E-19. | I-D-S/II System Functions | E-11 |
| Table E-20. | Terminal System Functions | E-11 |
| Table E-21. | IFMT Format Controls | E-12 |
| Table E-22. | Report Formatting Functions | E-12 |
| Table E-23. | Blind I/O Example Variable Names | E-13 |
| Table E-24. | Blind I/O Functions | E-13 |
| Table E-25. | CP-6 APL Character Set | E-14 |

**FIGURES**

| Figure 2-1. | Sample APL Session | 2-2 |
| Figure 6-1. | Summary of Common Formats for Branching | 6-4 |
| Figure 12-1. | File I/O Component Record Format | 12-2 |
| Figure 15-1. | Graphics Output Example | 15-2 |
| Figure 16-1. | Forms Mode Screen Display | 16-15 |
About This Manual

This manual is organized in the following manner:

Section 1 presents an overview of CP-6 APL, its features, capabilities, and compatibility with the CP-6 operating system.

Section 2 describes the use of APL.

Section 3 describes common elements of APL.

Section 4 describes APL expression evaluation.

Section 5 describes APL primitive functions.

Section 6 describes APL statements.

Section 7 describes APL defined functions.

Section 8 describes system commands and APL workspace concepts.

Section 9 describes APL report formatting.

Section 10 describes APL execution stops.

Section 11 describes system defined functions and variables.

Section 12 describes APL file I/O.

Section 13 describes APL I-D-S/II system functions.

Section 14 describes system functions for manipulating packages.

Section 15 describes functions and variables used in APL graphics.

Section 16 describes blind I/O.

Appendix A contains information on APL parameters.

Appendix B contains a comprehensive list of APL symbols.

Appendix C contains information on error messages.

Appendix D contains information on APL's compatibility with CP-V workspace management, information on APL's compatibility with CP-V file input/output, and summarizes CP-V APL intrinsic functions.

Appendix E contains a summary of CP-6 APL.
On-Line HELP Facility

CP-6 APL has an on-line HELP facility. APL users can list syntax formats, parameters, and function or command descriptions at the terminal. For a list of HELP topics from the system level (!), enter:

HELP (APL) TOPICS
Section 1
Introduction

APL is an acronym for A Programming Language, the language created by Kenneth
Iverson. It is a problem-solving language the symbology of which closely
approximates mathematical notation, making the language extremely attractive for use
by engineers, financial planners, scientists, and statisticians. APL is an
interpretive language designed for use on time-sharing computers. The term
"interpretive language" means that APL does not wait to receive a complete program
prior to compiling each statement into object code and executing it; instead APL
interprets each statement as it is entered and immediately executes it. An answer is
received by the user each time a portion of the total problem is stated.

APL is a powerful language: concise in notation, easy to learn and easy to use. It
has many features that make it attractive for use in business applications where user
interaction and rapid feedback are key requirements. One of APL's major strengths is
its ability to manipulate vectors and multi-dimensional arrays as easily as it does
scalar (single) values. For example, a matrix addition that might require a number
of statements and several loops in other languages can be accomplished as A+B in APL.
It is this type of simplification which best exemplifies APL's concise power.

This enhanced version of the processor is designed for operation under Control
Program-6 and is hereafter referred to as CP-6 APL. This manual is intended
primarily for use as a reference document by experienced APL programmers. Beginning
APL users may find it useful to consult an APL primer to augment the information
contained in this manual. Three such publications are "APL-An Interactive Approach"
by Leonard Gilman and Allen J. Rose (John Wiley Sons, Inc., New York), "A Course in
APL with Applications" by Louis D. Grey (Addison-Wesley Publishing Company, Inc.,
Reading, Mass), and "APL User's Guide" by Harry Katzan, Jr. (Van Nostrand and

CP-6 APL incorporates a broad range of improvements, including a number of
improvements that are unavailable on other APL systems. Some highlights of CP-6 APL
include:

- APL Standards Compatibility
  CP-6 APL is a superset of the ISO APL standard.

- On-line and Batch Operation
  Complete flexibility of operation is provided. Programs may be developed and
  executed in any mode. The batch mode is advantageous for either long execution
times or voluminous output. On-line mode is more advantageous for interactive
  program development and moderate amounts of execution time and output.

- Operation from Terminals without APL Characters
  APL characters may be represented by combinations of alphanumeric and special
  characters in order to allow programs to be created or modified on any terminal
  supported by CP-6.

- Input/Output Assignment Control
  The CP-6 APL system command, )SET, allows the assignment of normal and 'blind'
  I/O to files and devices such as line printers or magnetic tapes. It is also
  used to establish format control over printed output.

- Formatted Output
  Three separate formatting functions are available (monadic v, dyadic v, and OFHT) to facilitate the preparation of reports and tables.
File Input/Output

A program-controlled mechanism is provided for file input/output. Any variable in an APL workspace may be written to a file and later retrieved for subsequent processing, permitting an APL program to operate on more data than can be contained in a workspace. APL entities may also be written as data records without their APL attributes, and non-APL records can be read.

The CP-6 APL file I/O system operates with all CP-6 file types. File access may be with numeric keys or character keys. Files may be accessed in shared update mode, using the CP-6 Enqueue-Dequeue feature to coordinate shared access control.

Compound Statements

More than one statement can be included on a line using diamonds for separation. Since an item of a compound statement can be a branch, this feature permits conditional execution control within a single statement of a function.

Blind Input/Output

Blind input/output is a form of device input/output that permits input and output of character data. It is designed to facilitate the use of screen access modes, graphics terminals or other special devices with CP-6 APL. Using the )SIT command, blind I/O may be used to create or access sequential files or to access devices such as line printers or magnetic tapes.

Easy Function Copying

An entire function can be copied simply by changing the name of an already defined function.

Replicate

The / function has been extended to permit non-negative integers in the left argument. The selected items of the right argument are “replicated” the number of times indicated in the left argument.

Powerful Function Editor

CP-6 APL permits a range of lines to be specified for display or editing. Within the range specification, it is possible to request a display of all lines containing a string or identifier, or to replace all occurrences of a string with another string.

Enhancements to System Commands

- The )SEAL command provides protected workspaces. When )SEAL is executed, the current workspace is saved with all user functions locked. A sealed workspace cannot be accessed by other users unless they are running APL. The workspace owner retains full access.
- The )TERMINAL command allows independent setting of input and output terminal translation tables.
- The Quiet commands ()QLOAD, )QCOPY and )QPCOPY) suppress the SAVED message when loading or copying successfully.
- Options have been added to the )SI command to control function suspension due to errors.
- The )COPY and )PCOPY commands allow system variables to be copied if named explicitly.
- The )SIL command lists the lines in execution within the state indicator.

Availability of Other CP-6 Facilities

A user of CP-6 APL may use other CP-6 processors such as EDIT, PCL, and FORTRAN from the same terminal during the same session. An APL workspace may pass commands to a command processor (e.g., IBEX) and may link to other run units.
The Execute Function
The execute function has been extended to allow the execution of system commands.

Observation of Intermediate Results
The )OBSERVE command permits the user to view intermediate results as APL executes a statement.

Single Stepping
The )STEP command is used as a debugging aid. This command causes execution of one line of a defined function, and then immediately suspends execution.

Catching Assignments
The )CATCH command is a debugging aid which permits the user to catch (or intercept momentarily) every assignment to a named variable immediately following each assignment. The assignment is "caught" by means of a function defined by the user according to their debugging requirements.

Error and Break Control
CP-6 APL has a facility to provide the user with selective and dynamic control over errors and breaks. Since this facility permits bypassing of standard APL handling of breaks and errors, it is called the "sidetracking" capability.

Text Editing Functions
Five system functions are available to facilitate the manipulation of character vectors in CP-6 APL.

Shared Variable System Functions
Nine system functions are provided to support the sharing of variables between the workspaces of consenting CP-6 users. Any CP-6 user may access this facility.

Defined Function Extensions
A dyadic defined function may be used monadically or dyadically. If used monadically, the dummy name that references the missing left argument will be undefined.

Database Access
System functions are provided to access I-D-S/II databases. All of the standard Codasyl DML functions are provided and they are augmented by unique information functions tailored to the APL environment.

Packages
Packages provide the ability to manipulate aggregates containing variables and functions.

Extended Error Messages
Additional information concerning an error that APL has detected may be displayed with the )? command.

Nested Arrays
Items of an array in CP-6 APL may themselves contain APL arrays. In addition to extending most existing functions to accept nested arrays, new functions (enclose, disclose, equivalence, type, first, and depth) and a new operator (each) have been added. Defined functions, system functions, and derived functions are permitted as arguments to operators.

Vector Notation
CP-6 APL syntax has been extended to provide a simple notation for the entry of nested arrays.
- Vector Assignment
  This mechanism is used to assign each item of a vector to a different name in a single operation.

- Selective Assignment
  This capability allows items of an array that are selected by an APL expression to be assigned new values.

- Sorting
  The grade-up and grade-down functions have been extended to sort character arrays and arrays of any rank.

- Least Common Multiple Function
  The OR primitive function (v) has been extended to provide the Least Common Multiple function.

- Greatest Common Divisor Function
  The And (A) primitive function has been extended to provide the Greatest Common Divisor function.
Section 2
Using APL

Logging On

The user must first prepare the terminal for use, establish a connection with the CP-6 system, and then invoke the APL processor. This is done as follows:

1. Connecting to the CP-6 system:
   a. Press the number 8 several times until CP-6 responds with:

      PLEASE TYPE A LEFT PARENTHESIS

   b. The system requests that the user enter a left parenthesis. Once a left parenthesis is entered, a salutation is printed after which the system requests a logon. At this time a valid logon should be entered. A logon consists of an account, name, and optional password, separated by commas. This information is not echoed (printed) on the terminal to provide privacy.

      *** CP-6 AT YOUR SERVICE, LADC L66A
      14:30 THU OCT 17 'B5 LINE B(L6VI)-1480
      LOGON PLEASE:

   c. The CP-6 system will then allow the user to log on to the system with an attendant greeting, or inform the user of the reason for not logging on.

   d. When the CP-6 system prompts with !, the user is at the IBEX Command Processor level and may invoke APL by typing APL and pressing RETURN.

Figure 2-1 shows a sample APL session including logon and logoff, as performed from a Diablo 1620 or equivalent terminal with an APL typewheel.
General APL Input

The following paragraphs define the APL character set, APL names, and various input/output characteristics.

Character Set

One of CP-6 APL's unique characteristics is the richness of its character set. An APL keyboard normally has 94 printing graphics. All of these are legal characters. In addition, backspacing may be used to create the following overstrikes, all of which are legal characters:

```
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
```

Other legal characters are blank (the space bar), tab (the TAB key, treated as one or more blanks), and carriage return (the RETURN key). Two other characters are also accepted for control purposes: the <CTL-D> sequence and the BREAK key discussed below under "Line Corrections during Input" and "Control Keys".

Figure 2-1. Sample APL Session
Names

Names are used to identify certain CP-6 APL constructs. All variables, functions, groups, workspaces, and statement labels have names; the following restrictions apply to these names:

1. All names except workspace names can contain from 1 to 79 characters. Workspace names can contain from 1 to 31 characters (see Section 8).
2. Names may be composed of letters, numbers, $\Delta$, underlined letters, underlined $\Delta$, and underscore.
3. Names cannot begin with a number or underscore.
4. There can be no blanks embedded within a name.
5. A particular kind of name, called a distinguished name, begins with $\Delta$.

Some examples of names are:

$\Delta$ PAYROLL B01 S1234 TEMPERATURE OPW

User Input versus Computer Output

The user can enter input whenever the carrier or cursor is indented six spaces from the left margin. As soon as the user has typed any input and pressed the RETURN key, APL takes control. Characters entered by the user while APL is processing will be "stored" until APL has completed processing the previous input, printed any results, and prompted for more input (usually by indenting six spaces from the left margin).

User input and computer output are easily distinguished. Computer output usually begins at the left margin while user input is usually indented six spaces. For example:

```
3+9
0.33
4
4+2
2
```

Everything at the left margin in this example is printed by APL, while everything which is indented is typed by the user.

Line Corrections during Input

A line can be corrected during input as long as the RETURN key has not been struck. Simply strike the RUBOUT key, to delete characters up to the error and enter <ESC> R to retype the correct portion of the line. Then proceed with the entry of the line. For example, suppose the user mistakenly types 30-20 instead of 30+20. The user can correct this as follows:

```
30-20\<R>
30+20
50
```

enter three RUBOUTS and <ESC> R
the system displays 30; user enters +20
system responds with 50.
Perhaps the simplest line correction method is to delete all of the input with the control X character. Another correction method can be employed if the user discovers that a character has been omitted. As long as the RETURN key has not been struck, the user can simply backspace to where the character is to be inserted (or enter <ESC> V followed by the character at which to position), enter <ESC> J, and type it. For example, if the user types the following line and notices that one left parenthesis is missing:

\[(10H)*2]+(20H)*2\]

By simply backspacing and typing the required left parenthesis, the user can enter

\[((10H)*2)+(20H)*2\]

This illustrates that it is not always necessary to enter characters in order. The user can leave blanks in a line, then backspace and fill them in. As a rule, APL interprets what the user sees at the terminal; this is known as visual fidelity. For more information on standard CP-6 input line editing, see the CP-6 Programmer Reference Manual (CE40).

Execution and Definition Modes

From the user's viewpoint, CP-6 APL operates in two modes, execution mode and definition mode. In execution mode, the processor responds to each line of input by taking a specified action or by performing requested calculations and printing a result. For example, suppose the printout, in the following three lines is the result of the following program:

\[(3+9)\]

The first line is a system command that causes the processor to take some action and to respond with a message, and the third line performs a calculation, printing the results on the fourth line:

\[\)DIGITS 2\]

\[WAS 10 \quad 3+9\]

\[0.33\]

System commands can be entered during execution or definition mode. Calculations are performed only in execution mode.

In definition mode, statements (that is, calculations) are saved as part of a defined function instead of being executed immediately. System commands issued in this mode, however, are executed immediately. After functions are defined, they can be referenced in other defined functions or in statements entered in execution mode. The user must type the del symbol V to begin definition mode, and another V to return to execution mode. See section 7 under Defined Functions, for a detailed description of definition mode.

Prompts

CP-6 APL has four ways of prompting for (that is, requesting) input: direct line prompt, function line prompt, evaluated input prompt, and quote-quad prompt. These are described below.
Direct-Line Prompt

When APL is ready for user input in immediate execution mode, it automatically moves six spaces in from the left margin. This is a signal to the user to enter a statement or system command. Direct-line prompts are shown in the following example:

```
2+2
4
4+2
2
```

In this example, APL indented six spaces to prompt for user input, and the user entered the statement 2+2. The processor then printed the result of the calculation at the left margin, moved to the next line, and again indented six spaces to prompt for more input.

Function-Line Prompt

Within definition mode (that is, when a function is being defined) CP-6 APL prompts for user input by printing a line number in brackets at the left margin. After printing the line number, it moves three spaces to the right and waits for user input. As an example, look at the following portion of a function definition:

```
VSQUARE
[1] A+(B*B)
[2]
```

In this example, the user entered a function header (VSQUARE), and APL typed the [1] and moved three spaces to the right to prompt for user input. The user then entered the statement A+(B*B), and APL typed the [2] to prompt for more user input. This continues until the user ends the function definition with another del symbol ⌼.

Quad Prompt

The quad symbol ⌼ can be used in a statement to indicate evaluated input. When APL encounters the quad on execution of the statement, it halts and requests input by printing the symbols ⌼, moving to the next line, and indenting six spaces. The user can enter any valid APL expression. This expression will be evaluated, and its value substituted for the quad contained in the statement. Execution of the statement then resumes. Examples of the quad prompt are shown below:

```
A+,nil
7*2*4
A

ANSWER

'YES'

ANSWER

YES
```
Quote-Quad Prompt

The quote-quad symbol ~ (a quote symbol overstruck with a quad) is used to enter character data. It is executed similarly to the quad symbol except that nothing is printed to signal the user, and no six-space indentation takes place. The user enters character data without enclosing it in quotes. For example:

YES ~

A1

YES

Comments

Comments can be written on separate lines or can follow (that is, be tacked onto) statements. They may be included on any line except a system command line or a function edit control line. To enter a comment, type the symbol ~ and follow it with the comment. This symbol is produced by typing a ~ symbol (upper shift C) and overstriking it with a 0 symbol (upper shift J). Any valid APL characters may appear to the right of the ~ symbol. The ~ and any characters to the right are ignored in APL expression evaluation, but will be printed if the line is displayed. Examples of comments are shown below:

~ THIS IS A COMMENT.

A+B*B ~SET A = B-SQUARED.

[3] X+Y+5 ~ COMMENT: X IS SET TO Y+5

Control Keys

The BREAK key is used to interrupt execution or stop a lengthy display on the terminal.

Statements and System Commands

Each completed line of input in CP-6 APL is classified as either a statement or a system command. Statements specify the operations to be performed by APL, such as calculations, branching, and assignments of values or expressions. Some examples of statements are:

4+2
B*A=2
*START
VA PLUS B

[3] 'ENTER VALUES FOR A'

System commands are used to communicate directly with the APL system itself. They are concerned primarily with the mechanical aspects of the processor, such as logging on and off, saving, loading, and deleting workspaces. System commands always begin with a right parenthesis. A few examples of system commands follow:

)SAVE NEWJOB
)LOAD OLDJOB
)END
)DIGITS

Statements and system commands are described in detail in sections 6 and 8, respectively.
Variables and Functions

Data (numeric or character) can be assigned a name and stored in the active workspace. The name and the associated value are collectively known as a variable. The value may be a single data item (scalar) or a group of data items (array), and may be changed as needed during the course of a program. Examples of assignments of variables are shown below:

\[
A+5 \\
B2+1 2 3 \\
ABC+5+4 \\
B3=A*B2
\]

Some character symbols indicate that basic APL operations, such as addition or multiplication, are to be performed. These symbols are called primitive functions. Functions can be monadic (have one argument) or dyadic (have two arguments). Some examples of functions are:

\[
x \\
+ \\
\]

The domain and range of function arguments and a list of all the functions are presented in Section 3 under Primitive Functions. Section 5 is devoted to a detailed discussion of each function.

Defined Functions

In addition to the primitive functions, APL permits users to define new functions, name them, and store them in a workspace. Defined functions can then be referenced by name in subsequent statements, either as programs by themselves or as mathematical operations used in a formula. To define a function, the user enters it statement by statement while APL is in definition mode. This mode begins when the user types a del symbol \(\texttt{v}\) and ends when another \(\texttt{v}\) is typed.
Section 3
Common Elements in APL

Constants

Constants are either numeric or character.

Numeric Constants

Numeric constants can take the form of integer or real numbers. An integer is a whole number, requiring neither decimal point nor exponential form. A real number is a number, usually with a decimal point, expressed in either exponential form or decimal form. The user need not generally be concerned with whether a number is integer or real, or exponential or decimal, since APL automatically takes care of any necessary conversions. The representation of numeric data is accomplished with the following characters:

```
0 1 2 3 4 5 6 7 8 9 . - E
```

The numbers are the ordinary keyboard digits, and the decimal point is the keyboard period. The `-` character, called the negative sign, is found over the digit 2 on an APL keyboard and is used to indicate negative numbers. It should be distinguished from the `-` character, which is found over the + symbol and is used for subtraction. The negative sign is only valid for numeric constants; it is not valid in any other context. The `E` is the letter E on the keyboard and is used to indicate an exponent. Embedded blanks, commas, and other punctuation are not allowed in APL numbers.

APL ignores leading and trailing zeros, so that the user need enter only the parts of numbers required for calculations. Thus, there is no need for the user to enter data as all integer or all fractional. For example, the number one may be entered as 1.00, 001.0, 1, etc. Examples of numeric constants entered in decimal form are shown below:

```
10.55
0.34
5 + 5.55
6.8 + 20
```

The negative symbol (-) can be used only with a numeric constant to indicate a negative number; it can never be used with a name. The symbol immediately precedes the applicable number; that is, no blanks are allowed between the symbol and the number. The use of the negative symbol is shown below:

```
-2
-4 + -5
-9
4 - -3
```

It is often easier to enter very large numbers in exponential form rather than decimal form. Exponential representation is written as a number, followed by E, followed by an integer indicating a power of 10. (E can be interpreted as "times 10 to the following power".) The exponent (the number following the E) can be a positive or negative number. Following are some examples of numeric data in exponential form:
APL Exponential Notation  Mathematical Notation

-8.37E14  -8.37 \times 10^{14}
4.2E-6  4.2 \times 10^{-6}
.99E5  .99 \times 10^{5}
3.8E-80  3.8 \times 10^{-80}

The maximum and minimum magnitude representable numbers in CP-6 APL are approximately:

8.37878956E152
4.661462957E-156

Note that non-integer values are handled internally as "double precision floating point" numbers. Fractions that are representable exactly in decimal notation, such as .1, are not exactly representable in this internal form. In some instances, this will cause results of operations to deviate from expected results, particularly if the anticipated result is displayed to 20 decimal places or is a value near zero.

Character Constants

Character constants are enclosed in quote symbols and can contain any keyboard character including legal overstrikes and the space character. The quote symbols are used to distinguish a character constant from a number, the name of something, or a constant in the language. They are not printed in the display of the literal. For example:

```
A+'?'
```

In this example, the name A has been assigned the value of a character constant.

Vector Notation

When two or more values appear together separated by one or more blanks, a vector is formed. The vector that is formed has the properties of length (the number of items), type (numeric, character or nested), and rank (vector). Some examples of numeric vectors are:

```
1 1 3
1 2.5 -726E12
```

Character vectors may be formed either as a series of character scalars with each item enclosed in quotes, or by enclosing the entire string in quotes. For example:

```
'HI THERE'
'H I THERE'
'HI THERE'
```

Both character vectors are equivalent. If a quote is to be used within text, it must be represented by two quotes. The use of the quote character is shown below:

```
A+'THE "a" CHARACTER IS USED FOR COMMENTS.'
```

THE 'a' CHARACTER IS USED FOR COMMENTS.
Character arrays may be generated, compared for equality, indexed and catenated just like any other arrays.

A character constant may contain one or more carriage returns. If a carriage return is entered before the closing quote is given, APL will automatically type the closing quote at the beginning of the next line to indicate that a closing quote is required to end this string. If the constant is to be extended, a RUBOUT may be entered to delete the closing quote.

Parentheses may also be used to separate items in vector notation. For example:

\[
\begin{align*}
A+1(2) \\
A+(1) \ 2 \\
A+(1) \ (2)
\end{align*}
\]

The three examples above are all equivalent ways of forming the two item vector 1 2. Multiple blanks and extra parenthesis are also always permitted:

\[
\begin{align*}
A+19 \ 20 \\
A+((19)) \ \((20))
\end{align*}
\]

The use of parenthesis in vector notation is used to produce a single item out of any array that they enclose. The parenthesis may also enclose any array. For example:

\[
\begin{align*}
A+('YEAR') \ 1983 \ ('SALES') \ (2619 \ 5250) \\
A[3]
\end{align*}
\]

SALES

In this example, vector notation has produced a four item vector which contains the vector 'YEAR' as the first item, the scalar 1983 as the second item, the vector 'SALES' as the third item, and the numeric vector 2619 5250 as the final item. Parentheses are not required around character vectors because the enclosing quotes are already grouping them. For example:

\[
A+('YEAR' \ 1983 \ 'SALES' \ (2619 \ 5250)
\]

This example produces the same four item vector as the previous example.

Names

All of the following constituents of the APL language have names (sometimes known as identifiers) so that they may be easily referenced: variables, functions, groups, statement labels, and workspaces.

Name Format

A name can include only letters, the letters underscored, digits, $\alpha$, $\Delta$, and _ characters. A name cannot start with a digit or on underscore. Distinguished names follow the other rules for names, but always start with a single _ character.

Lengths of names may vary, depending on their use. The names of variables, functions, groups, and statement labels can be of any length up to 79 characters. Workspace names (also known as fids in CP-6 APL) can be up to 31 characters in length.
The uses of APL names are described below:

1. A variable refers to the name given to scalar or array values by the assignment symbol (the character '←') described later in this section under Assignment.

2. Defined function names are treated briefly later in this section under Function References, and in detail in Section 7, Defined Functions.

3. A collection of names can be referenced using groups. Included in the group can be the names of variables, functions, and other groups (see the )GRP command in Section 8).

4. A label is given to a statement within a user-defined function so that it may be referenced by other statements of that function. Statement labels are used as branch reference points.

5. A workspace name is used to identify an active workspace so that it can be saved and later recalled. Workspace names are referenced in system commands which are described in Section 8 (also see item 8).

6. A password is assigned to a workspace or file to prevent other users from accessing it. The password must always be used in order to access the workspace or file. Passwords are described in Section 8 (also see item 8, below). Passwords may contain any characters.

7. An account is the identifier of a recognized user's account. The account must be specified when logging on to the CP-6 system and when accessing a workspace or file in another user's account. The use of accounts is described in Section 8 (also see item 8, next). Accounts may be, but are not restricted to, letters or digits.

8. In CP-6 APL, a saved workspace is a CP-6 file. A file identifier (fid) refers to the information needed in a system command to save a workspace or to reference it after it has been saved. A file identifier takes the following form:

   ```
   workspace[,][acct][[password]]
   ```

   where
   
   workspace is the name assigned to the workspace, or file. It can consist of up to 31 characters from the set A-Z, A-Z, - , :, _, $, and 0-9.
   
   acct is the identifier of a recognized user's account. It can consists of up to eight characters from the set of accounts authorized by the installation manager.
   
   password is assigned to a workspace, or file, in order to restrict user access. It can consist of up to eight characters.

   The bracketed items in the above form indicate optional items. File identifiers are used in the following system commands, all of which are described in Section 8: )LIB, )COPY, )DROP, )LOAD, )PCOPY, )QCOPY, )QLOAD, )QPCOPY, )SAVE, )SET, and )WSID.

   Accounts and Passwords may include any characters except the period, comma, semicolon, or embedded blanks.

   For further information on file identifiers, see the the documentation on the command processor IBEX in the CP-6 Programmer Reference Manual (CE40). Set names and serial numbers are also discussed there.
Variables

A variable must be assigned a value before it can be used. The value assigned can be numeric, character, or nested and can be a scalar or an array (a vector, a matrix, or a higher-order array). The user can display the value of a variable at any time simply by typing the variable name. Examples of the assignment and use of variables are shown below:

\[
\begin{align*}
A+2 \\
B+2 & 3 4 5 \\
A+B \\
4 & 5 6 7 \\
C+4 & 5pt20 \\
C \\
1 & 2 3 4 5 \\
6 & 7 8 9 10 \\
11 & 12 13 14 15 \\
16 & 17 18 19 20 \\
D+B+2 \\
\end{align*}
\]

A variable can be respecified at any time simply by assigning a new value to the variable name. The most recent value specification replaces any previous value. For example, notice the following:

\[
\begin{align*}
ABC+1 \\
ABC*0 & 1 2 3 4 5 \\
0 & 1 2 3 4 5 \\
ABC+2 \\
ABC*0 & 1 2 3 4 5 \\
0 & 2 4 6 8 10 \\
\end{align*}
\]

In this example, ABC is first assigned a value of 1 and calculations are performed with that value. The variable ABC is then assigned a value of 2 and the calculations are performed using this new value.

Another way of respecifying a variable value is to decrease or increase its value by a certain amount. For example, suppose variable A has a value of 2 and the user want to increase this value by 1. This can be accomplished as follows:

\[
\begin{align*}
A=A+1 \\
A \\
3 \\
\end{align*}
\]

Notice that the calculation 2+1 is performed first, and then the result 3 is assigned to a variable A. This type of operation is particularly useful for setting up a counter to test the number of occurrences of an event, such as the number of passes through a program loop. Each time through the loop the counter can be increased or decreased by 1 and then tested against a desired value to determine further action.

Local and Global Variables

Local variables exist while user-defined functions (Section 7) are active, that is, while the function is pendent or suspended. Local variables, described below, are classified as follows:

- Dummies
- Result
- Locals
- Labels

Dummies, result, and locals are indicated by their presence in the header of a defined function. Labels are indicated on statements within a defined function.
At a given point in time if a variable is not local, it is global. It is possible (in fact useful) to allow global variables to be identified by the same name as local variables (or local variables for one function to use the same name as local variables for another function). This concept is useful in APL because it allows a defined function to be formed without regard to name conflicts. Its local variables are totally independent of any previously assigned variables. Furthermore, if the function calls itself, a new set of variables exist independent of the original local variables. As each such function call exits (that is, becomes inactive again), the current set of local variables disappear and the earlier values associated with their names once more become accessible.

When a function call occurs, its local variables are said to "shadow" previous definitions for the names used by the local variables. Shadowing can be repeated extensively as functions are called. As these functions exit, their shadowing effect is removed. Only globals will exist when no function is active. Global variables also exist if their names are not shadowed by any currently active functions (for example, the local variables use unique names). Shadowing is illustrated in Figure 3-1.

Local Variables

The following local variables are named in a function header: result, dummies, and locals. These are all optional; a function is not required to use any local variables. Notice the following example:

VR+Y F X;A;B;C

In this example, the function F names the following local variables in its header line:

R (result) — note that R is followed by a + symbol, which designates that R is the result name.

X (dummy) — one name to the right of F separated by blanks(s), designates the right dummy. When F is called, the right argument’s value is automatically assigned to local variable X.

Y (dummy) — one name to the left of F, separated by blank(s), designates the left dummy. When F is called, the left argument’s value is automatically assigned to local variable Y.

A, B, and C (locals) — note that each local name is preceded by a semicolon.

The remaining type of local variable is the label. Its name appears in a function line as in the example below.

[3] L:+A THIS LINE IS LABELED.

Notice that the label’s name, L, follows the line number, [3], and is in turn followed by a colon. Although labels are classified as local variables, it is more appropriate to consider them local constants. They cannot be assigned values; that is, the following expression is a syntax error when $L$ is a label:

$L+4$

The value of a label is the line number of its function line (which cannot change during execution of the function).

The example in Table 3-1 illustrates the effect of shadowing as functions F1 and F2 become active and inactive.
<table>
<thead>
<tr>
<th>Example</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLEAR WS</td>
<td>Set V, W, X, Y to be global variables.</td>
</tr>
<tr>
<td>V='+V=GLOBAL'</td>
<td>Define F1, naming X and Y as its locals.</td>
</tr>
<tr>
<td>W='+W=GLOBAL'</td>
<td>Define F2, naming W and X as its locals.</td>
</tr>
<tr>
<td>X='+X=GLOBAL'</td>
<td>Verify V, W, X, Y.</td>
</tr>
<tr>
<td>Y='+Y=GLOBAL'</td>
<td>Call F2.</td>
</tr>
<tr>
<td>F1;X;Y</td>
<td>V and Y are still global. W and X are local to F2.</td>
</tr>
<tr>
<td>V ; W; X</td>
<td>V, W, X, Y are global again.</td>
</tr>
<tr>
<td>F2 ; ....F2 CALLED....</td>
<td>Call F1.</td>
</tr>
<tr>
<td>V=GLOBAL</td>
<td>V and W are still global. X and Y are local to F1.</td>
</tr>
<tr>
<td>W=LOCAL (F2)</td>
<td>F1 calls F2.</td>
</tr>
<tr>
<td>X=LOCAL (F2)</td>
<td>V is still global. W and X are local to F2. Y is still local to F1.</td>
</tr>
<tr>
<td>Y=GLOBAL</td>
<td>V, W, X, Y are again global.</td>
</tr>
</tbody>
</table>
Arrays and Indexing

As mentioned earlier, a variable may represent a scalar or an array. A scalar is always a single item, an item being a character, number, or nested array. One example of a scalar is:

```
SCLR=33
SCLR
33
```

Although an array may be made up of more than one item, it can also consist of a single item or even no items. An array with no items is called an empty array.

In addition, arrays can be classified as vectors, matrices, or higher-order arrays. A vector is an array of one dimension, and is displayed as a collection of items arranged on one line. As a typical example, notice the vector named VECT which has four items:

```
VECT=5 7 9 11
VECT
5 7 9 11
```

A matrix is an array with two dimensions, (a dimension is sometimes called a coordinate) and is displayed as a collection of items arranged in a rectangular pattern. An example of a two-dimensional matrix, named HAT, is shown below:

```
HAT
1 2 3 4 5
6 7 8 9 10
11 12 13 14 15
```

Notice that this matrix has three rows and five columns. It is two-dimensional because it is made up of rows and columns.

A higher-order array is an array with three or more dimensions, displayed as a collection of items in a set of rectangular patterns. An example of a higher-order array is:

```
CUBE
1 2 3 4 5
6 7 8 9 10
11 12 13 14 15
16 17 18 19 20
21 22 23 24 25
26 27 28 29 30
```

This higher-order array is three-dimensional. It has two planes, and each plane has three rows and five columns.

The user can find out if a variable is a scalar, a vector, a matrix, or a higher-order array by using \( \text{pp} \) to test for the rank (that is, number of dimensions) of the variable. For example, testing the previous variables SCLR, VECT, HAT, and CUBE will give:

```
ppSCLR
0
ppVECT
1
ppHAT
2
ppCUBE
3
```

A 0 indicates a scalar, a 1 indicates a vector, a 2 indicates a two-dimensional array, a 3 indicates a three-dimensional array, and so on, up to a maximum of 62 dimensions.
The user can also determine the size of each dimension in an array (that is, the "shape" of the array) by using \( p \). For example, testing the same variables \( SCLR, VECT, \) \( MAT, \) and \( CUBE \) will give

\[
\begin{align*}
pSCLR &= 4 \\
pVECT &= 4 \\
pMAT &= 3 \ 5 \\
pCUBE &= 2 \ 3 \ 5 \\
\end{align*}
\]

Since a scalar has no dimensions, \( p \) of a scalar produces an empty (vector) result; nothing is displayed (other than the next input prompt). The above example confirms that \( SCLR \) is a scalar (no dimension); that \( VECT \) is a vector with four items; that \( MAT \) is a two-dimensional matrix with three rows and five columns (15 items); and that \( CUBE \) is a three-dimensional array with two planes, each with three rows and five columns. One other situation should be noted, \( p \) of an empty vector will return the value zero, and \( p \) of an empty array will return one or more zeros depending on which dimension or dimensions have length zero.

Indexing of Arrays

Items in an array can be referenced by their positions within the array. The position number is called an index. The index can also be used for several items, and to index other indexed arguments. The following topics are discussed in this subsection:

- Referencing a Single Item
- Referencing More Than One Item
- Assigning a Value to an Array
- Indexing an Indexed Argument

Referencing a Single Item

An item in an array is referenced by its position within the array, which is indicated by one or more numbers called indexes. One number is used as the index of an item in a vector array; two numbers, as the index of an item in a two-dimensional matrix; three numbers, as the index of an item in a three-dimensional array; and so on, with one number for each dimension.

The indexes of all arrays start with 0 or 1, depending on the index origin. When the user first enters APL, the index origin is 1 by default. It can be set to 0 by assigning the \( \text{IO} \) system variable to 0, and reset to 1 by reassigning the \( \text{IO} \) variable to 1.

\[
\begin{align*}
V &= \text{"ABCDE"} \\
\text{IO}+1 &= V[2] \\
B &= \text{IO}+0 \\
B &= \text{IO}+1 \\
\end{align*}
\]

The indexes of a two-dimensional matrix also start with 0 or 1, depending on the index origin, but two numbers are used in each index. The first number selects the items from a row, and the second number selects the items from a column. The indexes are ordered with the rightmost position varying the fastest, then the next rightmost, and so on. For purposes of illustration, consider the matrix named \( MAT3 \):

\[
\begin{align*}
MAT3 &= \begin{bmatrix}
3 & 1 & 11 & 2 & 12 \\
13 & 15 & 4 & 8 & 14 \\
6 & 10 & 7 & 9 & 5
\end{bmatrix}
\end{align*}
\]
The indexes for this matrix, with index origin 1, will be

\[
[1;1] [1;2] [1;3] [1;4] [1;5]
[2;1] [2;2] [2;3] [2;4] [2;5]
[3;1] [3;2] [3;3] [3;4] [3;5]
\]

Thus \( \text{MAT3}(1;1) \) is 3; \( \text{MAT3}(1;2) \) is 1; \( \text{MAT3}(1;3) \) is 11; \( \text{MAT3}(1;4) \) is 2; and so on. Notice that semicolons must be used to separate the numbers of each dimension.

An item in an array of more than two dimensions is selected in the same way as an item of a two-dimensional array, except that more numbers are included in the index. An index contains one number for each coordinate of the associated array. For example, consider the following three-dimensional array:

\[
\text{MAT4} =
\begin{bmatrix}
1 & 4 & 7 \\
15 & 13 & 8 \\
11 & 12 & 6 & 16 \\
5 & 3 & 9 & 10
\end{bmatrix}
\]

To reference the value 8 in this array, one uses the index \( \text{MAT4}(1;2;4) \), where 1 denotes the first plane, 2 denotes the second row, and 4 denotes the fourth column. Notice that each additional coordinate always adds a number to the beginning of an index. The rightmost number of an index always refers to a column; the next rightmost to a row; the next rightmost to a plane; the next to a panel of planes; and so on.

Referencing More Than One Item

To reference items within an array, simply include the index of each desired item in brackets after the array name. For example, notice the following vector:

\[
A = 5 \ 4 \ -1 \ 3 \ 9 \ -2 \ 7 \ 4
\]

To select the items 5, -1, and 3 from this vector (assuming an index origin of 1), one uses the expression \( A[1 \ 3 \ 4] \) as shown here:

\[
A[1 \ 3 \ 4] = 5 \ -1 \ 3
\]

Other examples of referencing several items in vector A are shown below. Notice in the second example that indexing can be used to create larger and differently shaped arrays:

\[
A[1 \ 3 \ 4 \ 6] = 5 \ 5 \ 4 \ 4
\]

\[
A[3 \ 2 \ 1 \ 3 \ 4 \ 2 \ 6 \ 5] = 5 \ -1 \ 3 \ 4 \ -2 \ 9
\]

There are a variety of ways to reference several items in a matrix. Consider the following matrix:

\[
\text{MAT5} =
\begin{bmatrix}
1 & 10 & 9 & 8 & 11 \\
2 & 15 & 4 & 5 & 6 \\
15 & 3 & 12 & 13 & 7
\end{bmatrix}
\]

Examples of referencing several items in this matrix are shown below. These examples assume an index origin of 1.

\[
\text{MAT5}(1;4 \ 5 \ 2) = 8 \ 11 \ 10
\]

\[
\text{MAT5}(1 \ 2) =
\begin{bmatrix}
1 & 10 & 9 & 8 & 11 \\
2 & 15 & 4 & 5 & 6
\end{bmatrix}
\]

\[
\text{MAT5}(1 \ 2, 1 \ 2 \ 3 \ 4 \ 5) =
\begin{bmatrix}
1 & 10 & 9 & 8 & 11
\end{bmatrix}
\]

3-10

Indexing of Arrays

CE38-04
In fact, the shape of the indexing result has a rank equal to the shape of each of the index expressions joined together. If an index expression is elided, the result shape has the length of the elided coordinate inserted.

Several items in a three-dimensional array are referenced similarly to a matrix, except that the third coordinate must also be added to the index. Consider the following three-dimensional array:

```
MAT6
1 2 3 4 5
6 7 8 9 10
11 12 13 14 15
16 17 18 19 20
```

Examples of referencing several items in this array are shown below. These examples assume an index origin of 1.

```
MAT6[1;2;5]
10
MAT6[;2;1]
6 7 8 9 10
16 17 18 19 20
MAT6[;2;1 3]
6 8
16 18
MAT6[1 1 2;1 2;1 2 4]
1 2 4
6 7 9
1 2 4
1 2 4
6 7 9
1 2 4
11 12 14
16 17 19
11 12 14
```

Assigning a Value into an Array

One or more items in an already existing array can be assigned values via the assignment symbol `<`. The user simply places the variable name and the index designation to the left of the symbol, and the new value to the right. Examples follow, all of which assume an index origin of 1.

Example of vector:
Example of matrix:

\[ \text{MAT7} = \begin{bmatrix} 1 & 2 & 3 & 4 & 5 \\ 6 & 7 & 8 & 9 & 10 \end{bmatrix} \]

\[ \text{MAT7}(2; 5) = 0 \]

\[ \text{MAT7} = \begin{bmatrix} 1 & 2 & 3 & 4 & 5 \\ 6 & 7 & 8 & 9 & 0 \end{bmatrix} \]

\[ \text{MAT7}(1; 2; 3; 5) = -1 \]

\[ \text{MAT7} = \begin{bmatrix} 1 & 2 & -1 & 4 & -1 \\ 6 & 7 & 1 & 9 & -1 \end{bmatrix} \]

\[ \text{MAT7}(;:) = 2 \]

\[ 2 \]

Notice from examples above (MAT7(;2;), V[;2], and MAT7(;1;2)) that if an index position is not filled, all index values for that position are assumed to be applicable. Assigning a new value to an indexed variable does not change the rank or shape of the variable, it merely changes some items in the variable.

The value that is assigned to a variable or indexed variable is also the "result" of the assignment. This is illustrated by the example WHOOPS+V[;]+2. Since V is a 10-item vector, all 10 index values received the value 2. But the result as far as the assignment operation is concerned is the scalar 2. Thus, WHOOPS becomes a scalar variable having the value 2. When analyzing APL expressions, it is helpful to imagine that assignments are "invisible". For example,

\[ 3+\text{MAT7}(;4) = 5 \]

can be analyzed as if the assignment were not present, i.e.,

\[ 3+5 = 8 \]

making the result (8) apparent.

Indexing an Indexed Argument

In APL, an indexed argument may itself be indexed. For example:

\[ A[1;][2] \]

which is equivalent to the expression \((A[1;])[2]\) and is interpreted as follows. Obtain the first row of matrix \(A\). This row temporarily forms a vector, call it \(T\), whose length is the number of columns originally given for \(A\). Select the second item from vector \(T\), and (in this case) display the value of that item.

Only arguments can be followed by multiple indexes. Specifications and coordinates cannot; thus the following is a syntax error:

\[ A[1;][2]=X \]

LINESCAN ERR A
The user instead is advised in this case to use
\[ A[1;2]+X \]

Functions and Arguments

APL expressions are derived from three fundamental entities: operators, functions, and values. Functions may be formed by the user (see section 7 under Defined Functions) or are included as an inherent part of the language. In the latter case, they are called primitive functions. Most primitive functions are represented by a single character. A general treatment of these functions is given in this section; for a detailed treatment, see Section 5, APL Functions.

Operators usually take APL functions as arguments and return a new (or derived) function. The derived function typically applies the function arguments to the value arguments in an operator defined order. Examples of APL operators include axis, inner product, and outer product.

Values are APL arrays and have certain attributes: type, rank, depth, and length or shape. The domain of an array may be character type, numeric type, or nested type. There are three numeric domains: logical, integer, or real; however, the user seldom needs to be concerned with this distinction. Logical data represents 1's or 0's and is stored in bit form. Integer data represents positive and negative numbers (using neither decimal point nor exponential form) whose range is limited to the size of one computer word. Real data is stored in doubleword form (that is, in floating-point form). Text or character data is stored in byte form. The nested domain type can have an array item which contains other APL arrays or both character and numeric data items. If a numeric argument contains numbers that could fit in more than one domain, it is made to uniformly contain numbers in the largest size domain necessary. Thus the following vector argument has integer domain since that is necessary to represent the 2:

1 0 1 0 2

The rank of an array is the number of its dimensions (or coordinates). A scalar has a rank of zero, a vector has a rank of one, a matrix has a rank of two, and so forth. The maximum allowed rank in CP-6 APL is 62.

The length of a vector is its number of items or components (zero for an empty vector). The shape or dimension of an array (including a vector) is an ordered vector containing the lengths of its coordinates. Single-item vectors and single-item arrays of higher order (for instance, a 1 1 reshape of 5 is a single-item three-dimensional array) are not equivalent to scalars but may be used interchangeably with scalars in many operations. Vectors and arrays of higher ranks may also be 'empty'. This is the case when the length of a coordinate is zero.

The depth of an array indicates the maximum level of nesting of items within the array. A simple scalar character or number has depth 0. An array containing only simple scalar character or scalar numeric items has depth 1. An array containing items of depth 0 and 1 has depth 2. In general, an array containing items of depth less than or equal to N has a depth of N+1. Simple arrays have depth 0 or 1. Nested arrays have depth 2 or more.

Functions are classified as monadic or dyadic according to the number of their arguments. A monadic function has one argument to the right of the function. A dyadic function has two arguments, one to the right of the function and one to the left.

In many cases, the same function can be used both monadically and dyadically, but the resulting functions are different, although usually related in a natural way. Each function has its own domain, rank, and length or shape requirements, and the result of a function may have a new set of these characteristics.
Axis Operator

Certain functions are coordinate-dependent. For example, a matrix rotation can occur about the first coordinate (rotation of rows) or about the second coordinate (rotation of columns). For such functions, the user has the option of specifying this coordinate in the form of a bracketed expression to the right of the function. The value of this expression must be an integer of appropriate range. These coordinate specifications are called the Axis operator. The Axis operator takes the coordinate specified and the function to its left and creates a new "derived" function which operates on the requested coordinate. The following functions may use a coordinate specification:

- Reduction
- Compression
- Enclose
- Reversal
- Expansion
- Disclose
- Rotation
- Catenation
- Scan

NOTE: Catenation may also use a fractional coordinate specification. This form of catenation is called lamination. Enclose and disclose permit the specification of a vector of axes.

APL Functions and Operators

Tables 3-2, 3-3, and 3-4 include summary information about Scalar Functions, Mixed Functions and Operators, respectively. Each table lists dyadic and monadic operations, if any, and gives simple examples. For a detailed description of these functions and operators, see Section 5.

Scalar Function Summary

Scalar functions are pervasive. That is, when they are applied to nested arrays, the function is applied to every numeric and every character scalar in the array.

<table>
<thead>
<tr>
<th>Function</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>Monadic - Conjugate: Leaves argument unchanged. Example:</td>
</tr>
<tr>
<td></td>
<td>+10</td>
</tr>
<tr>
<td></td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Dyadic - Addition: Adds two arguments. Example:</td>
</tr>
<tr>
<td></td>
<td>10+20</td>
</tr>
<tr>
<td></td>
<td>30</td>
</tr>
<tr>
<td>Function</td>
<td>Usage</td>
</tr>
<tr>
<td>----------</td>
<td>-------</td>
</tr>
</tbody>
</table>
| **-**    | **Monadic** — Minus:  
Negates the argument that follows it. Example:  
\[-(10+5)\]  
\[-15\]  
**Dyadic** — Subtraction:  
Subtracts the right argument from the left argument. Example:  
\[10-5\]  
\[5\] |
| **x**    | **Monadic** — Signum:  
Returns -1, 0, or 1, depending on whether its argument is negative, zero or positive. Example:  
\[x^{-15}\]  
\[-1\]  
**Dyadic** — Multiplication:  
Multiplies the left argument by the right argument. Example:  
\[10 \times 15\]  
\[150\]  
\[150\]  
\[1500\] |
| **+**    | **Monadic** — Reciprocal:  
Divides 1 by the value of its argument. Example:  
\[+1 \ 3 \ 5\]  
\[1 \ 0.3333333333 \ 0.2\]  
**Dyadic** — Division:  
Divides the left argument by the right argument. Example:  
\[10+5 \ 2 \ 1.5\]  
\[2 \ 5 \ 10 \ 20\] |
### Table 3-2. Scalar Functions (cont.)

<table>
<thead>
<tr>
<th>Monadic</th>
<th>Exponential:</th>
</tr>
</thead>
<tbody>
<tr>
<td>*</td>
<td>Raises $e$ (i.e., the base of the natural logarithms, having the value of approximately 2.71828...) to the power of its argument. Examples:</td>
</tr>
<tr>
<td></td>
<td>$*1$</td>
</tr>
<tr>
<td></td>
<td>2.718281828</td>
</tr>
<tr>
<td></td>
<td>$*10$</td>
</tr>
<tr>
<td></td>
<td>22026.46579</td>
</tr>
<tr>
<td></td>
<td>$*2.2$</td>
</tr>
<tr>
<td></td>
<td>9.025013499</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dyadic</th>
<th>Exponentiation:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Raises the left argument to the power indicated by the right argument. Examples:</td>
</tr>
<tr>
<td></td>
<td>$10^{10} 2^{42103}$</td>
</tr>
<tr>
<td></td>
<td>$100^{10} 8$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Monadic</th>
<th>Natural logarithm:</th>
</tr>
</thead>
<tbody>
<tr>
<td>log</td>
<td>Computes the natural logarithm of its argument (that is, log base $e$ of the argument). Examples:</td>
</tr>
<tr>
<td></td>
<td>$log1$</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>$log2$</td>
</tr>
<tr>
<td></td>
<td>0.6931471806</td>
</tr>
<tr>
<td></td>
<td>$log3$</td>
</tr>
<tr>
<td></td>
<td>1.098612299</td>
</tr>
<tr>
<td></td>
<td>2.302585093</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dyadic</th>
<th>Logarithm:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Computes the logarithm of the right argument to the base indicated by the left argument; that is, computes the power to which the left argument must be raised to equal the right argument. Examples:</td>
</tr>
<tr>
<td></td>
<td>$100log2$</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>$100log1$</td>
</tr>
<tr>
<td></td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>$10log0.1$</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>$2log1$</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Monadic</th>
<th>Floor:</th>
</tr>
</thead>
<tbody>
<tr>
<td>l</td>
<td>Returns the greatest integer less or equal to its arguments. Examples:</td>
</tr>
<tr>
<td></td>
<td>l10.7</td>
</tr>
<tr>
<td></td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>l2</td>
</tr>
<tr>
<td></td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td>l8.9</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>l-2</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Function</td>
<td>Usage</td>
</tr>
<tr>
<td>----------</td>
<td>-------</td>
</tr>
<tr>
<td>Dyadic - Minimum:</td>
<td>Compares two arguments and returns the value of the smaller argument. Examples:</td>
</tr>
<tr>
<td></td>
<td>5L2</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>9L3 11 8</td>
</tr>
<tr>
<td></td>
<td>3 9 8</td>
</tr>
<tr>
<td></td>
<td>4 3 2L3</td>
</tr>
<tr>
<td></td>
<td>3 3 2</td>
</tr>
<tr>
<td>Monadic - Ceiling:</td>
<td>Returns the least integer greater than or equal to its argument. Examples:</td>
</tr>
<tr>
<td></td>
<td>f 10.7</td>
</tr>
<tr>
<td></td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>f 2 4.1 8.9 2</td>
</tr>
<tr>
<td></td>
<td>2 5 -8 -2</td>
</tr>
<tr>
<td>Dyadic - Maximum:</td>
<td>Compares two arguments and returns the value of the larger argument. Examples:</td>
</tr>
<tr>
<td></td>
<td>5f2</td>
</tr>
<tr>
<td></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>9f3 11 8 -2 10</td>
</tr>
<tr>
<td></td>
<td>9 11 9 9 10</td>
</tr>
<tr>
<td>Monadic - Absolute value:</td>
<td>Returns the absolute value of its argument. Example:</td>
</tr>
<tr>
<td></td>
<td>1^-10</td>
</tr>
<tr>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Dyadic - Residue:</td>
<td>Returns the remainder from dividing the right argument by the left argument. Examples:</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>0 1 2 3</td>
</tr>
<tr>
<td></td>
<td>2 3</td>
</tr>
<tr>
<td></td>
<td>1 1</td>
</tr>
</tbody>
</table>
## Table 3-2. Scalar Functions (cont.)

<table>
<thead>
<tr>
<th>Function</th>
<th>Usage</th>
</tr>
</thead>
</table>
| !        | **Monadic — Generalized factorial:**  
For integer arguments, returns the factorial of its argument. The argument may not be a negative integer. (See Section 5 for explanation of ! with non-integer argument.) Examples:  
\[
\begin{align*}
!3 & \quad 6 \\
!0 & \quad 1 \ 2 \\
!1 & \quad 1 \ 1 \ 2
\end{align*}
\]  
**Dyadic — Generalized combination:**  
For positive integer arguments, the right argument represents a population size and the left argument represents a sample size. The result is the number of different samples that can be drawn from the population (see Section 5 for explanation of ! with non-integer arguments.) Examples:  
\[
\begin{align*}
13!5 & \quad 6.350135596\times11 \\
2!10 & \quad 45 \\
3!10 & \quad 120
\end{align*}
\]  
0        | **Monadic — Pi times:**  
Multiplies the value of pi (approximately 3.141592653589793) times its argument. Examples:  
\[
\begin{align*}
01 & \quad 3.141592654 \\
02 & \quad 6.283185307 \ 0.3141592654
\end{align*}
\]  
**Dyadic — Circular:**  
Returns the result of any of a number of trigonometric functions. The left argument specifies the trigonometric function and must be one of the integers from -7 to 7, as follows:  
\[
\begin{align*}
0 & \quad (1-X^2)+0.5 \\
1 & \quad \text{sine } X \\
2 & \quad \text{cosine } X \\
3 & \quad \text{tangent } X \\
4 & \quad (1+X^2)+0.5 \\
5 & \quad \text{sinh } X \\
6 & \quad \text{cosh } X \\
7 & \quad \text{tanh } X
\end{align*}
\]  
\[
\begin{align*}
-1 & \quad \text{arcsine } X \\
-2 & \quad \text{arccos } X \\
-3 & \quad \text{arctan } X \\
-4 & \quad B*(1-B^2)+0.5 \\
-5 & \quad \text{arcsinh } X \\
-6 & \quad \text{arccosh } X \\
-7 & \quad \text{arctanh } X
\end{align*}
\]  
Examples:  
\[
\begin{align*}
20(10\times2.5) & \quad 0.9912028119 \\
102 & \quad 4 \\
0.9082974266 & \quad -0.7568024953
\end{align*}
\]
<table>
<thead>
<tr>
<th>Function</th>
<th>Usage</th>
</tr>
</thead>
</table>
| `<` | Dyadic - Less than:  
Tests if the left argument is less than the right argument. Returns 1 if the test is true, and 0 if the test is false. (See Section 5 for effect of comparison tolerance on relational functions.)  
Examples:  
2<3  
1  
1 1 2 5  
1 1 0 1 |
| `≤` | Dyadic - Less than or equal to:  
Tests if the left argument is less than or equal to the right argument. Returns 1 if the test is true, and 0 if the test is false. (See Section 5 for effect of comparison tolerance on relational functions.)  
Examples:  
2≤3  
1  
1 1 2 3 4  
0 1 1 1 |
| `>` | Dyadic - Greater than:  
Tests if the left argument is greater than the right argument. Returns 1 if the test is true, and 0 if the test is false. (See Section 5 for effect of comparison tolerance on relational functions.)  
Examples:  
2>3  
0  
1 1 0 0  
0 2>3  
1 1 0 3 |
| `≥` | Dyadic - Greater than or equal to:  
Tests if the left argument is greater than or equal to the right argument. Returns 1 if the test is true, and 0 if the test is false.  
Examples:  
2≥3  
0  
1 1 1 0  
0 2≥3  
1 1 0 3
<table>
<thead>
<tr>
<th>Function</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>=</td>
<td>Dyadic — Equal to: Tests if the left argument is equal to the right argument. Returns 1 if the test is true, and 0 if the test is false. (See Section 5 for effect of comparison tolerance on relational functions.) Examples:</td>
</tr>
<tr>
<td></td>
<td>1=0</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>2=0 1 2 3</td>
</tr>
<tr>
<td></td>
<td>0 0 1 0</td>
</tr>
<tr>
<td></td>
<td>'A'='CANADA'</td>
</tr>
<tr>
<td></td>
<td>0 1 0 1 0 1</td>
</tr>
<tr>
<td>#</td>
<td>Dyadic — Not equal: Tests if the left and right arguments are unequal. Returns 1 if the test is true, and 0 if the test is false. (See Section 5 for effect of comparison tolerance on relational functions.) Examples:</td>
</tr>
<tr>
<td></td>
<td>2#1</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>3#3 0 3 6</td>
</tr>
<tr>
<td></td>
<td>1 1 0 1</td>
</tr>
<tr>
<td></td>
<td>'A'='CANADA'</td>
</tr>
<tr>
<td></td>
<td>1 0 1 0 1 0</td>
</tr>
<tr>
<td>^</td>
<td>Dyadic — And: (The arguments must be 0 or 1.) Returns 1 if both arguments are 1, and 0 for any other combination of arguments. Examples:</td>
</tr>
<tr>
<td></td>
<td>0^0</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(1=2)^3(3&lt;4)</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(1&lt;2)^3&lt;1</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(1=1)^3&lt;4</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Least Common Multiple: Returns the least common multiple of the left and right arguments. The LCM of a set of numbers is defined as their product divided by the GCD of the numbers. Examples:</td>
</tr>
<tr>
<td></td>
<td>3^2</td>
</tr>
<tr>
<td></td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>4^6</td>
</tr>
<tr>
<td></td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>0.5^0.3</td>
</tr>
<tr>
<td></td>
<td>1.5</td>
</tr>
<tr>
<td>Function</td>
<td>Usage</td>
</tr>
<tr>
<td>----------</td>
<td>-------</td>
</tr>
<tr>
<td>v</td>
<td>Dyadic - Or: Returns 1 if either or both arguments are 1, and 0 if neither argument is 1. Examples:</td>
</tr>
<tr>
<td></td>
<td>0v1</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>(1=2)v(4&lt;3)</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(3&lt;4)v4&lt;5</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Greatest Common Divisor: Returns the greatest common divisor of the left and right arguments. The GCD of a pair of numbers is defined as the largest divisor of both which produces an integer or near-integer result. Examples:</td>
</tr>
<tr>
<td></td>
<td>.5v3</td>
</tr>
<tr>
<td></td>
<td>0.1666666667</td>
</tr>
<tr>
<td></td>
<td>2v8</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Nand: Returns 0 if both arguments are 1, and 1 for all other combinations. Examples:</td>
</tr>
<tr>
<td></td>
<td>0v0</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>(2&lt;1)v(5&lt;1)</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>(1&lt;2)v(1&lt;5)</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Nor: Returns 1 if both arguments are 0, and returns 0 for all other combinations. Examples:</td>
</tr>
<tr>
<td></td>
<td>0v0</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>0v1</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(1=2)v(2&lt;1)</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>(1=2)v2&lt;3</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>
Table 3-2. Scalar Functions (cont.)

<table>
<thead>
<tr>
<th>Function</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>~</td>
<td>Dyadic - Not: &lt;br&gt; Returns 0 if the argument is 1, and returns a 1 if the argument is 0. Examples: &lt;br&gt; ~0 1 &lt;br&gt; 1 0 &lt;br&gt; ~0 &lt;br&gt; 0 1</td>
</tr>
</tbody>
</table>

Mixed Function Summary

The mixed functions produce results with a structure that is different from that of its arguments. Mixed functions can be sub-divided into the structural mixed functions and the transformation mixed functions:

- The structural mixed function subset re-orders the array right argument under the optional control of a left argument. The re-ordering is generally dependent on the right argument's rank and shape but independent of the actual elements within it.

- The transformation mixed functions produce results which typically depend upon the value of the array arguments.

The following table is a summary of APL mixed functions.

Table 3-3. Mixed Functions

<table>
<thead>
<tr>
<th>Function</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>Monadic - Index generator: &lt;br&gt; Generates a vector whose length is the value of the argument. If the index origin (□/0) is 1, the vector will contain positive integers 1 through value of the argument. If the index origin is 0, the vector will contain the positive integers 0 through the value of the argument minus 1. Examples: &lt;br&gt; t5 &lt;br&gt; 1 2 3 4 5 &lt;br&gt; □/0+0 &lt;br&gt; t5 &lt;br&gt; 0 1 2 3 4 &lt;br&gt; □/0+1</td>
</tr>
<tr>
<td>-</td>
<td>Dyadic - Index of: &lt;br&gt; Returns the position of the right argument in the left argument. If the right argument is not found in the left argument, it is given a value of the last index position of the left argument plus 1. Examples:</td>
</tr>
</tbody>
</table>
### Table 3-3. Mixed Functions (cont.)

<table>
<thead>
<tr>
<th>Function</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>)</td>
<td></td>
</tr>
<tr>
<td>p</td>
<td></td>
</tr>
<tr>
<td>ρ</td>
<td></td>
</tr>
</tbody>
</table>

#### Mixed Function Summary

- **Monadic - Ravel:**
  - Generates a vector from either a scalar or an array of higher dimension. Examples:
    - `A+2 4p18`  | `1 2 3 4`  | `5 6 7 8`  | `A`  | `1 2 3 4 5 6 7 8` |

- **Dyadic - Catenation:**
  - Joins together scalars or arrays of conforming dimension. Examples:
    - `A+1 2 3`  | `B+4 5 6 7`  | `A,B`  | `1 2 3 4 5 6 7`  | `(C+2),C×3-2`  | `1.5 3` |

- **Monadic - Shape:**
  - Returns an empty vector if the argument is a scalar, the length (or number of items) if the argument is a vector, or a vector containing the length of each dimension if the argument is a higher-order array. Examples:
    - `pA+2`  | `pB+1 5 6 7`  | `4`  | `pC+3 3p+9`  | `3 3`  | `pA`  | `0` |

- **Dyadic - Reshape (restructure):**
  - Generates an array whose dimensions are the left arguments and whose items are taken from the right argument. Examples:
    - `5p1`  | `1 1 1 1 1`  | `2 4p8`  | `8 8 8 8`  | `8 8 8 8`  | `2 4p8`  | `1 2 3 4`  | `5 6 7 8` |
<table>
<thead>
<tr>
<th>Function</th>
<th>Usage</th>
</tr>
</thead>
</table>
| * | Monadic – Grade-up:  
Ranks the components of its argument in ascending order, and returns the positions (i.e., indexes of the components). Example:  
\[
\begin{align*}
\text{A+4} & \quad 1 \quad 2 \quad 3 \quad 1 \\
\text{AA} & \quad 1 \quad 3 \quad 6 \quad 4 \quad 5 \quad 2
\end{align*}
\]  
Dyadic – Grade-up:  
Ranks the components of its right argument in ascending order defined by the collating sequence given by the left argument. Similar to the monadic grade-up function except that both arguments must be character and the ordering is defined by the left argument. Examples:  
\[
\begin{align*}
\text{A+3 4p'ABRACODEBACK'} & \\
\quad 'ABCDEFHGIJK'\text{AA} & \quad 1 \quad 3 \quad 2
\end{align*}
\]  
| |  
| * | Monadic – Grade-down:  
Similar to Grade-up, except that it returns the indexes in descending order. Examples:  
\[
\begin{align*}
\text{A+4} & \quad 1 \quad 2 \quad 3 \quad 1 \\
\text{AA} & \quad 2 \quad 5 \quad 4 \quad 1 \quad 3 \quad 6
\end{align*}
\]  
Dyadic – Grade-down:  
Ranks the components of its right argument in the descending order defined by the collating sequence given by the left argument. This is similar to the monadic grade-down function except that both arguments must be character and the ordering is defined by the left argument. Examples:  
\[
\begin{align*}
\text{A+3 4p'ABRACODEBACK'} & \\
\quad 'ABCDEFHGIJK'\text{AA} & \quad 2 \quad 3 \quad 1
\end{align*}
\]  
| |  
| ? | Monadic – Roll:  
Returns an integer pseudorandomly selected from \(1 \text{ to } B\). Examples:  
\[
\begin{align*}
?5 & \\
3 & \quad ?3 \quad 3 \quad 3 \\
3 \quad 2 \quad 1 & \quad ?5 \quad 8 \quad 11 \quad 13 \\
2 \quad 5 \quad 8 \quad 2
\end{align*}
\]  
Note that this function is modified by \[10\] (index origin).
<table>
<thead>
<tr>
<th>Function</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dyadic — Deal:</strong></td>
<td>Returns the number of integers specified in the left argument, each pseudorandomly selected from the integers specified in the right argument, and with no repetition of numbers in the result. Examples:</td>
</tr>
<tr>
<td></td>
<td>4?8</td>
</tr>
<tr>
<td></td>
<td>8 3 4 2</td>
</tr>
<tr>
<td></td>
<td>4?4</td>
</tr>
<tr>
<td></td>
<td>1 3 2 4</td>
</tr>
<tr>
<td></td>
<td>Note that this function is modified by □/O (index origin).</td>
</tr>
</tbody>
</table>

**Dyadic — Base value:**
Switches from one number system to another. The right argument contains the numbers to be converted and the left argument contains the increments needed to convert from one unit to another. The left argument, usually called the radix vector, can be thought of as the base of the number system. Examples:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>10 10 10</td>
<td>6 5</td>
</tr>
<tr>
<td>565</td>
<td>60 10 20</td>
</tr>
<tr>
<td>620</td>
<td>2 2 2 2 1 0 0 1</td>
</tr>
<tr>
<td>9</td>
<td>2 1 0 0 1</td>
</tr>
<tr>
<td>9</td>
<td>2 1 0 0 1</td>
</tr>
</tbody>
</table>

**Dyadic — Encode:**
Converts a number to some predetermined representation. It works in reverse of the base value operation above. The following shows how to reconvert to the initial arguments used above in the base value. Examples:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>10 10 10</td>
<td>565</td>
</tr>
<tr>
<td>5 6 5</td>
<td>60 10 20</td>
</tr>
<tr>
<td>10 20</td>
<td>2 2 2 2 9</td>
</tr>
<tr>
<td>1 0 0 1</td>
<td></td>
</tr>
</tbody>
</table>

**Monadic — Format:**
Converts numeric arrays to character arrays. The result is the same as if the argument were printed. Examples:

<table>
<thead>
<tr>
<th>w</th>
<th>3 3 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 3 1</td>
<td></td>
</tr>
<tr>
<td>Function</td>
<td>Usage</td>
</tr>
<tr>
<td>----------</td>
<td>-------</td>
</tr>
<tr>
<td><strong>Dyadic - Format:</strong></td>
<td>Converts numeric arrays to character arrays while controlling the format with the left argument. The left argument specifies the width and precision to be used in the display of the right argument. Examples:</td>
</tr>
<tr>
<td></td>
<td>2 0*3 4.15</td>
</tr>
<tr>
<td></td>
<td>3 4 5</td>
</tr>
<tr>
<td></td>
<td>5 2* 3 0.61 5.5</td>
</tr>
<tr>
<td></td>
<td>3.00 0.61 5.50</td>
</tr>
</tbody>
</table>

| **Monadic - First** | Returns an array whose value is the first item of the right argument. If the right argument is empty, then the result is the prototype of the right argument. For a scalar right argument, this function is the inverse of the enclose function. Examples: |
| | *10 |
| | 1 |
| | 'ONE' 'TWO' 'THREE' |
| | ONE |

| **Dyadic - Take:** | Selects the number of components indicated by the left argument from the right argument. If the left argument is positive, the take function selects the components from the beginning of the right argument. If the left argument is negative, the take function selects the components from the end of the right argument. Examples: |
| | A+2 4 6 8 |
| | 3*A |
| | 2 4 6 |
| | -3*A |
| | 4 6 8 |

| **Dyadic - Drop:** | Similar to take except that the indicated items are dropped instead of selected. Examples: |
| | A+2 4 6 8 |
| | 2*A |
| | 6 8 |
| | -1*A |
| | 2 4 6 |
### Mixed Functions (cont.)

<table>
<thead>
<tr>
<th>Function</th>
<th>Usage</th>
</tr>
</thead>
</table>
| • | **Monadic** - **Type:**  
| | Returns an array containing 0 where argument items are numeric or blank where argument items are text. Example:  
| | ```  
| '1 'BRUCE' 2 (3 4)  
| 0 1 0 0 0  
| '=1 'HI' 2  
| 0 1 1 0  
| ```  
| | **Dyadic** - **Membership:**  
| | Returns 1 if a given item of the left argument is an item of the right argument, and 0 if it is not. The result has the same dimensions as the left argument. Examples:  
| | ```  
| A←16  
| B←2×4  
| B×A  
| 1 1 1 0  
| C←'ABCDEFGHIJKLMNOPQRSTUVWXYZ'  
| D←3 3p'HOWAREYOU'  
| D×C  
| 1 0 0  
| 1 0 1  
| 0 0 0  
| ```  
| | **•**  
| | **Monadic** - **Execute:**  
| | Treats its argument (a character scalar or vector) as an APL statement. Examples:  
| | ```  
| $'2+3'  
| ```  
| | **c**  
| | **Monadic** - **Enclose:**  
| | Increases the depth of the argument by 1 and decreases the rank. If an axis is not specified, all axes are enclosed and the result is a scalar. When an axis is specified, the rank of the result is the rank of the argument minus the number of axes being enclosed.  
| | The enclose of a simple scalar yields the scalar unchanged. Examples:  
| | ```  
| c'B'  
| ```  
| | ```  
| B  
| ```  
| | ```  
| c'VENICE'  
| ```  
| | ```  
| VENICE  
| ```  
| | ```  
| c[1]3 3p$9  
| ```  
| | ```  
| 1 2 3 4 5 6 7 8 9  
| ```
<table>
<thead>
<tr>
<th>Function</th>
<th>Usage</th>
</tr>
</thead>
</table>
| >        | Monadic - Disclose:  
          | Decreases the depth of the argument by 1 and increases the rank. If the axes are not specified, the new axes are inserted after the last axis of the argument.  
          | The disclose of a simple array yields the array unchanged. Examples:  
          | | p0+~c'HI'  
          | | HI  
          | | 2  
          | | p0+~(1 2) (3 4 5)  
          | | 1 2 0  
          | | 3 4 5  
          | | 2 3  
|          | Dyadic - Pick:  
          | Select an item from the right argument specified by the path indices in the left argument. Each item of the left argument must be a simple scalar or vector of integer indices which selects an item to be indexed by the next item of the left argument. Example:  
          | | 2 >7 8 9  
          | | 8  
          | | 2 1 (2 1) > 1 ((2 2p3 4 5 6) 7) 8  
          | | 5 't' >9  
|          | Monadic - Depth:  
          | Returns a simple non-negative integer scalar indicating the maximum depth of nesting in the right argument.  
          | A simple scalar number or character has depth 0. Arrays containing simple scalar numbers or characters have depth 1. Examples:  
          | | 1'A'  
          | | 0  
          | | 1 2 3  
          | | 1 'ABC' (4 (5 6)) 7  
|          | Dyadic - Equivalence:  
          | Returns a simple logical scalar. The result is 1 if the left argument is identical to the right argument, otherwise the result is 0.  
          | Arrays are identical if they have the same shape and the same values in all corresponding positions. Empty arrays are identical only if their prototypes are identical. Examples:  
<p>| | | |
|          | | |</p>
<table>
<thead>
<tr>
<th>Function</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>'APPLE'='APPLE'</td>
<td>Monadic - Matrix Inverse: Used to invert matrices. Examples:</td>
</tr>
<tr>
<td>'CPV'='CPV'</td>
<td></td>
</tr>
<tr>
<td>9=,9</td>
<td></td>
</tr>
<tr>
<td>0 't'=0</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Dyadic - Matrix Divide: Used for solving systems of linear equations. Examples: |

| A+3 3p4 2 -5 5 -4 4 2 2 -20 | BP+2 |
| 0.17 | 0.072 | -0.029 |
| 0.26 | -0.17 | -0.099 |
| 0.043 | -0.0097 | -0.063 |

Monadic - Transpose: Performs row column transposition on its matrix argument. Examples: |

| A | QA |
| 1 2 3 4 5 | 1 6 11 |
| 6 7 8 9 10 | 2 7 12 |
| 11 12 13 14 15 | 3 8 13 |
| 4 9 14 | 4 9 14 |
| 5 10 15 | 5 10 15 |

Dyadic - Transpose: Returns an array similar to the right argument except that the coordinates (dimensions) are changed according to the left argument (that is, the left argument specifies the new position of the original coordinates). Examples: |

| B+2 4 3p124 | 2 1 39B |
| 1 2 3 | 1 2 3 |
| 13 14 15 | 13 14 15 |
### Table 3-3. Mixed Functions (cont.)

<table>
<thead>
<tr>
<th>Function</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 5 6</td>
<td>16 17 18</td>
</tr>
<tr>
<td>7 8 9</td>
<td>19 20 21</td>
</tr>
<tr>
<td>10 11 12</td>
<td>22 23 24</td>
</tr>
<tr>
<td>Φ</td>
<td>Monadic - Reversal:</td>
</tr>
<tr>
<td></td>
<td>Reverses the order of the components of a vector, or the components of each each row of a matrix. Examples:</td>
</tr>
<tr>
<td>A+1 2 4 6</td>
<td>ΦA</td>
</tr>
<tr>
<td>6 4 2 1</td>
<td>Φ+5</td>
</tr>
<tr>
<td>5 4 3 2 1</td>
<td></td>
</tr>
<tr>
<td>Dyadic - Rotation:</td>
<td></td>
</tr>
<tr>
<td>Rotates the items in the right argument as specified by the left argument (i.e. according to the number of places specified in the left argument). Examples:</td>
<td></td>
</tr>
<tr>
<td>A+1 2 4 6</td>
<td>ΦA</td>
</tr>
<tr>
<td>2 4 6 1</td>
<td>2ΦA</td>
</tr>
<tr>
<td>4 6 1 2</td>
<td></td>
</tr>
<tr>
<td>θ</td>
<td>Monadic - Reversal along the first coordinate:</td>
</tr>
<tr>
<td>Same as Φ above except along the first coordinate instead of the last. This is equivalent to Φ[1:0]. Example:</td>
<td></td>
</tr>
<tr>
<td>θ+HAT+3 4φ+12</td>
<td></td>
</tr>
<tr>
<td>1 2 3 4</td>
<td></td>
</tr>
<tr>
<td>5 6 7 8</td>
<td></td>
</tr>
<tr>
<td>9 10 11 12</td>
<td>θHAT</td>
</tr>
<tr>
<td>9 10 11 12</td>
<td>6HAT</td>
</tr>
<tr>
<td>5 6 7 8</td>
<td>1 2 3 4</td>
</tr>
<tr>
<td>Dyadic - Rotation along the first coordinate:</td>
<td></td>
</tr>
<tr>
<td>Same as Φ above, except along the first coordinate instead of the last. This is equivalent to Φ[1:0]. Examples:</td>
<td></td>
</tr>
<tr>
<td>θ+HAT+3 4φ+12</td>
<td></td>
</tr>
<tr>
<td>1 2 3 4</td>
<td></td>
</tr>
<tr>
<td>5 6 7 8</td>
<td></td>
</tr>
<tr>
<td>9 10 11 12</td>
<td>θHAT</td>
</tr>
<tr>
<td>5 6 7 8</td>
<td>1 2 3 4</td>
</tr>
</tbody>
</table>
Operator Summary

APL operators usually take functions (primitive, system, or user-defined) and produce a derived function which is then applied to array arguments. The manner in which the function argument is applied to the array arguments distinguishes the various operators.

The letters f and g in the following table represent any functions.

<table>
<thead>
<tr>
<th>Function</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>f/</td>
<td></td>
</tr>
<tr>
<td><strong>Monadic</strong> - Reduction:</td>
<td></td>
</tr>
<tr>
<td>Inserts the APL function specified to the left of the / between each item of the right argument, performs the operation from right to left, and returns a value with one less coordinate than the right argument. Examples:</td>
<td></td>
</tr>
<tr>
<td>+/1 2 3 4 5</td>
<td>15</td>
</tr>
<tr>
<td>-/1 2 3 4 5</td>
<td>3</td>
</tr>
<tr>
<td>□*N+3 4%12</td>
<td>1 2 3 4</td>
</tr>
<tr>
<td>5 6 7 8</td>
<td>9 10 11 12</td>
</tr>
<tr>
<td>+/N</td>
<td>10 26 42</td>
</tr>
<tr>
<td>-/N</td>
<td>-2 -2 -2</td>
</tr>
</tbody>
</table>

| Dyadic - Compression and Replicate: |       |
| Suppresses some items of a vector and retains others. Items of the right argument corresponding to a 1 in the left argument are retained while those corresponding to a 0 are dropped. If either argument contains just one item, it applies to all items of the other arguments. Examples: |       |
| ABCD |       |
| A*5 7 9 11 | B*12ABCD |
| 1 0 1 1/A | 5 9 11 |
| 1 0 1 1/B | ACD |
| □*MAT+3 4%12 | 1 2 3 4 |
| 5 6 7 8 | 9 10 11 12 |
| 1 0 1 0/MAT | 1 3 |
| 5 7 | 9 11 |

Replicate is like compression but this function will replicate items as well as suppress. In this case, the left argument is an integer vector, whose items are greater than or equal to zero. Each item of the left argument indicates the number of times the corresponding item in the right argument is to be replicated. Examples:
<table>
<thead>
<tr>
<th>Function</th>
<th>Usage</th>
</tr>
</thead>
</table>
| f/f      | Monadic — Reduction along the first coordinate:  
Same as f/ above except reduction occurs along the first coordinate rather than the last (equivalent to f/[010]). Examples:  
\[
\begin{array}{c}
\text{fH^N+3 4p12} \\
1 2 3 4 \\
5 6 7 8 \\
9 10 11 12 \\
\text{+fH} \\
15 18 21 24 \\
\text{-fH} \\
5 6 7 8
\end{array}
\]  
Dyadic — Compression along the first coordinate:  
Same as above except that compression or replication is along the first coordinate instead of the last. Equivalent to /[010]. Examples:  
\[
\begin{array}{c}
\text{fHAT*3 4p12} \\
1 2 3 4 \\
5 6 7 8 \\
9 10 11 12 \\
\text{0 1 0fHAT} \\
5 6 7 8
\end{array}
\]  
| f.g      | Dyadic — Generalized inner product:  
This operator is a generalized form of the inner product of matrix multiplication. The particular form that corresponds to traditional matrix multiplication is \(A+.xB\), where the second dimension of matrix \(A\) is the same as the first dimension of \(B\). The result has the same first dimension as \(A\) and the same second dimension as \(B\). In the conventional matrix inner product, each item of the result is the sum of products of items from \(A\) and \(B\) (see Section 5 for detailed description). The APL generalized inner product allows different forms such as the sum of equality tests, the maximum of sums, etc. Examples:  
\[
\begin{array}{c}
A=2 3p16 \\
B=3 2p-16 \\
A \\
1 2 3 \\
4 5 6 \\
\text{-1 -2} \\
\text{-3 -4} \\
\text{-5 -6} \\
A+.xB
\end{array}
\]  

Table 3-4. Operators (cont.)
### Table 3-4. Operators (cont.)

<table>
<thead>
<tr>
<th>Function</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>-22 -28</td>
<td></td>
</tr>
<tr>
<td>-49 -64</td>
<td></td>
</tr>
<tr>
<td>A+.=B</td>
<td></td>
</tr>
<tr>
<td>0 0 0 0</td>
<td></td>
</tr>
<tr>
<td>A+.+B</td>
<td></td>
</tr>
<tr>
<td>0 -1 3 2</td>
<td></td>
</tr>
</tbody>
</table>

The general form is $Af.gB$ where $f$ and $g$ represent any function. $A$ and $B$ may be vectors, matrices, or higher order arrays, subject to conformability rules described in Section 5.

#### Dyadic - Generalized outer product:

This operator is a generalization of matrix outer product, $Aof+B$. The conventional form multiplies each item of $A$ by each item of $B$. The shape of the result is the catenation of the shapes of $A$ and $B$. In the generalized form, multiplication may be replaced by any APL function. Examples:

```apl
A+1+15
A+4+A
0 1 2 3 4
1 2 3 4 5
2 3 4 5 6
3 4 5 6 7
4 5 6 7 8
Aο.×A
0 0 0 0 0
0 1 2 3 4
0 2 4 6 8
0 3 6 9 12
0 4 8 12 16
Aο.<A
0 1 1 1
0 0 1 1
0 0 0 1
0 0 0 0
```

#### Monadic - Scan:

Returns value of same shape as argument. For vectors, the $i$'th result item is formed by taking the first $i$ argument items, placing $f$ between them, and evaluating right to left. For example:

```apl
+\1 3 5 7 9
1 4 9 16 25
1 3 \1 1 5
3 2 \3 2 2
```

A coordinate specification $[X]$ may be used; if omitted, the last coordinate is assumed.

```apl
+\[1]2 3p+6
1 2 3
5 7 9
```
<table>
<thead>
<tr>
<th>Function</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dyadic</strong> - Expansion:</td>
<td></td>
</tr>
<tr>
<td>Inserts additional items into an array. For each 0 in the left argument, a prototype item (blank for character, zero for numeric) is inserted in the result, which otherwise is the same as the right argument. Examples:</td>
<td></td>
</tr>
<tr>
<td>$A+1 2 3 4$</td>
<td></td>
</tr>
<tr>
<td>$B+'ABCD'$</td>
<td></td>
</tr>
<tr>
<td>$1 0 1 0 1 0 \backslash A$</td>
<td></td>
</tr>
<tr>
<td>$1 0 2 0 3 0 4$</td>
<td></td>
</tr>
<tr>
<td>$1 0 1 0 1 0 \backslash B$</td>
<td></td>
</tr>
<tr>
<td>$A B C D$</td>
<td></td>
</tr>
<tr>
<td>$0 \backslash H+3 4 \backslash 0 \backslash AV[65+12]$</td>
<td></td>
</tr>
<tr>
<td>$ABCD$</td>
<td></td>
</tr>
<tr>
<td>$E F G H$</td>
<td></td>
</tr>
<tr>
<td>$I J K L$</td>
<td></td>
</tr>
<tr>
<td>$1 0 1 0 1 0 \backslash H$</td>
<td></td>
</tr>
<tr>
<td>$A B C D$</td>
<td></td>
</tr>
<tr>
<td>$E F G H$</td>
<td></td>
</tr>
<tr>
<td>$I J K L$</td>
<td></td>
</tr>
<tr>
<td><strong>Monadic</strong> - Scan along the first coordinates:</td>
<td></td>
</tr>
<tr>
<td>Same as $f \backslash [0]$. Thus, as above,</td>
<td></td>
</tr>
<tr>
<td>$+%2 3 % 6$</td>
<td></td>
</tr>
<tr>
<td>$1 2 3$</td>
<td></td>
</tr>
<tr>
<td>$5 7 9$</td>
<td></td>
</tr>
<tr>
<td><strong>Dyadic</strong> - Expansion along the first coordinate:</td>
<td></td>
</tr>
<tr>
<td>Same as above, except expansion occurs along the first coordinate rather than the last. This is equivalent to $\backslash [0]$. Example:</td>
<td></td>
</tr>
<tr>
<td>$0 \backslash H+3 4 \backslash 0 \backslash AV[65+12]$</td>
<td></td>
</tr>
<tr>
<td>$ABCD$</td>
<td></td>
</tr>
<tr>
<td>$E F G H$</td>
<td></td>
</tr>
<tr>
<td>$I J K L$</td>
<td></td>
</tr>
<tr>
<td>$1 0 1 0 1 \backslash H$</td>
<td></td>
</tr>
<tr>
<td>$ABCD$</td>
<td></td>
</tr>
<tr>
<td>$E F G H$</td>
<td></td>
</tr>
<tr>
<td>$I J K L$</td>
<td></td>
</tr>
<tr>
<td><strong>Monadic</strong> - Each:</td>
<td></td>
</tr>
<tr>
<td>Returns a value of the same shape as the argument. Each item of the result is formed by applying the monadic function to the corresponding item of the right argument. Examples:</td>
<td></td>
</tr>
<tr>
<td>$6''ABC' 'HAPPY'$</td>
<td></td>
</tr>
<tr>
<td>$3 5$</td>
<td></td>
</tr>
<tr>
<td>$12123$</td>
<td></td>
</tr>
<tr>
<td>$0''XYZ' 'HOOD'$</td>
<td></td>
</tr>
<tr>
<td>$ZYX DOOM$</td>
<td></td>
</tr>
</tbody>
</table>
### Defined Function References

Defined functions are used in much the same way as primitive functions, but defined functions must first be formed by the user instead of being an inherent part of the language. Once a defined function has been formed, or "defined", it is referenced by its assigned name. (Naming conventions are described earlier in this section under Names.) A general discussion of functions is given in this section; for a detailed discussion, see Section 7, Defined Functions.

Like primitive functions, defined functions can have arguments which in turn have attributes of domain, rank, length, and shape (see Functions and Arguments above). Functions are classified as monadic, dyadic, or niladic, according to their number of arguments. A monadic function has one argument to the right of the function name. A dyadic function may have one or two arguments, one to the right of the function name and one optionally to the left. A niladic function has no arguments; the function name is referenced by itself.

The right argument is the value of the largest, complete APL expression immediately to the right of a function. For the example below, *F* is a function whose right argument is 2+3.

\[(F \ 2+3) \ 'POUNDS'\]

In this case, the character vector 'POUNDS' is not included in the argument since the parenthesis splits the example into two distinct expressions.

The left argument is the value of the smallest complete APL expression to the left of a function. In the example below, *D* is a dyadic function whose left argument is (3).

\[2+ \ (3) \ D \ 4\]

In this case, the parenthetical expression (3) is the smallest complete APL expression immediately to the left of *D*. 2+(3) is also an APL expression, but it is larger. Therefore, the above example is interpreted as

2+result

where "result" is the result supplied by the function reference

\[(3) \ D \ 4\]

In addition, any of the classes of defined functions may specify an implicit or explicit result. Thus there are actually six types of defined functions: monadic, dyadic, and niladic each of which may optionally produce a result.

---

**Table 3-4. Operators (cont.)**

<table>
<thead>
<tr>
<th>Function</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dyadic - Each:</td>
<td>Returns a value of the same shape as the left and right arguments (a singleton argument is extended to the shape of the higher ranked argument).</td>
</tr>
<tr>
<td></td>
<td>Each item of the result is formed by applying the dyadic function to the corresponding items of the left and right argument. Examples:</td>
</tr>
<tr>
<td></td>
<td>2°°°ABC 'HAPPY'</td>
</tr>
<tr>
<td></td>
<td>AB HA</td>
</tr>
<tr>
<td></td>
<td>10''BCA' (t4)</td>
</tr>
<tr>
<td></td>
<td>CAB 2 3 4 1</td>
</tr>
</tbody>
</table>
The class is determined by the way a function is defined (that is, the function header), and it affects the way a function is referenced in an expression. Defined functions with explicit results may appear in compound expressions, much like primitive functions. Defined functions without results may appear alone; they cannot appear in compound expressions except as the last function to be executed.

A defined function may reference itself; that is, it may be recursive. A recursive function is one that references itself in the process of its execution.

When a function is invoked, it may complete execution and return a result or it may become suspended or pendent during execution. A suspended function is one in which execution has been stopped before completion (the reasons for stopping execution are given under Suspending Execution in Section 7). A pendent function is usually one that has referenced a suspended function and is unable to complete execution because of the suspended function. Suspended functions are always stopped "between" lines, but a pendent function is stopped in the process of executing a line. A function can be both suspended (stopped at some point) and pendent (in execution at some point). For instance, if a recursive function is stopped after it calls itself, it is suspended (at the stop) and pendent (where it called itself).

Assignment

The following paragraphs define simple assignment, multiple assignment, and indexed assignments.

Simple Assignment

The assignment symbol, denoted by a left-pointing arrow, is used to assign values to named variables or to a system variable. (Some programmers may refer to this symbol as the specification symbol or the replacement symbol, but the term assignment symbol is used throughout this manual.) It is the assignment that causes a variable to be a scalar, a vector, a matrix, or a higher-order array. The assignment of a value or an expression to a quad displays the value. Examples of assignments are shown below:

\[
\begin{align*}
A & = 5 + 2 \times 4 \\
B & = 1 2 3 4 5 \\
C & = 2 \ 4 \ 6 \\
D & = 2 \ 3 \ 5 \ 6 \ 1 \ 2 \ 8 \ 9 \\
E & = D
\end{align*}
\]

Assigns the value of the expression \(5 + 2 \times 4\) to variable \(A\).

Indicates that \(B\) is to be a vector with the values 1, 2, 3, 4, and 5.

Another way of assigning the numbers 1 through 5 to variable \(B\). (Assuming an index origin of 1.)

Indicates that \(C\) is to be a matrix (with two rows and four columns) and that it is to be made up of the values 1 through 8 (assuming an index origin of 1), as shown here:

\[
\begin{bmatrix}
1 & 2 & 3 & 4 \\
5 & 6 & 7 & 8
\end{bmatrix}
\]

Indicates that \(D\) is to be a matrix (with two rows and three columns) and that it is to be made up of the values 5, 6, 1, 2, 8, and 9, as shown here:

\[
\begin{bmatrix}
5 & 6 & 1 \\
2 & 8 & 9
\end{bmatrix}
\]

Indicates that the value of \(D\) is assigned to \(E\).
Multiple Assignments

APL allows repeated use of assignment, or multiple assignments, in a single statement. Examples of multiple assignment are shown as follows:

\[
\begin{align*}
A &+ 5, B &+ 6 \\
5 & 6 & 6 \\
Z &+ 2 + Y &+ 2 + X &+ 5 \\
X, Y, Z &+ 5 \\
D &+ C &+ 2 &+ 3 &+ 4 &+ 5 \\
2 &+ 3 &+ 4 &+ 5
\end{align*}
\]

Vector Assignment

This notation may be used to assign each item of a vector to a name in a list of names. In this case, the specification symbol (\(\_\)) is preceded by the list of names enclosed in parentheses. The specification symbol must be followed by an APL expression which produces a vector having the same length as the number of names.

Examples:

\[
\begin{align*}
\text{(A B C)} &+ 1 2 3 \\
A &\_ B &\_ C \\
1 &2 &3
\end{align*}
\]

\[
\begin{align*}
\text{(NAME ADDRESS)} &+ \text{"JOE WHO" \ '21 CENTURY BLVD, LOS ANGELES"} \\
\text{NAME} &\_ \text{JOE WHO} \\
\text{ADDRESS} &\_ \text{21 CENTURY BLVD, LOS ANGELES} \\
28
\end{align*}
\]

Indexed Assignment

One or more items of an already established array may be assigned new values. This is done by placing the variable name and the index designation(s) to the left of the assignment symbol, and the new value(s) to the right, as shown below (these examples all assume an index origin of 1):

\[
\begin{align*}
D &+ A &+ 1 5 4 3 2 \\
1 &5 &4 &3 &2 \\
A &\_ [1 2] &+ 2 3 \\
A &2 &3 &4 &3 &2 \\
A &\_ [1] &+ 0 \\
A &0 &0 &0 &0 \\
D &\_ B &+ 2 &3 &+ 0 \\
1 &2 &3 &4 &5 &6 \\
B &\_ [1 2] &+ 4 \\
B &1 &4 &3 &4 &5 &6 \\
B &\_ [1] &+ 0 \\
B &0 &0 &0 &0 &0
\end{align*}
\]
Selective Assignment

This operation permits selected elements of a named array to be given new values while leaving the shape and the unselected elements unchanged. Bracket indexing or use of the selection functions are used to select the array elements to be changed. The selection functions that are used with selective specification are ravel (monadic \(\cdot\)), reshape (monadic \(\rho\)), take (dyadic \(\oplus\)), drop (+), first (+), transpose (\(\otimes\)), reversal (monadic \(\otimes\)), rotate (dyadic \(\otimes\)), compression (\(\otimes\)), pick (dyadic \(\otimes\)) and disclose (monadic \(\otimes\)).

The result of the selection expression must be a subset or re-arrangement (or both) of selected element locations. Only those selected locations receive the new value. The value being assigned must have the same shape as the selection expression after skipping all dimensions of length 1 in both.

Examples:

\[
\begin{align*}
N+5 & 5p 1 2 4 3 \\
(4*,N)/,N)+0 & \quad \text{a REPLACE ALL 4S WITH 0} \\
1 & 2 0 3 1 \\
2 & 0 3 1 2 \\
0 & 3 1 2 0 \\
3 & 1 2 0 3 \\
1 & 2 0 3 1 \\
\end{align*}
\]

\[
\begin{align*}
(1 10^N)+55 & \quad \text{a REPLACE DIAGONAL} \\
N & 55 2 0 3 1 \\
2 & 55 3 1 2 \\
0 & 3 55 2 0 \\
3 & 1 2 55 3 \\
1 & 2 0 3 55 \\
\end{align*}
\]

Input/Output

This subsection describes how the user can enter input and display output.

Input/Output Devices

The CP-6 APL system gives the user a choice of five input/output methods:

- APL/ASCII terminal input/output: a terminal with either bit paired or typewriter paired APL/ASCII character transmission codes.
- ASCII terminal input/output.
- Batch input/output.
- File input/output.
- Blind input/output.

The input/output described in this section refers to terminals with the APL character set.
General Input/Output

After logging on to CP-6 and invoking APL, the user is in immediate execution mode and can enter input whenever the carriage or cursor is indented six spaces. The fundamental item of input to APL is the line. A line is a collection of characters that does not include the carriage return. Striking the RETURN key completes a line, and APL attempts to interpret it and perhaps output data. An incomplete line can be corrected as described in Section 2. User input and computer output are easily distinguished at the terminal; computer output usually begins at the left margin while user input is usually indented six spaces from the left margin. An input line is limited to 390 characters in length, not counting the carriage return (overstrikes count as single characters).

Types of Input

CP-6 APL acknowledges four kinds of input: direct, evaluated, quote quad, and blind. Direct input occurs when APL is not executing the user's program. Evaluated input results from quad-input execution, quote-quad input results from quote-quad execution, and blind input results from quad-0 through quad-9 execution. Direct input, evaluated input, and quote-quad input are described below and are considered to exist only after input translation and current-line editing. Blind input is covered in Section 16.

Direct Input

Direct input is entered during execution mode. APL is ready to accept direct input when it skips to a new line and indents six spaces. Evaluation of direct input occurs immediately, and the response is either printed at the left margin (if the input was a non-assignment statement) or assigned to a variable (if the input was an assignment statement). Examples of direct input follow:

```
5+2*4
0.625
A+A+5
10
1+8+3 4px12
1 2 3 4
5 6 7 8
9 10 11 12
```

Evaluated Input

The quad symbol ⌥ can be used as an argument in a statement, to denote that input is desired. When APL encounters the quad during statement execution it halts execution and requests input by printing the symbols ⌥ at the left margin. A response of any valid APL expression causes execution to continue, using the value obtained in response to the quad symbol. Examples:

```
⌥: 8+⌥
  2
  4
  5*⌥
⌥: 1 2 3 4
  5 10 15 20
```
If the quad symbol is built into an input loop, the user can terminate the input requested by entering the symbol + (not followed by an argument). Simply entering nothing and pressing the RETURN key is not sufficient to terminate the input request; it will merely cause the 0: to reappear at the left margin. An example of escaping from an input request is shown below:

```
VCUBE:A

CUBE
0: 3
27
0: 4
64
0: 5
125
```

Entering any of the following system commands will terminate an input request: ;CLEAR, ;LOAD, ;OFF, ;END, ;SIC, or ;CONTINUE. Entering other system commands merely causes the 0: to reappear after the command is executed.

Functions can be defined during evaluated input. This is similar to function definition during normal (direct) input except that at the conclusion of the definition, APL re-requests evaluated input. This is to be expected since when APL originally requested evaluated input it needed a value, and defining a function provides no value. This enhancement is not limited to just providing definition capability. The full range of function definition mode features are available during evaluated input:

- Creating a new function
- Revising an existing non-pendent function (If a function makes an evaluated input request, the function becomes pendent. Therefore, that function cannot be opened during the evaluated input request): inserting a line, deleting a line, replacing a line, and editing characters of a line.
- Displaying one or more lines of the open function.

Entering an ;SI or ;SINL command in response to an input request will cause the state indicator to contain a 0. For example:

```
10+ [0: 10+]
0: ;SI
0: [0:]
5
```
Quote-Quad Input

The quote-quad symbol ~ (except when to the left of an assignment arrow) denotes literal input. When APL encounters this symbol during statement execution, it awaits user input (nothing is printed to prompt for input). Literal character strings are entered without beginning and ending quote symbols, and a quote within a string is represented by one quote. Quote-quad input always produces a vector result. To terminate a request for literal input without having any value associated with the variable being requested, press the BREAK key twice.

Note that if the request for literal input is initiated from within an executing function and a double break is entered, execution of the defined function is suspended at that point. Examples of quote-quad input are:

```
A+~
B+~
Q U O T E S  A R E N ' T  N E E D E D
B
Q U O T E S  A R E N ' T  N E E D E D
X+'C A L I F O R N I A' + ~
A B C D E F G H I J K L M N
X
1 1 1 1 1 0 0 1 1 1
```

Output

As previously mentioned, the display of most computer output begins at the left margin. Important output characteristics are described below.

1. Width of line. The user can change the number of characters displayed on a line to any number from 32 to 390 via the `WIDTH` system command (see Section 8), or the `PW` system variable (see Section 11). Output processing always assumes that the left and right margin stops are placed full left and full right.

2. Fractional number. A fractional number is displayed with one leading zero to the left of the decimal point, even if the number was entered without zero. Examples of fractional numbers are:

```
.2+.4
0.6
2+3
0.6666666667
.123
0.123
```

3. Exponential notation. APL usually uses exponential form for printing numbers less than $10^{-5}$, or greater than $10^N$ where $N$ is the value of the `PP` system variable. Decimal form is used for other cases. Numbers printed in exponential form have a magnitude between one and ten followed by an appropriate exponent.

When an array is displayed, some numbers may be printed in exponential form and some in decimal form, depending on the size of each number. Numbers in a vector are printed with one space between each number, as shown below:

```
1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 1 0
```

When a matrix is displayed, each column of numbers is printed all in exponential form or all in decimal form. One number requiring exponential form in a column will cause all the numbers in that column to be printed in exponential form. One column of blanks separates columns of numbers. Numbers in a matrix are printed with decimal points aligned, as shown below:
4. Significant digits. CP-6 APL carries out all calculations to approximately 18 significant digits, and displays the result rounded off to the value of ODP digits. Any trailing zeros are suppressed in the display. Examples are shown below:

\[ \begin{align*}
4+3 & \approx 7.333333333 \\
5+2 & = 7
\end{align*} \]

The user can use the \texttt{DIGITS} system command (see Section 8) or the \texttt{OPP} system variable to change the number of significant digits displayed, to a number ranging from 1 to 20. Examples are shown below:

\[ \begin{align*}
\texttt{OPP} & +4 \\
4+3 & = 7.333333333 \\
5+2 & = 7
\end{align*} \]

5. Comparison Tolerance. The arithmetic functions (addition, subtraction, multiplication, and division) are implemented in the computer as functions which represent real numbers through a set of discrete numbers. In CP-6 APL, calculations are carried out to approximately 18 decimal digits. Comparison tolerance is provided by APL to partly disguise the fact that only 18 digits of precision are available. The default value of comparison tolerance in a clear workspace is \(10^{-13}\) which causes the equals function to return 1 if the numbers being compared are equal in the first 13 digits. An example of comparison tolerance in comparison is:

\[ \begin{align*}
1=1+2E^{-13} & \approx 1.000000000 \\
0 & \approx 1.000000000 \\
1 & \approx 1.000000000 \\
1 & \approx 1.000000000
\end{align*} \]

6. Numeric and character vectors. Numeric vectors are displayed with one blank between items, while character vectors are displayed with no blanks between items, as shown:

\[ \begin{align*}
2 & 3 4 5 6 7 8 \\
'ABCXYZ' & \equiv ABCXYZ
\end{align*} \]

If an array contains both numeric and character scalar values, a trailing blank column is included after each numeric column (except the last column).

\[ \begin{align*}
1 & 'A' 2 \\
1 & A2
\end{align*} \]

7. Arrays of two or more dimensions. The components of a two-dimensional array (i.e., a matrix) are displayed in a rectangular arrangement. The components of an array of more than two dimensions (i.e., a higher-order array) are displayed as a set of rectangles. Character arrays of two or more dimensions are displayed with no spaces between columns. In addition, arrays of more than two dimensions are displayed with extra blank lines separating planes. Examples are shown below:
3 5p-2+15
-1 0 1 2 3
4 5 6 7 8
10 11 12 13
2 3 4p+24
5 6 7 8
10 11 12
13 14 15 16
17 18 19 20
21 22 23 24
25 26 27 28
3 4p'NOWISTHETIME'
NOW
STHE
TIME
2 2 5p'ABCDEF GHJKLMNOPQ'
ABCDE
F GH
JKL MNOPQR

8. Simple. An APL array is simple if every item of the array is either a scalar character or a scalar number.

9. Nested Arrays. An array is nested if it is not simple. That is, an array is nested if an item of the array contains another APL array of rank greater than 0. Nested arrays, like other APL arrays, are displayed with columns aligned. The column width is determined by the widest formatted representation of the items in the column.

The space required to display non-simple items is controlled by the system variable OPS. The column width for a non-simple item may be stated as the width of the formatted value plus the value (1+1+OPS). The row depth for a non-simple item can be stated as the number of rows required to display the value plus the value (1+1+OPS).

The first two items in OPS control the placement of the arrays within the column and row. The first item controls the vertical placement of the formatted array and the second item controls the columnar placement of the formatted array. The first item of OPS can be -1 (top), 0 (center), or 1 (bottom). The second item of OPS can be -1 (left), 0 (center), or 1 (right).

The last two items of OPS can be negative to indicate that a vertical bar or box be drawn around the border of the array. The magnitude of the value must be greater than 1 for the box to be drawn.

The following is an example of displaying nested arrays:

OPS+0 0 "3 "3 a CENTER AND DRAW BOXES
A+2 2p14 0 B+3 4p'ABCDEFGHJKLMNOPQR'
C+2 3pA B T 'Z' A B
C

+++++ ++++++
1 2 | ABCD |
3 4 | EFGH |
+++++ ++++++

Z
1 2 | ABCD |
3 4 | EFGH |
+++++

+++++ ++++++
1 2 | ABCD |
3 4 | EFGH |
+++++ ++++++
10. Prototypes. Every APL array contains a prototype which is the type of the first item of the array. For an array whose first item is a simple scalar number, the prototype is 0; for an array whose first item is a simple scalar character, the prototype is a blank. For all arrays, the prototype has the same structure (shape and depth) as the first item and contains zeroes where the corresponding item is numeric, and blanks where the corresponding item is character.

11. Empty arrays. An empty array (an array of no components) can take the form of a vector or an array of two or more dimensions. An empty array produces no display (just another prompt for input). An empty vector (also known as a null vector) can be entered in one of the following ways: 10 or 'o. Similarly, examples of entering empty arrays of two or more dimensions are 0 2p4 and 0 0 0p0. The display of an empty vector and an empty matrix are shown below:

```
10.
0 2p6
2+2
```

Note that an empty numeric vector is represented by the expression 10 and any empty character vector is represented by the expression ''. These expressions cannot always be used interchangeably because their prototypes differ. An example is in their use as the right argument in an expansion operation:

```
0''
0"0
```

Empty vectors are useful in initializing vectors, in branching, and in the limiting cases of some algorithms.

Note that the use of an empty array as the argument of a scalar function will result in an empty array:

```
34+0p0
0\2 0p5
```

12. Blind output. Blind output (see in Section 16) is output as one record of character (literal) data.

13. Stopping a display. The user can stop display of output by pressing the BREAK key.

14. Quad output. When \ appears immediately to the left of an assignment arrow, the value of the expression to the right of the arrow is output. Example:

```
\+A\+2\+3
```

5

15. Bore output. Normal output includes a concluding carriage return in order that the succeeding entry (whether it is input or output) will begin at the first position on the following line. Bore output, denoted by expressions of the form ~X, does not include a carriage return if the expression is followed either by another expression denoting bore output or character input (of the form X~). For example:

```
\v F
[1] \p'TRUE OR FALSE: THE SQUARE OF '
[2] \p\p4
[3] \p' IS '
[4] \p((\p4)\p2
[5] X\p v
```

Output CE38-04
TRUE OR FALSE: THE SQUARE OF 2 IS 9

FALSE

The carriage returns normally caused by the width setting (OPW) are still present in bare output.

Because any expression of the form ^X entered at the keyboard (rather than being executed within a defined function) is followed by another keyboard entry, (concluded by a carriage return), its effect is indistinguishable from the effect of the corresponding normal output.
Section 4
Expression Evaluation

Order of Evaluation
The following subsections describe the order in which APL evaluates expressions.

Right to Left
APL evaluates expressions from right to left, not from left to right as in most written languages. Each function or assignment symbol in an expression operates on the entire expression to the right of it, with the rightmost expression evaluated first, then the next rightmost, and so on. In illustration, notice the following expression:

\[ 20 \times 4 + 5 + 2 = 130 \]

In this expression the result of \( 5 + 2 \) is added to 4, and the result of that is multiplied by 20, thereby yielding the value 130.

Precedence of Functions
Unlike most programming languages (and unlike common algebraic usage) no APL function has precedence over another function. A division operation, for example, is not performed before an adjacent addition unless, of course, the division appears to the right of the addition. Note that in the example cited above, the conventional algebraic function hierarchy would have treated the expression as equivalent to \((20 \times 4) + (5 + 2)\), which would have resulted in the value 82.5.

Parentheses
Parentheses can be used in an expression to depart from the right-to-left rule for function execution or left-to-right order for operator execution. They are used just as they are in mathematics for grouping. APL evaluates everything within a pair of parentheses (from right to left) before evaluating the expression of which they are a part. There must be an equal number of left and right parentheses. The beginning APL user may find parentheses convenient to avoid confusion over the difference between APL and conventional algebraic notation.

Some examples of the use of parentheses are shown below:

\[ (((3+5)) \times 2 + 1) \]
\[ 12 \ 15 \ 18 \ 21 \ 24 \]
\[ ((6+2) \times 5 \times 4) + 3 + 12 \]
\[ 4 \]
\[ 6 + 2 \times 5 \times 4 + 3 + 12 \]
\[ 2.25 \]
\[ (20 \times 4) (+) (5 + 2) \]
\[ 82.5 \]
Precedence of Operators

Operators have higher precedence than functions. They may be monadic or dyadic (but not both); they always produce a function which may be monadic, dyadic or both. The left operand of an operator is the expression to the left of the operator up to a function (or array) with an array or function to its left. The right operand of a dyadic operator is the first function or array to its right. Monadic operators have their only argument on their left.

Unlike functions, operators are permitted to have arguments that are functions.

Operators and their arguments combine to produce functions (called "derived functions") which are then executed like all other APL functions. In fact, the derived function that is produced by an operator may be used as an argument to another operator.

\[ A+o.+/(0 100)(0 10 20)(1 2 3 4) \]
\[ A \]
\[ 1 2 3 4 \]
\[ 11 12 13 14 \]
\[ 21 22 23 24 \]
\[ 101 102 103 104 \]
\[ 111 112 113 114 \]
\[ 121 122 123 124 \]

In this example, the plus-outer-product reduction is performed on the vector argument to produce the scalar enclosed matrix (which is subsequently disclosed by the first function). Notice that the + is the argument to the outer product operator o. and that this derived function (called plus outer product or \( o.+ \)) is the argument to the reduction operator (/).

Value of a Variable versus its Name

When APL encounters a name, it obtains the associated value immediately. This value becomes an argument, and the argument will not change value even if the named variable is assigned a new value. The following example illustrates this evaluation procedure:

\[ (K+2)+K+1 \]
\[ 3 \]

The \( K \) to the right of the plus sign was evaluated to the argument having, at that time, value 1. This argument did not change even though \( K \)'s value changed before the addition was completed.

Default Output

Default output occurs when a non-assignment statement is evaluated. That is, the result is displayed instead of being stored in memory. For example, \( 2*4 \) gives default output:

\[ 2*4 \]
\[ 8 \]

Default output is killed by assignment. For example, the expression \( A*2*4 \) prints no output at the terminal.

\[ A*2*4 \]

Instead, the value 8 is assigned to variable \( A \) and stored in computer memory.

When a compound statement (Section 6) includes both non-assignment and assignment expressions, the non-assignment expressions produce output while the assignment expressions do not. Some examples are:
Errors and Breaks

If the user discovers an error in a statement before the RETURN key is pressed, the user can RUBOUT to the error and retype the rest of the line as described in Section 2. (On all terminals, the standard CP-6 input line editing mechanism is applicable. See the CP-6 Programmer Reference Manual (CE40)). An example (using the RUBOUT key) is:

```
A+5+2 0 A+5+2 0 4+3
X=+5 0 Y=2+4
```

Errors and Breaks

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```
A+5xB+8x<R>
A+5xB+8+4
```

(R indicates <ESC> R.)

If the user has entered a line and APL detects an error or double break during statement execution, execution of the statement is terminated. If the statement in execution contains multiple assignments or is a compound statement, the assignments and expressions to the right of the termination point (denoted by a caret) will be completed. The current expression and any expressions to the left of the termination point will usually not be completed. If a dyadic operator or function is indicated, however, its left argument expression (possibly containing assignments) will have been completed before the function or operator was invoked. Examples are shown below (it is assumed that sidetracking, see Section 10, is not applicable in these examples).

```
C+4/(D+0)xZ+5
```

DOMAIN ERR
```
C+4/(D+0)xZ+5
```

```
C
```

UNDEFINED
```
C
```
```
A
```

```
C
```
```
D
```
```
Z
```
```
5
```

```
A+4+25,5 0 F=0 0 E=4+2+1 0 E+F
```

DOMAIN ERR
```
A+4+25,5 0 F=0 0 E=4+2+1 0 E+F
```

```
E
```

1.333333333
```
F
```
```
0
```

In both of these examples the user has attempted to divide by zero, thus producing a LINE ERR message. In the first example the error is detected before variable C is assigned a value, so C remains UNDEFINED as shown. In the second example, E and F had values assigned to them before the error was detected.

If the user has entered a line and APL detects a simple error before any part of the line is executed, APL displays the message LINESCAN ERR and a caret at the error point. The user can type <ESC> D to recall the line in error and edit it to correct the problem. For example:
Note that the difference between a *LINESCAN ERROR* and a *BAD CHAR error* is that the former involves an error in expression logic or syntax, while the latter involves the typing of an illegal APL character.
Section 5
APL Primitive Functions

A primitive function is a symbol indicating that a basic APL function, such as
addition or division, is to be performed. A symbol denoting a primitive function is
either a non-alphanumeric character or a combination of such characters. For
example, addition is denoted by the + symbol and division is denoted by the ÷ symbol.

Some of the basic primitive functions are "monadic" and others are "dyadic". That
is, some require a single argument and others require two. For example, the
reciprocal function is monadic (e.g., ÷A) and the division function is dyadic (e.g.,
A÷B). Most of the symbols denoting functions are used for both monadic and dyadic
functions. APL distinguishes between the monadic and dyadic use of any given
function by testing for the absence or presence of a left argument.

Syntax Conventions

Syntax conventions used throughout this section are as follows:

R denotes the result of a function.
÷ denotes the replacement of any previous value of the symbolic variable to the
left of the arrow.
A denotes a left argument.
B denotes a right argument.
H denotes a monadic function.
D denotes a dyadic function.

Following are some examples of the use of these conventions:

R÷H B R÷A D B

Argument Characteristics

In discussing functions, certain argument characteristics will be referenced
frequently. The terms used are described below.

Domain – In general, the type of data item such as integer data or
floating-point data. For some functions the domain of an argument
may be especially restricted (see the example for the circular
function later in this section).

Rank – The number of coordinates in an array argument. (A rank of
zero indicates a scalar.)

Length – The number of items in a coordinate of an argument.

Shape – The vector made up of the lengths of all coordinates of an
argument.

Domain Tables

In the tables listing the domains of the results for various types of argument
data, the following symbology is used:

N denotes numeric data.
C denotes character data.
L denotes logical data (1 or 0).
I denotes integer data.
F denotes floating-point data.
DE denotes a DOMAIN ERR.
RE denotes a rank error.

Scalar Functions

APL functions vary considerably in how they reference the items of array arguments and in the characteristics (rank and dimensions) of the result compared with those of the arguments. A group of functions called scalar functions follow a common set of rules with respect to the characteristics of the arguments and results. These functions, comprising the arithmetic group, the relational group, and the logical group, are so named because they are defined in terms of scalar arguments. Extensions of scalar functions to array arguments are equivalent to performing item-by-item scalar functions.

If an item of an array contains another APL array, the operation is performed on each item within the nested array repeatedly, until the operation selects a simple scalar numeric or character item. All of the rank, length and domain checks are made at each level of nesting. The shape of the resulting structure follows the rules at each function application level.

- Monadic Scalar Functions

  The argument used with a monadic scalar function may have any rank and dimensions. The result has the rank and dimensions of the argument. The domain of the result may differ from the domain of the argument.

- Dyadic Scalar Functions

  If the rank and dimensions of the argument used with a dyadic scalar function are the same, the function is performed on corresponding items of the two arguments and the result has the same rank and dimensions. If the arguments have different ranks or dimensions and both contain other than one item, a rank or length error will be reported.

  If one argument has multiple items and the other is a scalar or single item array, the function is performed on the single item with each item of the multiple item argument. The result has the rank and dimensions of the multiple item argument. If neither argument has multiple items, the result is given the shape of the higher ranked argument. The shapes of results of scalar functions for various arguments are tabulated below.

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  If the rank and dimensions of the argument used with a dyadic scalar function are the same, the function is performed on corresponding items of the two arguments and the result has the same rank and dimensions. If the arguments have different ranks or dimensions and both contain other than one item, a rank or length error will be reported.

  If one argument has multiple items and the other is a scalar or single item array, the function is performed on the single item with each item of the multiple item argument. The result has the rank and dimensions of the multiple item argument. If neither argument has multiple items, the result is given the shape of the higher ranked argument. The shapes of results of scalar functions for various arguments are tabulated below.

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  The argument used with a monadic scalar function may have any rank and dimensions. The result has the rank and dimensions of the argument. The domain of the result may differ from the domain of the argument.

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  If the rank and dimensions of the argument used with a dyadic scalar function are the same, the function is performed on corresponding items of the two arguments and the result has the same rank and dimensions. If the arguments have different ranks or dimensions and both contain other than one item, a rank or length error will be reported.

  If one argument has multiple items and the other is a scalar or single item array, the function is performed on the single item with each item of the multiple item argument. The result has the rank and dimensions of the multiple item argument. If neither argument has multiple items, the result is given the shape of the higher ranked argument. The shapes of results of scalar functions for various arguments are tabulated below.
## Arithmetic Functions

Each function in the arithmetic group has a monadic and dyadic form. If any argument is in the character domain, a *DOMAIN ERR* is reported. Results are always in the numeric (integer or floating) domain. If during the execution of any function a numeric result exceeds the range of CP-6 APL numbers, a *DOMAIN ERR* is reported.
+ Function (Conjugate, Addition)

- Monadic + is the Conjugate function.

\[ R+B \]

Domain Table:

<table>
<thead>
<tr>
<th>B</th>
<th>C</th>
<th>L</th>
<th>I</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>C</td>
<td>L</td>
<td>I</td>
<td>F</td>
</tr>
</tbody>
</table>

Examples:

-5
5
\((-3 2 1.1)\)
\(-3 2 1.1\)
\(+0 \ 1 \ 0\)
0 1 0

- Dyadic + is the Addition function.

\[ R+A+B \]

Domain Table:

<table>
<thead>
<tr>
<th>(A)</th>
<th>C</th>
<th>L</th>
<th>I</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>(B)</td>
<td>C</td>
<td>L</td>
<td>I</td>
<td>F</td>
</tr>
<tr>
<td>C</td>
<td>DE</td>
<td>DE</td>
<td>DE</td>
<td>DE</td>
</tr>
<tr>
<td>L</td>
<td>DE</td>
<td>I</td>
<td>I</td>
<td>F</td>
</tr>
<tr>
<td>I</td>
<td>DE</td>
<td>I</td>
<td>1/F~</td>
<td>F</td>
</tr>
<tr>
<td>F</td>
<td>DE</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
</tbody>
</table>

- The result is floating-point if the value exceeds the integer range.

Examples:

2 3 1+5 -1 0
7 2 1 2 3
3.5 4.5 5.5
2.5 3.5+1 2 3
LENGTH ERR
2.5 3.5+1 2 3

- Function (Negate, Subtraction)

- Monadic - is the Negate function.

\[ R-B \]

Domain Table:

<table>
<thead>
<tr>
<th>B</th>
<th>C</th>
<th>L</th>
<th>I</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>DE</td>
<td>I</td>
<td>1/F</td>
<td>F</td>
</tr>
</tbody>
</table>
Examples:

-5  
5  
-(-3 2 1.1)  
3 -2 -1.1

> Dyadic - is the Subtraction function.

\[ R + A - B \]

Domain Table:

\[
\begin{array}{c|cccc}
A \setminus B & C & L & I & F \\
\hline
C & DE & DE & DE & DE \\
L & DE & I & I & F \\
I & DE & I & I/F & F \\
F & DE & F & F & F \\
\end{array}
\]

~ The result is floating-point if the value exceeds the integer range.

Examples:

<table>
<thead>
<tr>
<th>A</th>
<th>2</th>
<th>3</th>
<th>1</th>
<th>-5</th>
<th>-1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>-3</td>
<td>4</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.5</td>
<td>-1</td>
<td>2</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.5</td>
<td>0.5</td>
<td>-0.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>-2.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-1.5</td>
<td>-0.5</td>
<td>0.5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

> Function (Signum, Multiplication)

\[ x \]

> Monadic \( x \) is the Signum function.

\[ R \times B \]

If \( B \) is positive, \( R \) is 1. If \( B \) is zero, \( R \) is 0. If \( B \) is negative, \( R \) is -1.

Domain Table:

\[
\begin{array}{c|cccc}
B & C & L & I & F \\
\hline
R & DE & L & I & I \\
\end{array}
\]

Examples:

\[ x \times 2 \]

<table>
<thead>
<tr>
<th>A</th>
<th>3.5</th>
<th>0</th>
<th>.001</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>-1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

> Dyadic \( x \) is the Multiplication function.

\[ R \times A \times B \]
Domain Table:

<table>
<thead>
<tr>
<th>A \ B</th>
<th>C</th>
<th>L</th>
<th>I</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>DE</td>
<td>DE</td>
<td>DE</td>
<td>DE</td>
</tr>
<tr>
<td>L</td>
<td>DE</td>
<td>L</td>
<td>I</td>
<td>F</td>
</tr>
<tr>
<td>I</td>
<td>DE</td>
<td>I</td>
<td>1/F~</td>
<td>F</td>
</tr>
<tr>
<td>F</td>
<td>DE</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
</tbody>
</table>

The result is floating-point if the value exceeds the integer range.

Examples:

\[
\begin{align*}
5 \times 1 & = 1 7 \\
5 & = 5 3 5 \\
-1 2 0 \times 1.5 & = 2.5 \ 3.5 \\
-1.5 & = 5 0 \\
2.5 & = 3 \times \ 1.7 \ 12 \ 0.01 \\
LENGTH ERR & = 2.5 \ 3 \times \ 1.7 \ 12 \ 0.01 \\
\end{align*}
\]

÷ Function (Reciprocal, Division)

- Monadic \( \div \) is the Reciprocal function.
  
  \[ R \div B \]

  Domain Table:

<table>
<thead>
<tr>
<th>B \ C</th>
<th>L</th>
<th>I</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>DE</td>
<td>F</td>
<td>F</td>
</tr>
</tbody>
</table>

If \( B \) is zero, the error DOMAIN ERR is reported.

Examples:

\[
\begin{align*}
+1 & 2 5 \\
1 & = 0.5 \ 0.2 \\
+ & .01 \\
100 & \\
\end{align*}
\]

- Dyadic \( \div \) is the Division function.
  
  \[ R \div A \div B \]

  Domain Table:

<table>
<thead>
<tr>
<th>A \ B</th>
<th>C</th>
<th>L</th>
<th>I</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>DE</td>
<td>DE</td>
<td>DE</td>
<td>DE</td>
</tr>
<tr>
<td>L</td>
<td>DE</td>
<td>I/F~</td>
<td>1/F~</td>
<td>F</td>
</tr>
<tr>
<td>I</td>
<td>DE</td>
<td>I/F~</td>
<td>1/F~</td>
<td>F</td>
</tr>
<tr>
<td>F</td>
<td>DE</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
</tbody>
</table>

The quotient is integer if \( B \) is an exact multiple of \( A \); otherwise, it is floating-point.
If $B$ is zero and $A$ is other than zero, the error DOMAIN ERR is reported. If both $B$ and $A$ are zero, $R$ is 1. If $R$ exceeds the range of floating-point numbers, DOMAIN ERR is reported.

Examples:

```
7 8 9+2 10 10
3.5 0.8 0.5
0+12
0
0+0
1
```

* Function (Exponential, Exponentiation)

0 Monadic * is the Exponential function.

The monadic * is the equivalent of the dyadic form with $e$ (the base of the natural logarithms) supplied as a left argument. The value used for $e$ is approximately 2.71828182845904524.

\[ R^{*+B} \]

Domain Table:

<table>
<thead>
<tr>
<th>B</th>
<th>C</th>
<th>L</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>DE</td>
<td>F</td>
<td>F</td>
</tr>
</tbody>
</table>

If $B$ exceeds 352.118767244522173, DOMAIN ERR is reported. If $B$ is less than -355.2379300369719713, $R$ is 0.

Examples:

```
*1 .5 0^-190
2.718281828 1.648721271 1 3.048234951E^-83
```

0 Dyadic * is the Exponentiation function.

\[ R^{+A*B} \]

Domain Table:

<table>
<thead>
<tr>
<th>[A]</th>
<th>DE</th>
<th>L</th>
<th>I</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>DE</td>
<td>DE</td>
<td>DE</td>
<td>DE</td>
</tr>
<tr>
<td>L</td>
<td>DE</td>
<td>L</td>
<td>I</td>
<td>F</td>
</tr>
<tr>
<td>I</td>
<td>DE</td>
<td>I</td>
<td>I/F</td>
<td>F</td>
</tr>
<tr>
<td>F</td>
<td>DE</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
</tbody>
</table>

If both $A$ and $B$ are zero, $R$ is 1. If $A$ is zero and $B$ is less than zero, DOMAIN ERR is reported. If $A$ is less than zero and $B$ is not an integer, DOMAIN ERR is reported. If $R$ exceeds range of floating-point numbers, DOMAIN ERR is reported.

Examples:

```
0 1 2^-2+0.5 3 0.5 3
1 1 1.414213562^-8
^-2^*^-3
DOMAIN ERR
^-2^*^-0.3
```

CE38-04

Function (Exponential, Exponentiation) 5-7
\( \text{Function (Natural Logarithm, Logarithm)} \)

- **Monadic \( e \)** is the Natural Logarithm (base e) function.

  \[ R^+ e B \]

  Domain Table:

  \[
  \begin{array}{c|cccc}
  B & C & L & I & F \\
  \hline
  R & D & E & F & F \\
  \end{array}
  \]

  If \( B \) is not a positive number, \texttt{DOMAIN ERR} is reported.

  Example:

  \[
  e 2.718281828459 1 .049787068367893943 1 0 \sim 3
  \]

- **Dyadic \( e \)** is the Generalized Logarithm (base A) function.

  \[ R^+ A^B \]

  If \( A \) or \( B \) is not a positive number, \texttt{DOMAIN ERR} is reported. If \( A = 1 \) and \( B \) is other than 1, \texttt{DOMAIN ERR} is reported.

  Domain Table:

  \[
  \begin{array}{c|cccc}
  A \times B & C & L & I & F \\
  \hline
  C & D & E & D & E \\
  L & D & E & F & F \\
  I & D & E & F & F \\
  F & D & E & F & F \\
  \end{array}
  \]

  Examples:

  \[
  2 \ 3 \ 1601 \ 27 \ .25 \\
  0 \ 3 \ -0.5 \\
  10010 \ .1 \ 250 \\
  1 \ -1 \ 2.397940009
  \]

\( \text{Function (Ceiling, Maximum)} \)

- **Monadic \( i \)** is the Ceiling function.

  \[ R^+ i B \]

  For \( i \), \( R \) is the algebraically smallest integer greater than \( B-OCT \times 1B \). \( OCT \) is \( 1E-13 \) unless it has been reassigned.

  Domain Table:

  \[
  \begin{array}{c|cccc}
  B & C & L & I & F \\
  \hline
  R & D & E & L & I/F^~ \\
  \end{array}
  \]

  ~ The result is floating-point if the value exceeds the integer range.

  Examples:

  \[
  i 2.1 \ 2.01 \ -2.01 \ 2.0000000000000001 \\
  3 \ 3 \ -2 \ 2 \\
  \]

5-8  \( \text{Function (Ceiling, Maximum)} \)  CE38-04
o Dyadic * is the Maximum function.

\[ R = \max(A, B) \]

* is the larger value of \( A \) and \( B \).

Domain Table:

<table>
<thead>
<tr>
<th>( A )</th>
<th>C</th>
<th>L</th>
<th>I</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DE</td>
<td>DE</td>
<td>DE</td>
<td>DE</td>
</tr>
<tr>
<td></td>
<td>DE</td>
<td>L</td>
<td>I</td>
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<td>I</td>
<td>F</td>
</tr>
<tr>
<td></td>
<td>DE</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
</tbody>
</table>

Examples:

\( 5 \cdot 12 \)
\( 12 \)
\( (\frac{-1}{5}, 7) \cdot 5 \)
\( 5 \cdot 5 \cdot 7 \cdot \frac{-1}{3} \cdot 3 \cdot 2 \cdot 7.1 \)
\( -1 \cdot 2 \cdot 7.1 \)

\( \lfloor R \rfloor \)

Function (Floor, Minimum)

\\( o \) Monadic * is the Floor function.

\[ R = \lfloor R \rfloor \]

* is the largest integer less than \( R \)

Domain Table:

<table>
<thead>
<tr>
<th>( R )</th>
<th>C</th>
<th>L</th>
<th>I</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DE</td>
<td>L</td>
<td>I</td>
<td>F</td>
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<tr>
<td></td>
<td>DE</td>
<td>I</td>
<td>I</td>
<td>F</td>
</tr>
<tr>
<td></td>
<td>DE</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
</tbody>
</table>

* The result is floating-point if the value exceeds the integer range.

Examples:

\( 2.9 \)
\( 2.99 \)
\( 2.999999999999999999 \)
\( 2 \cdot 3 \cdot 3 \)

\( o \) Dyadic * is the Minimum function.

\[ R = \min(A, B) \]

* is the smaller value of \( A \) and \( B \).

Domain Table:

<table>
<thead>
<tr>
<th>( B )</th>
<th>C</th>
<th>L</th>
<th>I</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DE</td>
<td>DE</td>
<td>DE</td>
<td>DE</td>
</tr>
<tr>
<td></td>
<td>DE</td>
<td>L</td>
<td>I</td>
<td>F</td>
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<td></td>
<td>DE</td>
<td>I</td>
<td>I</td>
<td>F</td>
</tr>
<tr>
<td></td>
<td>DE</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
</tbody>
</table>
Examples:

```
5 12
5 1 5 7
1 5 5
```

Function (Absolute Value, Residue)

- **Monadic |** is the Absolute Value function.
  
  \( R + IB \)
  
  **Domain Table:**
  
  \[
  \begin{array}{c|ccccc}
  B & C & L & I & F \\
  \hline
  R & DE & L & I & F
  \end{array}
  \]
  
  **Examples:**
  
  \[
  \begin{array}{c}
  \left| \begin{array}{c}
  2.15 \\
  1.43 5 7.2
  \end{array} \right|
  \end{array}
  \]

- **Dyadic |** is the Residue function.
  
  \( R + AIB \)
  
  1. If \( A = 0 \) then \( AIB \) is \( B \).
  
  2. If \( A \neq 0 \) then \( R \) lies between \( A \) and zero (being permitted to equal zero but not \( A \)) and is equal to \( B - N \times A \) for some integer \( N \).
  
  3. If \( A = AIB \) (using OCT) then \( R \) is 0.
  
  **Examples:**
  
  \[
  \begin{array}{c|cccccccc}
  A & 0 & -3 & \text{B} & -5 & 4 & -3 & 2 & 1 & 2 & 3 & 4 & 5 & 6 \\
  \hline
  A & 1B \\
  0 & 1 & 2 & 0 & 1 & 2 & 0 & 1 & 2 & 0 \\
  -6 & -5 & 4 & -3 & 2 & -1 & 0 & 2 & 3 & 4 & 5 & 6 \\
  0 & -2 & 1 & 0 & -2 & 1 & 0 & -2 & 1 & 0 \\
  \end{array}
  \]
  
  \[
  \begin{array}{c}
  X+21.824 \\
  .011X
  \end{array}
  \]

  The definition of residue can be stated formally as follows:
  
  \( AIB \leftrightarrow B - A \times L + A + A = 0 \)
  
  **Domain Table:**
  
  \[
  \begin{array}{c|ccccc}
  \backslash B \times \Gamma & C & L & I & F \\
  \hline
  C & DE & DE & DE & DE \\
  L & DE & L & I & F \\
  I & DE & I & I & F \\
  F & DE & F & F & F \\
  \end{array}
  \]
Function (Pi Times, Circular)

- **Monadic O** is the Pi Times function.
  
  \[ R = OB \]
  
  The result is 3.14159265358979324 times \( B \).

**Domain Table:**

<table>
<thead>
<tr>
<th>( B )</th>
<th>C</th>
<th>L</th>
<th>I</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>E</td>
<td>D</td>
<td>F</td>
<td>F</td>
</tr>
</tbody>
</table>

**Examples:**

- 01
  3.141592654
- 02
  .5
  6.283185307 1.570796327

- **Dyadic O** is the Circular function.

  \[ R = AOB \]

  The value of \( A \) determines the computed function of \( B \) according to the following convention.

<table>
<thead>
<tr>
<th>( A )</th>
<th>( R )</th>
</tr>
</thead>
<tbody>
<tr>
<td>-7</td>
<td>[Arctanh](1 \leq B)</td>
</tr>
<tr>
<td>-6</td>
<td>[Arcosh](1 \leq B)</td>
</tr>
<tr>
<td>-5</td>
<td>[Arcsinh](1 \leq B)</td>
</tr>
<tr>
<td>-4</td>
<td>( B \cdot (1-B^2) \cdot 0.5 )</td>
</tr>
<tr>
<td>-3</td>
<td>Arctan ( MAX \geq B )</td>
</tr>
<tr>
<td>-2</td>
<td>[Arcos](1 \leq B)</td>
</tr>
<tr>
<td>-1</td>
<td>[Arccsin](1 \leq B)</td>
</tr>
<tr>
<td>0</td>
<td>( (1+B^2) \cdot 0.5 )</td>
</tr>
<tr>
<td>1</td>
<td>Sine ( 4096 \geq B )</td>
</tr>
<tr>
<td>2</td>
<td>Cosine ( 4096 \geq B )</td>
</tr>
<tr>
<td>3</td>
<td>Tangent ( 4096 \geq B )</td>
</tr>
<tr>
<td>4</td>
<td>( (1+B^2) \cdot 0.5 )</td>
</tr>
<tr>
<td>5</td>
<td>Sinh ( 352.811914905 \geq B )</td>
</tr>
<tr>
<td>6</td>
<td>Cosh ( 352.811914905 \geq B )</td>
</tr>
<tr>
<td>7</td>
<td>Tanh ( MAX \geq B )</td>
</tr>
</tbody>
</table>

- The domains of \( B \) and ranges of \( R \) are narrower than those theoretically possible. The limitations reflect the precision with which real numbers are represented and with which computations are made in the computer.

  \( MAX = 6.379879956 \times 10^5 \)

  \( MAX \cdot .5 = 2.894802231 \times 10^7 \)

  For sine, cosine, and tangent functions and their hyperbolic counterparts, \( B \) is expressed in radians. For the inverse trigonometric functions, the value of \( R \) is in radians. The domain of the result is always floating-point.

**Examples:**

- 0002
  -2.064961208E-18
  00.4 .5 .6
  0.916515139 0.8660254038 0.8
  70.5
  0.54993061443
Notice in the first example that the result (the sine of $2 \times \pi$) should actually be zero. The actual result reflects the effect of computing with approximately 18 decimal-place precision.

! Function (Factorial, Binomial)

- Monadic ! is the Generalized Factorial function.
  
  $R+!B$

  The result is $B$ factorial for non-negative integral value of $B$. If $B$ is not an integer, the result is the gamma function of $B+1$.

  Domain Table:
  
  $\begin{array}{|c|c|c|c|c|}
  \hline
  B & C & L & I & F \\
  \hline
  R & DE & L & I/F & F \\
  \hline
  \end{array}$

  Examples:
  
  $5!40$
  $!1.66 \approx 0.75 0$
  $0.9016653712 3.625609908 1$

- Dyadic ! is the Binomial function.

  $R+!A!B$

  If the arguments are positive integers and $A$ is less than or equal to $B$, the result is the number of combinations of $B$ things taken $A$ at a time. In general, $(A!B)$ is:

  $$R+((!B)+(!A)\times!B-A)$$

  Domain Table:

  $\begin{array}{|c|c|c|c|c|c|}
  \hline
  A\backslash B & C & L & I & F \\
  \hline
  C & DE & DE & DE & DE \\
  L & DE & L & I & F \\
  I & DE & I & 1/F & F \\
  F & DE & F & F & F \\
  \hline
  \end{array}$

  Examples:

  $1!2$
  $2$
  $1.512$
  $1.697652726$
  $1.512.5$
  $2.5$
  $5!2$
  $2598960$
Relational Functions

The six relational functions are used to compare two values and return a value of 1 if the relation is true or a value of 0 if the relation is false. The truth value can be used in calculations in the same way as any other value of 1 or 0. The relational functions are strictly dyadic, requiring a left argument.

The expressions used below to define the relational functions includes a value $\text{DELTA}$. This is a relative tolerance value related to the user-established comparison tolerance in the following way:

\[ \text{DELTA} + \text{OCT} \times (|A|/|B|) \]

< Function (Less Than)

- Dyadic $<$ is the Less Than function.

$R+A<B$

The result is 1 if $(A-B)<\text{DELTA}$, and is 0 otherwise.

Domain Table:

<table>
<thead>
<tr>
<th>A</th>
<th>C</th>
<th>L</th>
<th>I</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>DE</td>
<td>DE</td>
<td>DE</td>
<td>DE</td>
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<td>L</td>
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<td>I</td>
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<tr>
<td>F</td>
<td>DE</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
</tbody>
</table>

Examples:

$2<4.5$

1 1 2 3<3 2 1

The result is 1 if $(A-B)<\text{DELTA}$, and is 0 otherwise.

\leq Function (Less Than or Equal)

- Dyadic $\leq$ is the Less Than or Equal function.

$R+A\leq B$

The result is 1 if $(A-B)\leq\text{DELTA}$, and is 0 otherwise.

Domain Table:

<table>
<thead>
<tr>
<th>A</th>
<th>C</th>
<th>L</th>
<th>I</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>DE</td>
<td>DE</td>
<td>DE</td>
<td>DE</td>
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<tr>
<td>L</td>
<td>DE</td>
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<tr>
<td>I</td>
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</tr>
<tr>
<td>F</td>
<td>DE</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
</tbody>
</table>
Examples:

```
1 ≤ 2
1 0
1 2 3 ≤ 3 2 1
1 1 0
```

≥ Function (Greater Than or Equal)

- Dyadic ≥ is the Greater Than or Equal function.

```
R + A ≥ B
```

The result is 1 if \((A - B) ≥ \text{DELTA}\), and is 0 otherwise.

Domain Table:

<table>
<thead>
<tr>
<th>(A)</th>
<th>C</th>
<th>L</th>
<th>I</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>L</td>
<td>L</td>
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</tr>
<tr>
<td>F</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
</tbody>
</table>

Examples:

```
0 1 0
'THIS' = 'THAT'
1 1 0
'A' = 5
0
```

≤ Function (Equal)

- Dyadic = is the Equal function.

```
R + A = B
```

If \(A\) and \(B\) are numeric, the result is 1 if \(|A - B| ≤ \text{DELTA}\), and is 0 otherwise. If \(A\) and \(B\) are characters, \(R\) is 1 if \(A\) and \(B\) are the same, and 0 if they are not. If one argument is character and the other numeric, \(R\) is 0.

Domain Table:

<table>
<thead>
<tr>
<th>(B)</th>
<th>C</th>
<th>L</th>
<th>I</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>L</td>
<td>L</td>
<td>L</td>
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<tr>
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<tr>
<td>F</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
</tbody>
</table>

Examples:

```
0 0
0 0
'A' = 5
0
```
> Function (Greater Than)

Dyadic > is the Greater Than function.

\[ R + A > B \]

The result is 1 if \((A - B) > \text{DELTA}\), and is 0 otherwise.

**Domain Table:**

<table>
<thead>
<tr>
<th>B</th>
<th>C</th>
<th>L</th>
<th>I</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>DE</td>
<td>DE</td>
<td>DE</td>
<td>DE</td>
</tr>
<tr>
<td>L</td>
<td>DE</td>
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<tr>
<td>I</td>
<td>DE</td>
<td>L</td>
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</tr>
<tr>
<td>F</td>
<td>DE</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
</tbody>
</table>

**Examples:**

2 > 3.4
0
1 2 3 > 3 2 1
0 0 1

≠ Function (Not Equal)

Dyadic ≠ is the Not Equal function.

\[ R + A ≠ B \]

If \(A\) and \(B\) are numeric, the result is 1 if \((|A - B|) > \text{DELTA}\), and is 0 otherwise. If \(A\) and \(B\) are characters, \(R\) is 0 if \(A\) and \(B\) are the same, 1 if they are not. If one argument is character and the other numeric, \(R\) is 1.

**Domain Table:**

<table>
<thead>
<tr>
<th>B</th>
<th>C</th>
<th>L</th>
<th>I</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>L</td>
<td>L</td>
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<td>L</td>
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<tr>
<td>F</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
</tbody>
</table>

**Examples:**

1 2 3 ≠ 3 2 1
1 0 1
'THIS' ≠ 'THAT'
0 0 1
'A' ≠ '5'
1
Logical Functions

The five logical functions are used to perform logical operations, returning a result of 0 or 1. The first four operations are strictly dyadic, and the last (the "not" operator) is strictly monadic.

∧ Function (And, LCM)
- Dyadic ∧ is the And function.
- \( R+A\land B \)

For logical values of \( A \) and \( B \) (0,1) the result is 1 if \( A \) and \( B \) are both 1, and is 0 otherwise. Otherwise, the result is the least common multiple of \( A \) and \( B \).

**Domain Table:**

<table>
<thead>
<tr>
<th>A\B</th>
<th>C</th>
<th>L</th>
<th>I</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>DE</td>
<td>DE</td>
<td>DE</td>
<td>DE</td>
</tr>
<tr>
<td>L</td>
<td>DE</td>
<td>L</td>
<td>I</td>
<td>F</td>
</tr>
<tr>
<td>I</td>
<td>DE</td>
<td>I</td>
<td>I/F</td>
<td>F</td>
</tr>
<tr>
<td>F</td>
<td>DE</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
</tbody>
</table>

**Examples:**
- \( 1\land 1 \)
- \( (1<2)\land(3=4) \)
- \( 0 \)
- \( 1\land 0\land 1\land 0 \)
- \( 0\land 0\land 0 \)
- \( 3\land 2 \)
- \( 6 \)
- \( 0.2\land 0.7 \)
- \( 1.4 \)

⊕ Function (Or, GCD)
- Dyadic ⊕ is the Or function.
- \( R+A\lor B \)

For logical values of \( A \) and \( B \) (0,1) the result is 1 if either \( A \) or \( B \) are both 1, and is 0 otherwise. Otherwise, the result is the greatest common divisor of \( A \) and \( B \).

The greatest common divisor of two values will always be less than or equal (in magnitude) to each of the values. The result of this function is always non-negative.
Domain Table:

<table>
<thead>
<tr>
<th>( A )</th>
<th>C</th>
<th>L</th>
<th>I</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>DE</td>
<td>DE</td>
<td>DE</td>
<td>DE</td>
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<tr>
<td>L</td>
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<tr>
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<td>DE</td>
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<td>I</td>
<td>F</td>
</tr>
<tr>
<td>F</td>
<td>DE</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
</tbody>
</table>

Examples:

1\(v\)1
1
(1<1)\(v\)(3=4)
0
1 1 0 0\(v\)1 0 1 0
1 1 1 0
4\(v\)6
2

* Function (Nand)

- Dyadic * is the Nand function.
  
  \( R*A*B \)
  
  The result is 0 if \( A \) and \( B \) are both 1, and is 1 otherwise.

Domain Table:

<table>
<thead>
<tr>
<th>( A )</th>
<th>C</th>
<th>L</th>
<th>I</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>DE</td>
<td>DE</td>
<td>DE</td>
<td>DE</td>
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<tr>
<td>L</td>
<td>DE</td>
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<tr>
<td>F</td>
<td>DE</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
</tbody>
</table>

* A DOMAIN ERR results if both \( A \) and \( B \) are not equal to either 1 or 0.*

Examples:

1*1
0
(1<2)* (3=4)
1
1 1 0 0*1 0 1 0
0 1 1 1
\( \lor \) Function (Nor)

- Dyadic \( \lor \) is the Nor function.
  
  \( R \land \neg A \lor B \)
  
  The result is 0 if either \( A \) or \( B \), or both, are 1, and is 1 otherwise.

  Domain Table:

  \[
  \begin{array}{c|ccccc}
  \text{A} & \text{C} & \text{L} & \text{I} & \text{F} \\
  \hline
  \text{C} & \text{DE} & \text{DE} & \text{DE} & \text{DE} \\
  \text{L} & \text{DE} & \text{L} & \text{L} & \text{L} \\
  \text{I} & \text{DE} & \text{L} & \text{L} & \text{L} \\
  \text{F} & \text{DE} & \text{L} & \text{L} & \text{L} \\
  \end{array}
  \]

  A \text{ DOMAIN ERR} results if both \( A \) and \( B \) are not equal to either 1 or 0.

  Examples:

  \[
  \begin{align*}
  &1 \lor 1 \\
  &0 \lor ((1\geq2) \lor (3\leq4)) \\
  &1 \lor 0 \lor 1 \lor 0 \lor 1 \\
  &0 \lor 0 \lor 1
  \end{align*}
  \]

\( \sim \) Function (Not)

- Monadic \( \sim \) is the Not function.
  
  \( R \sim B \)
  
  The result is 1 if \( B \) is 0, and is 0 if \( B \) is 1.

  Domain Table:

  \[
  \begin{array}{c|ccccc}
  \text{B} & \text{C} & \text{L} & \text{I} & \text{F} \\
  \hline
  \text{C} & \text{DE} & \text{DE} & \text{DE} & \text{DE} \\
  \text{R} & \text{DE} & \text{L} & \text{L} & \text{L} \\
  \end{array}
  \]

  A \text{ DOMAIN ERR} results if \( B \) is not equal to either 1 or 0.

  Examples:

  \[
  \begin{align*}
  &\sim 1 \\
  &0 \sim 0 \\
  &1 \sim (2.5-1.5) \\
  &0
  \end{align*}
  \]
Mixed Functions

Functions not categorized previously as monadic or dyadic scalar functions are called mixed functions. Rules for shapes and domains of the arguments and results vary and are described for the individual functions.

? Function (Roll, Deal)

- Monadic ? is the Roll function.
  $R+?B$
  Each item $R[i]$ of the result is an integer selected pseudorandomly from $\{B[i]\}$. The range of the result depends on the value of the index origin (see the deal operator below). The shape of the result is the same as that of the right argument.
  Examples:
  
  ?5
  3
  2 4 6
  2 4 1
  1 2 3 1

- Dyadic ? is the Deal function.
  $R+A?B$
  The result is a vector of integers comprising $A$ components pseudorandomly selected from $\{B\}$ without replacement, preventing the duplication of integers in $R$. The range of the result depends on the index origin. If the index origin is 0, the range is 0 through $B-1$. If the index origin is 1, the range is 1 through $B$.
  A may not exceed $B$, and both must be simple numeric items.
  Examples:
  
  2?4
  4 2
  1 3 5 4 6
  4+10 20 30 40 50 60 70 80
  4[?8]
  70 20 10 40

? Function (Index Generator, Index Of)

- Monadic ? is the Index Generator function.
  $R+\sim B$
  $B$ must be a single simple numeric item, equal to an integer. The result is a simple integer vector comprising $B$ items, beginning with the index origin and incrementing monotonically by 1. The index origin can be changed by assigning a value to $\sim 0$. If $B$ is 0 the result is an empty numeric vector.
Dyadic $\$, $r$ is the Index Of function.

$R \$, $B$

The value of each item of the result is the smallest index $I$ such that $A[I]$ is equivalent to the corresponding item in $B$. The left argument must be a vector. The right argument may have any rank. If no match for an item of $B$ is found in $A$, that item of the result is set to $(pA)^{1/0}$. The shape of the result is the same as the shape of the right argument. The result is simple and in the integer domain.

Note that $A$ may be an empty vector and the value of the result depends on whether the index origin is 1 (the default case) or 0. $A$ and $B$ may be of any domain. Note, however, that if $A$ is all character data, for example, and $B$ is all numeric, the result will be entirely "no match" values.

Examples:

```
2 4 6 8 3
'XYZ' 'W'
4 'DOG' 'COT'
4 2 4
'XYZ' 'DOG' 'O' 'XYZ' 'X' 'DOG'
```

c Function (Enclose)

Monadic $c$ is the Enclose function.

$R \cdot c B$

$R \cdot c (K) B$

$B$ may be any APL array. This function increases the depth of $B$ by 1 and decreases the rank. If an axis is not specified, the result is a scalar whose only item is the array $B$. If $B$ is a simple scalar character or number, the result is $B$ unchanged.

If an axis is specified, all of the axes specified by $K$ are enclosed, resulting in an array of rank $(pB)-p,K$, containing items of rank $p,K$. The shape of the result is $(pB)[-(tpB)+K]/pB]$ and the shape of each item of $B$ is $(pB)[K].$

Examples:

```
0 3 3
6
+ - +
[6]
+-++
[SENATE]
+-++
```

5-20 c Function (Enclose) CE38-04
Function (Disclose, Pick)

> Monadic > is the Disclose function.

\[ R \rightarrow B \]

\[ R \rightarrow (K)B \]

The result is an array whose depth is one less than that of \( B \) and whose rank has increased by the rank of the non-scalar items of \( B \). All of the non-scalar items of \( B \) must have the same rank although they may vary in shape. If \( B \) is a simple array then the result is \( B \).

If \( B \) is a simple scalar, the result is \( B \). Otherwise if \( B \) is a scalar, the result is the array contained in \( B \).

If axes are specified, they indicate where to insert the axes of the items of \( B \) into the result. When no axes are specified, the new axes are inserted after the axes of \( B \). The number of axes specified must equal the rank of the non-scalar items of \( B \).

Examples:

\[ p[] \rightarrow 'WHO' 'WHAT' 'WHEN' 'WHERE' \]

\[ p[] \rightarrow [1]'STEVE' 'MARK' 'TOM' 'BRUCE' \]

> Dyadic > is the Pick function.

\[ R + A \rightarrow B \]

The result is an item from the \((pA)\)th level of nesting in \( B \) selected by the path specified in \( A \). \( A \) must be a scalar or vector containing only simple integer scalars or vectors.

The first item of \( A \) must contain valid indices of \( B \). These indices select an item of \( B \) which is then indexed by the next item of \( A \) until all items of \( A \) have been used. The final array is the result of this function.

If \( A \) is empty, the result is \( B \).
Examples:

3 'ABCDEF

C
2 3 (2 1) > 1 (1 2 (2 2 3 4) 4) 3 2 1
3 2 (4 0) > 90 91 92

≡ Function (Depth, Equivalence)

.o Monadic ≡ is the Depth function.

R+B
The result is a simple non-negative integer scalar indicating the maximum depth of nesting in B. B may be any APL array.

The depth of a simple scalar character or number is defined as 0. Non-scalar arrays containing only depth 0 items have depth 1. All other arrays have a depth of 1+1/≡"B.

A depth greater than 1 indicates that an array is not simple.

Examples:

1 2 3 4

0 ≡ 29
1 ≡ 29 31
3 ≡ 'ABC' 4 (5 (6 7))
2 ≡ 'CABLE' 'CARS'

.o Dyadic ≡ is the Equivalence function.

R+A=B
The result is a simple logical scalar indicating whether every item of the left argument is equivalent to every item of the right argument. The result is 0 if any item of A is not equivalent to the corresponding item of B.

Comparison tolerance is used if corresponding items of A and B are numeric. Arrays are equivalent if they have the same shape and structure, and if all corresponding values in each structure are equal.

Empty arrays are equivalent only if their prototypes are also equivalent.

Examples:

5-22

Function (Depth, Equivalence)
Monadic, is the Ravel function.

\[ R, B \]

The result is a vector comprising the components of the argument \( B \) in index sequence. The argument can have any shape and dimensions.

Examples:

\[
\begin{align*}
B & = 2 2p14 \\
& = 1 2 3 4 \\
& = 1 2 3 4 \\
& = B \\
& = 1 2 2 \\
& = 3 4 \\
& = A, B \\
& = 1 2 3 4 \\
& = 3 4 \\
& = [C+2 4p'LEVELSIX' LEVELSIX, C] \\
\end{align*}
\]

Dyadic, is the Catenation and Lamination function.

\[ R=A, (K)B \]

The catenation coordinate \( K \) is acceptable if \((\{K\} \cup \{ppA\}) \cup \{ppB\} \). The catenation coordinate is \( \{K\} \).

If \( A \) and \( B \) are vectors or scalars, the result is a vector comprising all items of \( A \) followed by all items of \( B \).

Examples:

\[
\begin{align*}
A &= 1 2 3 \\
B &= 4 5 6 \\
A, B &= 1 2 3 4 5 6 \\
C &= 'STR' \\
D &= 'AND' \\
C, D, A &= STRAND1 2 3 \\
\end{align*}
\]

Catenation

Arguments \( A \) and \( B \) are conformable for catenation if:

1. The ranks are equal and all coordinates except the catenation coordinate are equal.

2. The rank of one argument is one less than the other and all coordinates except the catenation coordinate of the higher rank argument are equal to all coordinates of the lower rank argument. The lower rank argument is subsequently treated as if its rank were equal to the other argument and its catenation coordinate length were 1.

3. Either \( A \) or \( B \) is a scalar. The scalar argument is subsequently treated as if its shape were equal to the other argument with a catenation coordinate length of 1.
If A and B have conformable shapes and one or both are of higher rank than vector, catenation joins A and B along an existing coordinate. If no coordinate is specified, catenation occurs along the last coordinate. Scalar arguments are extended for catenation in this case.

Examples:

If a non-integer coordinate value is indicated in catenation, and its ceiling is a valid coordinate, the function performed is termed lamination. In this case the variable A and B are joined on a new coordinate. The length of the new coordinate is always 2.

In the following examples, the index origin is 1. If a coordinate of zero or less, or three or more, were specified, RANK ERR would be reported.

Examples:
pH, [1.5) - 4.7

(Revel, Catenation, Lamination)
ρ Function (Shape, Reshape)

o Monadic ρ is the Shape function.

$$R + ρB$$

The result is an integer vector comprising the number of items each index of B contains. That is, R contains the highest index in each coordinate of B in origin 1. Thus, the expression ρB represents the rank (number of dimensions) of B. If B is a scalar, ρB results in an empty vector.

Examples:

```
B = 2 4 6 8
ρB
```

```
4
```

```
C = 2 3 'PIFFLE'
ρC
```

```
2 3
```

o Dyadic ρ is the Reshape function.

$$R + A ρ B$$

The result is an array with the dimensions specified by vector A and the contents of B. Items of A may be positive integers or zero. If any component of A is zero, R is empty. If A is empty, R is a scalar. If B is empty, the prototype of B is used to fill the result. If the reshape requires fewer items than B contains, only the required items are in the result. If the result requires more items than B contains, B is cyclically reused as required. B may be of any rank or domain.

Examples:

```
2 3 4 5 6
3 4
2 4 ρ 5
1 2 3 4
5 1 2 3
```

```
3 3 ρ 'AB' 'CDE' 'FGHI' 'JKLHN'
AB  CDE  FGHI
JKLHN  AB  CDE
FGHI  JKLHN  AB
```

θ Function (Reversal, Rotation)

o Monadic θ is the Reversal function.

$$R + θ[K] B$$

The result is a reversal along the K'th coordinate of B. If K is omitted, the last coordinate is assumed. (If θ is used instead of θ; the first coordinate is assumed).

Examples:

```
θ 'EMIT'
TIME
θ[1] 3 ρ 9
7 8 9
4 5 6
```
Dyadic $\odot$ is the Rotation function.

$$R + A \odot B$$

The result is a cyclic rotation of $B$ by the number of components determined by $A$. If $A$ is positive, rotation is to the left; if $A$ is negative, rotation is to the right. Rotation is performed along the $K$'th coordinate of $B$. If $K$ is omitted, the last coordinate is assumed. (If $\odot$ is used instead of $\odot$, the first coordinate is assumed).

Arguments $A$ and $B$ are conformable for rotation if:

1. $A$ is a scalar or one element vector.
2. The rank of $A$ is one less than the rank of $B$ and the shape of $A$ is equal to the shape of $B$ omitting axis $K$.

$A$ must be a simple integer array.

Examples:

```
3 3
2 3 9
3 2 1
6 5 4
9 8 7
```

```
'FOX' 'WOLVERINE' 'DOG' 'CAT'
```

```
CAT DOG WOLVERINE FOX
```

Function (Transpose)

The monadic Transposition function has the following syntax:

$$R + B$$

The result is an array comprising the items of $B$ with the order of all coordinates reversed. For any $B$, $(pB) - 1 (pB)$. If $B$ is a matrix, for example, the result is a matrix whose rows are the columns of $B$ and whose columns are the rows of $B$. Monadic transpose of a scalar or vector yields $R + B$.

Examples:

```
5p3p'AGENTVIGORAGONY'
```

```
AGENT
VIGOR
AGONY
```
The dyadic Transposition function has the following syntax:

\[ R + A \otimes B \]

The result is an array similar to \( B \) except that the coordinates of \( B \) are permuted according to \( A \). The shape of \( A \) and \( B \) must be related by

\[ (\rho A) = \rho B \]

There are two cases of dyadic transposition:

Case 1:

\( A \) is a permutation of \( \top B \) (the coordinates of \( B \)). \( A \) is described as the inverse permutation vector. The \( A[I]'th \) component of \( \rho R \) is the \( I'\)th component of \( \rho B \), and thus the \( A[I]'th \) coordinate of the result is the \( I'\)th coordinate of \( B \).

Examples:

\[
\begin{array}{c}
2 & 1 & 0 & 2 \\
1 & 4 & 2 & 5 \\
3 & 6 & 2 & 1 & 0 & 2 & 3 & 'EXASPERATION'
\end{array}
\]

Case 2:

\( A \) satisfies the relationship \( (\phi A) + A \); that is, \( A \) is a dense set of the first \( K \) coordinates of \( B \), permuted, with some coordinates duplicated. If \( B \) is a matrix, the one possible form for \( A \) is \( (1 \ 1) \), and the result is the principal diagonal of the matrix.
Example:

\[ X + 3 \Rightarrow \text{GETEARTRY} \]

If \( B \) has rank 3 or more, the rule is that the rank of \( R \) equals the highest value in \( A \). If \( 1 < \text{rank}(A) \) and \( N \geq \text{rank}(A) \), then the \( A[N][i] \)th coordinate of \( R \) is made up of those components of \( B \) whose \( N \)th coordinate indices are the same. All other coordinates of the result are structured as in Case 1.

For higher order arrays, the generalized "diagonal" case of dyadic transpose is varied and somewhat difficult to visualize. The examples below show some forms for Case 2:

\[ Z + 2 \Rightarrow \text{ABCD} \text{EFGHJKLMNOPQRSTUVWXYZ} \]
\[ A + 2 \Rightarrow \text{ABCD} \text{EFGHJKLMNOPQRSTUVWXYZ} \]
\[ B + 2 \Rightarrow \text{ABCD} \text{EFGHJKLMNOPQRSTUVWXYZ} \]
\[ C + 2 \Rightarrow \text{ABCD} \text{EFGHJKLMNOPQRSTUVWXYZ} \]
\[ D + 2 \Rightarrow \text{ABCD} \text{EFGHJKLMNOPQRSTUVWXYZ} \]
G+1 2 ZG 2
G
AFKP
QVCH
2 4
X+2 3 4 5 p+ 120
1 1 1 10
1 87
1 1 1 26
1 2 3 4 5
86 87 88 89 90
2 2 2 10
1 86
2 87
3 88
4 89
5 90
1 1 2 26
1 7 13 19
81 87 93 99
2 2 1 10
1 81
7 87
13 93
19 99
1 2 2 30
1 2 3 4 5
26 27 28 29 30
51 52 53 54 55
61 62 63 64 65
86 87 88 89 90
111 112 113 114 115
3 2 2 10
1 61
26 86
51 111
2 62
27 87
52 112
3 63
28 88
53 113
4 64
29 89
54 114
5 65
30 90
55 115
Function (Grade-up)

Monadic \( \& \) is the Grade-up function.

\( R \& B \)

The result is a vector of indices (index origin sensitive) of the first coordinate of \( B \) ranked in ascending order of magnitude. \( B \) may be any simple non-scalar array containing only numbers or only character items. Identical components of \( B \) are ranked in index order.

If \( B \) is a vector, then the result values are the indices of the individual items of \( B \). If \( B \) is a matrix, the result values are indices of rows of \( B \), and the rows are ranked such that a difference in the first column of \( B \) is more significant than a difference in the remaining columns. This ranking extends to higher ranked arrays by sorting on the first coordinate and treating all other dimensions in ravel order.

Ranking Numeric Arrays

\[
\begin{array}{c}
\begin{array}{c}
1 2 3 4 \\
2 4 1 3 \\
5 2 3 1 4
\end{array}
\end{array}
\]

Ranking Character Arrays

If \( B \) is a character array, then \( A \& B \) is treated as \( A \& B \) where \( A \) is the default collating sequence shown in Table 5-2. For this default array, difference in case (lower or uppercase) is less significant than a difference in spelling. Also, numeric suffixes sort in numeric order.

Examples:

\[
A=\{\text{l1, l2, l3, l4, l5, l6, l7, l8, l9, l10}\}
\]

\[
A[\& A;]
\]

\[
\begin{array}{c}
L \\
L L \\
L L X \\
L 1 \\
L 3 \\
L 6 \\
L 7 \\
L 9 \\
L 10 \\
L 30 \\
L 33
\end{array}
\]
Table 5-2. Default Collating Sequence Array

(10 27 2, 1 2 28 MOV(65 97, 126)), '0123456789', [1.5], 'ABCDEFCHIJKLMNOPQRSTUVWXYZ

1
2
3
4
5
6
7
8
9

\( \text{γ} \text{A} \) is the Grade-up function.

\( \text{R} = \text{A} \text{A} \text{B} \)

The result is a vector of indices (1/0 sensitive) of the first coordinate of \( B \) ranked in ascending order of magnitude using the collating sequence specified by the array \( A \). \( A \) and \( B \) must be simple non-scalar arrays containing only character items.

The left argument collating sequence array is arranged such that the indices of the first occurrence of each character determines the significance and order for the ranking operation. When two characters differ in their indices along the columnar axis (the last dimension), this difference is more significant than a difference in indices along the row axis or plane axis.

For example, to sort an array containing letters and underscored letters, a matrix might be used. In this case, if the first row of the matrix contained the letters and the second row contained the underscored letters, the sort would rank a difference in spelling (letters) higher than a difference in case. The result would cause all similarly spelled words to sort together regardless of their case.

Any characters occurring in \( B \) but not in \( A \) are treated as though their index position in \( A \) is beyond the end of each axis of \( A \).

Examples:

\( \text{γ} = \text{A} ' \text{ABCDEFCGIJKLMNOP', [1.5]'ABCDHGEJLKMNOP' \}
\text{ABCDEFCGIJKLMNOP}
\text{ABCDEFCGIJKLMNOP}
\text{ABCDFCGIJKLMNOP}
\[ \text{γ} = 5 ' \text{AHAAMAEI AHAAM}' \]

\( \text{AHA} \)
\( \text{AHA} \)
\( \text{EI} \)
\( \text{AHA} \)
\( \text{AHH} \)
\[
\begin{array}{c}
A \downarrow B \\
4 1 2 5 3 \\
'ABCDEFGHJKLMNOPABCDEFHJKLMNOP' \downarrow B \\
4 5 3 1 2 \\
'AABCCDEEEFGCHIJJKLMMNQOP' \downarrow B \\
4 5 1 2 3
\end{array}
\]

\textbf{\(\downarrow\) Function (Grade-Down)}

\begin{itemize}
\item \textbf{Monadic} \(\downarrow\) is the Grade-down function.
\end{itemize}

\(R+\downarrow B\)

The result is a vector of indices (010 sensitive) of the first coordinate of \(B\) ranked in descending order of magnitude. \(B\) may be any simple non-scalar array containing only numbers or only character items. Identical components of \(B\) are ranked in index order.

If \(B\) is a vector, the result values are the indices of the individual items of \(B\).

If \(B\) is a matrix, the result values are the indices of rows of \(B\) and the rows are ranked such that a difference in the first column of \(B\) is more significant than the remaining columns. This ranking extends to higher ranked arrays by sorting on the first coordinate and treating all other dimensions in ravel order.

\textbf{Examples:}

\[
\begin{array}{c}
\downarrow 3 1 4 1 5 9 \\
6 5 3 1 2 4 \\
\downarrow 7 2 3 1 1 3 2 7 3 4 6 1 5 7 1 4 \\
5 6 4 1 3 7 2
\end{array}
\]

\textbf{Ranking Character Arrays}

If \(B\) is a character array, \(\downarrow B\) is treated as \(A \downarrow B\) where \(A\) is the default collating sequence shown in Table 5-2. For this default array difference in case (letter or underscored letters) is less significant than a difference in spelling. Also, numeric suffixes sort in numeric order.

\textbf{Examples:}

\[
\begin{array}{c}
A+12 3p'NFDNS NB PEIQUEONTMANSASALBBC NSWYUK' \\
A[12\downarrow A] \downarrow 12 8 5 4 6 11 1 2 1 3 7 10 9 \\
YUK \\
SAS \\
QUE \\
PEI \\
ONT \\
NYT \\
NS \\
NFD \\
NB \\
HAN \\
BC \\
ALB
\end{array}
\]

\begin{itemize}
\item \textbf{Dyadic} \(\downarrow\) is the Grade-down function.
\end{itemize}

\(R+\downarrow A\downarrow B\)

The result is a vector of the indices of the first coordinate of \(B\) arranged such that \(B\) is ranked in descending order of magnitude using the collating sequence specified by the array \(A\). \(A\) and \(B\) must be simple non-scalar arrays containing only character items.
The left argument collating sequence is arranged such that the indices of the first occurrence of each character determines the significant and order of the ranking. When two characters differ in their indices along the columnar axis (the last dimension), this difference is more significant than a difference in indices along the row axis or plane axis.

Any characters occurring in \(B\) but not in \(A\) are treated as though their index position in \(A\) is beyond the end of each axis of \(A\).

Examples:

\[
\begin{align*}
\text{A0} &= 'ABCDEFGHIJKLMNOPQRSTUVWXYZ \ldots' \\
\text{A1} &= 'ABCDEFGHIJKLMNOPQRSTUVWXYZ \ldots' \\
\text{A2} &= 6 7 8 \\
B &= 6 \text{'TOSOONTRUDEPHOTO UNDER TOSOONTRUDETEK'}
\end{align*}
\]

\[
\begin{align*}
\text{A0B} &= 6 1 7 3 4 2 5 \\
\text{A1B} &= 4 6 1 7 2 5 3 \\
\text{A2B} &= 4 6 2 1 5 7 3
\end{align*}
\]

\[
\begin{align*}
\text{B}[\text{A0B}];' \ldots \text{B}[\text{A1B}];' \ldots \text{B}[\text{A2B}];'
\end{align*}
\]

\[
\begin{align*}
\text{TRUDE UNDER UNDER} \\
\text{TOSOON TRUDE TRUDE} \\
\text{TEK TOSOON TRUDE} \\
\text{PHOTO TEK TOSOON} \\
\text{TOSOON TOSOON TEK} \\
\text{TOSOON PHOTO PHOTO}
\end{align*}
\]

1 Function (Base Value, Decode)

- Dyadic 1 is the Base Value function.

\[
\text{R} = \text{A} \downarrow \text{B}
\]

The argument \(A\) is referred to as the radix or radix vector. If \(A\) is a scalar, it is conceptually expanded to a vector. \(A\) and \(B\) must be simple and numeric; \(R\) is numeric.

The argument \(A\) is used internally to generate a set of weights, \(W\), to operate on \(B\) as follows. Let \(l\) be the length of \(B\). Then:

\[
\begin{align*}
W[1] &= 1 \\
\end{align*}
\]

Note that \(A[1]\) has no effect on the result.

Example:

\[
\begin{align*}
A &= 0 60 6011 2 3 \\
W[3] &= 1 \\
W[2] &= W[3] \times A[3], \text{ or } 60 \\
\end{align*}
\]
The result is formed by \( W \cdot xW \):

\[
\begin{array}{c|c|c}
1 \times 3600 & 2 \times 60 & 3 \times 1 \\
\end{array}
\]

\( W \cdot xW \) is 3600

\( R \) is 3723

If \( A \) is a vector and \( B \) is an array, \( R \) must be the same as the length of the first coordinate of \( B \). If \( B \) is a matrix for example, \( B \) must have the same number of rows as the length of \( A \). Each column of \( B \) is decoded to provide one item of the result. If \( A \) is also an array, each row of \( A \) represents a different radix vector. The shape of \( R \) is the catenation of the shape of all but the last coordinate of \( A \) with all but the first coordinate of \( B \). (Structure rules for \( A \), \( B \), and \( R \) are the same as for inner product.)

Examples:

\[
\begin{align*}
211 & 0 1 1 \\
11 & 413 2 1 0 \\
228 & 1019 8 7 \\
987 & 1 2 3 4 5 6 7 8 9 \\
560 & \\
\end{align*}
\]

\( K \) is a table of times represented in days (row 1), hours (row 2), minutes (row 3), and seconds.

\[
\begin{align*}
10 100 1000 10000 100000 1000000 \\
\end{align*}
\]

(Structure rules for \( A \), \( B \), and \( R \) are the same as for outer product.)

T Function (Representation, Encode)

- Dyadic \( T \) is the Encode function.

\( R = ATB \)

\( R \) is a "base \( A \)" representation of \( B \). \( R \) satisfies the relationship \(((x/A)\mid B=ATR)=0\). \( A \) and \( B \) must be simple and numeric, \( R \) is numeric. Note that the \( T \) and \( i \) functions are inverses (opposites). Note also that since Encode carries out a residue operation, its values are subject to the rules for that function.

If vector \( A \) contains too few items for \( B \) to be represented, the most significant digits of the result are truncated. If \( A[1] \) is 0, any unencodeable portion of \( B \) will be returned as \( R[1] \) rather than being truncated. Note that \( A \) and \( B \) may be negative or non-integer values. In this case, the result is as well defined but not as intuitively clear as for positive integer values.

\( B \) may be an array rather than a scalar, and the shape of the result will be the catenation of the shapes of the arguments. (The structure rules for \( R \), \( A \), and \( B \) are the same as for outer product.)
Examples:

a) **BINARY REPRESENTATION**

(8p2) T 75
0 1 0 0 1 0 1 1

b) **OCTAL REPRESENTATION**

(3p8) T 75
1 1 3

c) **DECIMAL REPRESENTATION**

(5p10) T 31415
3 1 4 1 5

d) **VARIED UNIT REPRESENTATION**

24 60 60 T 75 432
20 57 12

e) **EXAMPLE OF TRUNCATION**

10 10 T 31415
1 5

f) **THE ARGUMENTS FOR REPRESENTATION NEED NOT BE INTEGER**

(8p1.5) T 32.75
1 0.5 1 0 0 0.5 0 1.25

H is a vector of time values in seconds

H = 10 100 1000 10000 100000 1000000

H can be encoded in terms of days, hours, minutes and seconds.

365 24 60 60 T H
0 0 0 0 1 11
0 0 0 2 3 13
0 1 16 46 46 46
10 40 40 40 40 40

In the result, each column represents one element of H

Row 1 is days, row 2 is hours, row 3 is minutes and
row 4 is seconds.

The encode function Τ is based on the residue function in the manner specified by
the following function for vector A and scalar B:

\[ Z \equiv A \text{ ENCODE } B \]

\[ \begin{array}{l}
(1) Z \equiv 0 \times A \\
(2) I \equiv p A \\
(3) L \equiv ((I = 0) \times 0 \\
(4) Z[I] \equiv (I[I] \times B \\
(5) + (A[I] = 0) \times 0 \\
(6) B \equiv (B - Z[I]) + A[I] \\
(7) I \equiv I - 1 \\
(8) +L \\
\end{array} \]
Monadic W is the Format function.

\[ R = W(B) \]

The symbol \( W \) (\( \uparrow \) and \( \downarrow \) overstruck) defines two format functions which convert numerical arrays to character arrays. The monadic function produces a character array which is identical to the array which would be produced if the argument were merely printed; the difference (and advantage) is that the result is made explicitly available. The monadic format function can also be applied to a character array and will return the same character array. When applied to numeric arrays, however, the shape of the result is the same as the shape of the argument except for the required expansion along the last coordinate, each number being expanded, in general, to several characters. When applied to a nested array, the result is a vector or a matrix.

Examples:

\[
\begin{align*}
\text{PTABLE} &\times 2 = 74 \ 4p2 \\
\text{PTABLE} &\times 1 \ 1 \ 0 \\
&\ 0 \ 0 \ 1 \\
&\ 1 \ 0 \ 0 \\
&\ 0 \ 0 \ 1 \\
\text{PTABLE} &\times 4 \ 4 \\
\text{DFORMAT} &\times \text{PTABLE} \\
&\ 1 \ 1 \ 0 \ 1 \\
&\ 0 \ 0 \ 1 \ 0 \\
&\ 1 \ 0 \ 0 \ 0 \\
&\ 0 \ 0 \ 0 \ 1 \\
\text{DFORMAT} &\times 4 \ 7 \\
\text{LITERAL} &\times \text{LITERAL} \\
\end{align*}
\]

Dyadic W is the Format function.

\[ R = A \ W(B) \]

The dyadic format function accepts only simple numeric arrays for its right argument, and uses the left argument to provide detailed control over the result. In general, a pair (or pairs) of numbers in the left argument controls one or more columns of the result. The first number of the pair determines the total width of a number field and the second number specifies the desired precision. For decimal form numbers, precision is defined as the number of digits to the right of the decimal point; for scaled form it is defined as the number of digits in the multiplier. The form to be used is defined by the sign of the precision number in the control pair. Negative numbers indicate scaled form. For example:

\[
\begin{align*}
\text{DMATRIX} &\times 3 \ 2p12.34 \ -34.567 \ 0 \ 12 \ -26 \ -123.45 \\
&\ 12.34 \ -34.567 \\
&\ 0 \ 12 \\
&\ -0.26 \ -123.45 \\
&\ 3 \ 2 \\
\text{DMATRIX} &\times 12 \ 3pDMATRIX \\
&\ 12.340 \ -34.567 \\
&\ 0.000 \ 12.000 \\
&\ -0.260 \ -123.450 \\
&\ 3 \ 24 \\
\text{SISED} &\times 9 \ 2pDMATRIX \\
&\ 1.2E1 \ -3.5E1 \\
&\ 0.0E0 \ 1.2E1 \\
&\ -2.6E1 \ -1.2E2 \\
&\ 3 \ 18 \\
\end{align*}
\]

A single control number may also be used, and is treated as a number pair with a width indicator of zero. In this event, a field width is chosen such that at least one space will appear between adjacent numbers. For example:
Each column of an array can be individually formatted by defining a left argument containing a control pair for each column of the array. For example:

```
\$\cdot2\cdot\text{DMATRIX}
12.34 \quad -34.57
0.00 \quad 12.00
-0.26 \quad -123.45
3 \ 14
```

```
\$\cdot-2\cdot\text{DMATRIX}
1.2E1 \quad -3.5E1
0.0E0 \quad 1.2E1
-2.6E1 \quad 1.2E2
3 \ 20
```

When applied to an array having a rank greater than two, the format specifications apply to each of the planes defined by the last two coordinates. For example:

```
\text{HATRIX3D}+2\cdot2\cdot5p2
\text{HATRIX3D}
1 \ 2 \ 0 \ 1 \ 1
0 \ 0 \ 1 \ 1
0 \ 1 \ 0 \ 1 \ 1
0 \ 0 \ 0 \ 0 \ 0
```

```
4 \ \text{HATRIX3D}
1.0 \ 0.0 \ 1.0 \ 1.0 \ 1.0
0.0 \ 0.0 \ 1.0 \ 1.0 \ 0.0
0.0 \ 1.0 \ 0.0 \ 1.0 \ 1.0
0.0 \ 0.0 \ 0.0 \ 0.0 \ 0.0
```

Tabular displays which incorporate row and column headings or other information between columns or rows, can be configured using the format function together with extended catenation. For example:

```
\text{ROWHEADS}+4 \cdot3\cdot'\text{JANAPRJULOCT'}
\text{YEARS}+7\cdot5\cdot15
\text{TABLE}+.001\cdot-4\cdotE5\cdot+7\cdot2\cdot5pE5
```

```
(' \ ',[1\cdot\text{ROWHEADS}),(2\cdot9 \cdot0\cdot\text{YEARS}),(1\cdot9 \cdot2\cdot\text{TABLE}
79 \ 80 \ 81 \ 82 \ 83
JAN \ -159.97 \ 153.85 \ 269.01 \ 208.60 \ -88.20
APR \ 6.89 \ -322.64 \ 293.61 \ 297.76 \ 213.28
JUL \ 254.56 \ 73.44 \ 255.15 \ -134.65 \ 305.28
OCT \ 52.33 \ 1.25 \ -6.41 \ -234.24 \ -314.15
```

A DOMAIN ERR results when the width indicator of the control pair does not specify a size large enough to hold the requested form. The width need not, however, provide for blanks between adjacent numbers.
Function (First, Take)

- Monadic \( \oplus \) is the First function.
  \( \mathbf{R} \oplus \mathbf{B} \)

  \( \mathbf{B} \) may be any APL array. The result is the APL array which is within the first item of \( \mathbf{B} \). If \( \mathbf{B} \) is empty, the result is the prototype value of the array \( \mathbf{B} \).

  Examples:
  \[
  \begin{align*}
  10 & \quad \oplus \text{'HIYA'} \\
  & \quad \oplus \text{'SASKATOON' 'HOOSE JAW'} \\
 & \quad \oplus \text{'SASKATOON' 'HOOSE JAW'} \\
 S & \quad \oplus \text{'SASKATOON' 'HOOSE JAW'} \\
 & \quad 0 \mathbf{p}(1 2) 3 (4 5) \\
 0 & \quad 0
  \end{align*}
  \]

- Dyadic \( \oplus \) is the Take function.
  \( \mathbf{R} \oplus \mathbf{A} \oplus \mathbf{B} \)

  \( \mathbf{A} \) must be an integer scalar or vector, and the length of \( \mathbf{A} \) must equal the rank of \( \mathbf{B} \). (If \( \mathbf{B} \) is a scalar it is treated as though it were a 1 item array whose rank is the length of \( \mathbf{A} \).) Each item of \( \mathbf{A} \) controls the "take" from a coordinate of \( \mathbf{B} \). \( \mathbf{R} \) has the same rank as \( \mathbf{B} \). The shape of \( \mathbf{R} \) is \( |\mathbf{A}| \).

  If \( |\mathbf{A}| \geq 0 \), then the \( I \) th coordinate of \( \mathbf{R} \) is the first \( |\mathbf{A}| \) items in the \( I \) th coordinate of \( \mathbf{B} \). If \( |\mathbf{A}| < 0 \), the last \( |\mathbf{A}| \) items are used. If \( |\mathbf{A}| \) indicates more items than are present in the coordinate of \( \mathbf{B} \), \( \mathbf{R} \) is padded with prototype values of \( \mathbf{B} \).

  Examples:
  \[
  \begin{align*}
  3 & \oplus 5 \\
  3 & \oplus 5 \\
  1 & \oplus 3 & 4 & 5 & 0 & 0 \\
  3 & \oplus (1 2 3) & (4 5) \\
  1 & \oplus 3 & 4 & 5 & 0 & 0 \\
  '10' & \oplus \text{'OLYMPICS'} \\
  0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
  +\mathbf{B} & 2 & 2 & \oplus \mathbf{B} \\
  1 & 2 \\
  3 & 4 \\
  5 & 6 \\
  7 & 8 \\
  1 & 2 & 3 & \oplus \mathbf{B} \\
  1 & 2 & 0 \\
  3 & 4 & 0
  \end{align*}
  \]
\[ Function \ (Drop) \]

- **Dyadic** + is the Drop function.

\[ R + A \times B \]

\( A \) must be integer scalar or vector, and the length of \( A \) must equal the rank of \( B \).

(If \( B \) is a scalar it is treated as through it were a 1 item array whose rank is

the length of \( A \).) Each item of \( A \) controls the "drop" from a coordinate of \( B \). \( R \)

has the same rank as \( B \). The shape of \( R \) is \( O(\rho B) - |A| \). If a dimension in the result

thus created would be negative it is set to zero.

If \( A[i] \geq 0 \), then the \( i \)'th coordinate of \( R \) is all but the first \( A[i] \) items of the

\( i \)'th coordinate of \( B \); that is, the first \( A[i] \) items are dropped. If \( A[i] < 0 \), the

last \( |A[i]| \) items of the \( i \)'th coordinate of \( B \) are dropped.

---

Examples:

\[
\begin{align*}
\begin{bmatrix}
    -3 & 5 \\
    1 & 2 \\
    4 & 5 \\
\end{bmatrix} & \rightarrow
\begin{bmatrix}
    3 & 5 \\
    1 & 2 \\
\end{bmatrix} \\
\begin{bmatrix}
    +B+2 & 2 & 8 \\
    1 & 2 \\
    3 & 4 \\
    5 & 6 \\
    7 & 8 \\
\end{bmatrix} & \rightarrow
\begin{bmatrix}
    1 & 2 & 2 + B \\
    2 & 2 + B \\
    1 & 1 + B \\
    8 \\
\end{bmatrix}
\end{align*}
\]

*NOTE: RESULT IS AN EMPTY ARRAY*

\[ \]
Examples:

\[ A = 'A LPHABET' \]
\[ B = 'A BCDE' \]
\[ C = 2 4 \cdot B \]
\[ A + B \]
\[ 1 0 0 1 1 1 0 \]
\[ 1 5 10 \cdot C \]
\[ 1 1 0 \]
\[ 'TWO' 'TEN' 'ONE' 'TWO' 'THREE' 'FOUR' \]
\[ 1 0 \]

\[ \text{NOTE THAT MEMBERSHIP MAY BE USED WITH NUMERIC VERSUS} \]
\[ \text{TEXT ARGUMENTS, BUT THE RESULT IS ALWAYS ZERO} \]

\[ A + C \]
\[ 0 0 0 0 0 0 0 0 \]
\[ C + A \]
\[ 0 0 0 0 \]
\[ 0 0 0 0 1 2 3 \cdot '1 2 3' \]
\[ 0 0 0 \]

\section*{Function (Execute)}

- Monadic \& is the Execute function.

\[ R + \& B \]

\( B \) must be a simple scalar or vector. The domain of \( B \) must be character unless \( B \) is an empty vector. Ordinarily, the argument \( B \) will be a small character vector. If \( B \) contains unbalanced quotes, the error OPEN QUOTE is reported.

Once the argument has met the above requirements, the execute function departs from the mold of the other functions. That is, the characters in its argument, if any, are treated as if they were an APL statement to execute.

It is even possible in CP-6 APL to execute system commands. Execute operations can be applied so that an application can create its own variable names, or compose new formulas and evaluate them.

The execute function is a powerful tool. It can, however, be costly in execution time. The cost stems from the translation process when accepting its argument as if freshly input. This translation is repeated each time the same execute operation is performed; a function line, on the other hand, is translated only once regardless of the number of times it is invoked. Thus, \( 'execute' \) should be used sparingly in interactive or recursive processes.

As stated previously, the execute function permits formula evaluation, or system command execution in the midst of any APL statement. As with evaluated input, the result of executing an expression is the value resulting from evaluating that expression. The following examples illustrate this:

\[ 4 + 2 + 2 \]
\[ 3 + \& 2 + 2 \]
\[ 7 \]
\[ X = 2 + 2 \]
\[ Y = 2 + 1 \]
\[ 3 + \& X, Y \]
\[ 7 \]

Executing an empty vector yields an empty (numeric) vector result.
There are three important differences between execute in CP-6 APL and execute in most other APL's. These are:

1. System commands may be the object of execute statements in CP-6 APL.
2. Function editing is possible using the execute functions in CP-6 APL.
3. Executing an empty or all blank vector results in an empty numeric vector.

Executing some system commands yields no result. For example: )OFF, )OFF HOLD, )CLEAR, and )LOAD yield no display. In CP-6 APL, the "execute" of a system command which produces a display is returned as a character vector. This character vector is directly usable by the program.

The argument to the execute function may contain a number of expressions separated by diamonds. The result of such an argument is the result of the last expression evaluated. For example:

\[ 4+1'0 2 0 3' \]
\[ 1 \]
\[ 2 \]
\[ 7 \]

prints the values 1 and 2, returns 3 as the result of execute, which is added to 4 to print 7. (The diamond separator is described in Section 6 under Compound Statements.)

The execute function can also be used to access function definition mode, but limitations are imposed. A basic limitation exists since only one "statement" (character vector) can be the argument of an execute function.

The result of executing function definition mode operation is an empty vector unless a function display was requested, in which case the text of the display is returned as the result.

When using the execute function, the argument cannot contain unbalanced quotes (the error message OPEN QUOTE is issued in such cases).

Error handling is unique in the case of the execute function. After the diagnostic message (such as DOMAIN ERR), the path leading to the error is displayed until a normal suspension point is reached. The following example illustrates error handling during an involved execute function.

\[ VZ+F X \]
\[ [1] A='Y+X' \]
\[ [2] B='Z' \]
\[ [3] C='A,B' \]
\[ [4] Z+100+&C \]
\[ 5 F 4 \]
\[ 109 \]
\[ 5 F 'FOUR' \]
\[ DOMAIN ERR \]
\[ Y*X \]
\[ ^A \]
\[ &A,B \]
\[ F[4] Z+100+&C \]
\[ ^A \]
Function (Matrix Inverse, Matrix Divide)

is the Matrix Inverse function.

This function is used to solve systems of linear equations and to invert matrices. The monadic form is equivalent to the dyadic form with an identity matrix as a left argument, and the function can best be explained in terms of the dyadic form. The right argument must be a one-column matrix; and a scalar is treated as though it were a one-by-one matrix, in terms of shape requirements. The first coordinate of the left and right arguments must have the same length; that is, \((1+pA) = 1+pB\). For inversion, the shape of the result is \((pR) = (1+pB)\). If \(B\) is a non-singular square matrix, then the minimum is (except for computational round-off errors) zero, and \(R\) is the solution of a set of simultaneous equations. If, in addition, \(A\) is an identity matrix, \(R\) is the inverse of \(B\) (that is equivalent to \(R+\)B). If \(A\) is a vector, \(R\) is the solution to one system of simultaneous equations. If \(A\) is a matrix, each column of \(A\) represents the constants for a linear system with coefficient matrix \(B\), and each column of \(R\) is the corresponding solution.

Examples:

\section*{Inverse of a Square Matrix}

\begin{align*}
3 & 1 4 \\
1 & 5 9 \\
2 & 6 5 \\
\end{align*}

\begin{align*}
0.3222222222 & -0.2111111111 & 0.1222222222 \\
-0.1444444444 & -0.7777777778 & 0.2555555556 \\
0.0444444444 & 0.1777777778 & -0.1555555556 \\
\end{align*}

\begin{align*}
\text{Verify that the inner product of } R \text{ and } B \text{ is essentially the identity matrix.} \\
1.0000\times10^{-5} & -5.4210E-19 & -8.6736E-19 \\
-4.3369E-19 & 1.0000\times10^{-3} & 3.2526E-18 \\
-2.7105E-20 & -8.1315E-20 & 1.0000\times10^{-5} \\
\end{align*}

\section*{Left Inverse of a Nonsquare Matrix}

\begin{align*}
3 & 1 4 \\
1 & 5 8 \\
2 & 7 4 \\
3 & 5 9 \\
8 & 7 6 \\
\end{align*}

\begin{align*}
0.074106 & -0.082157 & -0.072245 & -0.015323 & 0.13129 \\
0.10492 & 0.011612 & 0.17084 & 0.048546 & 0.013386 \\
0.061261 & 0.06862 & -0.073814 & 0.085902 & 0.04531 \\
\end{align*}
AGAIN, VERIFY THAT THE INNER PRODUCT OF R AND B IS
VERY CLOSE TO THE IDENTITY MATRIX

\[ R \cdot B \]
\[
1.0000E0 \quad 1.0642E-19 \quad -1.1926E-18 \\
-1.5179E-18 \quad 1.0000E0 \quad -1.4095E-18 \\
-1.9516E-18 \quad 8.6736E-19 \quad 1.0000E0
\]

SOLUTION OF A SINGLE LINEAR SYSTEM
\[ B \] IS THE COEFFICIENT MATRIX
\[ A \] IS THE VECTOR OF CONSTANTS

\[ \begin{pmatrix} 3 & 1 & 4 \\ 1 & 5 & 9 \\ 2 & 6 & 5 \end{pmatrix} \]
\[ \begin{pmatrix} 35 & 89 & 79 \end{pmatrix} \]

\[ \begin{pmatrix} R \cdot A \cdot B \end{pmatrix} \]
\[
2.1444 \quad 8.2111 \quad 5.0889
\]

VERIFY THAT \( B \cdot x \cdot R \) APPROXIMATELY EQUALS \( A \)

\[ A - B \cdot x \cdot R \]
\[
5.5511E-17 \quad 1.1102E-16 \quad 8.3267E-17
\]

SOLUTION OF A SET OF LINEAR SYSTEMS
\[ B \] IS A COEFFICIENT MATRIX
\[ A \] IS A MATRIX; EACH COLUMN IS A SET
OF CONSTANTS FOR \( B \).

\[ \begin{pmatrix} R \cdot A \cdot B \end{pmatrix} \]
\[
2.1444 \quad 8.2111 \quad 5.0889
\]

CHECKING...

\[ A - B \cdot x \cdot R \]
\[
5.5511E-17 \quad 2.7756E-17 \\
1.1102E-16 \quad 8.3267E-17 \\
8.3267E-17 \quad 5.5511E-17
\]

LEAST-SQUARES SOLUTION

\[ \begin{pmatrix} A \end{pmatrix} \]
\[
11.1213141516
\]

\[ A + 12.03 \quad 8.78 \quad 6.01 \quad 3.75 \quad -0.31 \quad -2.79 \\
A \]
\[ 12.03 \quad 8.78 \quad 6.01 \quad 3.75 \quad -0.31 \quad -2.79 \\
R \cdot A \cdot B \]
\[
14.941 \quad -2.9609
\]

THE RESULT GIVES THE INTERCEPT AND SLOPE OF THE INEQ...
THAT IS THE LEAST-SQUARES BEST FIT TO THE POINTS OF A.

\[ B^+ x R \]

\[
\begin{align*}
11.98 & \quad 0.0186 & \quad 6.0588 & \quad 3.0979 & \quad 0.13705 & \quad -2.8238 \\
A^+ B^+ x R & \\
0.049524 & \quad -0.23962 & \quad 0.048762 & \quad 0.6521 & \quad -0.44705 & \quad 0.03381
\end{align*}
\]

To find the values of \( X, Y, \) and \( Z \) in the following linear equations:

\[
\begin{align*}
4X + 2Y - 5Z &= 22 \\
5X - 4Y + 4Z &= -7 \\
2X + 2Y - 20Z &= 80
\end{align*}
\]

assign the values of the coefficients to \( A \) and the constant vector to \( B, \) as in:

\[
A = \begin{pmatrix}
4 & 2 & -5 \\
5 & -4 & 4 \\
2 & 2 & -20
\end{pmatrix}
\]

\[
B = \begin{pmatrix}
22 \\
-7 \\
80
\end{pmatrix}
\]

and then obtain the solution:

\[
A \cdot B
\]

Thus in the linear equations provided above, \( X \) has the value 1, \( Y \) has the value -1 and \( Z \) has the value -4.

Operators

The five operators in CP-6 APL extend functions to arrays. In the following descriptions of these operations, the bracketed value \( K \) represents that coordinate of the argument array along which the specified operator is to act. If \( K \) is unspecified, the last coordinate of the array is assumed. The symbols \( d, f, \) and \( g \) represent any dyadic function, including a primitive function, a system function, a defined function, or a derived function.

Reduction \( d/ \) Operator

- Monadic \( d/ \) is the Reduction operator.

\[ R+d/\{K\}B \]

The result is an array having dimensions equal to that of array \( B \) except that the \( K' \)th component is not present. If \( f \) is used instead of \( f/ \), the first coordinate axis is used.

For a vector argument, the value of the result is that produced by placing the function \( d \) between each pair of adjacent components of vector \( B. \) A minus reduction results in an alternating sum and a divide reduction results in an alternating product.

For a scalar or an array comprising a single component along the reduction coordinate, the result has the same value as \( B. \) For an empty array the result has the value of the identity item of function \( d \) as shown in the table below or a \textit{DOMAIN ERR} if no identity exists.
### Table 5-3. Identity Values for Scalar Functions

<table>
<thead>
<tr>
<th>d</th>
<th>Identity Item</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>x</td>
<td>1</td>
<td>Right identity only.</td>
</tr>
<tr>
<td>+</td>
<td>0</td>
<td>Right identity only.</td>
</tr>
<tr>
<td>-</td>
<td>0</td>
<td>Right identity only.</td>
</tr>
<tr>
<td>*</td>
<td>1</td>
<td>Right identity only.</td>
</tr>
<tr>
<td>=</td>
<td>0</td>
<td>Left identity only.</td>
</tr>
<tr>
<td>@</td>
<td>None</td>
<td>Left identity only.</td>
</tr>
<tr>
<td>O</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>V</td>
<td>0</td>
<td>Right identity only.</td>
</tr>
<tr>
<td>^</td>
<td>1</td>
<td>Left identity only.</td>
</tr>
<tr>
<td>!</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>l</td>
<td>8.379879956E152</td>
<td>Right identity only.</td>
</tr>
<tr>
<td>f</td>
<td>-8.379879956E152</td>
<td>Left identity only.</td>
</tr>
</tbody>
</table>

Domain restrictions for function d apply. If the function argument d is not a scalar function, then the result is a possibly nested array. If B has more than one item, the domain of the result is the same as indicated in the domain tables for the dyadic scalar functions, or a nested array for all other functions.

Examples:

```
20
20/2 4 6 8

-4
-4/2 4 6 8

10
10/=10
1/10
1/APPLE', 'APPLE'

0
0/A+2 4p18
1 2 3 4
5 6 7 8
+/A
10 26
+/A
6 8 10 12
+/+/A

36

0P$=0 0 -3 -3
0P$+.4 5p'ONE TWO THREEFOUR'
+/ ONE | TWO | THREE | FOUR |
+/+ ONE | TWO | THREE | FOUR |

4
1/(2 3 4) 5 (6 7 8)

[1 2 3 4 5 6 7 8]
```
Compression A/ Operator (Replicate)

- Monadic A/ is the Compression operator.

\[ R = A /[K] B \]

The result includes all items in \( B \) that correspond to a 1 in \( A \). Those corresponding to a 0 are suppressed. If either argument is scalar, it is applied to all items of the other argument.

Compression is performed along the \( K \)'th coordinate of \( B \). If \( K \) is omitted, the last coordinate is assumed. (If \( f \) is used instead of \( / \), the first coordinate is assumed.)

\( A \) may be a simple logical scalar or vector, and \( B \) may be of any rank or domain. If \( A \) consists of more than one item, its length must be the same as that of the coordinate of \( B \) being compressed.

Examples:

\[ B + 2 \ 3 \ p^2 \]

\[ A = \begin{bmatrix} 1 & 3 \end{bmatrix} \]

\[ B = \begin{bmatrix} 14 & 4 & 4 & 4 \end{bmatrix} \]

\[ 2 \ D^4 = - \begin{bmatrix} 1 & 1 & 0 & 2 \end{bmatrix} \]

\[ B + 2 \ 3 \ p^4 \ 24 \]

\[ B = \begin{bmatrix} 1 & 2 & 3 & 4 \\ 5 & 6 & 7 & 8 \\ 9 & 10 & 11 & 12 \end{bmatrix} \]

\[ 13 & 14 & 15 & 16 \\ 17 & 18 & 19 & 20 \\ 21 & 22 & 23 & 24 \]

\[ + / B \]

\[ 10 & 26 & 42 \\ 58 & 74 & 90 \]

\[ + / [2] B \]

\[ 15 & 18 & 21 & 24 \\ 51 & 54 & 57 & 60 \]

\[ + / + / B \]

\[ 78 & 222 \]

\[ + / + / + / B \]

\[ C + 3 \ 4 p^1 \ 1 \ 1 \ 0 \ 1 \ 1 \ 0 \ 0 \ 0 \ 0 \ 0 \]

\[ C \]

\[ 1 & 1 & 1 & 0 \\ 1 & 0 & 0 \]

\[ 0 & 0 & 0 \]

\[ + / C \]

\[ 0 & 0 & 0 \]

\[ + / C \]

\[ 1 & 0 & 0 \]
The compression operator may be used in a test and branch situation. In this case, when the left argument has a value 1, a branch is made to the statement indicated by the right argument. If the left argument has the value 0, a branch is not taken and execution proceeds with the next statement. For example, the statement:

\[ *(2>3)/\text{END} \oplus \text{'NO BRANCH'} \]

\text{NO BRANCH}

fails through to the next statement; whereas

\[ *(3>2)/\text{END} \oplus \text{'BRANCH'} \]

causes a branch to the statement labeled \text{END}.

\begin{itemize}
  \item The Replicate operator.
  \begin{align*}
  R + A / (1) B
  \end{align*}

  Like compression, the result includes \(A[I]\) copies of each \(B[I]\). That is, if \(A[I]=0\) then the corresponding item of \(B\) is suppressed, if \(A[I]=2\) then the corresponding item of \(B\) appears twice and so on.

  Replication follows all the rules of compression except that \(A\) may be an integer scalar or vector of non-negative values.

  Examples:
  \[
  B=2 \begin{pmatrix} 2 & 3 \end{pmatrix} \begin{pmatrix} 1 & 2 & 2 \\ 3 & 4 & 4 \end{pmatrix}
  \]
\end{itemize}

Scan \(d\) \(\backslash\) Operator

\begin{itemize}
  \item Monadic \(d\) \(\backslash\) is the Scan operator.
  \begin{align*}
  R + d \backslash (1) B
  \end{align*}

  The result has the same shape as that of \(B\). If \(\backslash\) is used instead of \(\backslash\), the first coordinate axis is used.

  For a vector argument, the result is a vector of the same length with values as follows:

  \[
  \vdots
  \]

  Thus the last component of the result is equal to \(d/B\).

  For a scalar or a one-component array, the result is the same as \(B\). For an empty argument, the result will be empty.

  Domain restrictions for function \(d\) apply. If \(B\) has more than one item, the result domain is that indicated in the domain table for \(d\) if \(d\) is a scalar function; otherwise the result is a nested array.

  Examples:
  \[
  \begin{pmatrix} 1 & 3 & 5 & 7 \\ 1 & 4 & 9 & 16 \\ -5 & 2 & 2 & 3 \\ 3 & -6 & -1 & -2 \end{pmatrix}
  \begin{pmatrix} 5 \end{pmatrix}
  \begin{pmatrix} 0 & 7 & 0 & 1 \end{pmatrix}
  \begin{pmatrix} 3 \end{pmatrix}
  \begin{pmatrix} 9 & 5 & 1 \end{pmatrix}
  \]
\end{itemize}
Scan generalizes to higher ranked arguments in the same way reduction does, by doing the operation along the \(K\)’th coordinate as shown by the example below:

\[
\begin{align*}
B+2 & \quad 3 \quad 4p1.24 \\
1 & \quad 2 & \quad 3 & \quad 4 \\
5 & \quad 6 & \quad 7 & \quad 8 \\
9 & \quad 10 & \quad 11 & \quad 12 \\
14 & \quad 16 & \quad 18 & \quad 20 \\
22 & \quad 24 & \quad 26 & \quad 28 \\
30 & \quad 32 & \quad 34 & \quad 36 \\
& \quad & \quad & \\ +\{2\}B \\
1 & \quad 2 & \quad 3 & \quad 4 \\
6 & \quad 8 & \quad 10 & \quad 12 \\
15 & \quad 18 & \quad 21 & \quad 24 \\
13 & \quad 14 & \quad 15 & \quad 16 \\
30 & \quad 32 & \quad 34 & \quad 36 \\
51 & \quad 54 & \quad 57 & \quad 60 \\
& \quad & \quad & \\ +\B \\
1 & \quad 3 & \quad 6 & \quad 10 \\
5 & \quad 11 & \quad 18 & \quad 26 \\
9 & \quad 19 & \quad 30 & \quad 42 \\
13 & \quad 27 & \quad 42 & \quad 58 \\
17 & \quad 35 & \quad 54 & \quad 74 \\
21 & \quad 43 & \quad 66 & \quad 90
\end{align*}
\]

Expansion \(A\)\ Operator

\(\text{o Monadic } A \text{ is the Expansion operator.} \)

\(R+A\{K\}B\)

\(A\) must be a vector of 1’s and 0’s and must include the same number of 1’s as the length of the coordinate to be expanded. \(B\) may be of any rank and domain. Expansion occurs along the \(K\)’th coordinate of \(B\). If \(K\) is omitted, the last coordinate is assumed. If \(\\) is used instead of \(\\), the first coordinate is assumed. Thus, the difference between \(\\) and \(\\) is

\(R+A\B\) expands along the last coordinate of \(B\).

\(R+A\B\) expands along the first coordinate of \(B\).

Expansion consists of extending the length of the affected coordinate of \(B\) by insertion of prototype values in positions indicated by zeros in the argument \(A\). The process is best described by example. The prototype for a simple numeric array is 0. The prototype of a simple character array is ‘ ‘. In general, the prototype of an array \(B\) is \(<<\B\>\).

\[
\begin{align*}
1 & \quad 0 & \quad 1 \\\\1 3 \\
1 & \quad 0 & \quad 2 & \quad 0 & \quad 3 \\
1 & \quad 0 & \quad 1 & \quad (1 & \quad 2) & \quad (3 & \quad 4 & \quad 5) \\
1 & \quad 2 & \quad 0 & \quad 0 & \quad 3 & \quad 4 & \quad 5 \\
\end{align*}
\]

\(a\) \text{ THE FOLLOWING EXAMPLES SHOW EXPANSION ON EACH OF THE}

\(a\) \text{ COORDINATES OF A RANK 3 ARRAY.} \)
Inner Product f.g Operator

- Dyadic f.g is the Inner Product operator.

R+ f.g B

The result is an array having shape equal to all except the last dimension of array A concatenated with all except the first dimension of array B. If the function g is a scalar function, the length of the last dimension of A must be the same as that of the first dimension of B, or one of those lengths must be 1. The domain of the result is indicated by the functions f and g. Functions f and g may be any dyadic functions. For example, R+ A+.xB gives the conventional matrix inner product.

For vector arguments, the result is:

f/A g B
Examples:

3 4+.x5 6
39
+/3 4x5 6
39
1 2 3+.x4 5 6
32
+/1 2 3x4 5 6
32
1 0 1 0+.v 1 1 0 0
1
1 0 1 0+.v 1 1 0 0
3

If $A$ is a vector and $B$ is a matrix, the $i$'th component of the result is:

$f/A g B[i;i]$

Example:

\[
\begin{align*}
A &= \begin{bmatrix} 4 \\ 2 \end{bmatrix} \\
B &= \begin{bmatrix} 3 & 2 & 6 & 8 & 5 & 4 & 9 & 4 \\ 5 & 4 & 9 & 4 \\ 2 & 6 & 8 & 32 \\ 3 & 5 \\ 2 & 4 \\ 6 & 9 \\ 8 & 4 \\ 26 & 40 & 20 \\ 40 & 45 & 4 & 9 & 4 \\ 26 & 40 & 45 & 4 & 9 & 4 \\ 123 & 3 & 9 & 3 & 8 & 9 \\ 42 & 68 & 102 \\
\end{bmatrix}
\end{align*}
\]

If $A$ is a matrix and $B$ a vector, the $i$'th component of the result is:

$f/A[l;i] g B$

Example:

\[
\begin{align*}
C &= \begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \\
5 & 7 & 6 & 8 \\
3 & 2 & 6 & 8 \\
5 & 4 & 9 & 4 \\
57 & 56 \\
\end{bmatrix}
\end{align*}
\]

For matrix arguments, the $i;J$'th component of the result is:

$f/A[l;i] g B[i;J]$
Example:

\[
(2 \ 4 \ 6) \ast \times 4 \ 2 \ 3 \ 8
\]

\[
50 \ 60
114 \ 140
\]

\[
X+3 \ 3 \ 'CANDIDATE'
Y+3 \ 3 \ 'DRAHATIZE'
X \
= Y
\]

\[
0 \ 0 \ 0
0 \ 0 \ 0
0 \ 0 \ 1 \ X
\]

\[
CAN
DID
ATE
Y
\]

\[
DRA
MAT
IZE
X \ast Y
0 \ 1 \ 0
1 \ 0 \ 0
0 \ 0 \ 1 \ X \ast Y
1 \ 0 \ 1
0 \ 1 \ 1
1 \ 1 \ 0
\]

Inner product also applies to higher order arrays. For the example below, the arguments are each three dimensional and the result has four dimensions. The \( I;J;K;L \)th item of the result is: \(+/A[I;J;K;L]B[I;K;L].\)

\[
A+2 \ 2 \ 3 \ 12
\]

\[
A
1 \ 2 \ 3
4 \ 5 \ 6
7 \ 8 \ 9
10 \ 11 \ 12
- \ D+3 \ 2 \ 12 \ + \ 12
13 \ 14
15 \ 16
17 \ 18
19 \ 20
21 \ 22
23 \ 24
A+ \times B
110 \ 116
122 \ 128
263 \ 278
293 \ 308
\]

\[
416 \ 440
464 \ 488
569 \ 602
635 \ 668
+ \ A[I;J;1] \times B[I;K;1]
110
+ \ A[I;1;1] \times B[I;1;2]
116
+ \ A[I;1;2] \times B[I;2;2]
308
Outer Product o . d Operator

- Dyadic o . d is the Outer Product operator.

\[ R + A \circ \cdot d \circ B \]

The result is an array having a shape equal to the shape of \( A \) catenated with the shape of \( B \). The dyadic function \( d \) is performed for each item of \( A \) with respect to all items of \( B \). The domain of the result is determined by the rules for the function \( d \).

For vector arguments, the \( i,j \)th component of the result is:

\[ A[i] \circ d \circ B[j] \]

Example:

\[
\begin{array}{cccc}
1 & 2 & 3 & 4 \\
2 & 4 & 6 & 8 \\
3 & 6 & 9 & 12 \\
\end{array}
\]

\[
\begin{array}{cccc}
1 & 2 & 3 & 4 \\
2 & 3 & 4 & 9 & 12 \\
\end{array}
\]

Outer product is valid for arguments of higher rank. If, for example, \( A \) has a rank 3 and \( B \) has rank 2, the items of the result are defined by:

\[ R[i; j; k; l] \leftrightarrow A[i; j; k] \circ \cdot d \circ B[l; n] \]

Each Operator

- Monadic \( d \) is the Each operator.

\[ R + d''B \]

The result is an array with the same shape as \( B \). Each item of the result contains the result of applying the monadic function \( d \) to the corresponding item of \( B \). \( d \) may be any monadic function including a monadic primitive function, a monadic system function, a monadic defined function, or a monadic derived function.

Examples:

\[
\begin{array}{cccc}
7 & 6 & 5 \\
\end{array}
\]

\[
\begin{array}{cccc}
'NOW' & 'POOL' & 'ON' \\
WON LOOP NO \\
\end{array}
\]

\[
\begin{array}{cccc}
'2' & 3 \\
1 & 2 & 1 & 2 & 3 \\
\end{array}
\]

\[
\begin{array}{cccc}
'1+1' & 'PW+80' & '4x3+42' \\
2 & 80 & 16 & 20 \\
\end{array}
\]

- Dyadic \( d \) is the Each operator.

\[ R + A \circ d''B \]

The result is an array where each item of the result contains the result of applying the dyadic function \( d \) to the corresponding items of \( A \) and \( B \).
A RANK ERR is reported if both $A$ and $B$ are not singletons and their ranks differ.
A LENGTH ERR is reported if both $A$ and $B$ are not singletons and the lengths of $A$ and $B$ are not the same. If $A$ or $B$ is a singleton, it is reshaped to the rank of the higher ranked argument before performing the Each operation.

d may be any dyadic function, including a dyadic primitive function, a dyadic system function, or a dyadic defined function.

Examples:

```
1 10 20 30 40
1 10 1 20 1 30 1 40

```
Section 6

APL Statements

As mentioned in Section 2, each completed line of input is classified as either a statement or a system command. Statements specify the operations to be performed by APL, such as calculations, branching, and assignment of values or expressions. System commands (treated in Section 8) are concerned with the mechanical aspects of the system, such as logging off and saving, loading, and deleting workspaces. Statements can be entered when the system is in either execution mode or function definition mode. The user indicates the end of a statement by pressing the RETURN key. In execution mode, the computer then executes the operations contained in the statement. In definition mode, the computer stores the statements until the function is invoked. Blanks may appear anywhere in a statement except embedded within a number or a name. In general, an APL statement cannot be continued on another line. A character constant, however, may include one or more carriage returns, thus allowing multi-line statements.

When a character constant is being entered and APL detects a carriage return before receiving the closing quote, it automatically types a closing quote at the beginning of the next line. The assumption is that the user may simply have forgotten the closing quote. If that is not the case, the user may delete the closing quote and continue the text constant.

In this example, note that APL automatically provides the closing quote in the first specification of A. In the second specification, the user cancels APL's action and continues the character constant on the second line.

For all practical purposes there are four kinds of statements in CP-6 APL: comment, branch, assignment and non-assignment, and compound.

Comment Statements

To enter a comment statement, the user types the symbol A at the beginning of a line and follows it with a comment. The A symbol is produced by typing a n symbol (upper shift C) and overstriking it with a o symbol (upper shift J). This symbol signals APL that the line is a comment and is not to be executed. Any valid APL characters may be included in a comment; invalid APL characters produce an error message. If a comment extends over several lines, each line must begin with the A symbol. Some examples of comments are shown below:

A ROOM AREA ROUTINE.
A
A EACH LINE OF A MULTIPLE-LINE
A COMMENT MUST BEGIN WITH A A.
A comment statement can be entered as a direct input line (during execution mode) or it can be entered as part of a defined function. If a comment statement is entered as a direct input line, it is not retained in the workspace. If a comment statement is used in a function definition, however, the statement will have a line number, will occupy workspace, and will be displayed like any other function line. Function definition mode cannot be closed on a comment line, because the closing V symbol will be treated as just another symbol in the comment. An example of a comment in a function definition is shown below:

```
V A+H TRIAREA B
[1]  V A+H TRIAREA B
[3]  V
```

In CP-6 APL, any executable statement may include a comment to its right. Everything to the left of a V character is considered executable. Everything to the right is considered comment. Some examples are:

```
[10]  COST+HOURSXRATE  a  COST FOR STRAIGHT-TIME LABOR.
[15]  OC+1.5xHOURSXRATE  a  COST FOR OVERTIME LABOR.
```

When functions are displayed, comment lines are highlighted by indenting them one space less to the left of executable lines.

### Branch Statements

Branch statements are generally used within defined functions to alter the sequential execution of statements. Another form of branch statement, covered later, is the branch arrow that is not followed by an expression. A branch arrow by itself can be used to terminate execution of a suspended function and the functions that invoked it, thus effectively clearing the state indicator to the next suspension (if any). This application of the branch arrow is described in Section 7. A branch statement has the general form

```
+exp
```

where exp stands for an integer value. The value determines the line number of the statement to be executed next, as follows:

1. **If the value is a line number within the current function, that line is executed next.** Thus the statement

   `[5]  +2>A)x3`

   where A has a value of zero, causes a branch to line 3 of the current function. (The value 3 is derived as follows: the expression (2>A) returns a value of 1; and this value is multiplied by 3.)

2. **If the value is a line number outside the function being executed, then execution of that function terminates.** For example, the statement

   `[4]  +0`

   indicates a branch to line 0, which is outside the function. Since functions begin with line 1, branching to line 0 is an effective way to exit a function.

3. **If the value is an empty vector, then no branch occurs and the next sequential line is executed.** If there are no more lines, execution of the function is terminated. An empty vector can be created in any of the following ways:

   `0/S, 0pS, O,S`

   where 0 may be the result of a comparison expression, and S represents a line number. (If the result of the comparison statement is 1 instead of 0, the next line executed is the one indicated by the line number.) Substituting the comparison expression A=4, which produces a value of 0 or 1, and line 2 in the above expressions illustrates the simplicity of this type of branching:
In each case if the value of \( A \) equals 4 (that is, the comparison expression returns a 1), then line 2 is executed next. If \( A \) is any other value, then the comparison expression returns a 0, yielding an empty vector, and line 6 will be executed next if it exists; otherwise execution of the function terminates.

The expression indicating the line numbers can be a scalar or a vector. In other words, the user can specify branching to one line, to one of two lines, or to one of any number of lines. Branching to one line is described above. Branching to one of two lines can take either of the following forms:

\[
+(S1,S2)(1+X \text{ OP } Y) \\
+(X \text{ OP } Y),(\neg X \text{ OP } Y)/S1,S2
\]

where
- \( S1 \) is the line number to be branched to if the comparison expression yields a 0.
- \( S2 \) is the line number to be branched to if the comparison expression yields a 1.
- \( X \text{ OP } Y \) is a comparison expression; \( X \) and \( Y \) are the values to be compared, and \( \text{OP} \) is any of the following functions: \(<, \leq, =, \geq, \neq, \forall, \exists, +, \cdot, \circ, \triangledown \).

Both of these forms cause a branch to the first line number if the comparison yields 0, or to the second line number if the comparison yields 1. In illustration, the second form is entered in a defined function, and then executed with values for \( X \) and \( Y \).

\[
\text{VX FY} \text{ [1]} \\
+(1<Y),(\neg X<Y)/A1,A2 \text{ [2]} \\
A1:'\text{STEP A1}' \text{ [3]} \\
+0 \text{ [4]} \\
A2:'\text{STEP A2}' \text{ [5]} \\
+0 \text{ [6]} \\
V \text{ [7]}
\]

1 F 2
STEP A1
2 F 1
STEP A2

Clearly the second form can be expanded to include more line numbers. Similarly, a branch to one of several statements can also take the form:

\[
+I\Phi V
\]

where
- \( I \) is a counter.
- \( \Phi \) is the rotation function.
- \( V \) is a vector of line numbers, the first of which must be a positive integer or zero.

In this case the branch function selects statement \( I\Phi V \) as the next one to be executed. The following illustration shows how this branch function is carried out (see line number 3):

\[
\text{VNUMB I} \text{ [1]} \\
+(I>4)/2 \circ 'LOW' \circ +0 \text{ [2]} \\
+(I<6)/3 \circ 'HIGH' \circ +0 \text{ [3]} \\
+(I<4)\Phi 4 \text{ [4]} \\
'FOUR' \circ +0 \text{ [5]} \\
'FIVE' \circ +0 \text{ [6]} \\
'SIX' \circ +0V
\]
See Figure 6-1 for a summary of common branch function formats that can be used; APL also offers many other forms of branching.

```
Branch to line S or to next line:
  +(X OP Y)/S
  +(X OP Y)pS
  +(X OP Y)+S

Branch to line S1 or line S2:
  +(S1,S2)(1+X OP Y)
  +(X OP Y),X OP Y)/S1,S2

Branch to one of several lines:
  +(X OP Y),(X OP Y),X OP Y)/S1,S2,S3
  +IQV
  +(S1 S2 S3)[1]
```

Figure 6-1. Summary of Common Formats for Branching

Statement Labels

Instead of referencing a line number in a branch statement, a statement label can be assigned to the branch destination. Referencing that label will obtain the current line number of the line. To assign a label to a line, precede the first statement with a variable name and a colon, as shown:


The label END can now be used in a branch statement to transfer execution to this statement. For example, the statement

[3]  +(A<1)/END

will cause a branch to line 5 if A is less than 1, or a branch to line 4 if A is 1 or more.

The value of a label is the line number with which it is associated at the close of function definition. If new lines are inserted via function editing (see Section 7), then the values of the labels are automatically respecified at the closing of the function definition. The value of a label cannot be respecified by an assignment; any attempt to do so will produce a SYNTAX ERR message.

Like local variables (Section 3), the integer values of labels in one function can be accessed in other functions invoked by the function.
Use of a statement label in a branch statement is preferable to use of a line number, since function editing may change the original line number. If any lines are inserted or deleted during function editing, all lines will be renumbered at the close of a function definition mode. For example, consider the following statement which specifies a branch to line 5.

\[ \text{[3]} \rightarrow 5 \]

If two new statements are inserted between lines 3 and 4, the old line 5 is renumbered as line 7 at the close of function definition. However, the branch statement will still cause a branch to statement 5 instead of line 7 as now desired. This problem can be avoided if labels are used instead of statement numbers as branch points. (See Changing Suspended Functions in Section 7 for other considerations about labels.)

When labeled lines are displayed within a function, they are highlighted by indenting them one space less than usual.

**Assignment and Non-assignment Statements**

An assignment statement assigns the result of an expression or a value to a variable name. It has the general form:

\[ \text{name + expression} \]

where name can be any variable name and expression can be any APL expression. Three examples of assignment statements are

\[ B+6 \]
\[ A+B+2 \]
\[ Z+(B<1)+3*5 \]

A non-assignment statement is similar to an assignment statement except that it does not have the assignment arrow and the variable name to the left of it; however, a non-assignment statement can contain embedded assignments. Examples are:

\[ B+2 \]
\[ 3 \]
\[ (B<1)+3*5 \]
\[ 15 \]
\[ 2*4+A+2 \]
\[ 12 \]
\[ +A+1 \]
\[ 1 \]

Notice the differences between assignment and non-assignment statements: (1) execution of an assignment statement ends on the assignment, and (2) an assignment statement produces no display, while a non-assignment statement displays the resulting value of the statement.
Compound Statements

Using diamonds for separation, all of the preceding kinds of statements can be combined in "compound" statements. Compound statements have the following characteristics:

1. The statements are evaluated in left-to-right order, with each individual statement evaluated in the normal APL manner. Example:
   \[ A + 2 4 6 \Diamond pA \Diamond A, 1 \]
   would produce two lines of output, an integer 3 corresponding to the result of the second statement, and a vector 2 4 6 1 corresponding to the third.

2. An assignment statement produces no display. Example:
   \[ 5 \times 4 + 2 \Diamond A + 4 \]
   \[ 10 \]
   \[ 5 \times 4 + 2 \Diamond + A + 4 \]
   \[ 10 \]
   \[ 4 \]
   An assignment statement produces no display. Example:

3. A comment statement can have no statement to its right. All characters from the comment symbol \( A \) up to the end of the line are considered to be commentary. Example:
   \[ 312 \Diamond A \text{SHOWS} \Diamond \text{FUNCTION} \Diamond \text{THIS IS STILL A COMMENT}. \]

4. A branch statement implies no special display. In the no-branch case, statements to the right of the branch will be executed; they are ignored if a branch occurs. This provides conditional execution capability. Example:
   \[ \text{VERACITY} X \]
   [1] \( +(X \# 1)/2 \Diamond \text{TRUE} \Diamond 0 \Diamond 0 \)
   [2] \( +(X \# 0)/3 \Diamond \text{FALSE} \Diamond 0 \Diamond 0 \)
   [3] \( \text{NEITHER} \text{ TRUE} \text{ NOR} \text{ FALSE} \)
   \[ \text{VERACITY} 4 = 2 + 2 \]
   \[ \text{TRUE} \]
   \[ \text{VERACITY} 2 + 2 = 4 \]
   \[ \text{NEITHER} \text{ TRUE} \text{ NOR} \text{ FALSE} \]
   \[ 2 + 2 = 4 \]
   \[ 2 \]
   \[ \text{VERACITY} (2 + 2) = 4 \]
   \[ \text{TRUE} \]

5. If the statement is the subject of an execute function or evaluated input request, then the result of the function (or input request) is the result of the last expression executed. For example:
   \[ A + s ' 15 \Diamond + 15 ' \]
   \[ 1 \ 2 \ 3 \ 4 \ 5 \]
   \[ A \]
   \[ 15 \]
Section 7
Defined Functions

As mentioned in Section 3, defined functions are used in the same way as primitive functions. Defined functions must first be formed by the user instead of being an inherent part of the APL language.

User-Defined Functions

The following tasks are handled in function definition mode:

- Creating user-defined functions
- Displaying user-defined functions
- Editing user-defined functions

Once created, most functions can be edited and displayed. Once a locked function is created, however, it cannot be edited or displayed (see "Locking Functions" later in this section). Locked function lines cannot even be displayed for error diagnosis. It is possible, however, to erase a locked function.

User-defined functions can be created or modified by function definition mode or by the orx system function. They can be loaded or copied from a library workspace or "packaged" and read or written to a file (see Section 14).

Function definition mode begins when a function is opened and continues until a function is closed or abandoned. (It is possible to close a different function than was originally opened by revising the name of the function.) A function may be "opened" during direct input or evaluated input (see Section 3), and it may be opened briefly during execution (see the Execute Operator, s, Section 5). A function cannot be opened during any other form of input, such as quote-quad input or blind input; and a different existing function cannot be opened while still in function definition mode. Until a function is closed during function definition mode, APL execution is impossible except for system commands (which are executed and do not become part of the function being defined). Most system commands leave the currently open function intact and return the user to definition mode; however, some system commands cause a function definition to be abandoned (see Issuing System Commands later in this section).

Function Definition Mode

A del symbol, \$, followed by a function name specifies a change from execution mode to function definition mode. A second \$ symbol ends function definition mode and declares a change back to execution mode. No execution of statements occurs during function definition, and no errors are reported except for linescan errors, character errors, and definition errors. Instead, each statement is stored as part of the function.

Upon entry to definition mode, the editor is selected depending upon the setting of the last EDITOR command. The default function editor is a line-oriented editor similar to the editor provided by other APL systems. A screen editor is also available and the capabilities unique to screen editing are described under the heading Screen Editor later in this section.
Each defined function has a header and a body. The function header is the opening line of a function and declares the name (the identifier used to reference the function) and type of a function. The body of a function is the rest of the function. After the user enters a function header, APL responds with a statement number as follows:

VCUBE

[1]

The line number [1] signifies that the first line of the function program may be entered. Each line thereafter is numbered sequentially until the function is completed. The statements are stored and are not executed until definition mode is exited and the function named has been referenced.

Syntax of Defined Functions

A defined function can be niladic, monadic, or dyadic; that is, it can have zero, one, or two arguments. In addition, a defined function may return an explicit result or no result. Thus, there are actually six types of defined functions as illustrated by the following table of function header syntax possibilities:

<table>
<thead>
<tr>
<th>Function</th>
<th>No Explicit Result</th>
<th>Explicit Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Niladic function</td>
<td>Vname</td>
<td>Vr + name</td>
</tr>
<tr>
<td>Monadic function</td>
<td>Vname y</td>
<td>Vr + name y</td>
</tr>
<tr>
<td>Dyadic function</td>
<td>Vx name y</td>
<td>Vr + x name y</td>
</tr>
</tbody>
</table>

where

name is the user-assigned function name.

r is a variable to which the result is returned.

x and y are dummy variable names.

The syntax of the function header affects the way a function can be referenced in a statement; that is, whether the function requires zero, one, or two arguments for execution. Defined functions with explicit results may appear in compound expressions, much like primitive functions. Defined functions without an explicit result must appear alone; they cannot appear in compound expressions except as the last function to be executed. Examples of creation and use of each function type are shown in Table 7-2.

Dyadic defined functions are not strictly dyadic. They may be executed monadically, in which case the left argument will be undefined at execution time. The \( \text{ONe} \) function may be used to test for the presence of the left argument. (If the function is being executed monadically, the name class of the left argument is 0).

The result name in the function header may optionally be enclosed in braces \{\}. If it is enclosed, then the result of the function execution will not print if it is the primary function on the line (the last function executed).
<table>
<thead>
<tr>
<th>Function Type</th>
<th>Header Syntax</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Niladic function with explicit result</td>
<td>( \forall r \rightarrow \text{name} )</td>
<td>( \forall \text{RESULT} \rightarrow \text{PI} )</td>
</tr>
<tr>
<td></td>
<td>[1] ( \text{RESULT} \rightarrow 0 )</td>
<td>[2] ( \forall )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \text{PI} \rightarrow 3.141592654 )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \forall \text{RESULT} \rightarrow \text{TRIANGLE} )</td>
</tr>
<tr>
<td></td>
<td>[1] ( \text{AREA} \rightarrow 0.5 \times \text{BASE} \times \text{HEIGHT} )</td>
<td>[2] ( \text{DIAGONAL} \rightarrow (\text{HEIGHT}^2 + \text{BASE}^2) \times 0.5 )</td>
</tr>
<tr>
<td></td>
<td>[3] ( \text{RESULT} \rightarrow \text{AREA, DIAGONAL} )</td>
<td>[4] ( \forall )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \text{BASE} \rightarrow 5 )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \text{HEIGHT} \rightarrow 8 )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \text{TRIANGLE} \rightarrow 20 )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \text{AREA} \rightarrow 9.433981132 )</td>
</tr>
<tr>
<td>Niladic function with no explicit result</td>
<td>( \forall \text{name} )</td>
<td>( \forall \text{PI} )</td>
</tr>
<tr>
<td></td>
<td>[1] ( \text{X} \rightarrow 0 )</td>
<td>[2] ( \forall )</td>
</tr>
<tr>
<td></td>
<td>[3] ( \forall )</td>
<td>( \text{PI} \rightarrow 3.141592654 )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \forall \text{TRIANGLE} )</td>
</tr>
<tr>
<td></td>
<td>[1] ( \text{AREA} \rightarrow 0.5 \times \text{BASE} \times \text{HEIGHT} )</td>
<td>[2] ( \text{DIAGONAL} \rightarrow (\text{HEIGHT}^2 + \text{BASE}^2) \times 0.5 )</td>
</tr>
<tr>
<td></td>
<td>[3] ( \text{AREA IS } ' \times \text{AREA} )</td>
<td>[4] ( \text{DIAGONAL IS } ' \times \text{DIAGONAL} )</td>
</tr>
<tr>
<td></td>
<td>[5] ( \forall )</td>
<td>( \text{BASE} \rightarrow 5 )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \text{HEIGHT} \rightarrow 8 )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \text{TRIANGLE} \rightarrow )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \text{AREA IS } 20 )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \text{DIAGONAL IS } 9.433981132 )</td>
</tr>
<tr>
<td>Monadic function with explicit result</td>
<td>( \forall r \rightarrow \text{name y} )</td>
<td>( \forall \text{RETURN} \rightarrow \text{EXPAND INPUT} )</td>
</tr>
<tr>
<td></td>
<td>[1] ( \text{RETURN} \rightarrow ((2 \times \text{INPUT}) \rightarrow 0) \rightarrow \text{INPUT} )</td>
<td>[2] ( \forall )</td>
</tr>
<tr>
<td></td>
<td>[3] ( \forall )</td>
<td>( \text{EXPAND 'COPY COMMAND'} )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \forall \text{RETURN} \rightarrow \text{DESCENDINGSORT INPUT} )</td>
</tr>
<tr>
<td></td>
<td>[1] ( \text{RETURN} \rightarrow \text{INPUT} \rightarrow \text{INPUT} )</td>
<td>[2] ( \forall )</td>
</tr>
<tr>
<td></td>
<td>[3] ( \forall )</td>
<td>( \text{DESCENDINGSORT} \rightarrow 5 \rightarrow 3 \rightarrow 10 \rightarrow 5 \rightarrow 6 \rightarrow 8 )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( 10 \rightarrow 8 \rightarrow 6 \rightarrow 5 \rightarrow 3 \rightarrow 5 )</td>
</tr>
<tr>
<td>Monadic function with no explicit result</td>
<td>( \forall \text{name y} )</td>
<td>( \forall \text{EXPAND INPUT} )</td>
</tr>
<tr>
<td></td>
<td>[1] ( \text{EXPAND INPUT} \rightarrow ((2 \times \text{INPUT}) \rightarrow 0) \rightarrow \text{INPUT} )</td>
<td>[2] ( \forall )</td>
</tr>
<tr>
<td></td>
<td>[3] ( \forall )</td>
<td>( \text{EXPAND 'COPY COMMAND'} )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \forall \text{DESCENDINGSORT INPUT} )</td>
</tr>
<tr>
<td></td>
<td>[1] ( \text{INPUT} \rightarrow \text{INPUT} \rightarrow \text{INPUT} )</td>
<td>[2] ( \forall )</td>
</tr>
<tr>
<td></td>
<td>[3] ( \forall )</td>
<td>( \text{DESCENDINGSORT} \rightarrow 5 \rightarrow 3 \rightarrow 10 \rightarrow 5 \rightarrow 6 \rightarrow 8 )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( 1 \rightarrow 8 \rightarrow 6 \rightarrow 5 \rightarrow 3 \rightarrow 5 )</td>
</tr>
</tbody>
</table>
### Table 7-2. Defined Function Examples (cont.)

<table>
<thead>
<tr>
<th>Function Type</th>
<th>Header Syntax</th>
<th>Examples</th>
</tr>
</thead>
</table>
| Dyadic function with explicit result | ∀r + x name y | ∀RESULT+BASE TRIANGLE HEIGHT
|                                   |               | [1] AREA=0.5*BASE*HEIGHT |
|                                   |               | [2] DIAGONAL=((HEIGHT*2)+BASE*2)*0.5 |
|                                   |               | [3] RESULT=AREA,DIAGONAL |
|                                   |               | [4] ∀ |
| Dyadic function with no explicit result | ∀x name y     | ∀BASE TRIANGLE HEIGHT |
|                                   |               | [1] AREA=0.5*BASE*HEIGHT |
|                                   |               | [2] DIAGONAL=((HEIGHT*2)+BASE*2)*0.5 |
|                                   |               | [3] 'AREA IS ',∀AREA |
|                                   |               | [4] 'DIAGONAL IS ',∀DIAGONAL |
|                                   |               | [5] ∀ |
|                                   |               | 5 TRIANGLE 8 |
|                                   |               | 20 9.433981132 |
|                                   |               | ∀X PLUS Y |
|                                   |               | [1] ANS=X+Y |
|                                   |               | [2] ANS |
|                                   |               | [3] ∀ |
|                                   |               | 2 PLUS 5 10 15 20 |
|                                   |               | 7 12 17 22 |

### Variables Local to a Defined Function

The three types of variables that can be local to a defined function are:

- **Dummies**
- **Locals**
- **Labels**

Dummies and locals are named in the function header, while labels are named in the body of the function.

#### Dummies

Dummies are used in the header of a defined function to indicate the syntax of a function. For example, notice the header of the following simple function (this function calculates the area of a triangle):

```
∀A+H TRIAREA B
```

The dummies A, H, and B in the function header indicate that the function named TRIAREA returns an explicit result and that the function operates on two arguments which must be furnished by the user. For example, suppose the user calls this function with the statement

```
AREA=10 TRIAREA 5
```
The dummy \( H \) in the function is assigned the value 10, and the dummy \( B \) is assigned the value 5. The result is returned in the dummy \( A \), and is finally assigned to the variable \( \text{AREA} \) in the calling statement. Dummies possess values only within the function. That is, the use of \( A, H, \) and \( B \) as dummies does not affect their use as variables outside the function. If variables \( A, H, \) and \( B \) have values assigned to them before the function is called, they will have the same values after the function is executed. For example, suppose the variable \( A \) (with value 21) existed in the workspace before function \( \text{TRIAREA} \) was called. A display of variable \( A \) after the execution of \( \text{TRIAREA} \) demonstrates that \( A \) still has the value 21:

\[
\begin{align*}
A & \leftarrow 21 \\
\text{AREA} & \leftarrow 10 \\
\text{TRIAREA} & \leftarrow 5 \\
\text{AREA} & \leftarrow \quad A \\
25 & \quad A \\
21 &
\end{align*}
\]

Body of a Function

After the opening statement, in which the user creates the function header, the process of creating a function consists of inputting function statements and, finally, closing function definition. The user is prompted with a function line number each time the system is ready for further input. The process is ended by typing a closing \( \varnothing \) followed by a RETURN key.

Locals

Locals are variables that retain their values only within the function in which they are defined. While a function is active, its local variables take precedence over any externally defined variables of the same name. A list of a function's local variables is added to the end of the function header, with each variable in the list preceded by a semicolon. For example, the function header

\[
\begin{align*}
\varnothing R & \leftarrow \text{CIRCLE} \; B;X;Y;Z
\end{align*}
\]

indicates that the function named \( \text{CIRCLE} \) has locals \( X, Y, \) and \( Z \). The values for these variables are assigned within the function; if these variables are referenced without having a value assigned within the function, an \text{UNDEFINED} \ error will be produced. If variables \( X, Y, \) and \( Z \) have values assigned to them before the function is called, they will revert to those values after the function has finished execution.

Labels

Function lines may be labeled to allow symbolically controlled branching (if a function is edited, line numbers may change). A labeled line has the form

\[
\begin{align*}
[n] \; \text{name} & \leftarrow \text{statement}
\end{align*}
\]

where \( n \) is the line number, \( \text{name} \) is the label, and \( \text{statement} \) is the content of the line. For example:

\[
\begin{align*}
[4] \; \text{ERREXIT} & \leftarrow \text{ 'ERROR EXIT' } \circ \circ \circ 0
\end{align*}
\]

In this example, the label \( \text{ERREXIT} \) has the value 4. If an attempt is made to assign a value to \( \text{ERREXIT} \) during function execution, a syntax error message will be reported. If the function is edited and the line number changes to \( 5 \), \( \text{ERREXIT} \) will then have the value 5.
Changing Suspended Functions

At the time a function is suspended, its (current) local variables have been determined by APL, and its labels have already been assigned their values. Changing the suspended function does not alter these assignments. Resuming execution of a suspended function causes the determined items to remain in effect, regardless of how the function was altered.

Directives

During function definition mode, editing directives are used to display, modify, and add new lines. A directive may take any one of the following forms:

1

Directs APL to a line - here line 1.

10

Directs APL to display a line and to stay at that line for further editing - here line 1.

1-50

Directs APL to display a range of lines, here lines 1 through 5.

12

Directs APL to display from a line to the end of the function - here beginning at line 2.

[]

Directs APL to display the entire function.

3-9;/x/]

Directs APL to display lines containing a string - here string "x" in lines 3 through 9.

106

Directs APL to edit a line, starting at a given column - here line 1 at column 6.

1-20;2/x/S/y/

Directs APL to change all occurrences of one string to another string in the specified range of lines - here the second occurrence on each line of the string "x" is changed to string "y" in lines 1 through 20.

The separator S may be replaced by the letter F (in which case the replacement string will follow the search string), the letter P (in which case the replacement string will precede the search string), or the letter D (in which case the replacement string may not be specified and the search string will be deleted).

If the occurrence number is omitted, only the first occurrence is replaced. If the occurrence number is 0, then all occurrences on each line are replaced.

/x/]

Directs APL to search for the next occurrence of the string 'x' starting at the current line number through the end of the function.
Directs APL to search for the next occurrence of the string 'x' starting at the current line to the beginning of the function.

Directs APL to delete a line — here line 2.

Directs APL to delete a range of lines — here lines 4 through 9.

Directs APL to delete lines from a range which contain a string — here lines 5 through 8 containing string "x".

Directs APL to abandon definition mode and ignore all editing changes made.

In screen editing mode, APL will scroll down. If not in screen editing mode, an error is reported.

In screen editing mode, APL will scroll up. If not in screen editing mode, a DEFN ERR is reported.

A directive always starts with a left bracket and ends with a right bracket. With the exception of search or replacement strings, only legal line numbers, a dash, quad, delta, semicolon, slash or backslash are permitted within directives.

A line number is a number in the range 0 through 9999.999 which contains at most three digits after the decimal point. Scientific or E notation is not permitted. A line number range contains a dash separating the first line number of the range and the last line number of the range. At least one of the line numbers in a range directive must be specified. If the first number of a range is omitted, it is assumed to be 0. If the second number is omitted, it is assumed to be 9999.999. Examples of legal line numbers are:

0
123
0.999

A quad appearing within the directive indicates a display directive and a delta appearing immediately following the left bracket indicates a line delete directive.

Directives must be the leftmost items input during function definition mode. Several directives may be used on one line, however, the rightmost directive overrides all directives to the left of it. For example, notice the following portion of a function definition:

\[ \text{vFF} \]
\[ [1] \ X+Y \]
\[ [2] \ [1] \ Y+X \]
\[ [2] \ [5] \ A+B \]
\[ [6] \]

The [1] directive on the third line overrides the [2] directive to its left and causes the statement on line 1 to be replaced with \( Y+X \); notice that the next prompt is [2]. (It should be obvious by now that a function line prompt is a form of directive.) Similarly, the [5] directive on the next line overrides the [2] directive to its left and causes line 5 to become the expression \( A+B \). The next line prompt is then [6].
Search and Replacement Strings

Directive strings are delimited by either a slash or backslash. They may contain any characters in the CP-6 APL character set, but if they contain the delimiting character, it must be doubled. For example:

<table>
<thead>
<tr>
<th>Delimited string</th>
<th>String</th>
</tr>
</thead>
<tbody>
<tr>
<td>/2*A+0.5/</td>
<td>2*A+0.5</td>
</tr>
<tr>
<td>/B/C/D/</td>
<td>B/C/D</td>
</tr>
<tr>
<td>/NAME/</td>
<td>NAME</td>
</tr>
</tbody>
</table>

In the last example, the string NAME would be found in a line containing '1+NAME+2' or in a line containing '1+VARNAMES+2'.

When a search string is specified, the final delimiter may be followed by the character N, which is used to indicate that a string match should only be made if the characters before and after the match are not in the permitted set of identifier name characters. This option then allows searches for all occurrences of a specified identifier name. For example:

```
[3) [0-4;/X/]
[0] R+A FUN B;EXTRA;X
[1] EXTRA=\"TESTS\"
[3] EXTRA=EXTRA,*,X

[5] [0-4;/X/N]
[0] R+A FUN B;EXTRA;X
[3] EXTRA=EXTRA,*,X
```

In the first example above, every occurrence of the letter X is displayed, but in the second example, only those occurrences of the identifier X are displayed. Note that if the identifier X appears within quotes, that line is still displayed.

Displaying User-defined Functions

A user-defined function can be displayed in any of the following ways:

- Display all lines of the function.
- Display one line.
- Display a range of lines.
- Display the next line.
- Display lines containing a string.
- Display the next line containing a string.

Displaying All Lines

To display a function, the user opens the function with a del symbol, names the function, and specifies what is to be displayed, all on the same line. The user can then either close the function with another del symbol (if no editing is to be done) or leave the function open for further editing.

If the user wants to display all of a function, function TRIANGLE for example, the procedure is as follows:

```
VTRIANGLE [\]V
V BASE TRIANGLE HEIGHT
[1] AREA=0.5*BASE*HEIGHT
[2] DIAGONAL=((HEIGHT*2)+BASE*2)*0.5
[3] 'AREA IS ',*AREA
[4] 'DIAGONAL IS ',*DIAGONAL
V
```
Displaying One Line

If the user wants to display only one line of a function, say line 3 of function TRIANGLE, the procedure is

```
vTRIANGLE[3]v
[3] 'AREA IS ',*AREA
```

Displaying a Range of Lines

If the user wants to display from one line to the end of a function, say from line 2 to the end of function TRIANGLE, the procedure is

```
vTRIANGLE[2-]v
[2] DIAGONAL=((HEIGHT*2)+BASE*2)*0.5
[3] 'AREA IS ',*AREA
[4] 'DIAGONAL IS ',*DIAGONAL
```

If the user wants to display a range of lines, for example, lines 1 through 2 of function TRIANGLE, the procedure is:

```
vTRIANGLE[1-2]v
[1] AREA=0.5*BASE*HEIGHT
[2] DIAGONAL=((HEIGHT*2)+BASE*2)*0.5
```

The display of lengthy functions can be stopped at any point by pressing the BREAK key. The user can request the display to start at line 10 and then press the BREAK key after line 15 has been displayed. If the display command is closed with a del symbol, APL is in execution mode after the interruption. If the closing del is omitted, APL is in function definition mode after the interruption.

Notice that the display commands in all of the above examples are closed with a del symbol. This symbol causes control to be returned to execution mode as soon as the display is complete. To remain in function definition mode and edit the function instead, the user merely omits the closing del in the display command. See how the above examples appear without a closing del in each display command.

```
vTRIANGLE[0]
\v BASE TRIANGLE HEIGHT
[1] AREA=0.5*BASE*HEIGHT
[2] DIAGONAL=((HEIGHT*2)+BASE*2)*0.5
[3] 'AREA IS ',*AREA
[4] 'DIAGONAL IS ',*DIAGONAL
\v
[5]
```

```
vTRIANGLE[3]
[3] 'AREA IS ',*AREA
[3]
```

```
vTRIANGLE[0 2]
[2] DIAGONAL=((HEIGHT*2)+BASE*2)*0.5
[3] 'AREA IS ',*AREA
[4] 'DIAGONAL IS ',*DIAGONAL
[5]
```

Notice that after a single-line display, APL reprompts with the same line number; and that after a multiple-line display, APL prompts with the next available line number. The user can then edit the function as described below or can enter another del symbol to close the function. Closing the function definition with a del symbol does not alter the content of that line. For example, the following operation does not change the value of line 3; it will still be 'AREA IS ',*AREA:

```
vTRIANGLE[3]v
[3] 'AREA IS ',*AREA
[3] \v
```

CE38-04  Displaying a Range of Lines  7-9
In order to find and display the line following a particular line, enter linefeed after the closing bracket of a simple line number directive. For example, to display the line following 1.5, the procedure is:

(4) (1.5)
(2) \texttt{DIAGONAL}+((\texttt{HEIGHT}+\texttt{BASE})+0.5

The entire function can be displayed one line at a time by entering linefeed after each line is displayed. In summary remember that

\begin{verbatim}
[0] displays entire function.
[20] displays a single line (here 2).
[0 2] displays from a line (here 2) to end of the function.
[1-20] displays a range of lines (here 1 through 2)
\end{verbatim}

Displaying Lines Containing a String

In order to display all lines containing a particular string of characters, the line range to search is followed by a semicolon, an optional count, and either a slash or backslash delimited string. If the count is present, the line is displayed only if it contains at least count occurrences of the string. When count is not present, 1 is assumed. For example, to display all lines in the function \texttt{TRIANGLE} containing the string \texttt{BASE}, the procedure is:

\begin{verbatim}
VTRIANGLE[0-9;IBASE/]
[0] \texttt{BASE TRIANGLE HEIGHT}
[1] \texttt{AREA}+0.5*\texttt{BASE})*\texttt{HEIGHT}
[2] \texttt{DIAGONAL}+((\texttt{HEIGHT}+\texttt{BASE})+0.5

If the search string is for a particular identifier, the closing slash or backslash may be followed by the letter \texttt{N} which causes APL to display only those lines in which the string is both preceded and followed by characters that are not legal within a name. For example, if the search is for all occurrences of the identifier \texttt{A}, then the directive:

\begin{verbatim}
[7-20;/A/N]
\end{verbatim}

will not display a line containing \texttt{AREA} (unless it also contains the name \texttt{A}).

Displaying the Next Occurrence of a String

In order to search for the next occurrence of a string, (either forward or backward), the directive must contain only a search string. If the search string is delimited by a slash, the search begins at the next line through the end of the function. If the search is delimited by a backslash, the search begins at the previous line through to line zero. If the string is found, APL displays that line and issues a prompt for that line. If the string is not found, APL then prompts for the line at which the search ended (either zero or \texttt{1+} the last line number in the function). For example, if the search is for the first occurrence of the string \texttt{D} after line 2, the procedure is:

\begin{verbatim}
VTRIANGLE[2]/D/]
[4] \textquoteleft\texttt{DIAGONAL IS \textquoteleft \textquoteleft DIAGONAL}
[4]
\end{verbatim}
Editing User-defined Functions

Editing of user-defined functions is oriented to line-at-a-time editing capabilities:

- Deleting a line
- Inserting a line
- Replacing a line
- Modifying a line

The first three capabilities can be performed as shown in Table 7-3. The last capability, modifying a line, permits character editing (that is, deletion, insertion, and replacement of characters), adding to a line, and overstriking existing characters on a line. All of these capabilities are detailed below. Column one of Table 7-3 states the action to be performed. Column two gives an example of the action within definition mode. Column three gives an example of the same action when exiting definition mode. In both examples the functions are already open.

<table>
<thead>
<tr>
<th>Action</th>
<th>Within Definition Mode</th>
<th>Exiting Definition Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Display entire function</td>
<td><img src="CE38-04" alt="Example 1" /></td>
<td><img src="CE38-04" alt="Example 2" /></td>
</tr>
<tr>
<td>Display a line</td>
<td><img src="CE38-04" alt="Example 3" /></td>
<td><img src="CE38-04" alt="Example 4" /></td>
</tr>
<tr>
<td>Display line and change</td>
<td><img src="CE38-04" alt="Example 5" /></td>
<td><img src="CE38-04" alt="Example 6" /></td>
</tr>
<tr>
<td>Display function beginning with specified line</td>
<td><img src="CE38-04" alt="Example 7" /></td>
<td><img src="CE38-04" alt="Example 8" /></td>
</tr>
<tr>
<td>Delete a line</td>
<td><img src="CE38-04" alt="Example 9" /></td>
<td><img src="CE38-04" alt="Example 10" /></td>
</tr>
<tr>
<td>Delete a range of lines</td>
<td><img src="CE38-04" alt="Example 11" /></td>
<td><img src="CE38-04" alt="Example 12" /></td>
</tr>
<tr>
<td>Insert a line</td>
<td><img src="CE38-04" alt="Example 13" /></td>
<td><img src="CE38-04" alt="Example 14" /></td>
</tr>
<tr>
<td>Replace a line</td>
<td><img src="CE38-04" alt="Example 15" /></td>
<td><img src="CE38-04" alt="Example 16" /></td>
</tr>
<tr>
<td>Override a line number</td>
<td><img src="CE38-04" alt="Example 17" /></td>
<td><img src="CE38-04" alt="Example 18" /></td>
</tr>
<tr>
<td>Display a range of lines</td>
<td><img src="CE38-04" alt="Example 19" /></td>
<td><img src="CE38-04" alt="Example 20" /></td>
</tr>
<tr>
<td>Find occurrences of a string</td>
<td><img src="CE38-04" alt="Example 21" /></td>
<td><img src="CE38-04" alt="Example 22" /></td>
</tr>
</tbody>
</table>
Table 7-3. Displaying and Editing Defined Functions (cont.)

<table>
<thead>
<tr>
<th>Action</th>
<th>Within Definition Mode</th>
<th>Exiting Definition Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Find occurrences of identifier</td>
<td>[4] [0-4]/B/N</td>
<td>[4] [0-4]/B/N</td>
</tr>
<tr>
<td></td>
<td>[4]</td>
<td></td>
</tr>
<tr>
<td>Find next occurrence of a string</td>
<td>[4] [1]//C/</td>
<td>[4] [1]//C/</td>
</tr>
<tr>
<td></td>
<td>[3]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[2]</td>
<td></td>
</tr>
<tr>
<td>Abort changes, restore original version of function</td>
<td>[4] [+]</td>
<td></td>
</tr>
<tr>
<td>Change all occurrences of a string in a range of lines</td>
<td>[4] [1-3;A/S/AB/]</td>
<td>[4] [1-3;A/S/AB/]</td>
</tr>
<tr>
<td></td>
<td>[4]</td>
<td></td>
</tr>
<tr>
<td>Change function header</td>
<td>[4] [0] F;B</td>
<td>[4] [0] F;B</td>
</tr>
<tr>
<td></td>
<td>[1]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[4]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[4]</td>
<td></td>
</tr>
</tbody>
</table>

A simple three-line function named F has been assumed in the examples in this table (see the first display entry in the table for the original content of function F).

Note: The example which illustrates changing a function header, adds a local variable to the functional header.

Deleting a Line

A statement in a defined function can be deleted by using the delete directive. A delete directive may specify all of the line numbers to be deleted. For example, to delete line 2 of the following function:

VBASE TRIANGLE HEIGHT
[1] a THIS FUNCTION CALCULATES AREA AND HEIGHT OF TRIANGLE
[2] a BASE AND HEIGHT CANNOT EXCEED 5 AND 15 RESPECTIVELY
[3] AREA=0.5*BASE*HEIGHT
[4] DIAGONAL=((HEIGHT*2)+BASE*2)*0.5
[5] 'AREA IS',*AREA
[6] 'DIAGONAL IS ',*DIAGONAL
[7] *

First, the user opens the function and issues the delete directive:

VTRIANGLE[62]

APL responds with a prompt for line 3.

The user can now either close the function with a del symbol or proceed with further editing (including deleting the next line). (The user can also press the RETURN key if nothing is to be done to the line. APL simply responds with the line number, in this case [3]. A linefeed may be used in place of RETURN in which case APL displays the next line of the function.) A display of the function at this point illustrates that line 2 is deleted:
The function can now be closed with a del symbol.

Once definition mode is exited, APL rennumbers the line in sequential order, as illustrated by another display of the function:

```
VTRIANGLE
  (0) V BASE TRIANGLE HEIGHT
  (1) " THIS FUNCTION CALCULATES AREA AND HEIGHT OF TRIANGLE
  (2) AREA+0.5*BASE*HEIGHT
  (3) DIAGONAL=((HEIGHT*2)+BASE*2)*0.5
  (4) "AREA IS ", AREA
  (5) "DIAGONAL IS ", DIAGONAL
  (6) ;
```

Inserting a Line

A new line can be inserted in a defined function simply by reopening the function and entering the statement as described below. The user reopens the function by typing a del and the function name, to which APL responds by printing the line number of the next statement to be entered. If the new line is to be inserted at the end of the function, the user can now enter the new statement and close the function as shown:

```
VTRIANGLE
  (6) " THIS FUNCTION IS USED IN ROUTINES 1 AND 2.
  (7) ;
```

If the new line is to be inserted between two existing lines, however, the user must specify a line number between those two lines. For example, suppose the user wants to add a comment as the first line of function TRIANGLE instead of the last line. This can be done as follows:

```
VTRIANGLE
  (6) [0.5]
  (0.5) " THIS FUNCTION IS USED IN ROUTINES 1 AND 2.
  (0.6)
```

Notice the [0.6] prompt in this example. After an insert statement is entered, APL adds 1 to the last place of the number chosen for the insert, and prompts with the new number. (The next prompt after [0.6] will be [0.7]; the next, [0.8]; and so on.) This allows the user to insert several lines.

A display of function TRIANGLE illustrates that line [0.5] has been added:

```
(0.6) [ ]
  \ V BASE TRIANGLE HEIGHT
  [0.5] " THIS FUNCTION IS USED IN ROUTINES 1 AND 2.
  (1) " THIS FUNCTION CALCULATES AREA AND HEIGHT OF TRIANGLE
  (2) AREA+0.5*BASE*HEIGHT
  (3) DIAGONAL=((HEIGHT*2)+BASE*2)*0.5
  (4) "AREA IS ", AREA
  (5) "DIAGONAL IS ", DIAGONAL
  (6) ;
```

After the function is closed, APL automatically rennumbers the lines, as illustrated by the following display:

CE38-04 Inserting a Line 7-13
PROGRAM TRIANGLE
\[ V \]
\[ BASE \quad TRIANGLE \quad HEIGHT \]
\[ (1) \quad \text{m THIS FUNCTION IS USED IN ROUTINES 1 AND 2.} \]
\[ (2) \quad \text{m THIS FUNCTION CALCULATES AREA AND HEIGHT OF TRIANGLE} \]
\[ (3) \quad \text{AREA} = 0.5 \times \text{BASE} \times \text{HEIGHT} \]
\[ (4) \quad \text{DIAGONAL} = (\text{HEIGHT}^2 + \text{BASE}^2)^{0.5} \]
\[ (5) \quad \text{AREA IS } ' , \text{AREA} \]
\[ (6) \quad \text{DIAGONAL IS } ' , \text{DIAGONAL} \]
\[ \n \]
Line Numbers

APL allows the user to type a line number with up to four numbers to the left of the decimal point and up to three numbers to the right. As noted above, after each insert line is entered, APL adds 1 to the last place of the insert. As illustrated in the following portion of a printout, the next prompt after an [.88] insert will be [0.89]; the next, [0.9]; the next, [0.91]; and so on:

\[ V \]
\[ (7) \quad [.88] \]
\[ (8) \quad [0.88] \]
\[ (89) \quad [0.89] \]
\[ (9) \quad [0.9] \]
\[ (91) \quad [0.91] \]

The highest integer line number printed by APL is [9999]; thus the highest possible line number is [9999.999]. If the user is prompted with [9999.999] and enters a legal statement, APL will prompt with the same line number since it cannot go any higher.

Replacing a Line

A line in a defined function can be replaced simply by reopening the function, directing control to the statement that is to be replaced, and entering the desired statement. For example, line 1 of function TRIANGLE is to be replaced with another statement. The user reopens the function by typing a del and the function name and directs control to line 1 by typing that line number in brackets. After the RETURN key is pressed, APL responds to this entry by printing the specified line number at the left margin, as shown:

\[ V \]
\[ (1) \quad \text{VTRIANGLE[1]} \]

Any statement the user enters at this point will replace what previously existed at that line. Suppose the user now enters the following comment statement:

\[ (1) \quad \text{INPUT MUST BE IN FEET} \]

Notice that the next prompt is at line 2. If no more editing is required, the user can close the function by entering another del:

\[ (2) \quad v \]

This action has no effect on line 2; it merely closes the function. The following display of function TRIANGLE illustrates the change to line 1:

\[ V \]
\[ (1) \quad \text{VTRIANGLE [1]} \]
\[ \text{V BASE TRIANGLE HEIGHT} \]
\[ (1) \quad \text{INPUT MUST BE IN FEET} \]
\[ (2) \quad \text{INPUT MUST BE IN FEET} \]
\[ (3) \quad \text{THIS FUNCTION CALCULATES AREA AND HEIGHT OF TRIANGLE} \]
\[ (4) \quad \text{AREA} = 0.5 \times \text{BASE} \times \text{HEIGHT} \]
\[ (5) \quad \text{DIAGONAL} = (\text{HEIGHT}^2 + \text{BASE}^2)^{0.5} \]
\[ (6) \quad \text{AREA IS } ' , \text{AREA} \]
\[ (6) \quad \text{DIAGONAL IS } ' , \text{DIAGONAL} \]
**Issuing Multiple Directives**

APL allows the user to open a function, change a line, and close the function all on one line. For example:

\[ \text{VG}[1][2]2.2v \]

In this case, the user opens function \( G \), issues a directive to line 1 (realizes line 2 was meant), changes the directive to line 2, replaces whatever exists on that line with the value 2.2, and then closes the function. This shortcut operation allows the user to change a function without having to interact extensively with the computer. Another example is shown below:

\[ \text{VG}[0][1]1.11v \]

\[ \begin{align*}
1 & \quad 1.1 \\
\text{VG} & [0]v \\
\text{G} & [1] 1.11 \\
& [2] 2.2 \\
\end{align*} \]

The first line requests that line 1 of function \( G \) be displayed, and the contents of that line changed to the value of 1.11. The display of function \( G \) shows that line 1 has indeed been changed from 1.1 to 1.11. It should be noted that the user can display one line and change it at the same time, but cannot display an entire function and change something at the same time.

**Modifying a Line**

As mentioned earlier, modifying a line involves character editing (that is, deletion, insertion, and replacement of characters), adding to a line, and overstriking existing characters in the line. Modifications to a line can be specified by overriding the present line number with the directive:

\[ \text{[n)c] \]

where \( n \) is the number of the line to be edited (0 for a function header), and \( c \) is the column at which to begin editing (the column position is the number of spaces from the left margin). APL will normally display the specified line, and position to the designated column. The editing column specified may be 0, in which case APL displays the line and stops at the end. If the designated line does not fit on a single line, no character editing can be done. In this case, APL simply displays the line and then reprompts the user with the same line number. The following is an example of such a line:

\[ \begin{align*}
2 & \quad 'A' \\
& \quad 'B' \\
\end{align*} \]

If the typing element is still not in the proper position, the user can backspace, tab or use \(<\text{CTL-R}>\) to space forward until the desired position is reached.

The line-modifying capabilities of CP-6 APL are identical to those described in the CP-6 Programmer Reference Manual (CE40). In summary, the user may enter escape sequences to successively modify the content of function lines in a manner similar to that afforded direct input.

**NOTE:** An escape sequence is generated by pressing the \(<\text{ESC}>\) key once and then the appropriate key for the action desired (e.g., \(<\text{ESC}>\) followed by \( R \) for an escape-R sequence). The CP-6 system prints \(<R>\) on the terminal in response to an \(<\text{ESC}>\) \( R \) sequence.

For example, suppose the following function had been previously defined by the user.

\[ \text{VG} A \text{ PLUS } B \]

\[ \begin{align*}
1 & \quad 'THE \text{ SUM \ of } ',(*A),', \ AND ',(*B),', \ IS ',*A+B \\
\end{align*} \]
Now the user wants to change the function to perform a multiplication rather than an addition. Suppose the function that will do this is called TIMES. To proceed with the example, the user opens the function for editing with

```
VPLUS
```

and APL responds with [2]. The user types [10 0] to tell APL to display line 1 and remain at the end to await new instructions.

```
[2] [10 0]
```

APL waits at the end of the displayed line. The user presses RUBOUT twice to delete the B and then the +, and enters <ESC> followed by R to retype the line. The line appears as:

```
```

The two backslashes indicate the rubouts and <R> indicates the <ESC> R sequence. APL immediately types

```
[1] 'THE SUM OF ',(A),' AND ',(B),' IS ',A
```

and waits after the last A. Now the user types *B and enters <ESC> V S to move to the S in SUM.

```
```

The terminal now waits at the S for more instructions. Now the user presses RUBOUT three times to delete S then U then M enters <ESC> J to switch to CP-6 insert mode types PRODUCT and then <ESC> R to show the line.

```
 \PRODUCT\<R>
```

APL now waits for input at the T in PRODUCT. The user has decided to change the name of the function to TIMES. First, the user presses RETURN to tell APL that a new line 1 has been defined. APL responds with [2]. The user rewrites line 0 directly and ends function definition all in one line.

```
[2] [0] A TIMES BV
```

Now the user demonstrates the new function.

```
4 TIMES 6
THE PRODUCT OF 4 AND 6 IS 24
0 TIMES 9
THE PRODUCT OF 0 AND 9 IS 0
```

Adding Characters to End of Line

To add one or more characters to the end of a line, specify zero as the column at which to begin editing. APL will then display the line unaltered and wait at the end of the line for the user to add something. An example of adding local variables to a function header is shown below:

```
[3] [00 0]
[0] RETURN\+FUNC X;A;B
[1]
```

In this case APL typed the header as RETURN\+FUNC X and waited at the end of the line, and the user typed ;A;B.
Overstriking a Character

To edit a line and create a legal overstrike, specify zero as the column at which to begin editing. APL will display the line and wait at the end of it; the user can then backspace to the character to be overstruck, and type the second character. An example of overstriking a character is shown below:

[8] [50 0]
[5] A+~

In this case the first line caused statement 5, consisting of the expression A+~, to be displayed and APL to wait at the end of the line. The user then backspaced to the quad and typed an apostrophe, thus creating the legal overstrike ~.

Editing a Line Number

Line numbers may be edited in the same way that the content of a line is edited. One application of editing line numbers is in repeating a statement at several different lines. For example, the following procedure can be used to repeat the contents of line 2 at line 4.1:

VEC[2 1]
[2] A+30+12x A

APL waits under the [2. The user presses <CTRL-R> to move under the 2, presses RUBOUT to delete it, enters <ESC> J to switch to insert mode, types 4.1, and enters <ESC> R to see the result.

[2] A+30+12x A
\4.1<R>
[4.1] A+30+12x A

When the user now presses RETURN, a new line 4.1 has been defined. The contents of line 2 remain the same; that line was merely copied to line 4.1.

Changing a Function Header

There are four changes the user can make to a function header (that is, to line zero).

1. Change the name of the function. Suppose the user reopens an existing function called FF1 and changes only the name of the function to G1 as shown below:

VEFF1[0]
[0] RETURN=G1 ARG
[1]

This example assumes that G1 does not already exist. (If it did, a DEFN ERR message would be reported.)

Changing the function name has no effect on function FF1, the function still exists as it did before the reopen. Of course, FF1 is no longer the open function, G1 is. G1 is initially a copy of FF1 and any modifications subsequently made while in function definition mode apply only to G1. This feature allows synonymous function names as long as only the header is revised. It is possible for a user to make a locked version of an unlocked function in this manner, retaining the unlocked version only until satisfied that the locked version is error-free. Erasing the original function does not affect a synonymous function, nor does subsequent revision of the original. A synonymous function retains the stop and trace vectors supplied with the original function when it was copied.

2. Change the name of the result, change a function with a result to a no-result function, or change a no-result function to a function with a result. The following illustrates the change of function FF1's result name from RETURN to R:
3. Change the name of an argument. An example is shown below, where function FFL's argument is changed to X:

```
VFF1[0]
[0] R=FF1 ARC
[1]
```

4. Change the names of locals, insert locals, or delete locals. APL does not allow the user to delete a function header. Any attempt to do so will cause APL to print an error message and reprompt the user with line zero. To get rid of the current function, the user must issue an ERASE command.

Screen Editing

CP-6 APL provides a screen-oriented editor for editing defined functions. The screen editor is requested by the )EDITOR system command. In this mode, a portion of the function being edited is always on the screen, and the bottom of the screen typically contains an area for error messages and the output of system commands. To modify a line, position to the character or characters to be changed and enter the appropriate characters to be inserted or replaced. To position the cursor to a particular line, enter <ESC> X and one of the line positioning directives listed below. In order to leave screen editing mode, enter a V character at the end of a line or enter an <ESC> XV sequence. Please note that in this section, the sequence "<ESC>" indicates pressing of the escape key on the terminal.

Whenever the cursor moves off a line, APL determines whether the line is changed or if a directive was entered. A directive can be entered at anytime by typing <ESC> X followed by the directive. The line that was erased in order to enter the directive reappears as soon as the directive is acted upon. Display directives are not permitted in screen editing mode (mainly because the function is already being displayed). If the screen does not contain the portion of the function requiring modification, the line to be modified can be reached by entering linefeed characters to get to it, or by entering a bare line number directive such as [6] (which would position the cursor to line 6).

Table 7-4 contains a list of character sequences to perform some common input editing. For a complete list of screen editing input editing sequences, see the CP-6 Programmer Reference Manual (CE40). Table 7-5 contains a list of the directives that may be entered in screen editing mode and their meaning.

<table>
<thead>
<tr>
<th>Input</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;ESC&gt;A</td>
<td>Position one line up.</td>
</tr>
<tr>
<td>&lt;ESC&gt;P</td>
<td>Restore line to its contents when the cursor arrived.</td>
</tr>
<tr>
<td>&lt;ESC&gt;N</td>
<td>Position to the end of the line.</td>
</tr>
<tr>
<td>&lt;ESC&gt;</td>
<td>Repoint the screen.</td>
</tr>
<tr>
<td>&lt;ESC&gt;V?</td>
<td>Position the cursor to the next '?' character.</td>
</tr>
<tr>
<td>&lt;ESC&gt;J</td>
<td>Toggle insertion mode.</td>
</tr>
<tr>
<td>&lt;ESC&gt;K</td>
<td>Delete characters to the end of the line.</td>
</tr>
<tr>
<td>&lt;ESC&gt;X</td>
<td>Delete all characters on the line.</td>
</tr>
<tr>
<td>&lt;ESC&gt;*</td>
<td>Remember the characters in the insertion window (or line)</td>
</tr>
<tr>
<td>&lt;ESC&gt;:</td>
<td>Copy characters remembered by &lt;ESC&gt;* into line.</td>
</tr>
<tr>
<td>&lt;ESC&gt;&lt;ESC&gt;&gt;&lt;LF&gt;</td>
<td>Insert a line after the current line.</td>
</tr>
<tr>
<td>&lt;ESC&gt;&lt;BS&gt;</td>
<td>Join current line to previous or next line.</td>
</tr>
<tr>
<td>&lt;ESC&gt;&lt;LF&gt;</td>
<td>Split current line by inserting a new line following the current line.</td>
</tr>
<tr>
<td>&lt;BS&gt;</td>
<td>Position backward one character.</td>
</tr>
<tr>
<td>&lt;CTRL-R&gt;</td>
<td>Position forward one character.</td>
</tr>
<tr>
<td>&lt;CTRL-I&gt;</td>
<td>Position forward to next tab setting.</td>
</tr>
<tr>
<td>&lt;TAB&gt;</td>
<td>Position forward to next tab setting.</td>
</tr>
</tbody>
</table>
Table 7-5. Screen Editing Directives

<table>
<thead>
<tr>
<th>Input</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>[n]</td>
<td>Position to line n if directive has nothing following it. Otherwise replace line n with the remaining text.</td>
</tr>
<tr>
<td>[/string/]</td>
<td>Position to the next higher line number which contains the string 'string'.</td>
</tr>
<tr>
<td>[\string]</td>
<td>Position to the next lower line number which contains the string 'string'.</td>
</tr>
<tr>
<td>[\n]</td>
<td>Delete line number n.</td>
</tr>
<tr>
<td>[\n-m]</td>
<td>Delete line numbers n through line m.</td>
</tr>
<tr>
<td>[\n-m;/str/]</td>
<td>Delete line numbers n through line m if they contain the string 'str'.</td>
</tr>
<tr>
<td>[+]</td>
<td>Abandon screen editing mode ignoring all editing changes.</td>
</tr>
<tr>
<td>[n-m;c/x/S/y/]</td>
<td>Replace the c'\text{th}' occurrence of the string 'x' with the string 'y' in lines n through m.</td>
</tr>
</tbody>
</table>

Issuing System Commands

CP-6 APL allows the user to enter any system command while in function definition mode. Most system commands keep the user in function definition mode, while some system commands (described below) return the user to execution mode or even exit APL. After commands that keep the user in definition mode, APL will prompt with the same line number at which the command was given. For example, suppose the user is at line 5 of a function and wants to find out the names of variables in the workspace:

```
(5) )VARS
AAA BAT DDD
(5)
```

The system commands that exit function definition mode are: )CLEAR, )LOAD, )COPY, )PCOPY, )QLOAD, )QCOPY, )PCOPY, )CONTINUE, )CONTINUE HOLD, )OFF, )OFF HOLD, )END, )SAVE, and an )ERASE of the current function. All of these commands force a close of the definition mode as though the user had closed it, but the resulting disposition of that function depends on the command. The )CLEAR, )LOAD, )QLOAD, )ERASE, )OFF, and )END commands cause the function to be discarded; the )SAVE, )COPY, )PCOPY, )QCOPY, )QPCOPY, )CONTINUE, and )CONTINUE HOLD commands automatically reopen the function after the command has finished. In the last situation, as soon as the command has finished, APL signals the user of the reopening by printing the function name (with an opening del) and prompting with the next available line number. With the )CONTINUE and )CONTINUE HOLD commands, of course, the function is not opened until the next APL session. The user should display the function before doing any more editing, since renumbering may have occurred because of the forced close.
Function Execution

APL permits recursive functions (those which reference themselves when they are executed). APL also allows the user to suspend function execution. These topics are discussed in detail below.

Recursive Functions

Recursive functions reference themselves in the body of their definitions. As an example, notice the following function which returns the factorial of its argument:

```
VZ+*FAC N
[1] Z+1 0 +(N≤1)/0 0 Z+N*FAC N-1V
   FAC 0
   1
   FAC 1
   1
   FAC 4
```

Suspending Execution

Execution of a function is suspended (stopped) before completion, if any of the following occurs: the BREAK key is pressed, an error is encountered (unless sidetracking occurs, see section 10), or a user-set stop control is reached (see OSTOP). When a suspension occurs, APL prints the name of the suspended function and the line number at which it was suspended. At this point, APL is in direct execution mode (subject to any OSA requirements, see Section 11). Any functions that can be performed in execution mode are applicable during function suspension. As long as a function is suspended, its local variables are active and can be examined and modified.

The user can resume execution of a suspended function by specifying a branch. Entering a branch arrow followed by a RETURN key clears that suspension, while specifying a branch to a particular line number resumes execution at the beginning of that line (that is, at the right end of that line). Branching to a line outside a function’s range of line numbers, or zero, terminates the execution of that function.

As a general rule, it is best not to leave a function suspended, because the information about that function occupies workspace which is valuable to the APL user (see State Indicator). In addition, each time the user attempts to execute an already suspended function, even more information about that function is added to computer memory. Thus, if the user has no specific reason to leave a function suspended, it should be cleared before proceeding with the rest of the program. (See also the )SIC command in Section 8.)

State Indicator

APL maintains a "state indicator" that gives a list of all suspended and pendent functions (that is, all "active" functions). A suspended function is one where execution is stopped before completion (see Suspending Execution). A function is pendent unless specifically suspended. Most commonly, this is observed when one (pendent) function has called a suspended function. As a rule, suspended functions are stopped between lines, while pendent functions are stopped in the middle of a line. Note, however, when a function is suspended due to an error, the error marker may indicate the middle of the line; nevertheless, the function is stopped between that line and its predecessor. A display of pendent and suspended functions can be obtained via the )SI system command, with the most recent active function displayed first.
An asterisk after an entry indicates a suspended function; absence of an asterisk indicates a pendent function. The bracketed number after a function name is the number of the next line to be executed. If there are no suspended or pendent functions in the state indicator, no report will result from the )SI command. The number of items in the state indicator can be determined by typing the expression $pOLe$.

Unlike suspended functions, pendent functions cannot be erased, copied over, or edited. As an example, look at the state indicator list shown above. Functions $Z$ and $W$ can be edited but functions $X$ and $Y$ cannot. Notice that function $X$ is listed as both pendent and suspended; it cannot be edited because it is pendent in one of its states. Also notice that function $Z$ has been suspended twice.

There is one instance in which a pendent function will not be listed in the state indicator. Suppose a dyadic function is about to be executed, pending resolution of its left argument. Assume that argument is obtained as the result of some function, say $F$, and $F$ is suspended. Then the dyadic function is pendent, because it is ready to execute as soon as $F$ is resumed. But the dyadic function is not listed in the state indicator because it has not yet entered a state of execution. Fortunately, this situation is rare and seldom will confuse the user.

The system command )SINL lists the contents of the state indicator, including a list of variables local to pendent and suspended functions. Using the command )SINL lists the following:

)SINL

$Z[2] \ast A B$
$X[4] \ast AA$
$Y[3]$
$Z[2] \ast A B$
$X[2] AA$
$W[5] \ast$

As with the )SI command, the most recent active function is displayed first. This example indicates that variables $A$ and $B$ are local to function $Z$ and that variable $AA$ is local to function $X$. Only the local variables of the most recent active functions can be accessed by the user. Thus, the user can access local variables $A$ and $B$ of the last invocation of function $Z$, and variable $AA$ of the last invocation of $X$. But, the user cannot access local variables $A$ and $B$ of the first invocation of function $Z$ or local variable $AA$ of the earlier invocation of function $X$ (see $X[2]$).

The user can clear the state indicator by using the branch arrow (that is, $\ast$). Each branch arrow clears one suspended function and its associated pendent functions; thus, to clear the entire state indicator, the user enters a branch arrow for each asterisk in the list. For example, the user can clear the previous indicator.

$+$

)SINL

$X[4] \ast AA$
$Y[3]$
$Z[2] \ast A B$
$X[2] AA$
$W[5] \ast$

$+$

)SINL

$Z[2] \ast A B$
$X[2] AA$
$W[5] \ast$

$+$

)SINL
The \textit{SINL} commands in this example show what is left in the state indicator after each branch arrow. The user can also clear the same state indicator by entering four successive branch arrows.

\begin{verbatim}
+  
+  
+  
+  \textit{SINL}
\end{verbatim}

In this case, the \textit{SINL} command shows that nothing is left in the state indicator. The easiest way to completely clear the state indicator is to issue a \textit{SIC} command.

CP-6 APL provides limited protection against \textit{SI DAMAGE}. As an example, suppose the user opens function \textit{F} and modifies the header, changing the function's type (e.g., monadic to dyadic, result to no-result) and then attempts to close function \textit{F}. If \textit{F} is not suspended, the function is closed as usual. If \textit{F} is suspended, APL issues a warning (to the effect that references in the state indicator will be damaged by the change to the header) and requests a response from the user. The user can either order the close to occur with \textit{SI DAMAGE} by typing \textit{YES} followed by a RETURN, or cancel the close in order to revise the function further, hopefully correcting the header. Only a type change requires this protection. It is perfectly permissible to make other changes to the header, such as adding locals or renaming the result or dummy arguments; however, this is seldom advisable (see Changing Suspended Functions above).

Locking Functions

A function can be locked during definition or editing by using an opening or closing $\leftarrow$ (\textit{V} overstruck with $\rightarrow$) instead of a \textit{V}. A locked function can be executed, copied, or erased, but it cannot be displayed, suspended, or altered. After a function is locked, any associated trace control or stop control is automatically reset.

Examples of locking functions are:

\begin{verbatim}
$\leftarrow$ HH $\leftarrow$HH $\leftarrow$ HH [0] $\leftarrow$ [0] $\leftarrow$ [0] $\leftarrow$
\end{verbatim}

Once locked, if an error exists that is not sidetracked in the function, the error is implicitly sidetracked by APL to the line on which the locked function was invoked and the error report occurs on that line.

System Functions Controlling Defined Functions

CP-6 APL provides system functions which have the ability to create, modify, display, and set or query the attributes of defined functions. This section also introduces the terms namelist and canonical representation which are defined in Section 11 under the heading "Namelist and Canonical Representations". The system functions covered in this section are:

\begin{verbatim}
\textit{OTRACE} Set/query function trace attribute  
\textit{OSTOP} Set/query function stop attribute  
\textit{OCR} Obtains function character representation  
\textit{OFX} Creates or modifies a function  
\textit{OAT} Query function attributes
\end{verbatim}

Each function is discussed in detail below.
DTRACE System Function (Tracing Execution)

Syntax:

\[ R+OTRACE F \]
\[ R+V \ OTRACE F \]

Parameters:

- **F** is a namelist containing the name of a displayable defined function.
- **V** is an integer or vector of integers that specify the line numbers for which execution results are to be displayed. Only the integers that correspond to line numbers in the named function are significant.
- **R** is an integer vector containing the original trace settings.

Description:

Function execution can be traced by displaying the results of statements (some or all) as execution of the function progresses. When any of the traced line numbers is executed, the result of its statements are printed. If the specified line contains a branch statement, a branch arrow followed by the new line number is printed. Specifying a trace vector of \((\texttt{t0})\) discontinues the trace.

Examples:

\((\texttt{t0})\) \texttt{OTRACE 'FAC'}

stops trace of function \texttt{FAC}.

Below is an example of tracing the execution of a function. Notice that all output resulting from a trace is identified by the function name and line number.

\[
\begin{align*}
\texttt{V2=FAC N} \\
\texttt{[1]} \quad & \texttt{Z+1} \\
\texttt{[2]} \quad & \texttt{+(N\leq 1)/0} \\
\texttt{[3]} \quad & \texttt{Z*N*FAC N-1} \\
\texttt{[4]} \quad & \texttt{V} \\
\end{align*}
\]

\[
\begin{align*}
1 \quad & 2 \quad 3 \quad \texttt{OTRACE 'FAC'} \\
\texttt{FAC 0} \\
\texttt{FAC[1]} \quad & 1 \\
\texttt{FAC[2]} \quad & +0 \\
& 1 \\
& \texttt{FAC 1} \\
& \texttt{FAC[1]} \quad 1 \\
& \texttt{FAC[2]} \quad +0 \\
& 1 \\
& \texttt{FAC 4} \\
& \texttt{FAC[1]} \quad 1 \\
& \texttt{FAC[2]} \quad +10 \\
& \texttt{FAC[1]} \quad 1 \\
& \texttt{FAC[2]} \quad +10 \\
& \texttt{FAC[1]} \quad 1 \\
& \texttt{FAC[2]} \quad +10 \\
& \texttt{FAC[2]} \quad +0 \\
& \texttt{FAC[3]} \quad 2 \\
& \texttt{FAC[3]} \quad 6 \\
& \texttt{FAC[3]} \quad 24 \\
\texttt{24} \quad & \texttt{(t0) OTRACE 'FAC'} \\
\texttt{1 \quad 2 \quad 3}
\end{align*}
\]
The same function written as a compound statement produces the following trace output:

\[
\begin{align*}
VZ &= \text{FAC }N \\
\texttt{[1]} &\rightarrow (\text{NSZ+1})/0 \text{ } \& \text{ } Z+N\times\text{FAC }N-1V \\
1 &\text{ OTTRACE 'FAC' } \\
\text{FAC}[1] &\rightarrow 0 \\
1 &\text{ FAC }1 \\
\text{FAC}[1] &\rightarrow 0 \\
1 &\text{ FAC }4 \\
\text{FAC}[1] &\rightarrow 10 \\
\text{FAC}[1] &\rightarrow 10 \\
\text{FAC}[1] &\rightarrow 0 \\
\text{FAC}[1] &\rightarrow 2 \\
\text{FAC}[1] &\rightarrow 6 \\
\text{FAC}[1] &\rightarrow 24 \\
24 \\
\end{align*}
\]

The dyadic OTTRACE function requires that the right argument contain a valid name or a DOMAIN ERR is reported. The explicit result of dyadic OTTRACE is an integer vector containing the original trace setting of the named function.

Setting a trace vector can also be included as part of a defined function. For example, if the statement 1 OTTRACE 'FAC' is included within the above function, line 1 will also be traced each time the function is invoked. More complex expressions can be used to produce conditional tracing. In such cases, the condition produces one or more values (line numbers) that are the left argument of OTTRACE. This generalization also applies to the stop vector described below.

The )OBSERVE command, described in Section 8, extends the tracing facility. It permits the user to see not only the final result of a trace command, but every intermediate result occurring as APL executes a traced statement.

The current trace settings may be obtained by the monadic execution of the OTTRACE system function. In this case, the right argument is the same as in the dyadic usage of OTTRACE and the result is an integer vector containing the current trace settings.

For example:

\[
\begin{align*}
1 &\text{ )OTTRACE 'FAC' } \\
1 &\text{ ' )OTTRACE 'FAC' } \\
1 &\text{ OTTRACE 'FAC' } \\
\end{align*}
\]

Possible Errors:

A RANK ERR is reported if:

\- the left argument (new trace settings) is not a scalar or vector.

A DOMAIN ERR is reported if:

\- the left argument is not a simple array containing only integers.
System Function (Stopping Execution)

Syntax:

\[ R+OSTOP F \]
\[ R+V OSTOP F \]

Parameters:

- \( F \) is a namelist containing the name of a displayable defined function.
- \( V \) is an integer or vector of integers that specify the line numbers at which the function is to stop. Of course, only the integers that correspond to line numbers in the named function are significant. If 0 is an item of \( V \), the function stops on exit.
- \( R \) is an integer vector containing the original stop settings.

Description:

A planned suspension of function execution, called a function stop, can be established by setting a stop control vector. This vector is set in the same manner that a trace control vector is set for a function trace.

When each specified line number is reached, APL stops execution and prints the function name, the line number, and optionally the line about to be executed. Function execution is now in a normal suspended state (subject to OSA setting), and can be terminated or resumed by appropriate branching (see Suspending Execution). Specifying \(~O\) discontinues the stop control vector; for example, \(~O) OSTOP 'FAC'\) discontinues any function stops in function \( FAC \). The \( )REPORT \) system command is used to include the APL statements in the stop report.

Examples:

Below is an example of stopping execution of a function named \( CIRCLE \):

\[ 2 5 OSTOP 'CIRCLE' \]
\[ CIRCLE \]
\[ CIRCLE[S] \]

Suspension activities

\[ +2 \]
\[ 13 \]
\[ 10 \]
\[ 30 \]
\[ CIRCLE[S] \]

The explicit result of \( OSTOP \) is an integer vector containing the original stop settings of the named function. Like the trace control vector, the stop control vector can also be used within a defined function to stop execution after a certain number of loops. Editing a line that has a trace or stop control set removes the control for that line. Deleting, copying the function from a saved workspace, or locking a function also deletes trace control and stop control vectors associated with a function.

The current stop settings may be obtained by executing the \( OSTOP \) function monadically. In this case, the right argument is the same as in the dyadic usage of \( OSTOP \) and the result is a simple integer vector of the current stop settings. For example:
```
STOPS='STOP 'CIRCLE'
STOPS
2
STOPS
2 5
" 'STOP 'CIRCLE'
2 5
  "STOP 'CIRCLE'
```

Possible Errors:
A **DOMAIN ERR** is reported if:
- the right argument does not contain a valid name.

A **RANK ERR** is reported if:
- the left argument (new stop settings) is not a scalar or vector.

A **DOMAIN ERR** is reported if:
- the left argument is not a simple array containing only integers.

**OCR System Function (Canonical Representation)**

**Syntax:**
```
R+OCR F
```

**Parameters:**
- **F** is a namelist containing the name of a displayable defined function.
- **R** is a simple character matrix.

**Description:**
The **OCR** system function is used to obtain the character representation of a defined function. The right argument must be a namelist containing the name of a single defined function. The result is a matrix containing the canonical representation of the function (if it is displayable) or a 0 by 0 matrix if the name is not a defined function or not displayable.

The canonical representation of a function contains the function header in the first row, followed by the function lines in the remaining rows.

**Examples:**
```
pR+OCR 'FAC'
4 11
R
R+FAC N
R+1
+(N+1)/0
R+N+FAC N-1
```
OFX System Function (Fix Definition)

Syntax:

\[ R+OFX \ CR \]
\[ R+AT \ OFX \ CR \]

Parameters:

- **CR** is a simple character matrix (or vector with carriage returns) containing the canonical representation of a defined function.
- **AT** is a scalar or four-item vector containing only the scalar values 1 or 0.
- **R** is a simple character vector containing the name of the function established or an integer scalar row index of **CR**.

Description:

The **OFX** system function creates a defined function from its canonical form. The right argument must be a character matrix (or vector with carriage returns separating lines). The first row of the matrix must be a valid function header and the remaining rows must be valid function lines. The explicit result of this function is the name of the function that was established, or the integer row index of the line which caused the definition attempt to fail.

Before the function is established, APL makes sure that the name is not currently in use for anything other than a defined function. A **DOMAIN ERR** is reported if the name is in use and not a defined function or if the right argument is not a simple character array. A **RANK ERR** is reported if the right argument is not a scalar, vector or matrix. If the name is currently a local symbol to an active or executing function, then this function will exist as a local function.

When **OFX** is used dyadically, the left argument must either be a scalar or four-item vector of simple booleans (1's and 0's). The left argument specifies the execution properties of the defined function. The four properties in order are:

1. not displayable
2. not suspendable
3. not interruptable
4. execution errors converted to **DOMAIN ERR**

If a scalar is used as the left argument, all four properties are set to that value. Setting all of the properties to 1 is the same as locking the function.

Examples:

\[ pR+OFX CR+(24+R+FAC N'),[0.5]'+(N\times R+1)/0 \, R+N\times FAC \, N-1' \]

3

\[ R \]

\[ FAC \]

\[ CR \]

\[ R+FAC \ N \]

\[ +(N\times R+1)/0 \, R+N\times FAC \, N-1 \]

\[ n\mbox{FAC}(\mbox{R})n \]

\[ R+FAC \ N \]

\[ +(N\times R+1)/0 \, R+N\times FAC \, N-1 \]

\[ n \]
OAT System Function (Function Attributes)

Syntax:

\[ R+I \text{ OAT NAMES} \]

Parameters:

- **NAMES** is a namelist containing the names of defined functions.
- **I** is the simple scalar integer value 1, 2, 3, or 4.
- **R** is a simple matrix containing the requested function attributes.

Description:

The system function OAT returns attributes for each function named in the right argument. When a function is created by function definition or by the OFX system function, four attributes specific to the function are defined. The attributes include the valence of the function, the creation time, the execution properties, and the account which created the function.

The right argument of the OAT system function must be a namelist containing the names of the functions whose attributes are to be returned. The left argument is an integer scalar in the range 1 through 4 whose value determines the attribute to be returned. The result is a matrix (or vector if the namelist is a vector containing one name) with one row for each name in the namelist.

The left argument value and the associated attributes are:

1 - Valences

Three items indicating whether a result may be produced and the number of arguments. The first item is 0 if there is no result, or 1 if there is a result. The second item is 0, 1, or 2 for niladic, monadic or dyadic functions. The third item is 0 and is reserved for future use.

2 - Creation Time

A seven-item vector indicating the time that the function was created. The items are in the following order: year, month, day, hour, minute, second, and millisecond.

3 - Execution Properties

A four-item vector, indicating execution properties of this function. The first item is 1 if the function may not be displayed (OCR not permitted). The second item is 1 if the function may not be suspended (by double attention or an error). The third item is 1 if the function is not interruptable by a single attention. The fourth item is 1 if any execution error (non-resource) produces a DOMAIN_ERR report. The action of locking a function sets all but the last of these properties to 1. The dyadic use of the OFX system function permits each of these properties to be set independently.

4 - Creator

An eight-item character vector, indicating the account that created (or last modified) this function.
Examples:

\[ pR+1 \text{ DAT 'FAC'} \]

3

\[ R \]

1 1 0

2 \text{ DAT 'FAC'}

1983 10 11 12 29 59 610
Section 8
System Commands

System commands allow the user to control the mechanical aspects of APL, and can be divided into three categories:

1. Workspace Control Commands – commands that affect the state of active and saved workspaces.
2. Inquiry Commands – commands that supply information about the active workspace.
3. Communications Commands – commands that send messages to the computer operator and log the user off APL.

System commands always begin with a right parenthesis and can be entered when the system is in execution mode or definition mode. By using the Execute operator (see Section 5), system commands can be embedded in an APL expression and in a function line. Thus, a system command can be placed under control of such expressions or functions. Only the first four letters of command names are significant. Name characters after the fourth are ignored. Thus )CLEA and )CLEAVAGE are both interpreted to be the )CLEAR command. Note that a blank must separate the command name and any following parameters; for example, )WIDTH 30 is not the same as )WIDTH30. A number of conventions are used in this section to describe the command formats.

1. Uppercase letters and special symbols must be typed exactly as they appear (except that only the first four letters of a command are required, as noted above).

2. Lowercase letters are employed to indicate where in a command to substitute a name or numerical value. The meanings or the notations in lowercase letters are as follows:

- **account**: User account.
- **fid**: CP-6 file identifier of the form:
  - name.account.password.
  - Name can consist of up to 31 characters. Account and password can consist of up to 8 characters.
- **fname**: Name of a function.
- **grpname**: Name of a group.
- **list**: List of names (of functions, variables, groups), separated by blanks.
- **message**: Actual message to computer operator.
- **n**: An integer value.
- **objname**: Name of function, variable, or group.
- **string**: Any sequence of characters not including a blank or carriage return. If a string includes more than 79 characters, those past the 79th are ignored. Strings are used for range demarcation in certain commands.
- **vname**: Name of a variable.
wsname  A workspace name; can consist of up to 31 characters (letters, underscored letters and numbers) as long as the first character is not a number. It has the same form as fid.

The actual system commands are detailed later in this section, but first it is necessary to describe the concept of a workspace in order to understand how certain commands are used.

Workspace Concept

Each user has a storage area containing control information which can be saved for future use.

Active Workspace

Associated with each user is a storage area in the computer known as an active workspace. This active workspace contains the following:

1. All control information currently applicable to the terminal session.
2. The variables, functions, and groups entered for calculations and still active during the session.
3. A state indicator that keeps track of the names of suspended and pendent functions and at what point they were interrupted.
4. System variables that control several features of APL, such as index origin, seed for random number generation, line width, and number of significant digits (decimal places) printed. These system variables all assume default values when the user first invokes APL, but they can be respecified with system commands, or by assignment.

When APL is invoked, the active workspace is usually clear (that is, there is nothing in it except the default values of the parameters mentioned above in item 4). An active workspace can also be cleared with the system command )CLEAR.

Saved Workspace

An active workspace can be saved for future use with the )SAVE command. Once a workspace is saved, any user who knows the workspace name can load it as an active workspace using the )LOAD command. The workspace's variables, functions, and groups can be copied into an active workspace using the )COPY command. The workspace can also be dropped using the )DROP command (if file access controls permit). In addition, the names of saved workspaces in an account can be listed with the )LIB command.
Continue Workspace

A line disconnect or either of the following commands cause the active workspace to be saved in the logon account:

)`CONTINUE
)`CONTINUE HOLD

The CONTINUE workspace is automatically loaded as an active workspace the next time the user invokes APL unless it is directed to load another workspace. In general, the CONTINUE workspace can be used the same as any other named workspace. It can be saved, copied, loaded, etc. However, it should only be used for temporarily saving a workspace, since another `)CONTINUE command or line disconnect would save another active workspace over what was previously saved. That is, the previous CONTINUE workspace will be overwritten.

Since the CONTINUE workspace is part of the user’s logon account, it is subject to the granule restrictions imposed by an installation. If the user’s account is near that limit, the CONTINUE workspace may not be saved, and the information in the active workspace may be lost if a line disconnect occurs (see User Accounts). The CONTINUE workspace is saved with its access controls set to restrict access of the workspace to the user who created it.

Initiating an APL Session

APL is invoked with the following IBEX command syntax:


Parameters:

`fid1` is a CP-6 file identifier designating either a workspace to be loaded, or a file containing APL statements to be used as input. In either case, `fid1` indicates "source input" (the current setting of M$SI). If `fid1` is a workspace file or if `fid1` is not specified, then APL input will default to the terminal on-line or the default input device in batch (ME). The APL `)SET INPUT` command may be used to redirect input after entering APL.

`ON` specifies that if `fid3` already exists, the file is not to be overwritten. An error is reported.

`OVER` specifies that `fid3` is to be overwritten even if it currently exists.

`INTO` specifies that APL output is to be appended to the end of file `fid3` (if it exists).

`fid2` is the CP-6 file name that is to be used by APL to designate the CONTINUE workspace name (the current setting of M$OU). If not specified, the CONTINUE workspace name defaults to the string ‘APL:’ followed by the current user’s logon name (established when logging onto CP=6). The account used to hold the CONTINUE workspace is always the logon account. APL uses this file identifier in the event of a line disconnect, an uncontrolled error, or a limit exceeded error in batch mode, or if a `)CONTINUE` command is issued.

`fid3` is the CP-6 file identifier that specifies the file containing output generated by the APL session (the current M$LO setting). If `fid3` is not specified, then APL output will default to the terminal on-line and the line printer in batch. The APL `)SET OUTPUT` command may be used to redirect output after entering APL.

`options` is the list of APL options to be used for this session separated by commas. The options permitted are QUIET, WS, and CPV. The QUIET option invokes APL without the initial version and either CLEAR WS or SAVED messages being displayed. The WS option must be followed by = and a file which identifies a workspace to be automatically loaded. If the WS option is specified, then `fid1` must contain the APL statements to be executed. The CPV option causes some of the primitive functions in CP-6 APL to perform as their counterparts in CPV APL performed.
User Accounts

Accounts are specified when logging onto CP-6 or when accessing files in accounts other than the default file management account for a user. CP-6 installations impose restrictions on file allocation space (and file access) of file management accounts. When an account is at (or very near) its space limit, other files (or workspaces) in the account may need to be deleted to create or update a file (or workspace). In this event, APL reports the error. The ? command can be used to obtain more information about the error.

Command Processor

The material which follows assumes that the Command Processor in effect when APL is invoked is the CP-6 IBEX processor. If this is not the case, the commands )CONTINUE, )OFF, )SET may operate in a manner other than specified here. In particular, for the transaction processing command processor (TPCP), some of these commands will result in the BAD COMMAND error.

System Command Summary

The system commands are detailed below in alphabetic order, and are summarized by category in Table 8-1.

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workspace Control Commands</td>
<td></td>
</tr>
<tr>
<td>)CATCH [vname VIA name]</td>
<td>Removes any current catches (i.e., intercepts of assignments to specified variable names) or designates that assignments to vname are to be &quot;caught&quot; (intercepted immediately after the assignment), and that the test function name, a niladic function or character vector, is to be executed.</td>
</tr>
<tr>
<td>)CLEAR</td>
<td>Clears active workspace and restores default width, print precision, index origin, comparison tolerance, random number link, etc.</td>
</tr>
<tr>
<td>)COPY fid [list]</td>
<td>Copies functions, variables, and groups from saved workspace. Any password must be included, and so must the account if different than the file management account. If list is present, then only those named are copied. If list is not present, all names in fid are copied.</td>
</tr>
<tr>
<td>Command</td>
<td>Description</td>
</tr>
<tr>
<td>-----------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>)DIGITS [n]</td>
<td>Displays the current value of <strong>PP</strong> (numeric print precision). If n is specified, sets the value of <strong>PP</strong>, and displays the previous value of <strong>PP</strong>.</td>
</tr>
<tr>
<td>)DROP [fid]</td>
<td>Deletes a saved workspace. If the file identifier is protected with a password, the</td>
</tr>
<tr>
<td>)ERASE list</td>
<td>Removes the named objects such as functions, variables, or groups from active workspace.</td>
</tr>
<tr>
<td>)GROUP grpname [list]</td>
<td>Groups objects and names the group. If list is not specified, disperses the named group.</td>
</tr>
<tr>
<td>)LOAD fid</td>
<td>Moves a copy of the saved workspace into the active workspace. If the file identifier is protected with a password, the password must be specified. Also, if the saved workspace is in another account, that account must be specified.</td>
</tr>
<tr>
<td>)OBSERVE</td>
<td>Specifies that the next (direct input) statement and any traced function statements executed are to be &quot;observed&quot;. This displays a number of &quot;observations&quot;, showing intermediate results as APL interprets those statements.</td>
</tr>
<tr>
<td>)ORIGIN [n]</td>
<td>Displays the current value of <strong>IO</strong> (the index origin). If n is specified, sets the value of <strong>IO</strong> where n can be 0 or 1, and displays the previous value of <strong>IO</strong>.</td>
</tr>
<tr>
<td>)PCOPY fid [list]</td>
<td>Same as )COPY, except that a name is not copied if it already has a value in the active workspace.</td>
</tr>
<tr>
<td>)QCOPY fid [list]</td>
<td>Same as )COPY, except that the SAVED message is suppressed, i.e., quiet copy.</td>
</tr>
<tr>
<td>Command</td>
<td>Description</td>
</tr>
<tr>
<td>-----------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>)QLOAD fid</td>
<td>Same as }LOAD, except that the SAVED message is suppressed, i.e., quiet load.</td>
</tr>
<tr>
<td>)QPCOPY fid [list]</td>
<td>Same as }PCOPY, except that the SAVED message is suppressed, i.e., quiet copy.</td>
</tr>
<tr>
<td>)SALVAGE fid [list]</td>
<td>Similar to }COPY except objects may be copied from broken workspaces.</td>
</tr>
<tr>
<td>)SAVE [fid]</td>
<td>Saves the active workspace. If fid is specified, saves active workspace under the specified name. To save a workspace and protect it with a password, follow the workspace name with two periods and the password name (i.e., )SAVE wsname..password).</td>
</tr>
<tr>
<td>)SEAL [fid]</td>
<td>Saves the current workspace as a sealed 'execute-only' workspace with the designated name.</td>
</tr>
<tr>
<td>)WIDTH [n]</td>
<td>Displays the value of (PW) (the current maximum width of output lines). If n is specified, the value of (PW) is changed, and the previous value of (PW) is displayed. The width parameter n can range from 32 to 390.</td>
</tr>
<tr>
<td>)WSID [fid]</td>
<td>Displays the file identifier of active workspace. If fid is specified, assigns the file identifier to active workspace, or changes the name if one already exists and displays the old name.</td>
</tr>
</tbody>
</table>

Inquiry and Communication Commands

| )CONTINUE [ON|OFF][HOLD][fid] | Ends terminal session, and saves the active workspace as a CONTINUE workspace. If HOLD is specified, returns control to the CP-6 IBEX command processor. If OFF is specified, suppresses automatic generation of CONTINUE workspace file. If ON is specified, reinstates such automatic generation. If fid is specified, it overrides the default CONTINUE workspace name. |
## Table 8-1. System Command Summary (cont.)

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>)EDITOR [CP6RR</td>
<td>STD</td>
</tr>
<tr>
<td>)END</td>
<td>Returns control to CP-6 IBEX.</td>
</tr>
<tr>
<td>)ERROR [BRIEF</td>
<td>FULL</td>
</tr>
</tbody>
</table>
| )FNS [string1 [string2]] | Alphabetically lists all defined function names in active workspace. CP-6 APL uses the following collating sequence in the process of alphabetizing:  
  o blank or end of name  
  o digits  
  o alphabetic letters without underlines (A through Z)  
  o underline  
  o underlined alphabetic letters (A through Z)  
  o Â, Â  
If string1 is specified, the list of names starts at the first name which is alphabetically equal to or greater than string1. If string2 is specified, the list of names ends before the first name alphabetically greater than string2. |
<p>| )GO | Resumes execution at the current line.                                                                                                       |
| )GRP name | Lists the names in the specified group.                                                                                                      |</p>
<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>)GRPS [string1 [string2]]</td>
<td>Alphabetically lists all group names in active workspace. CP-6 APL uses the following collating sequence in the process of alphabetizing:&lt;br&gt; - blank or end of name&lt;br&gt; - digits&lt;br&gt; - alphabetic letters without underlines (A through Z)&lt;br&gt; - underlined alphabetic letters (A through Z)&lt;br&gt; - Α, Α&lt;br&gt; If string1 is specified, the list of names starts at the first name which is alphabetically equal to or greater than string1. If string2 is specified, the list of names ends before the first name alphabetically greater than string2.</td>
</tr>
<tr>
<td>)IBEX message</td>
<td>Issues command to IBEX.</td>
</tr>
<tr>
<td>)LIB [account]</td>
<td>Lists the names of saved workspaces in an account.</td>
</tr>
<tr>
<td>)NMS [string1 [string2]]</td>
<td>Alphabetically lists all of the global names in use and their name class in the active workspace. The string1 and string2 parameters are used in the same way as the )FNS command.</td>
</tr>
<tr>
<td>)OFF [HOLD]</td>
<td>Ends the terminal session and discards the active workspace. If HOLD is specified, control returns to CP-6 IBEX, otherwise the user is logged off of CP-6.</td>
</tr>
<tr>
<td>)OPR message</td>
<td>Sends message to computer operator, and waits for a reply.</td>
</tr>
<tr>
<td>)OPRN message</td>
<td>Sends message to computer operator.</td>
</tr>
<tr>
<td>)QUIT</td>
<td>Same as )END.</td>
</tr>
<tr>
<td>Command</td>
<td>Description</td>
</tr>
<tr>
<td>------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>)REPORT</td>
<td>If FUNCTION is specified, APL displays the function name and line number when a function is stopped (default). If LINE is specified, APL displays function name, line number and the contents of the line when a function is stopped.</td>
</tr>
<tr>
<td>)RESET</td>
<td>Completely clears the state indicator. Same as )SIC.</td>
</tr>
<tr>
<td>)SET dcb fid</td>
<td>Allows routing of regular output, input and/or 'blind' I/O channels to files or various devices, and specification of formatting options for device output. Analogous to the SET command in CP-6 IBEX.</td>
</tr>
<tr>
<td>)SI [ON</td>
<td>OFF</td>
</tr>
<tr>
<td>)SIC</td>
<td>Completely clears the state indicator. Same as )RESET.</td>
</tr>
<tr>
<td>)SIL</td>
<td>Lists contents of the state indicator, a list of suspended and pendent functions, and the contents of lines in execution.</td>
</tr>
<tr>
<td>)SINL [ON</td>
<td>OFF</td>
</tr>
<tr>
<td>)SIV [ON</td>
<td>OFF</td>
</tr>
<tr>
<td>)STEP [LINE</td>
<td>FUNCTION] [n]</td>
</tr>
</tbody>
</table>
Table 8-1. System Command Summary (cont.)

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
</table>
| )TERMINAL [INPU[T]OUTP[UT]] [n] | Identifies to APL the input/output devices being used, where n can be any of the following values:  
  1,13,14 for devices with APL character set  
  2,3,4,5 for devices with ASCII character set |
| )VARS [string1 [string2]] | Alphabetically lists all global variable names in active workspace. CP-6 APL uses the following collating sequence in the process of alphabetizing:  
  o blank or end of name  
  o digits  
  o alphabetic letters without underlines (A through Z)  
  o underlined alphabetic letters (Å through Æ)  
  If string1 is specified, the list of names starts at the first name which is alphabetically equal to or greater than string1. If string2 is specified, the list of names ends before the first name alphabetically greater than or equal to string2. |
| )? | Displays the next highest detailed error message (if any) about the most recent error condition. |
| )CATCH | Intercepting Assignments |

Syntax:

)CATCH [vname VIA name]

Parameters:

vname is the name of the variable (which may be local or global).  
name is the name of a function or character vector.
The )CATCH command is primarily a debugging tool. It permits the programmer to intercept each assignment to a specified variable name, immediately after that assignment is completed. The function is defined according to the user's debugging needs. The only restriction is that the name must be a character vector or represent a niladic function with no result. This restriction isolates the name from the statement or statements assigning values to the specified variable. If the name is undefined or does not indicate a character vector or a niladic, no-result function, no error message occurs; the catch is simply ignored. Catches on shared variables are not permitted.

Catches are not saved when a workspace is saved, so loading a workspace does not automatically reinstall catches. The )CLEAR command also removes any current catches. The )CATCH command without options removes any existing catches. A maximum of two catches can be defined at one time.

Examples:

Suppose the programmer has invoked the following catch,

)CATCH V1 VIA F1

then all assignments to the name V1 cause function F1 to be called or if F1 is a character vector, the expression ~F1 is executed. This includes indexed assignments. F1 is executed regardless of whether V1 is a local or global variable. The programmer can modify this catch to enter a different test function. For example,

)CATCH V1 VIA F20

After the above specification, assignments to V1 cause test function F20 to be called (instead of F1).

The programmer can also invoke a second catch. For instance,

)CATCH VAR2 VIA FOTHER

The programmer can have both catches enter the same test function as in the next example.

)CATCH VAR2 VIA FSAME
)CATCH V1 VIA FSAME

The programmer cannot, however, invoke a third catch; this attempt produces a BAD COMMAND error.

Any current catches can be removed by issuing the command

)CATCH

Following this command, the programmer is free to specify one or two new catches.

The simplicity of the )CATCH command may obscure its power as a debugging aid. This power is brought to bear by the test expression. A few hypothetical examples are given below to suggest the potential of catch capability.

Using a catch to display values assigned to vname:

)CATCH X VIA SHOWX
SHOWX= ' "X IS : " X X X'

As long as the catch is in effect, every assignment to X will cause the new value of X to be displayed. A catch may be used to stop execution when a particular value is assigned to a name. (Assume that X is a scalar and 77 is the value of interest.)
As long as this catch is in effect, each assignment to X will be tested at line 1 of the CHECK function. If X is not 77, line 1 causes CHECK to exit. If X receives the value 77, line 2 is executed. Line 2 sets the stop-vector for the CHECK function so that when the line labeled STOP is reached, CHECK will suspend execution.

Using a catch to change the value of vname:

(Note that this does not affect the value used by the statement making an assignment to vname; the catch is isolated.)

As long as this catch is in effect, each assignment to X that occurs "outside" the CHANGE function will cause X to be set to 0. The assignment at line 1 of the CHANGE function will not be "caught" because calling the function temporarily declares the name CHANGE to be a local variable (shadowing the definition of CHANGE as a test function); see the function header line.

Suppose the following statement is executed with the above catch in effect.

\[ X + 100 + X + 55 \]

The answer of 155 results in the following way.

1. The value 55 is obtained.
2. \( X \) is assigned the value 55.
3. The catch occurs.
4. \( X \) is set to 0 by the CHANGE function.
5. Execution of the original statement resumes, undisturbed (so far, at least) by the catch. This means that the value 55 is the right argument of the next addition.
6. 100 plus that argument yields 155.
7. This value, 155, becomes the right argument of the next addition.
8. The value of \( X \) is obtained; it is now 0.
9. 0 plus 155 yields the final result.
)CLEAR    Clearing Workspace

Syntax:
)CLEAR

Description:
The )CLEAR command deletes all groups, functions, variables, and the state indicator from active workspace. Furthermore, it resets the following system variables and workspace attributes to the values in parentheses:

- Random number link (16807). □RL
- Comparison tolerance (1E-13). □CT
- Index origin (1). □IO
- Platen width (terminal dependent). □PW
- Significant digits (10). □PP
- Workspace identification (CLEAR WS).
- Latent expression (''). □LX
- Stop action (''). □SA
- State indicator control (ON); see also the )SI command description.
- Current catches (none), see the )CATCH command description.
- Error number (0), see Sidetracking on Errors and Breaks in Section 10
- Error location (line number 0 and function name an empty character vector). (See also Section 10).

APL responds to this command by printing the message CLEAR WS.

Example:

)CLEAR
CLEAR WS

)CONTINUE    Saving Active Workspace and Leaving APL

Syntax:
)CONTINUE [([ON|OFF|HOLD][fid])]
Parameters:

fid overrides the default CONTINUE workspace name.

HOLD causes APL to exit to IBEX rather than logging off.

ON specifies reinstatement of automatic generation of the CONTINUE workspace file.

OFF specifies suppression of automatic generation of the CONTINUE workspace file.

Description:

The }CONTINUE command saves the active workspace in a CONTINUE workspace, and logs the user off. This workspace is automatically loaded the next time the user invokes APL without specifying a workspace. The active workspace is also automatically saved as a CONTINUE workspace if the terminal is accidentally disconnected or other unexpected end of session (LIMIT exceeded, unexpected error, etc.) occurs, unless such automatic action is suppressed (see below).

A successful }CONTINUE command will produce a save report (time and date saved) and the CP-6 log off messages. If insufficient room remains in the user's account to save the workspace, APL prints an error message. If this happens, the user must delete some workspaces or other files before any APL workspaces may be saved.

The default CONTINUE workspace name can be overridden at APL invocation time or by appending a fid to the end of either form of this command. See "Initiating an APL Session" for more details on the continue workspace name.

NOTE: If a user's workspace is passworded, the password is retained in the CONTINUE workspace. In this case, the CONTINUE workspace is not automatically loaded the next time the user logs on.

If an account already contains a passworded CONTINUE workspace, any subsequent CONTINUE will fail until the passworded version is deleted. Sealed workspaces cannot be saved with CONTINUE.

If either form of the }CONTINUE command is given during function definition mode, the currently open function is closed by APL. When the CONTINUE workspace is loaded later, APL automatically reopens the function and prompts the user to continue function definition. The automatic saving of this workspace can be suppressed by issuing }CONTINUE OFF. It can be reinstated by issuing }CONTINUE ON.

The CONTINUE workspace can be used almost like any other named workspace. It can be saved, copied, loaded, etc. However, the default name should only be used for temporarily saving a workspace since any CONTINUE workspace can be erased by a new CONTINUE workspace save.

Examples:

}CONTINUE
APL:201 GEISERT SAVED 15:33 DEC 15 '84

Saves active workspace and ends terminal session after printing save report and CP-6 log off messages.

}CONTINUE HOLD
APL:201 GEISERT SAVED 15:31 DEC 15 '84

Saves active workspace and returns control to command processor after printing save report. IBEX prompts for commands with the ! character.
)COPY  Copying from Saved Workspace

Syntax:

)COPY fid [list]

Parameters:

fid is a CP-6 file identifier of a saved workspace.
list is a list of variable names, function names, or group names, separated by blanks.

Description:

The )COPY command copies information from a saved workspace into the active workspace. The information can consist of one, several, or all of the functions, global variables, and groups in the saved workspace. If the list parameter is not specified, all of the global names in the saved workspace are copied (except for system variables).

Note that if a workspace is saved with a password, that password must be included in the )COPY command. Also, if a workspace is copied from another user's account, the account must be specified in the )COPY command.

When a saved workspace is copied, only global functions, global variables, and groups are copied. If copied functions had sidetracks (see Section 10), then these settings also apply in the active workspace. All referents of a copied group are themselves copied into the active workspace. For instance, suppose group G1 is copied, where G1 contains A, B, and G2 with G2 being another group containing X, Y, and Z. Then the following are copied into the active workspace: G1, G2, A, B, X, Y and Z. The state indicator and system variables are not copied. (Most system variables can be copied by specifically naming them.)

A copy attempt may fail if there is not enough room in the active workspace to hold the items copied. In that case, an error message is displayed and the workspace will contain the same objects it contained before the )COPY command was issued. The error message TOO BIG TO LOAD is displayed when copying from a different account in which two conditions are met. First, the workspace copied from is large (so large that it could not even be loaded by the current user). Second, the referenced account is allocated more computer memory than is available to the current user's account (memory allocations are specified by the installation manager). This difficulty can be circumvented with the cooperation of the owner of the larger account, who can copy portions of the large workspace, forming one or more smaller workspaces. After this cooperative activity, the current user can copy required objects from those smaller workspaces.

If a )COPY command is issued during function definition mode, the currently open function is temporarily closed. When the copy is completed, the function is automatically reopened. The copy may have replaced the current function. If the )COPY command names functions that are pendent in the active workspace, they are not replaced. Suspended functions may be replaced and may cause an SI DAMAGE error message to be issued. Use of the )PCOPY command precludes this possibility.

The )PCOPY command is the same as the )COPY command except that an object is not copied if the active workspace already contains an object with the same name.

A group of objects can be copied even though the group definition is not copied. This happens if the group name matches the name of a pendent function in the active workspace or if the name matches any object in the case of )PCOPY. Alternatively, a group definition may be copied but some of its objects not copied.
Examples:

)COPY GRANOLA.ACCT33.SECRET
GRANOLA SAVED 15:08 DEC 15 '84

Copies a saved workspace named GRANOLA, and prints a save report giving the time and date GRANOLA was saved. The workspace GRANOLA is saved with the password SECRET in another user's account (account ACCT33).

)COPY KAWA
KAWA SAVED 15:00 DEC 15 '84

Copies an entire saved workspace named KAWA from the user's own account and produces a save report giving the time and date KAWA was saved.

)COPY WS.ATHF.CHEAP oPP
WS SAVED 13:31 DEC 01 '84

Copies a function named ATHF, a group named CHEAP, and the system variable oPP from a saved workspace named WS in the user's own account. A save report giving the time and date WS was saved is printed.

)COPY HENRY..SECRET
HENRY SAVED 15:08 DEC 15 '84

Copies a saved workspace named HENRY, and prints a save report giving the time and date HENRY was saved. The workspace named HENRY is saved with the password SECRET in the current user's account.

If the )COPY command is used to access a workspace sealed by another user, the error message SEALED WS is reported.

)DIGITS   Specifying Numeric Print Precision

Syntax:

)DIGITS [n]

Parameters:

n indicates the new value for oPP (the number of significant digits in printed output) which can be any integer number from 1 through 20. APL then prints the previous value of oPP. If n is not specified, APL prints the current value of oPP.

Description:

The )DIGITS command sets the number of digits in numeric output to a number between 1 and 20 inclusive. The default value in a CLEAR WS is 10, which displays a maximum of 10 significant digits. Only numeric output and the result of the monadic ⎕ function are affected by this command; internal calculations are not affected.

Examples:

)DIGITS
IS 10

This requests the value of oPP to be displayed. APL responds with the current value.

)DIGITS 15
WAS 10

This sets the value of oPP to 15. APL responds with the previous value.
Here, the result of a calculation is printed. APL displays the value to 15 significant digits.

)DIGITS 5
WAS 15
This sets DPP digits to 5, and APL responds with the previous value.

4+9
0.44444
The result of an expression is displayed again, showing 5 significant digits.

The number of significant digits to be output can also be changed by redefining the value of DPP.

)DROP  Dropping a Saved Workspace

Syntax:
)DROP [fid]

Parameters:

fid is a CP-6 file identifier (omission of fid implies the default CONTINUE workspace) of a saved workspace.

Description:

The )DROP command removes a saved workspace. It has two forms, one for removing unprotected workspaces, and another for removing the default CONTINUE workspace. If the workspace is not found, delete access is not available, or the proper password is not provided, APL returns the message WS NOT FOUND. If the workspace is deleted, APL returns a message identifying the workspace and the time it was last saved.

Examples:

)DROP GRANOLA..SECRET
GRANOLA SAVED 14:58 DEC 15 '84

Removes the workspace GRANOLA with password SECRET, from the user's account.
Selecting the APL Function Editor

Syntax:

)EDITOR [CP6RR|STD|SE]

Parameters:

CP6RR selects the CP-6 re-read mode of editing APL lines in definition mode when a [line position] directive is encountered.

STD selects APL "super-edit" mode of editing APL lines in definition mode. This is the editing method most often available on other APL implementations.

SE selects the CP-6 APL screen editor. It is available for most CRTs that may be connected to the CP-6 system. The terminal profile must indicate RETYP0VR=YES and EDITOVR=YES.

Description:

The )EDITOR command permits the APL user to choose the edit mode of line editing for the [line position] directive. If a mode is not specified, the current editor setting is displayed. CP-6 re-read mode is by far the more powerful line editing technique, but super edit mode is included for compatibility with other APL implementations.

Super edit is a two-pass editing method. In this mode, the line is displayed and APL awaits input on the line following at the position specified. Blanks or backspaces may be entered to position. The digits 0 through 9 insert that number of blanks, the letters A through Z insert 5, 10, 15, ..., blanks. A slash "/" is used to delete characters. A decimal point "." inserts all of the characters following it.

The line is re-displayed with all of the character insertions and deletions and the cursor is positioned at the first insertion position. Now all of the normal CP-6 line editing capabilities are available to modify the line.

Examples:

)EDITOR STD
WAS CP6RR
VFUN
[1] a THIS IS A TEST OF SUPER EDIT
[1] [4] 20
[1] a THIS IS A TEST OF SUPER EDIT
[1] [4]
[1] a THIS IS A TEST OF SUPER EDIT
[2] v

Selecting the APL Function Editor

8-18

CE38-04
Syntax:
)END

Description:
The )END command causes the contents of the active workspace to be discarded, following which control is passed to the process which invoked APL. This is usually IBEX, the CP-6 Command Processor. This command is functionally identical to the )OFF HOLD command.

)ERASE   Deleting Objects From Active Workspace

Syntax:
)ERASE list

Parameters:
list specifies the names of the global objects (i.e., functions, variables or groups) to be erased. Note that it is the value that is erased; the name may remain in the symbol table.

Description:
The )ERASE command deletes one or more named objects (i.e., global functions, global variables, or groups) from the active workspace. If a group is named in the )ERASE command, that group definition is erased along with any functions, groups, or variables named in the group. Pendent functions cannot be erased. It is impossible to erase a locked function in a sealed workspace. During function definition, if the function being defined is erased, definition mode is abandoned (equivalent to closing the function and then erasing it).

Examples:

)ERASE MATHFUNCTIONS
Erases a group named MATHFUNCTIONS and the functions and variables it names. It disperses any group named within the group MATHFUNCTIONS.

)ERASE PAYROUTINE GROSS INS
Erases a function named PAYROUTINES and two variables named GROSS and INS.

NOTE: The )ERASE command will not remove local variables.
)ERROR Selecting Error Message Information Level

Syntax:
)ERROR {BRIEF|FULL|SUMMARY}

Parameters:
BRIEF selects the most concise error messages for future error displays.
FULL selects the most informative error messages for future error displays (possibly multi-line error messages).
SUMMARY selects one-line error messages for future error displays.

Description:
The )ERROR command selects the default error message information level. APL error messages are often available in various levels of information. The most concise messages are known as BRIEF. This type includes DOMAIN, RANK, LENGTH, and other general messages. These messages often contain sub-divisions which provide information specific to this instance. These sub-divisions are known as SUMMARY and FULL. SUMMARY messages are typically one line and FULL messages can contain up to seven lines of error message text. The )? command may be used to obtain additional error information after an error has been reported.

Examples:

)ERROR SUMMARY
WAS BRIEF
5+0
DIVISION BY ZERO
5+0
^
)ERROR FULL
WAS SUMMARY
1 2 + 1 2 3
THIS FUNCTION REQUIRES THAT BOTH ARGUMENTS HAVE THE SAME SHAPE (DIMENSIONS) OR THAT AT LEAST ONE ARGUMENT IS A SINGLE ELEMENT ARRAY.
1 2+1 2 3
^

)ERROR BRIEF
WAS FULL
1 2+1 2 3
LENGTH ERR
1 2+1 2 3
^
Listing Global Function Names

Syntax:
)FNS [string1 [string2]]

Parameters:
string1 is any sequence of characters not including blank or carriage return.
string2 is any sequence of characters not including blank or carriage return.

Description:
The )FNS command alphabetically lists the names of functions in the active workspace. If string1 is specified, all function names that are alphabetically equal to or greater than string1 and are also less than or equal to string2 are displayed. If string1 is not specified, all function names are displayed. Alphabetic ordering is illustrated in the examples. Note particularly the first )FNS command since it indicates where each name character lies in alphabetic order.

If a string includes more than 79 characters, those past the 79th are ignored. Strings are only used for range demarcation in an alphabetic ordering.

Examples:
)FNS
F FO F1 FF FX FXY FE FA FA S T
)FNS FF
FF FX FXY FE FA FA S T
)FNS F FF
F FO F1 FF
)FNS FFF FX
FX
)FNS FXY FXY
FXY
)FNS A Z
F FO F1 FF FX FXY FE FA FA S T

GO Resume Execution

Syntax:
)GO
Description:
The )GO command resumes execution of the most recently suspended function at the start of the current line.

)GROUP Creating a Group

Syntax:
)GROUP grpname [list]

Parameters:
grpname is the name of the group. A group name follows the same formation rules as a variable or function name, except that a group name cannot be the same as a global function or global variable in the active workspace.
list is a list of the names that make up the group, separated by blanks.

Description:
The )GROUP command references a group of names, i.e., variables, functions, other groups, or just names collectively. Group definitions can be used in )ERASE and )COPY commands to facilitate erasing and copying a group of related objects. Names can be added to an already existing group by merely repeating the group name in any of the command forms:

)GROUP grpname grpname list
)GROUP grpname list grpname
)GROUP grpname list grpname list

A group can be dispersed with the command form

)GROUP grpname

This form disperses the group; that is, removes the name references previously associated with grpname. The names and their references are not themselves erased, only the group identity is lost. An )ERASE command can be used to remove the group, but the )ERASE command removes the group and deletes the group referents (the actual functions or variables) from the active workspace.

Examples:

)GROUP PROB1 COS TAN A B

Defines a group named PROB1, consisting of the variable and functions named COS, TAN, A, and B.

)GROUP PROB1 PROB1 D ST

Adds the variable D and ST to the already existing group named PROB1.

)GROUP PROB1

Disperses the group named PROB1 from the active workspace. The referents of PROB1 are not deleted.

Note that the last example disassociates the function and variable names from the group, but does not delete actual functions and variables from the active workspace. The )GRPS command can be used to verify that the group named PROB1 has been deleted, and the )FNS and )VARS commands can be used to verify that the named function and variables still remain in the active workspace.
Also see the )GRP and )GRPS commands, which list the members of a group and the names of groups in active workspace respectively.

)GRP  Listing Members of a Group

Syntax:
)GRP name

Parameters:
name is the name of a group.

Description:
The )GRP command prints all of the names contained in the specified group.

Examples:
)GROUP C1 A B C
)GRP C1
A B C
)GROUP C1 G1 D
)GRP C1
A B C D
)GROUP C1 X Y Z G1 G2
)GRP C1
X Y Z A B C D G2
)GROUP G2 X A F1
)GRP G2
X A F1
)GRPS
C1 G2
)GROUP C1
)GRPS
G2
)GRP C1
)GRP G2
X A F1
Listing Names of Groups

Syntax:

)GRPS [string1 [string2]]

Parameters:

string1  is any sequence of characters not including blank or carriage return.
string2  is any sequence of characters not including blank or carriage return.

Description:

The )GRPS command alphabetically lists the names of groups in the active workspace. Alphabetic ordering is illustrated in the examples. Note particularly the first )GRPS command since it indicates where each name character lies in alphabetic order.

If string1 is specified all group names that are alphabetically equal to or greater than string1 are displayed. If string1 is not specified, all group names are displayed. If a string includes more than 79 characters, those past the 79th are ignored. Strings are only used for range demarcation in alphabetic ordering. If string2 is specified, all group names that are alphabetically equal to or greater than string1, and are also less than or equal to string2 are displayed.

Examples:

)GRPS
G  CO  G1  GC  GH  GHI  GQ  GA  GA  H
)GRPS GG
GC  CH  GHI  GQ  GA  GA  H
)GRPS G  GC  G
C  CO  G1  GC  CH
)GRPS GGG  CH
GH
)GRPS GHI  GHI
GHI  )GRPS A  Z
C  CO  G1  GC  GH  GHI  GQ  GA  GA  H

Issuing CP-6 Commands

Syntax:

)IBEX message
)?message

Parameters:

message  specifies text of a legal IBEX command.
Description:

The `!` command directs a string of characters to the CP-6 Command Processor (IBEX) for further processing.

Examples:

```
!)IBEX DI
USERS = 63
ETHF = 1
90p RESPONSE < 100 MSECS
DEC 15 '84 15:10
!)DI
USERS = 63
ETHF = 1
90p RESPONSE < 100 MSECS
DEC 15 '84 15:11
```

`!)LIB` Listing Names of Saved Workspaces

Syntax:

`)LIB [account]`

Parameters:

account specifies a CP-6 account name.

Description:

The `!)LIB` command lists the names of workspaces saved in an account. If a password was saved with a workspace, the workspace name is listed, but not the password.

Examples:

```
!)LIB
APLQUIZ
APLSIDR
PROB1
PROB2
```

Lists names of saved workspaces in the current user's account.

```
!)LIB REI07207
EDITFILE
FACTOR
PAYROLL
```

Lists names of saved workspaces in another account (account REI07207).
Syntax:

)LOAD fid

Parameters:

fid is the CP-6 file identifier of a saved workspace.

Description:

The )LOAD command causes a copy of saved workspace to be loaded into the user's active workspace. The saved workspace may be retrieved from a user's own account or another account. Note that if a saved workspace is retrieved from another account, the account must be specified in the )LOAD command. Also, if the workspace is saved with a password, that password must be included in the )LOAD command. In response to a successful load, APL prints a message giving the time and day that the workspace was saved. If the workspace is not found or if a proper password is not used, APL prints the message \textit{WS NOT FOUND}. After a successful )LOAD the expression \texttt{X} is executed.

If a workspace is saved during function definition mode, the )LOAD command causes APL to automatically reopen that function and prompt the user to continue function definition or editing. (The user may choose to close the function immediately.) If )LOAD accesses a workspace sealed by another user, the workspace is sealed, prohibiting any form of function editing or display.

Examples:

)LOAD KAWA
KAWA SAVED 15:00 DEC 15 '84

Loads workspace KAWA into the active workspace and prints a save report. Workspace KAWA was previously saved in the current user's account.

)LOAD HENRY..SECRET
HENRY SAVED 15:08 DEC 15 '84

Loads workspace HENRY into the active workspace and prints a save report. Workspace HENRY was previously saved with password SECRET in the current user's account.

)LOAD GRANOLA.TESTAPL.PASSWRD
GRANOLA SAVED 15:08 DEC 15 '84

Loads workspace GRANOLA into active workspace and prints a save report. Workspace GRANOLA was previously saved with password PASSWRD in account TESTAPL.
))NMS Displaying Global Names

Syntax:
))NMS [string1 [string2]]

Parameters:
string1 is any sequence of characters not including blank or carriage return.
string2 is any sequence of characters not including blank or carriage return.

Description:
The )NMS command alphabetically lists the global names in the active workspace. Alphabetic ordering is illustrated in the examples. Note particularly the first )NMS command since it indicates where each name character lies in alphabetic order.

If string1 is specified all global names that are alphabetically equal to or greater than string1 are displayed. If string1 is not specified, all global names are displayed. If a string includes more than 79 characters, those past the 79th are ignored. Strings are only used for range demarcation in alphabetic ordering. If string2 is specified, all global names that are alphabetically equal to or greater than string1, and are also less than or equal to string2 are displayed.

Examples:
))NMS
A.2 A0.2 A1.2 AA.3 B.3
))NMS AA
AA.3 B.3
))NMS A1 A1
A1.2 AA.3

))OBSERVE Observing Intermediate Results

Syntax:
))OBSERVE

Description:
The )OBSERVE command observes intermediate results developed by APL as it interprets a statement. This could be thought of as a "super-trace" capability. Following an )OBSERVE command, the succeeding statement is observed along with any traced function lines that are encountered. Subsequent direct statements are not observed unless the user precedes each of them by a new )OBSERVE command. Thus, an )OBSERVE command is short-lived, applicable to only one direct statement. By setting trace-vectors for functions to be encountered during an execution, however, the user can observe arbitrarily selected statements until issuing another direct input line.
While an )OBSERVE command is in effect, CP-6 APL displays a series of observations. An observation consists of displaying: the current line being executed, a marker (error caret) beneath some character in that line, and the value resulting at that point in execution (empty results, as usual, cause no value to be displayed). The observation marker often marks the leftmost point reached, so far, during execution of the line; however, when a function yields its results, the marker is placed below the function for clarity. (The only exception is the Execute function in which case the "leftmost" rule applies.)

For "observed" lines, observations occur for:

- Each operator result
- Each function result
- Arguments that have not already been observed on this line
- Indexed arguments

Observations are not made for assignments since the assigned value has already been observed prior to the assignment. Observations are also not made for the full variable when it is used as an indexed variable; this eliminates lengthy displays in cases such as the following sample )OBSERVE command.

```
A+1000p'GORP'
)OBSERVE
B=A[5]  This is the observed line.
5
G
)^A  Observation of the indexed argument A[5].
```

Note in the above sample that A was not displayed. This is fortunate since its display would produce 1000 characters, most of which contribute nothing to the observe statement.

Usage Notes:

The )OBSERVE command has three valuable uses: for debugging, for learning how a calculation is performed, and for developing better APL functions. Its value in debugging is obvious. Suppose a complicated APL statement produces a LENGTH ERR. By using the OBSERVE command and reissuing that statement, the programmer can view development of values leading up to the error and readily see what caused the problem.

The )OBSERVE command can be a tremendous timesaver. When presented with a new APL statement or function, the user can spend a great deal of time analyzing how it accomplishes its result. By observing a sample run, the interpretation path and values can be readily inspected, simplifying analysis greatly. The reader might apply this process to the following function.

```
VPRIHESUPTO N:jR1jJ
{lIf(O~(1+R)o.IJ)v«R+~LN*O.5)o.=I»/J+1+1+~N-1v
```

This function produces the prime numbers from 2 up to the positive integer specified as its argument. To observe this function, the user might proceed as follows:

```
1 OTRACE 'PRIMESUPTO'  Set to trace line 1 of the function
)OBSERVE
PRIMESUPTO 15  Request observations.
)OBSERVE
```

About 30 observations are made; then the )OBSERVE command "disappears".

There are at least two ways in which the )OBSERVE command can be used to develop better APL functions. First, redundant calculations are made obvious and the programmer can then eliminate such redundancies. The following function is an inefficient version of the PRIMESUPTO function. The user might try observing the function to discover how apparent such redundancies become under the )OBSERVE command.

8-28 )OBSERVE CE38-04

Observing Intermediate Results
The PRIHESUPTO function takes considerably more execution time (and produces more observations) than the PRIHESUPTO function shown previously.

The fact that the OBSERVE command is useful for developing better APL functions is not obvious. It depends on the creativity and imagination of the user. By viewing the manner in which a calculation is carried out, the creative user may recognize patterns that can be more easily produced by other calculations. In other words, observations can suggest alternate approaches to solving a given problem.

One final note about the OBSERVE command should be presented. Suppose the user suspends execution during an observed run by hitting the break key, for instance. This removes the OBSERVE command. Subsequent execution will not be observed unless the user issues a fresh OBSERVE. As stated earlier, this command is short-lived. (At times its short life can be inconvenient, but considering the voluminous output possible with the OBSERVE command this is more often a convenience.)

)OFF Logging Off

Syntax:
)
Parameters: HOLD

HOLD requests APL to return to the calling run unit or IBEX.

Description:

The )OFF command discards the active workspace, exits APL, and logs the user off of CP-6 (producing the CP-6 log-off message). If HOLD is specified, the user is not logged off. NOTE: If APL has been called from a run unit, not directly from IBEX, )OFF HOLD returns to the calling run unit.

Examples:
)
CON=00:00:36 EX=00:00:00.36 SRV=00:00:01:98 PMME=235 CHG=.44
Logs the user off and displays the CP-6 log-off messages.
)

Ends APL communication and returns control to IBEX.
Communicating with Computer Center Operator

Syntax:

)OPR message

Parameters:

message is the actual message to the operator; it cannot exceed 254 characters. Note that the operator's console does not include special APL characters, so messages should be limited to ordinary alphanumeric characters.

Description:

The )OPR command allows the user to send messages to the operator in the computer center and requests a reply. APL prints the word SENT and enters WAIT mode until the user presses the BREAK key or the operator response is received.

Examples:

)OPR CP-6 UP SUNDAY?
SENT
YES, FOR A WHILE.
Illustrates sending message to the operator and receiving a reply.

Communicating with Computer Center Operator

Syntax:

)OPRN message

Parameters:

message is the actual message to the operator; it cannot exceed 254 characters. Note that the operator's console does not include special APL characters, so messages should be limited to ordinary alphanumeric characters.

Description:

The )OPRN command allows the user to send messages to the computer operator, without waiting for a reply. APL responds to this command with the message SENT and then is ready for more input.

Examples:

)OPRN TRIAL MESSAGE. DON'T REPLY
SENT
Illustrates sending a message to the operator, with no reply expected.
)ORIGIN Setting Index Origin

Syntax:
)ORIGIN [n]

Parameters:

n is either 0 or 1.

Description:

The )ORIGIN command sets or displays the value of 0/0 (index origin). There are two index origins available, 0 and 1. The functions affected are index of and index generator (t), indexing and axis operator ([[]]), grade up (#), grade down (?), and random number generation (?).

The )ORIGIN command causes APL to set the index origin (the value of 0/0) and to print a message indicating the previous index origin. If the user does not supply parameter n when issuing this command, the current index origin is displayed. Note that the )ORIGIN command affects the active workspace and is saved along with a workspace. The index origin can also be changed by assigning a value to the system variable 0/0.

Examples:

)ORIGIN
IS 1 )ORIGIN 0
WAS 1 )ORIGIN 1
WAS 0

)PCOPY Copying from Saved Workspace

Syntax:
)PCOPY fid [list]

Parameters:

fid is a CP-6 file identifier of a saved workspace.

list specifies a list of variable names, function names, or group names, separated by blanks.

Description:

The )PCOPY command, the Protected Copy command, is the same as the )COPY command except that a name is copied only if the name in the active workspace is undefined (see the )COPY command).
)QLOAD, )QCOPY, and )QPCOPY    Quiet Commands

Syntax:

)QLOAD fid
)QCOPY fid [list]
)QPCOPY fid [list]

Parameters:

fid is a CP-6 file identifier of a saved workspace.

list specifies a list of variable names, function names, or group names, separated by blanks.

Description:

The )QLOAD, )QCOPY, and )QPCOPY commands are slight variants of the )LOAD, )COPY, and )PCOPY commands. The Q stands for quiet. The SAVED message normally shown at the conclusion of a load or copy is suppressed on a quiet load or copy. No other messages (i.e., error diagnostic) are suppressed by the quiet commands.

Certain APL application programs benefit from the quiet commands, programs that use execute-operations to load or copy without user intervention. The user is unaware that such )LOAD or )COPY commands are executed, and would be puzzled by SAVED messages.

The quiet commands should be inserted in programs only after the application is well tested. In the event of an error subsequent to a quiet load or copy, it may be difficult to isolate the problem for lack of knowledge about the workspace environment.

)QUIT Leaving APL

Syntax:

)QUIT

Description:

The )QUIT command causes the contents of the active workspace to be discarded, following which control is passed to the process that invoked APL (usually IBEX, the CP-6 Command Processor). The command is identical to the )END command.
)REPORT Selecting the Function Stop Display

Syntax:
)REPORT (FUNCTION) | LINE

Parameters:

FUNCTION sets function stop display to function name and line number (default).

LINE sets function stop display to function name, line number and contents of the line.

Description:

The )REPORT command is used to control the information displayed when a function stop occurs. The default display is the function name followed by the line number in brackets. Specifying the LINE parameter causes APL to also display the contents of the line at which execution stopped.

Examples:

)REPORT LINE
WAS FUNCTION
VFUN
[1] 1+1+2
[2] a COMMENT
[3] の
  2 1 STOP 'FUN'
VFUN
FUN[1] 1+1+2
)REPORT FUNCTION
WAS LINE
=nlc
4
FUN[2]
=nlc

)SALVAGE Copying from Saved Workspace

Syntax:
)SALVAGE fid [list]

Parameters:

fid is a CP-6 file identifier of a saved workspace.

list specifies a list of variable names, function names, or group names, separated by blanks.
Description:
The \texttt{SAVAGE} command retrieves information from a workspace which the \texttt{LOAD} or \texttt{COPY} command report as broken. The process is identical to that performed for the \texttt{COPY} command except that the current workspace must be CLEARed prior to issuing the \texttt{SAVAGE} command, and any items in disrepair are not copied.

If the file contents which describes the major structure of the workspace is defective, the \texttt{SAVAGE} command will still be terminated with a broken workspace report.

\textbf{\texttt{SAVAGE} Saving a Workspace}

\textbf{Syntax:}
\texttt{SAVAGE [fid]}

\textbf{Parameters:}
\texttt{fid} is a CP-6 file identifier. Like other APL names, the workspace name can consist of one or more letters from a to z, or A to Z, or numbers. Unlike other APL names, a workspace name is limited to 31 characters. If omitted, the \texttt{fid} defaults to the current workspace name (set by the \texttt{WSID} command).

\textbf{Description:}
The \texttt{SAVAGE} command saves a copy of the active workspace. If the active workspace was loaded as a sealed workspace, the workspace cannot be saved by \texttt{SAVAGE} or \texttt{CONTINUE} commands. Attempts to do so will result in a BAD FILE REF error. A word of caution is necessary about using passwords in the \texttt{SAVAGE} command. If a saved workspace already exists with a given name and password, specifying the same name with a new password in the \texttt{SAVAGE} command will not change the password. Instead it results in the error message \texttt{BAD FILE REF}. The previously passworded workspace must be deleted before a new version can be saved. To delete the old workspace, use the \texttt{DROP} command with the name and password. The workspace is saved provided that file management write access is available to the current user for the \texttt{fid} (expressed or implied).

When a workspace is saved while in the direct input mode (not in evaluated input, function definition, or execute modes), the variable \texttt{~X} will be executed when that workspace is subsequently loaded.

When a workspace is successfully saved, APL prints a save report giving the name of the workspace and the time and date of the save. The \texttt{SAVAGE} command also updates the current workspace identification, i.e., WSID. The name of the saved workspace along with its password (if any) becomes the WSID for the active workspace. If the workspace cannot be saved because it exceeds the available space in the user account, APL prints an error message. In this case, the user must delete some workspaces or other files from the account before saving any APL workspace.

If a \texttt{SAVE} command is issued during function definition mode, the currently open function is temporarily closed. The saved workspace carries an indication that the function should be reopened on \texttt{LOAD}. After the \texttt{SAVE} command, APL reopens the function and prompts the user to continue function definition or editing.
Examples:

)`SAVE GRANOLA...SECRET
GRANOLA SAVED 14:50 DEC 15 '84
)`

Saves a copy of the active workspace with specified workspace name and password, and produces a save report.

)`SAVE
CONTINUE SAVED 14:59 DEC 15 '84
)`

Saves a copy of the active workspace and produces a save report.

)`SAVE KAWA
KAWA SAVED 15:00 DEC 15 '84
)`

Saves a copy of the active workspace named KAWA and produces a save report.

)`SEAL Saving a Sealed Workspace

Syntax:

)`SEAL [fid]

Parameters:

fid is a CP-6 file identifier of the workspace to be sealed.

Description:

The )SEAL command is identical to the )SAVE command, but in addition the workspace is created with READ access to all accounts using APL as the execution vehicle. Thus, the user who creates the workspace has unrestricted access to it. All other users can only access the workspace with APL. If the save is not successful, BAD FILE REF, FILE SPACE TOO LOW, or other relevant error messages may be issued and the active workspace will not be sealed.

)`SET Changing Assignments of Input/Output Streams

Syntax:

)`SET dcb fid

Description:

Refer to the CP-6 Programmer Reference Manual (CE40) for a complete description of the SET command in CP-6 IBEX. Any )SET command is passed to IBEX for processing with only a minor change to the DCB designation as noted below.

The inclusion of the )SET command within APL permits error action by the user or, if error control is used, in APL functions. If any of the listed strings noted below are detected by APL, the corresponding substituted string is substituted before referral to IBEX:
User Prompts

If either output or input is diverted from the terminal, the prompts normally issued to the user are omitted. On ASCII terminals with full duplex, the echoing of characters indicates that input is being accepted. The home device for on-line sessions is the terminal. In batch the home devices are the command stream (card reader) for input, and line printer for output.

Echoing of Input

If input is coming from somewhere other than the user's terminal, then APL input (but not blind-input) is echoed to the output setting depending upon the IBEX ECHO setting. If input is echoing and this is not desired then the APL command:

)DONT ECHO

should be issued. Conversely, echoing may be initiated by the APL command.

)ECHO

Errors on Input or Output

If normal input or output is reassigned from the home device by the )SET command and an I/O error occurs, the input (or output) setting is returned to the home device(s). This is the user's terminal for on-line users, the card reader and line printer for batch. If error control is not in effect, an I/O error message is then output. If control is in effect for I/O errors, no error message is output. The user's error control function should note that input and output have been restored 'home' from their )SET command assignments.

Break Response

If normal input or output is reassigned from the home device by a )SET command, it is restored to the home device by a break. If the user has taken break control, the function which manages break control should note that input and output have been restored to the home device and terminal.

)SI    Controlling the State Indicator

Syntax:

)SI [ON|OFF|CLEA[R]]
Parameters:

CLEA[R] removes every entry in the state indicator. This may free a substantial amount of workspace and is a valuable tool for recovering from WS FULL errors.

ON suspends the executing function if an error occurs (the default). This is useful when debugging the workspace since it allows access to local variables for the suspended function. Suspending the function, however, expends a certain amount of the active workspace, and this can be a disadvantage. The ON option sets state indicator control for errors that may occur during subsequent execution of functions in the active workspace.

OFF sets state indicator control to avoid suspending a function when an error occurs. Note that the OFF setting applies only to errors. It has no influence over execution breaks or stop vectors; these may still cause function suspension. The OFF option sets state indicator control for errors that may occur during subsequent execution of functions in the active workspace.

Description:

The )SI command displays the contents of the state indicator, which is a list of suspended and pendent functions. For a discussion of the state indicators and suspended and pendent functions, see State Indicators in Section 7.

Examples:

)SI
A(2) *
XY(5)
B(3) *

The most recently suspended function is listed first. An asterisk after an entry indicates a suspended function; no asterisk indicates a function that is pendent. In the above example, function A has been suspended just before line number 2, and function B just before line number 3. Function XY is pendent because it referenced function A at line number 5. If )SI is issued when evaluated input is pending, the input request will also be displayed, using the 0 character. If the )SI command is issued when an "execute" is pending, the execute state will be indicated, using the 1 character.

Errors causing suspended function should be corrected as soon as possible. Suspended functions can be cleared from the state indicator with the branch arrow (+). (Remember that the state indicator with its list of suspended and pendent functions and local variables may take up a lot of workspace.) Each branch arrow clears the most recent suspended function and all pendent functions associated with it. This can be repeated until all suspended and pendent functions have been cleared; that is, until the )SI command returns a blank line. Applied to the above example, this would give

+ )SI
B(3) *
+ + )SI

A more convenient method for clearing the state indicator is to issue the following command:

)SIC

To restore normal state indicator control, the command

)SI ON

may be issued. This setting also occurs automatically if a )CLEAR command is issued. The ON or OFF state indicator control is saved when the active workspace is saved, and loaded when the workspace is loaded. Copying does not alter the control of the active workspace.
)SIC Clearing the State Indicator

Syntax:
)SIC

Description:
The )SIC command removes every entry in the state indicator. This may free a substantial amount of workspace and is a valuable tool for recovering from WS FULL errors.

)SIL Listing the State Indicator Lines

Syntax:
)SIL

Description:
The )SIL command lists the same information as the )SI command and also lists the contents of the lines that are currently in execution. For pendent functions, it indicates the position within each line at which execution is to be resumed. An * in column 1 indicates a direct input line in execution.

Examples:

)SIL
A(2) CC+1 20 BB
XY[5] R+100*L(A N)+100
* XY

B(3) VAL+(PAY+100)/PAY □ PAY+OFREAD 1 20
* B

)SINL Listing the State Indicator

Syntax:
)SINL [ONOFFCLEAR]

Parameters:
CLEAR removes every entry in the state indicator. This may free a substantial amount of workspace and is a valuable tool for recovering from WS FULL errors.

ON suspends the executing function if an error occurs (the default). This is useful when debugging the workspace since it allows access to local variables for the suspended function. Suspending the function, however, expends a certain amount of the active workspace, and this can be a disadvantage. The ON option sets state indicator control for errors that may occur during subsequent execution of functions in the active workspace.
OFF sets state indicator control to avoid suspending a function when an error occurs. Note that the OFF setting applies only to errors. It has no influence over execution breaks or stop vectors; these may still cause function suspension. The OFF option sets state indicator control for errors that may occur during subsequent execution of functions in the active workspace.

Description:

The )SINL command lists the same information as the )SI command and additionally lists the local variable names appearing in the suspended and pendent functions. For a discussion of the state indicators and suspended and pendent functions, see State Indicators in Section 7.

Examples:

)SINL
XY[5]
B[3] * PAY VAL

where BB, CC, and DD are local variables appearing in function A; and PAY and VAL are local variables appearing in function B.

Errors causing suspended function should be corrected as soon as possible. Suspended functions can be cleared from the state indicator with the branch arrow (+). (Remember that the state indicator with its list of suspended and pendent functions and local variables may take up a lot of workspace.) Each branch arrow clears the most recently suspended function and all pendent functions associated with it. This can be repeated until all suspended and pendent functions have been cleared; that is, until the )SI command returns a blank line. Applied to the above example, this would give:

+ )SINL
B[3] * PAY VAL
+ )SI

)STEP Single Step Execution

Syntax:

)STEP [LINE\FUNCTION] [n]

Parameters:

n indicates the number of statements to step. This can be any integer from 1 to 99999.

LINE specifies to stop before the next APL line is executed within any function.

FUNCTION specifies to stop before the next line is executed within the current function.
Description:

The )STEP command executes the line at the top of the state indicator and stops before another function line is executed. That is in the simplest case where the current line does not call another user function, the line will be executed and execution will halt before executing the next line. A single right bracket and a carriage return on a line also has this effect.

Examples:

)STEP LINE
FUN 1
FUN[1] )STEP
FUN[2] )STEP
FUN[1] )STEP
FUN[1] )STEP
FUN[2] )STEP FUNCTION
FUN[1]

)TERMINAL  Specifying Input/Output Device

Syntax:

)TERMINAL [INPUT|OUTPUT] [n]

Parameters:

INPUT specifies that only the input translation tables are to be affected.

OUTPUT specifies that only the output translation process is to be affected.

n indicates the device to be assumed by APL and can be any of the values 1, 2, 3, 4, 5, 13, 14.

Description:

The )TERMINAL command is used to identify to APL the input/output device being used. This command is not normally needed for users operating on a terminal or submitting batch runs for card input and line printer output. New terminal declarations are acceptable at any time during an APL session, but the user should be aware of the consequences (such as error message discrepancies and input/output translation problems). 0FFT also results in the integer n; this may be useful for APL programs that are sensitive to terminal type. Using )TERMINAL INPUT or )TERMINAL OUTPUT modifies only the specified (input or output) translation table. This form is useful when APL input or output is diverted to an alternate device by the )SET command.

CP-6 supports two types of input/output devices with respect to APL sessions:

0 Those capable of printing the APL character set.
0 Those capable of printing the ASCII-96 character set.

Specifying a terminal of type 1, 13, or 14 indicates the APL character set; types 2, 3, 4, or 5 specify the ASCII set with types 4 and 5, representing underscored letters as lowercase letters. Types 2 and 3 represent underscored letters as the mnemonic combination $U followed by the letter. For types 3 and 5, certain characters (0, ±, ≤, ≠, ≠, and %) are represented via appropriate backspace overstrike combinations.
Examples:

)TERM 5
WAS 1
)

Indicates that a Diablo 1620 terminal (or equivalent) with a non-APL daisy wheel is being used.

)TERM
IS 5

Shows that the non-APL Diablo 1620 terminal was most recently declared.

)TERM OUTPUT 4
WAS 5

Sets output translation for the line printer, but does not change input translation.

APL recognizes three separate choices for input/output character translation.

Input terminal type is changed by either )TERM INPUT n or )TERM n. Output terminal type is changed by either )TERM OUTPUT n or )TERM n.

Usage Notes:

The combination of the )TERMINAL and )SET commands permits a variety of I/O operations with devices and files. The user should be warned that some choices, particularly changes to the home terminal, can result in difficulties carrying on further terminal communications. In general, )TERM OUTPUT 4 should be used for line printer output. Output which is filed and reread by the same user should preferably use home terminal type. If several users with different terminals want to access the file, a common type should be agreed on, probably 1 for APL or 4 for ASCII.

)VARS Listing Global Variable Names

Syntax:

)VARS [string1 [string2]]

Parameters:

string1 is any sequence of characters not including blank or carriage return. If string1 includes more than 79 characters, those past the 79th are ignored.

string2 is any sequence of characters not including blank or carriage return.

Description:

The )VARS command alphabetically lists the names of global variables in the active workspace. Strings are used only for range demarcation in alphabetic ordering. If string1 is not specified, all global variable names are displayed. If string2 is specified, global variable names that are alphabetically equal to or greater than string1 and are also less than or equal to string2 are displayed. Alphabetic ordering is illustrated in the example. Note particularly the first )VARS command since it indicates where each name lies in alphabetic order.
Examples:

)}VARS
A A0 A1 AA AB ABC AA A0 A0 B
)}VARS AA
AA AB ABC AA A0 A0 B
)}VARS A AA
A A0 A1 AA
)}VARS AAA AB
AB
)}VARS ABC ABC
ABC
)}VARS A Z
A A0 A1 AA AB ABC AA A0 A0 B

)WIDTH Setting Line Width

Syntax:
)WIDTH [n]

Parameters:

n is an integer number ranging from 32 to 390.

Description:

The )WIDTH command changes or displays the value of OPW (Platen Width). This system variable is used to indicate the length of the longest line that APL will output. In a clear workspace the platen width defaults to the platen width when APL was initially invoked, or the closest value acceptable by APL to the initial value. The value of OPW is saved with a workspace and is restored when a workspace is loaded.

Examples:

)WIDTH
IS 120
Displays the current width of a line output (i.e., 120 printing positions).

)WIDTH 50
WAS 120
Changes the width of an output line to 50 print positions. The previous line width setting was 120.
}WSID  Identifying the Active Workspace

Syntax:
})WSID [fid]

Parameters:

fid is the new CP-6 file identifier of the active workspace. If fid is not specified, the fid of the active workspace is displayed. APL responds with a message showing the previous workspace name. This name can be from 1 to 31 characters.

password a password may be specified, but a previous password is never displayed.

Description:
The }WSID command allows the user to identify the active workspace or to change its name. The }WSID command cannot be used to change the name of a sealed workspace.

Examples:

})WSID
IS JONES
Lists the name (JONES) of the active workspace.

})WSID
IS GOSTYLE.ZZZ02MAR
Lists the name GOSTYLE and account ZZZ02MAR of active workspace.

})WSID SMITH
WAS GOSTYLE.ZZZ02MAR
Changes the name of the active workspace from GOSTYLE to SMITH.
Section 9
Report Formatting

CP-6 APL provides a formatted output capability with the system function OFMT in addition to the ¥ function. OFMT utilizes a set of format control phrases that are applied to a list of APL expressions. Each APL expression may evaluate to numeric or character scalars, vectors, or matrixes. The format control phrases, called format specifications, are described in Table 9-1.

Format Specifications

OFMT recognizes twelve data format codes. Each code is described in the following table.

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Alphanumeric specification.</td>
</tr>
<tr>
<td>E</td>
<td>Floating-point with exponent (scientific format).</td>
</tr>
<tr>
<td>F</td>
<td>Floating-point to fixed decimal position.</td>
</tr>
<tr>
<td>I</td>
<td>Decimal integer.</td>
</tr>
<tr>
<td>X</td>
<td>Blank insertion.</td>
</tr>
<tr>
<td>T</td>
<td>Column Tabbing.</td>
</tr>
<tr>
<td>G</td>
<td>Picture formatting.</td>
</tr>
<tr>
<td>TEXT</td>
<td>Text insertion.</td>
</tr>
<tr>
<td>TEXT</td>
<td>Text insertion.</td>
</tr>
<tr>
<td>TEXT</td>
<td>Text insertion.</td>
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<td>TEXT</td>
<td>Text insertion.</td>
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<tr>
<td>TEXT</td>
<td>Text insertion.</td>
</tr>
<tr>
<td>TEXT</td>
<td>Text insertion.</td>
</tr>
</tbody>
</table>

Format specifications may be in any of the following forms:

[r] Aw
[r] Ew.s
[r] [q] Fw.d
[r] [q] Iw
[r] Xw
[r] TEXT
T c
where

- \( r \) is an optional unsigned integer constant indicating the specification is to be repeated \( r \) times. When \( r \) is omitted, it is taken as 1.
- \( w \) is an integer constant indicating the total field width, or number of print positions occupied by the formatted value (or blanks, for \( X \) type).
- \( s \) is an integer constant indicating the number of significant digits to be printed in \( E \) format; \( s \) must be less than \( w-3 \).
- \( q \) is an optional "qualifier" or "affixture" code used to position and affix characters to the results of \( I \) and \( F \) output forms. The available codes and their uses are described later in this section.
- \( d \) is an integer constant indicating the number of digits to the right of the decimal point in \( F \) formats; \( d \) must be less than \( w \).
- \( c \) is the column number at which the next field will start to be formatted.

Format Specifications versus Data Types

Format \( A \) may be applied to character data only. Formats \( E \), \( F \), and \( I \) may be applied to numeric data only.

Arrays with rank above 2 (matrix) cannot be processed. If a value cannot meaningfully be expressed in the format and field width specified, the field is filled with asterisks.

Format Statement (Left Argument)

A format statement is the left argument of \( \text{DFMT} \), operating on data values in the right argument. The format statement consists of a character vector made up of one or more format specifications separated by commas. The left argument of \( \text{DFMT} \) must always be a valid format statement. For example,

\[ '3/3,2E8.2,12,.13' \text{ DFMT} ... \]

Parenthesis may be used with repeat counts around phrases. For example:

\[ '15,3(12,F8.2)' \text{ DFMT} ... \]

Parenthesis may be nested up to 7 deep within format phrases.

Format Data List (Right Argument)

The right argument of \( \text{DFMT} \) must be a list of APL variables or expressions, separated by semicolons. The expression may represent scalars, vectors, or arrays. For example,

\[ ... \text{DFMT} (\text{VARIABLE}1;\text{VARIABLE}1+\text{VARIABLE}2;'\text{SUM}') \]

If the list contains only one value, the parentheses may be omitted. The value of each expression must be simple and all numeric or all character.
Operation of OFMT

OFMT uses the format specifications in its left argument (the format statement) to control printing of its data list (right argument) on one or more columns. The syntax is

- `'format stmt' OFHT expr`
- `'format stmt' OFHT list`

The result of executing OFHT is one or more "lines" of formatted character data. A line may be as long as workspace allows. In printing, long lines are broken up according to the OPW setting. If more than one line is produced (as will be the case if the data list includes vectors or arrays with more than one row) all lines are of the same length. The result, then, is a character matrix.

If OFMT is not used within a larger expression, the amount of temporary workspace required is only the length of one line. Thus, formatted output may be used to process output that would overflow available workspace if assigned or used in its entirety. If OFMT is used within a larger expression, the result is always a matrix, even if only one line, and space for the full matrix is required. The operation of OFMT on various right arguments is described below.

Formatting Scalar Arguments

If the data list consists exclusively of scalars, a single line is created. Format specifications are used in turn to process elements of the data list in left to right order. Blank insertion and text insertion specifications do not "use up" elements of the data list, however. A repetition indicator causes a particular specification to be applied the designated number of times to successive elements of the data list. If there are fewer format specifications (counting repetition indicators) than values to be formatted, the list of format specifications is reused as necessary until the data list is exhausted.

Examples:

- `'13.45.5x5' OFHT (100;'A';200;'B')`
  100 A  200 B
- `'5F5.2' OFHT (1;10;100;-10;-1)`
  1.00 1.00

This last example illustrates the use of the repetition indicator. Also note the asterisks indicating that the value 100 and -10 would not fit in the specified format.

Formatting Vector Arguments

If the data list includes vector and scalar arguments (or vectors only), the number of lines generated equals the length of the vector with the most elements. Each vector creates a "column" in the resulting character array. The columns of shorter vectors or scalars are extended by blanks.
Examples:

'Ell.4' OFMT 3.1 123.1 2.34 5678
3.100E0
1.230E1
-1.234E0
5.678E3

'EIS, A2' OFMT (1 2 3 4:10.4 10.6; 'ABCDEF')
1 10 A
2 11 B
3 C
4 D
E
F

In the last example, note the rounding off of values as required for I format specifications, and also note the different column lengths.

Formatting a Vector on One Line

The normal result for OFMT on vector arguments is columnar formatting, but it is often desirable to create a formatted row for vectors. There are two ways this can be done:

- **Ravel the result of OFMT.** This method is appropriate if the result contains a single column.

  Examples:

  'A2' OFMT 'DOUBLE SPACE'
  D O U B L E S P A C E

  'I5' OFMT 14 1.4 14 140 1400
  1 14 140 1400

- **Reshape the vector as a 1 by N matrix.** (This method uses a property of the operation of OFMT on matrixes, as discussed below.)

  \[ V+ 'TRIPLE+SPACE' \]
  \[ 'A3' OFMT (1,pV) p V \]
  T R I P L E + S P A C E

Formatting Matrix Arguments

If the data list includes a matrix argument, each column of the matrix occupies a column in the formatted output. Each row of the matrix creates an entry on a "line" of output. Note that a 1 by N matrix creates a single row, and an N by 1 matrix creates the same output form as an N element vector.

In essence, OFMT outputs matrixes in the same shape as unformatted output would, but permits control of decimal placement, column positioning, etc.

Examples:

\[ IOTA+3 5pt 15 \]
\[ 'F5.1' OFMT IOTA \]
1.0 2.0 3.0 4.0 5.0
6.0 7.0 8.0 9.0 10.0
11.0 12.0 13.0 14.0 15.0
Picture Format

Picture formatting provides the greatest control over the result of numeric formatting. The syntax of a picture format is:

\[ [r] [g] G \text{ TEXT} \]

The \( B \), \( C \), \( L \) and \( Z \) format qualifiers are not permitted with picture formatting. The text field may contain any text. The two characters, '9' and 'Z' by default control the formatting of the numeric data. The data may be scaled by \( K \) qualifiers and then rounded to integer for formatting.

A '9' in the text field selects the corresponding digit from the data. A 'Z' in the text field selects the corresponding digit from the data only if the digit is not a leading or trailing zero.

As the text is scanned, characters other than 9 or Z are copied to the result. If there are leading or trailing Z controls, non-special characters are copied into the result only if the last Z selected a digit.

Examples:

\[ 'K2G<ZZZ,ZZZ DOLLARS, ZZ CENTS>' \text{ OFMT} 31415.962 \]

\[ 'G99/99/990' \text{ OFMT} 52282 \]

Forms of Output Values

The following rules determine spacing and content of output fields for various format specifications.

- **Right-justification.** For \( A \), \( I \), and \( F \) specifications, the value is right-justified in the field and preceded by blanks where appropriate to fill out the field.

- **E format.** The letter \( E \) always occupied the fourth space from the right in the field. Three spaces are reserved for the exponent value and exponent sign. If less than three spaces are needed, the right-most space or spaces are blank. In this format, there is columnar alignment of the decimal points and letter \( E \).

- **TEXT format.** Characters between the quote-quads (or other text insertion format specifications) are inserted directly into the output line. There are as many insertions as there are lines of output. No data list elements are expended by text insertion.

- **Significance of results.** The value of \( OFP \) is ignored in \( OFMT \) output; a maximum of 20 significant positions are displayed, however. If a format specification requests more than 20 significant digits, digits beyond the eighteenth, and to the left of the decimal point are replaced by zeroes. Excess digits to the right of the decimal point are replaced by blanks.

- **Field width.** If field widths are too small to hold formatted values according to the specification, the fields are filled with asterisks.
Format Qualifier and Affixture Codes

I and F format specifications may be immediately preceded by one or more qualifier or affixture codes.

- **Qualifier codes**
  - **B**: Leaves the field blank if the result would otherwise be zero.
  - **C**: Inserts commas between triads of digits in the integer part of the result.
  - **L**: Left-justifies the value in the result field.
  - **Z**: Fills unused leading positions in the result with zeros (and commas if C is also used) instead of blanks.

- **Kn**: Scaling factor. Before formatting, the data is multiplied by the power of 10 indicated by n. n may be any positive or negative integer.

- **Affixture codes**
  - **H<TEXT>**: prefixes negative results with the text instead of the negative sign.
  - **N<TEXT>**: postfixes negative results with the text.
  - **P<TEXT>**: prefixes positive results with the text.
  - **Q<TEXT>**: postfixes positive results with the text.
  - **R<TEXT>**: presets the field to the text, which is used as many times as necessary to fill the field. The text is replaced in parts of the field filled by the result.
  - **S<TEXT>**: symbol substitution.

Note: If B and R are both specified, R overrides B.

Qualifier and affixture codes do not extend field widths. The modified result must fit in the field width specified or asterisks will be substituted.

N and Q affixtures, since they postfix the text, shift results to the left by the number of characters to be postfixed.

**Examples:**

```
V+128 0 -.25 -64 -12345.67
'BFI0.1,X2,B/8,X2,C10,X2,L19' OFHT (V;V;V)
  128.0 128 128 128
  0 0 0 0
  -64.0 -64 -64 -64
  -12345.7 -12346 -12,346 -12346

'BFI0.2,X2,H+++R++10.1,X2,P<<>78' OFHT (V;V)
  0000128.00 128.0 +128
  0000000.00 0.0 +0
  000000.25 ++0.3 +0
  0000064.00 ++64.0 +64
  012345.67 ++12345.7 -12346

'BFI0.1,X2,R<+++>78' OFHT (V;V)
  128+++ ******128
  0+++ ******0
  0+++ ******0
  0+++ ******0
  -64 ******64
  -12346 **12346
```

Combinations of qualifier and affixture may be used together to provide various output forms as shown below.
Format Symbol Substitution

OFHT uses predefined characters in formatting output and interpreting specifications. In some cases, the default characters may not be appropriate. The S qualifier allows these defaults to be changed. The default symbols and their applicable format phrases are listed in the following table.

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>USES</th>
<th>PHRASE</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>digit select</td>
<td>G</td>
</tr>
<tr>
<td>Z</td>
<td>zero suppress digit select</td>
<td>G</td>
</tr>
<tr>
<td>*</td>
<td>field overflow</td>
<td>FGI</td>
</tr>
<tr>
<td>0</td>
<td>Z qualifier fill/lead zero fill</td>
<td>FGI</td>
</tr>
<tr>
<td></td>
<td>non-significant digit</td>
<td>FGI</td>
</tr>
<tr>
<td>,</td>
<td>C qualifier character</td>
<td>FI</td>
</tr>
<tr>
<td>.</td>
<td>decimal point</td>
<td>F</td>
</tr>
</tbody>
</table>

The default character can be replaced by first specifying the default character followed by the character to be used in its place.

Examples:

'S<...>CF16.2' OFHT 2718235.49
2.718.235.49

Format Result

The principal use of OFHT is to provide lines of formatted output. However, if OFHT is used as part of a larger APL expression, the result of executing OFHT is a character matrix which may be manipulated and used just as any other character matrix.

Format Error Reports

If the right argument includes an array of higher order than matrix, or the left argument is not a vector, a RANK ERR results.

If the left argument is not simple and all character data, and contains no format specifications, or contains a format specification with inconsistent parameters (such as d greater than w, or w = 0), a DOMAIN ERR results.

If there is incorrect syntax in the right argument, a SYNTAX ERR results. If there is incorrect syntax in the left argument, a FORMAT SYNTAX ERR results.

If the line length of the result is too big for the remaining workspace, or OFHT is included in a larger expression and the total result exceeds the remaining workspace, WS FULL results.
Formatting Aids

In addition to OFMT, the following system functions may be used to aid in output formatting. The )SET and )TERMINAL commands, described in Section 8, may also be used in the overall process of output report generation.

□PGE Function (Skip to New Output Page)

Syntax:

□PGE

Description:

□PGE is a niladic function with an empty vector result. When executed, if output is to a printing device, the current page will be ejected. If output is to a unit record type device and OHDR has been established by the )SET command, a standard header line will also be produced.

□NLS Function (Number of Lines Remaining)

Syntax:

1+□NLS

Parameters:

I is a simple integer scalar.

Description:

□NLS is a niladic function with an integer result. If output is to a device with line count applicable, the result is the number of lines remaining to print on the current output page. If not, the result is zero.

□HDR Function (Set Page Heading)

Syntax:

□HDR T
Parameters:

$T$ is a simple character scalar or vector of maximum length 160.

Description:

This function establishes the output header line which will be displayed at the start of each page if output is set to a printing device. This system function uses a CP-6 facility which does not recognize special APL characters. If special characters or overstrikes are included, HDR may not produce correct headings.

Possible errors:

A DOMAIN ERR is reported if:
- $T$ is not text or simple.

A RANK ERR is reported if:
- $T$ is not a scalar or vector.

A LENGTH ERR is reported if:
- $T$ contains more than 160 items.

**OVFC Function (Set Line Spacing)**

Syntax:

```
OVFC C
```

Parameters:

$C$ is a simple character scalar or one-item vector.

Description:

OVFC is a monadic function with empty vector result. The right argument must be a single character. When OVFC is executed, the character in the right argument becomes the vertical format control character for the next print line. After that line is printed, the default character is restored as the vertical format control character. Refer to the CP-6 Programmer Reference Manual (CE40) for the specific values of vertical format codes.
OXL Function (Translate Text)

Syntax:

\[ R = A \ OXL \ B \]

Parameters:

- \( A \) is a simple character vector of length less than 513 (unspecified character positions are treated as blanks).
- \( B \) is a simple character array.
- \( R \) is the translated result with the same shape as \( B \).

Description:

The OXL function facilitates special character set translations within APL. The result of the OXL function has the same shape as the right argument and consists of a translation of the right argument. The index position in DV of each item of the right argument is used to index the left argument to obtain the corresponding result item. The result is exactly equivalent to:

\[ (513+A)[DVt B] \]

but requires much less workspace.

This feature is designed to overcome problems encountered in character set differences between various devices. It allows any character mapping, including mapping several characters to the same result character. An example of this use might be to map all 'illegal' characters to some unique character. Another example is as follows:

\[
\begin{align*}
L & \leftarrow 1+t256 \\
L & \leftarrow (97+t26)+64+t26 \\
L & \leftarrow \text{DV}[110+L]
\end{align*}
\]

This value of \( L \), used as left argument of OXL, converts lowercase letters in the right argument to similar uppercase letters in the result.

Possible errors:

- A **RANK ERR** is reported if:
  - \( X \) is not a vector.
- A **LENGTH ERR** is reported if:
  - \( X \) contains more than 512 items.
- A **DOMAIN ERR** is reported if:
  - any item of \( X \) is not a scalar character.
- A **DOMAIN ERR** is reported if:
  - the right argument \( T \) contains an item which is not a scalar character.
Section 10

Execution Stops

Execution is stopped if any of the following conditions occurs:

1. Execution is completed (a normal stop).
2. Execution break occurs (BREAK key is pressed), and sidetracking does not occur.
3. User input is required (quad or quote-quad input).
4. Stop control line is encountered.
5. Error is encountered, and sidetracking does not occur.

Normal Stop

Execution comes to a normal stop after any action indicated by direct input is completed. It should be noted, however, that a direct input prompt does not necessarily mean that all pending execution is completed. The user can determine whether any execution is pending via the )SI command.

Execution Break

An execution break (that is, the BREAK key) can be issued by the user at any time. There may be a short delay until output stops. Sidetracking can be used to gain break control within an APL function; in this case execution does not stop, but is "diverted" (see Sidetracking on Errors and Breaks).

Either a soft break or interrupt may be signalled by pressing the BREAK key. The first break during the execution of a line of APL is a soft break. Execution of the current line continues until the end of the line is reached at which time, the currently executing defined function will suspend. If a second break is sent before the soft break is processed, this signals a hard break or interrupt and the currently executing line is removed from execution. An INTERRUPT message is displayed along with the line that was in execution and a caret indicating the position in the line that execution was interrupted. In this case, if the APL line contains "side effects" such as embedded assignments or shared variable accesses, then the line may not be easily restartable.

APL's reaction to break also depends on whether the BREAK key is pressed during execution mode or definition mode. If break is used during (non-function) execution, APL stops any output in progress and skips to the next line and indents six spaces to prompt for new input. If break is used during execution of a defined function, APL displays the function name and the line number being executed.

If break is used during display of a function, APL will exit from function definition mode if a closing del was included in the display command. If the display command did not have a closing del, APL will remain in function definition mode and will prompt with the next line number after the line range being displayed.

Execution breaks are usually not allowed to interrupt the execution of a system command. However, those that produce lengthy display can be stopped: )FNS, )GRPS, )LIB, )SI, )SML, and )YARS. Break is also used to abort the wait resulting from the )GPR system command.
Stop For User Input

Execution may be stopped by an input request in a line. The normal response to a quad or quote-quad input request is a line of input. While quad input is pending, BREAKS are treated as normal execution errors and thus cause the quad input request to be re-issued. If the user’s program contains a loop such that the user is repeatedly prompted for input, the user may escape as follows:

1. For quad input, type a branch arrow (→) followed by a RETURN. An example is shown below:

```
VPITIHES[0]V
VPITIHES
[1] 0
[2] +1
VPITIHES
1: 3.141592654
0: -1
-3.141592654
0: ⋆SI
PITIHES([1])
0: +
)SI
```

In this example the user has defined a function, PITIHES, that repeatedly requests input and provides a result. The first ⋆SI command shows that an input request and line 1 of PITIHES are pendent. After the +, the input request is no longer repeated. The second ⋆SI command shows that the loop has been broken and PITIHES is no longer in use.

2. For quote-quad input, press the BREAK key twice to cause an INTERRUPT at the point of the quote quad input request.

Stop Control Vector

As described in Section 7 (under Suspending Execution), a stop control vector can be used to specify the exact place a function suspension is to occur. The user can set a stop control vector by executing the ⋆STOP system function with the function name enclosed in quotes as the right argument and the line numbers at which the function is to be suspended as the left argument. For example, suppose the user wants to suspend execution of function HH at lines 2 and 4; by typing the expression

```
2 4 ⋆STOP 'HH'
```

APL will then suspend function execution just before each specified line number is executed, print the function name and line number, skip to the next line and indent six spaces to prompt for user input. (See the possible effects of ⋆SA described in Section 11.)

```
HH
HH[2]
```

The user may then operate as desired, in direct input mode with the function suspended, and can resume or terminate function execution at any time. Function execution can be resumed by appropriate branching; for example, an entry of →3 will resume execution of the suspended function at statement 3. Termination can be accomplished by a branch to a non-existent line number (→0 is a convenient choice). The function suspension can also be abandoned by a suspension clear statement, which is a branch arrow without any line number.
A stop control vector can be specified during execution mode, or during function execution as one of the statements of a defined function. To discontinue an active stop control vector, assign an empty vector to that stop control vector; for example, "OSTOP 'HH' will turn off the stop control for function HH.

**Error Stop**

As soon as APL detects an error in a statement, execution of that statement is terminated and any partial result is lost, except for assignments that were completed before the error was detected. Unless sidetracking occurs, APL prints a message indicating the type of error, displays the erroneous statement with a caret below the place the error was detected, (see also the discussion of error messages for the Execute operator in Section 5), and prompts for input. (See the possible effects of OSA described in Section 11.) The user can then correct the statement. An example of error detection is shown here:

```
X1+4=0
DOMAIN ERR
X1+4=0
```

If a statement contains more than one error, only the first (rightmost) one detected by APL will result in an error report. The next error will not be detected until the user has corrected the first error, as illustrated here:

```
X1=(4+0)*(2+0)
DOMAIN ERR
X1=(4+0)*(2+0)
   ▲
X1=(4+0)*(2+1)
DOMAIN ERR
X1=(4+0)*(2+1)
   ▲
```

If an error is detected in a statement with multiple specifications, any assignments to the right of the error will be completed, as illustrated here:

```
B=5 0 4=C+Bx0
DOMAIN ERR
B=5 0 4=C+Bx0
   ▲
5
C
0
```

During function definition some types of errors are detected immediately while other types are not detected until later when the function is executed. Definition errors, and character errors are detected immediately and must be corrected as soon as an error report is printed.

```
VR+B TRI H
[1] AREA=0.5*BxH
[2] DIAGONAL=((H+2)B+2)*0.5
[3] R*AREA;DIAGONAL
[4] [0.5 TRI CALCulates AREA AND DIAGONAL OF TRIANGLE
DEFN ERR ▲
[0.5) a TRI CALCulates AREA AND DIAGONAL OF TRIANGLE
[0.6) v
```

Linescan errors are detected immediately and may be corrected immediately by function editing or its correction may be deferred. All other errors in a defined function are detected when the function is executed. When APL encounters each error during function execution, it suspends execution and prints an error report containing the type of error and the function name and offending line and statement (with a caret marking the place the error was detected). For example, the following error message is produced because a Not function had been entered instead of a multiplication sign:
An error that causes suspended execution can be corrected during the suspension or after termination of execution.

1. To correct an error during suspended execution, the user can follow normal function editing procedures (see Section 7). For example,

```
SYNTAX ERR
TRI[3] DIAGONAL+((H+2)-B+2)*0.5
```

After correcting an error, the user can resume execution at the line suspended by specifying a branch to that line number. Thus, the expression +3 will resume execution at line 3 (starting at the right, as usual for APL).

2. To correct an error with termination of execution, the user enters a branch arrow to terminate function execution, edits the function as necessary, and then reexecutes the function. For example:

```
SYNTAX ERR
TRI[3] DIAGONAL+((H+2)-B+2)*0.5
```

Each branch arrow removes the most recent suspension from the state indicator list. Thus if several suspensions have occurred since the last suspension clear, more than one branch arrow (suspension clear) will be required to clear the state indicator. A convenient method for clearing the entire state indicator is to issue a )SIC command.

**Sidetracking On Errors And Breaks**

In some APL applications, the programmer would like to bypass APL’s standard error and break procedure (for example, to substitute messages or institute corrective actions). Computer-assisted learning programs and commercial business aids are applications where this may be desired. Users of such applications may have little knowledge of APL, and messages such as DOMAIN ERR or WS FULL frustrate rather than help.

CP-6 APL allows the programmer to overcome this problem through “sidetracking”. The term “error control” is also used (with an understanding that break control is included).

Suppose a DOMAIN ERR has been detected by APL. With sidetracking, APL searches the state indicator for active functions for which the programmer has decided to sidetrack. If a sidetracking function wants control over DOMAIN ERR, then APL sidetracks (branches) to the line in the function specified for DOMAIN ERR. If no active function wants such control, then APL issues the standard diagnostic message.

Sidetracking is both flexible and dynamic. Different errors can be sidetracked to distinct lines of a function. Certain sidetracking functions may control some errors while other sidetracking functions control others. The system function OERS allows an APL program to simulate an error (which can be subject to sidetracking) by supplying the error number and optionally the error message. Sidetracking functions can also compete for control of the same error. In this case, the most recently invoked function gets control, and its competing predecessors never become aware that the error occurred. Sidetrack specifications can be changed at will. They can be turned on and off, the error selection can be altered, and the sidetrack branches can be changed, the application program itself can modify sidetracking specifications throughout its execution. This capability permits a simple or comprehensive treatment at the programmer's discretion.
Table 10-1 shows errors that are subject to sidetracking. Errors not listed in the table include SYSTEM ERR and BROKEN WORKSPACE.

Since recovery from these errors is impossible for an applications program, APL retains exclusive control. See the discussion following Table 10-1 for details concerning certain unique errors.

Associated with each item in Table 10-1 is an error number. Error numbers are informally grouped by common classifications: statement execution errors, input-translation errors, command errors, file input/output errors, etc. Gaps are provided in the error number sequence to accommodate future diagnostics.

The items in Table 10-1 contain four cases in which APL gives up control after displaying an error message:

- SI DAMAGE
  - name NOT COPIED
  - name NOT FOUND
  - name NOT ERASED

These cases, in which command processing or function definition is in effect, must reach an orderly conclusion. Therefore, APL unilaterally displays the messages and proceeds to conclusion. (Nevertheless, sidetracking is still possible, and an application program might issue explanatory messages after the APL messages, as one alternative.) As APL proceeds in these four cases, a series of such messages could be displayed (but this would be unusual). APL permits sidetracking only with regard to the latest error known at the conclusion of this kind of processing. Using the execute function, for example, suppose a )COPY command occurs while sidetracking is in effect. Suppose also that some object, X, is missing from the copied workspace — X NOT FOUND is displayed; furthermore, suppose that the data found will not fit in the active workspace. Then the )COPY command concludes without copying anything and would ordinarily issue a TOO BIG message. Sidetracking would then apply in this example to the TOO BIG error and, the NOT FOUND error would be "forgotten".

Note in the foregoing example that copying was attempted by means of an execute operation. This was a necessity. A function can obtain sidetracking only while it is actively in execution. Thus command and function definition errors can be sidetracked only when the function (or some function invoked by the sidetracking function) actually executes a command or function definition. Evaluated-input might seem to provide another way in which a function could, indirectly, invoke command or function definition activity. However, for the reason given below, evaluated input is not considered capable of being sidetracked (except while that input has itself invoked a sidetracking function).

The execute function makes it possible to execute via quote-quad input anything that could be entered via evaluated input. Quote-quad input has an advantage from the standpoint of error recovery. The input text can be assigned to a variable before it is executed. Thus, a sidetrack function can analyze this text to determine correct recovery action. Evaluated-input is not susceptible to this analysis; it is immediately interpreted by APL.
<table>
<thead>
<tr>
<th>Error Number</th>
<th>Error Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>WS FULL</td>
</tr>
<tr>
<td>2</td>
<td>SYNTAX ERR</td>
</tr>
<tr>
<td>3</td>
<td>UNDEFINED</td>
</tr>
<tr>
<td>4</td>
<td>DOMAIN ERR</td>
</tr>
<tr>
<td>5</td>
<td>RANK ERR</td>
</tr>
<tr>
<td>6</td>
<td>LENGTH ERR</td>
</tr>
<tr>
<td>7</td>
<td>INDEX ERR</td>
</tr>
<tr>
<td>8</td>
<td>NO RESULT</td>
</tr>
<tr>
<td>9</td>
<td>IMPLICIT ERR</td>
</tr>
<tr>
<td>10</td>
<td>SINGULAR MATRIX</td>
</tr>
<tr>
<td>11</td>
<td>FORMAT SYNTAX ERR</td>
</tr>
<tr>
<td>12</td>
<td>BAD CHAR</td>
</tr>
<tr>
<td>13</td>
<td>LINESCAN ERR</td>
</tr>
<tr>
<td>14</td>
<td>TRUNCATED INPUT</td>
</tr>
<tr>
<td>15</td>
<td>OPEN QUOTE</td>
</tr>
<tr>
<td>16</td>
<td>I/O ERR fcg-xxxxx-s</td>
</tr>
<tr>
<td>17</td>
<td>DEFN ERR</td>
</tr>
<tr>
<td>18</td>
<td>SI DAMAGE</td>
</tr>
<tr>
<td>19</td>
<td>NOT CLEAR WS</td>
</tr>
<tr>
<td>20</td>
<td>CLEAR WS</td>
</tr>
<tr>
<td>21</td>
<td>BAD COMMAND</td>
</tr>
<tr>
<td>22</td>
<td>NOT SAVED, THIS WS IS name</td>
</tr>
<tr>
<td>23</td>
<td>FILE IN USE</td>
</tr>
<tr>
<td>24</td>
<td>BAD FILE REF</td>
</tr>
<tr>
<td>25</td>
<td>WS NOT FOUND</td>
</tr>
<tr>
<td>26</td>
<td>TOO BIG TOO LOAD</td>
</tr>
<tr>
<td>27</td>
<td>TOO BIG</td>
</tr>
<tr>
<td>28</td>
<td>TOO MANY SYMBOLS</td>
</tr>
<tr>
<td>29</td>
<td>name NOT COPIED</td>
</tr>
<tr>
<td>30</td>
<td>name NOT FOUND</td>
</tr>
<tr>
<td>31</td>
<td>name NOT ERASED</td>
</tr>
<tr>
<td>32</td>
<td>name NOT GROUPED</td>
</tr>
<tr>
<td>33</td>
<td>NOT GROUPED</td>
</tr>
<tr>
<td>34</td>
<td>SEALED WS</td>
</tr>
<tr>
<td>35</td>
<td>OLD WS, MUST EXPORT</td>
</tr>
<tr>
<td>36</td>
<td>NOT HELD</td>
</tr>
<tr>
<td>37</td>
<td>HOLD ABORTED</td>
</tr>
<tr>
<td>38</td>
<td>HOLD DEADLOCK</td>
</tr>
<tr>
<td>39</td>
<td>ENQUEUE FULL</td>
</tr>
<tr>
<td>40</td>
<td>SV QUOTA EXHAUSTED</td>
</tr>
<tr>
<td>41</td>
<td>NO SHARES</td>
</tr>
<tr>
<td>42</td>
<td>FILE SPACE TOO LOW</td>
</tr>
<tr>
<td>43</td>
<td>FILE I/O ERR fcg-xxxxx-s</td>
</tr>
<tr>
<td>44</td>
<td>FILE DAMAGE</td>
</tr>
<tr>
<td>45</td>
<td>FILE NAME ERR</td>
</tr>
<tr>
<td>46</td>
<td>NOT APL FILE</td>
</tr>
<tr>
<td>47</td>
<td>FILE TBL FULL</td>
</tr>
<tr>
<td>48</td>
<td>FILE ACCESS ERR</td>
</tr>
<tr>
<td>49</td>
<td>FILE TIE ERR</td>
</tr>
<tr>
<td>50</td>
<td>PACKSET NOT MOUNTED</td>
</tr>
<tr>
<td>51</td>
<td>FILE INDEX ERR</td>
</tr>
<tr>
<td>52</td>
<td>NONCE ERR</td>
</tr>
<tr>
<td>53</td>
<td>INTERRUPT</td>
</tr>
</tbody>
</table>

Table 10-1. Events Subject to Sidetracking
**DSM Function (Set/Query Sidetrack Matrix)**

Syntax:

\[ E \odot DSM \ F \]
\[ R \odot DSM \ F \]

Parameters:

\( F \) is a namelist containing the name of a displayable defined function.

\( E \) is a simple 2-column matrix of integers in which the first column contains line numbers and the second column contains error numbers.

\( R \) is an empty numeric array.

Description:

A sidetracking setting resembles setting a stop or trace vector. The function must be defined when the DSM function is executed; it could even be a statement in the function.

The dyadic DSM function requires that the right argument contain a legal name or DOHAIN ERR is reported. The explicit result of dyadic DSM is an empty numeric vector. The left argument (sidetrack matrix) must be a matrix or RANK ERR is reported. The left argument must be a simple array containing only integers or DOHAIN ERR is reported.

In effect, the sidetrack table becomes part of the function's definition and is copied or loaded if the function is copied or loaded. Function editing has no influence on the sidetrack setting. Since the sidetrack table contains line numbers, the following precaution should be observed. If editing a sidetracking function alters the position of a line specified by the sidetrack table, a correct setting must be reissued. This is necessary to ensure that the proper line will be branched to if the sidetrack does take place.

Erasing a sidetracking function erases its sidetrack setting. A sidetrack setting can also be removed by being replaced with an empty matrix, as in the following example:

\[ (0 \ 2p0) \odot DSM \ 'FUN' \]

When a (non-empty) table is assigned for sidetracking, it consists of one or more rows. Each row contains a pair of integers – a line number and an error number. The line number designates which line of the function is to be sidetracked to (branched to) if the indicated error occurs. The following sample sidetrack setting specifies a branch to line number 9 in case of a DOMAIN ERR (error 4 in Table 10-1).

\[ (1 \ 2p9 \ 4) \odot DSM \ 'FUN' \]

A new sidetrack setting for a function entirely replaces any previous setting.

Examples:

The following example would remove FUN's control over DOMAIN ERR.

\[ (2 \ 2p9 \ 3 \ 9 \ 2) \odot DSM \ 'FUN' \]

In this example, FUN sidetracks to line 9 for UNDEFINED or SYNTAX ERR. This illustrates that a sidetrack table can contain duplicate line numbers; however, it is useless to duplicate an error number in the same table. Only the first such number would be effective.
In the above example, \textit{FUN} sidetracks on only two of the possible errors. If other errors occur, APL handles them in the standard manner unless some other function has specified sidetracking for those errors.

A special error number, 0, exists for sidetracking on all items in Table 10-1 except the break (number 100). In the following example, \textit{FUN} sidetracks:

- to line 8, if a break is detected
- to line 7, if \textit{WS FULL} occurs
- to line 9, for any other error subject to control.

\[(3 \text{ 2p8 100 7 1 9 0)} \text{OSH 'FUN'}\]

Breaks are sidetracked only if the sidetrack explicitly includes error number 100.

The current sidetrack matrix may be obtained by the monadic execution of the \textit{OSH} system function. In this case, the right argument is the same as in the dyadic usage, but the result is a simple N-by-2 matrix of integers. For example:

\[\text{OSH 'FUN'}\]

\[
\begin{array}{c}
8 \\
7 \\
9 \\
\end{array}
\]

The result of monadic \textit{OSH} for all names other than a displayable, active defined function is a numeric matrix of shape \((0,2)\).

The following example (assuming origin 1) shows a compact way of setting several different error numbers to the same line. Suppose \textit{ERRLAB} is the label of the desired line and sidetracking is set within the function \textit{FCN} containing \textit{ERRLAB}.

\[(\text{ERRLAB,[1.5]2 3 5 8 21)} \text{OSH 'FCN'}\]

sets the indicated errors to sidetrack to \textit{ERRLAB} (see Lamination).

The above examples illustrate how to set sidetracks. This does not imply that the function \textit{FUN} immediately receives control if an error occurs. If \textit{FUN} is not actively in execution, its sidetracking is disregarded. Even if \textit{FUN} is in execution, it may still not be given control. The error may have occurred in evaluated-input, or \textit{FUN} may have called another function which has a competing sidetrack.

### Dynamics of Sidetracking

A step-by-step outline reveals significant aspects of sidetracking dynamics. Assume a controllable error or break has occurred and APL is ready to check for sidetracking.

\textbf{Step 1:} APL designates and saves the current error number, replacing any previously recorded error number; the line in execution, the position in this line and the text of the error message are also saved. For the moment, it initializes the error location to be line zero and an empty function name. APL points to the top (latest) entry in the state indicator.

\textbf{Step 2:} The state entry is examined. If it is a pendent function, APL proceeds to Step 3. If it is an execute-operation state, APL points to the next entry and repeats Step 2. Otherwise, sidetracking is not applicable; so APL issues the standard diagnostic.

\textbf{Step 3:} (Pendent function state) The error location is tested. If still initialized (see Step 1), the line number and name of the pendent function are recorded. The function's definition is tested for sidetrack setting. If it features some sidetracking, APL proceeds to Step 4. Otherwise, APL points to the next state indicator entry and repeats Step 2, attempting to find a function with a sidetrack setting.
Step 4: (Sidetrack setting present) The sidetrack table is tested sequentially versus the recorded error number. If a match is found, or the error number is less than 100 or greater than 199 and the table has an error number entry for the error number \(100 \times M + 100\) (where \(M\) is the error number being reported) or the table has a zero error number, APL proceeds to Step 5. Otherwise, APL points to the next state entry and repeats step 2, attempting to find a function interested in the current error.

Step 5: If the specified line number is greater than or equal to zero, then APL proceeds to Step 6. Otherwise, the line number is assumed to represent one of the special actions in Table 10-2.

Step 6: (Sidetrack acknowledged) APL removes from the state indicator any entries it bypassed in reaching Step 5. This puts the sidetracking function at the top of the state indicator. APL then branches to the specified line number.

<table>
<thead>
<tr>
<th>Number</th>
<th>Special Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1</td>
<td>The state indicator is cleared to the entry before this function. The current error is then reported at the point of the sidetracking function call.</td>
</tr>
<tr>
<td>-2</td>
<td>This function explicitly requests no sidetracking for the error. The state indicator, however, is to be cleared to this function and this function suspended. (Debugging Aid)</td>
</tr>
<tr>
<td>-3</td>
<td>Similar to -2 except that the state indicator is not cleared to the sidetrack function. The function that was in execution when the error occurred is suspended and the error is reported at the point of the error. (Debugging Aid)</td>
</tr>
<tr>
<td>-4</td>
<td>When used in conjunction with an error class control, this allows a function to control all errors but a specific error. As in ((2 \ 2 \ -4 \ 1 \ 5 \ 0) \ D M ' X') This setting means that all errors other than a workspace full (1) will sidetrack to line 5.</td>
</tr>
<tr>
<td>-5</td>
<td>The APL session is terminated and a CONTINUE workspace is saved, suspending the function that had the error.</td>
</tr>
<tr>
<td>-6</td>
<td>The workspace is cleared.</td>
</tr>
</tbody>
</table>

Considerations after Gaining a Sidetrack

Once APL performs a sidetrack, it has no further interest in handling the break or error. Responsibility falls to the application programmer, depending on the line number dictated and statements supplied for the sidetracking function. Caution is advised.

If a mistake occurs in statements entered via a sidetrack, a new error may confuse the intended recovery procedure. It is possible for that statement to generate the error being considered, leading to the same sidetrack, the same mistake, and so on indefinitely. WS FULL can be particularly troublesome. In some cases, the statement reached by the sidetrack will itself cause another WS FULL. There is no general solution to this potential problem, but it is a rare difficulty for two reasons. First, intermediate results may be discarded after any error, freeing up sufficient workspace for recovery. Second, more workspace may become available if state indicator entries are removed in reaching the sidetrack (See Step 5 above).
Aids for Sidetrack Users

Eight system functions are of particular interest after an error has occurred. These functions are described next.

**ERN Function (Error Number)**

Syntax:

W+ERN

Description:
The result is a two-item integer vector, the first item is the latest error number and the second item is the line number of the function in which the error occurred. If the error did not occur in a defined function, the second item is 0.

**ERF Function (Error Function)**

Syntax:

F+ERF

Description:
The result is a character vector containing the name of the function in which the error occurred. If the error did not occur in a defined function, the result is an empty character vector.

**ERM Function (Error Message)**

Syntax:

T+ERM

Description:
The result is a character vector containing the text of the latest error message.
OERL Function (Error Line)

Syntax:
T+OERL

Description:
The result is a character vector containing the text of the line that was in execution when the error occurred.

OERP Function (Error Position)

Syntax:
I+OERP

Description:
The result is the integer scalar index in OERL of the error pointer. The result value is I/O dependent.

OERX Function (I/O Error)

Syntax:
T+OERX

Description:
The result is a character vector of length 12, containing the latest I/O error information available to APL. It represents one of the error codes given in the CP-6 Host Monitor Services Reference Manual, v.1, (CE74).

OERH Function (Error Help)

Syntax:
T+OERH
Description:

The result is a character matrix of shape N-by-120 containing the error message text from the system error message file pertaining to the latest CP-6 I/O error information.

Note: APL sometimes expects I/O errors. Thus, the value reported when using OERX does not necessarily indicate an error condition has occurred.

OERS Function (Error Simulation)

Syntax:

```
MESSAGE OERS I
OERS I
```

Parameters:

I is a simple integer scalar in the range 0 through 19999.

MESSAGE is a simple character vector containing an error message.

Description:

The OERS system function initiates an error report under program control that can be subject to sidetracking. The error simulated may be one of APL's standard execution errors such as DOMAIN ERR or the specific error message can be supplied. The left argument of OERS may be supplied only for error numbers greater than 499. Simulating error number 0 clears the current error status variables (OERN, OERF, OERM, OERL, OERP) to their initial values in a clear workspace.

If OERS is invoked by an active function, the error generated by the execution of OERS occurs in the environment of the line that invoked the currently executing defined function.
Section 11  
System Functions and Variables

CP-6 APL provides a complete set of system functions and variables. Each of these system-defined objects have names which begin with a quad (0) and are known as distinguished names.

All of the distinguished names are present in an active workspace, and the values of the system variables are saved with the workspace when a SAVE command is issued.

All CP-6 APL system variables have default values in a clear workspace, may be modified at any time by assignment, and are subject to the normal rules of scope. That is, a user-defined function may localize a system variable and subsequently modify it. When the function exits, the value of the system variable will revert to its original value. The following table lists system variables included in CP-6 APL.

<table>
<thead>
<tr>
<th>NAME</th>
<th>MEANING</th>
<th>VALUE IN CLEAR WS</th>
<th>RANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>OCT</td>
<td>Comparison tolerance</td>
<td>1E^-13</td>
<td>Non-negative less than 1E^-12</td>
</tr>
<tr>
<td>IO</td>
<td>Index origin</td>
<td>1</td>
<td>0 or 1</td>
</tr>
<tr>
<td>LX</td>
<td>Latent expression</td>
<td>''</td>
<td>character vector</td>
</tr>
<tr>
<td>PP</td>
<td>Print precision</td>
<td>10</td>
<td>integer in the range 1 .. 20</td>
</tr>
<tr>
<td>PS</td>
<td>Positioning and spacing</td>
<td>-1 1 0 2</td>
<td>a 4-item integer vector. The first two items are integers in the range -1 to 1. The last two items may be any integer value from 2<em>35 to 1+2</em>35.</td>
</tr>
<tr>
<td>PW</td>
<td>Platen width</td>
<td>device dependent</td>
<td>integer in the range 32 .. 390</td>
</tr>
<tr>
<td>RL</td>
<td>Random link</td>
<td>16807</td>
<td>integer in the range 1 .. (1+2*35)</td>
</tr>
<tr>
<td>SA</td>
<td>Stop Action</td>
<td>''</td>
<td>'EXIT', 'CLEAR' and ''</td>
</tr>
<tr>
<td>SP</td>
<td>Session Parameter</td>
<td>''</td>
<td>any array</td>
</tr>
</tbody>
</table>

Each of the APL system variables is described in detail next.
CT Variable (Comparison Tolerance)

The relational functions (< = > ≥ ≠), monadic 1, L and dyadic 1, =, and ≠ involve comparisons that are not absolute because of the internal representation of numbers. CT is used to establish a neighborhood of equality around any particular value. For the relational functions, any number between \( B + \text{CT} \times |B| \) and \( B - \text{CT} \times |B| \) will be considered equal to \( B \). The default value for CT is \( 1E^{-13} \) which is adequate for almost all situations.

Comparison tolerance is used in APL so that the finite precision of the internal representation of numbers can be partly disguised. Computer arithmetic with real numbers can only approximate the result to numbers which are mathematically close to the true result. Meaningful values of CT are real numbers in the range 0 to \( 1E^{-12} \) inclusive.

IO Variable (Index Origin)

The IO variable is used by APL during indexing, the axis operator, OFX, ?, dyadic 0, 1, 4, and 9. Its value indicates the index of the first value in a non-empty vector. The only permissible values are zero and one. The default value in a clear workspace is 1.

LX Variable (Latent Expression)

The LX variable is executed (as in $LX) whenever a workspace is loaded. The default value in a clear workspace is an empty character vector.

PW Variable (Platen Width)

All output is subject to the constraint that at most PW characters will appear on a line. Additional characters that would have appeared on a particular line are printed indented on the succeeding line. The meaningful values are integers in the range 32 through 390. The default value in a clear workspace is the CP-6 platen width setting when APL was invoked or the closest permissible value to the CP-6 platen setting.

PS Variable (Positioning and Spacing)

The value of the PS variable controls the display (and monadic format result) of nested arrays. The meaning of the values are described in Section 3 under Output.
OPP Variable (Print Precision)

The OPP variable is used to determine the number of digits to be used in the default display of numeric arrays. The meaningful values are integers in the range 1 to 20. The default value in a clear workspace is 10.

ORL Variable (Random Link)

This value is used in the ? function and reset after each use such that it cycles through the entire meaningful range. The meaningful values are integers between 0 and 2*35 exclusive.

OSP Variable (Session Parameter)

When APL is invoked, OSP is established with an initial value of an empty character vector. A new value may be specified at any time, by assignment (or a )COPY command containing OSP in the copy list). The value associated with OSP is carried across )LOAD and )CLEAR commands.

OSA Variable (Stop Action)

The OSA variable defines the action to be taken when a function terminates execution and direct input mode is entered for any reason. The default value of an empty character vector indicates that no action is to be taken. Other valid values of OSA are: 'CLEAR' which causes the workspace to be cleared, and 'EXIT' which causes APL to issue an )END system command. If the value of OSA is undefined the state indicator is scanned until a value associated for OSA is found and the associated action is taken.

System Functions

System functions are always present in a workspace, and can be used in defined functions. They are niladic, monadic, or dyadic as appropriate and have an explicit result. In many cases, they also have implicit results, in that their execution causes a change in the environment.

Workspace Management Functions

CP-6 APL provides a set of system functions, OCR, OFX,owl, OEX, OEXG, OLOK, OVC, OVCg, ORH, ORHC, OST, OTR, OSH, OSTOP and OTTRACE to aid in user workspace management and information display.
Namelist and Canonical Representations

The introduction of two concepts is useful to describe the argument and results associated with these system functions. A namelist is a character matrix in which each row represents an APL name. As an argument to a system function, a namelist may also consist of a character vector of names separated by blanks.

When a namelist argument is required, a RANK ERR occurs if the rank of the argument is greater than 2. A DOMAIN ERR occurs if the argument contains an item which is not a character scalar. A LENGTH ERR occurs if a row contains more than 262143 columns. A DOMAIN ERR is also reported when a system function which only accepts a single name, is provided with other than a single name. Examples of legal namelists are:

- 'A'
- 'AB'
- 2 `ABCD'
- 'AB CD'

A RANK ERR is reported if the rank of the canonical representation is greater than 2. A LENGTH ERR occurs if a row contains more than 262143 columns. A DOMAIN ERR is reported if the canonical representation contains an item which is not a character scalar. The canonical representation does not contain line numbers as provided by the function definition mode display.

Canonical Representation is a representation of a function as a character matrix. Each row of the matrix represents a line of the function. The first row must consist of a valid function header. Succeeding rows if present must be valid APL statements.

System Functions for Function Definition

CP-6 APL provides system functions to create, modify, and replace defined functions. These functions include OTRACE, OSTOP, OCR, OFX, and OAT discussed in section 7, and OSH in section 10 in addition to the following functions.

OLOK Function (Lock Function)

Syntax:

V+OLOK N

Parameters:

- N is a namelist containing the names of user-defined functions in the active workspace.
- V is a simple vector containing the integer values 0 or 1.

Description:

The OLOK function returns a numeric vector containing 1 if the corresponding name in N is now a locked function or 0 otherwise (also see function OAT in Section 7). The referenced functions are locked.
OST Function (Set/Query Stop)

Syntax:
\[
V + \text{OST} F \\
R + V \text{ OST} F
\]

Parameters:
- \( F \) is a namelist containing the name of a defined function.
- \( V \) is a simple integer vector.
- \( R \) is a simple integer vector.

Description:
For monadic \texttt{OST}, if \( F \) is a namelist containing the name of a defined function, the result \( V \) is the stop vector associated with that function.

For dyadic \texttt{OST}, if \( F \) is a namelist containing the name of a displayable defined function, stop control is set on the lines indicated by \( V \). The explicit result is an empty vector. Also see the function \texttt{$QSTOP}.

Possible Errors:
- A \texttt{RANK ERR} is reported if:
  - \( V \) is not a simple array containing integers.

OTR Function (Set/Query Trace)

Syntax:
\[
V + \text{OTR} F \\
V + V \text{ OTR} F
\]

Parameters:
- \( F \) is a namelist containing the name of a defined function.
- \( V \) is a simple integer vector.
Description:

For monadic $\mathbf{QTR}$, if $F$ is a namelist containing the name of a displayable defined function, then $V$ is the trace vector associated with that function.

For dyadic $\mathbf{QTR}$, if $F$ is a namelist containing the name of a displayable user defined function, trace control is set on the lines indicated by $V$. The explicit result is an empty vector. Also see the function $\mathbf{QTRACE}$.

Possible Errors:

A $\textit{RANK ERR}$ is reported if:

- the left argument is not a scalar or vector.

A $\textit{DOMAIN ERR}$ is reported if:

- $V$ is not a simple array containing integers.

Workspace Management System Functions

The following functions are used in the management of active workspace.

$\mathbf{OAV}$ Function (Atomic Vector)

Syntax:

$$X+\mathbf{OAV}$$

Parameters:

$X$ is a character vector of length 512.

Description:

The $\mathbf{OAV}$ function returns a character vector containing all of the possible characters in the APL character set. Many of these characters are not used in CP-6 APL to represent printing symbols. The positions of the individual characters differ between implementations of the APL language.

Example:

$$\mathbf{OAV}[65+27]$$

$ABCDEFGHIJKLMNOPQRSTUVWXYZ$
CPU Function (CPU Time Used)

Syntax:

\[ I + \text{CPU} \]

Parameters:

\( I \) is an integer scalar.

Description:

The CPU function returns an integer scalar containing the CPU execution time used since entering APL. The time returned is in units of milliseconds. Execution times vary widely between APL implementations and the model of CPU upon which the APL is executing.

Example:

\[ T + \text{CPU} \odot (2 + 5 \times 1E6) \odot \text{CPU-T} \]

3

In this example, the time required by CP-6 APL to execute the expression \( 2 + 5 \times 1E6 \) has been computed to be 3 milliseconds (or .003 seconds).

CVT Function (Convert)

Syntax:

\[ R + W \odot \text{CVT} \odot J \]

Parameters:

\( J \) is a simple array of either all numeric or all character items.

\( W \) is a simple integer vector of length two.

Description:

\( J \) must be a simple array containing only numeric or only character items. \( W \) is a simple two-item integer vector controlling the result type and values of \( R \). The first item of \( W \) is one of 1, 2, 3, or 4 meaning one of the following types:

<table>
<thead>
<tr>
<th>TYPE</th>
<th>INTERNAL BIT LENGTH</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Boolean</td>
</tr>
<tr>
<td>2</td>
<td>9</td>
<td>Character</td>
</tr>
<tr>
<td>3</td>
<td>36</td>
<td>Integer</td>
</tr>
<tr>
<td>4</td>
<td>72</td>
<td>Floating Point</td>
</tr>
</tbody>
</table>

The second item of \( W \) is a value whose magnitude indicates the number of bits of the right argument to use to represent each item of the result. If the second item of \( W \) is less than zero, then the sign of each item of \( R \) is negative if the sign bit of a field is 1. A DOMAIN ERR occurs if the first item of \( W \) is not one of 1, 2, 3, or 4, or if \( J \) is either a nested array or index sequence. A LENGTH ERR occurs if the number of bits in the last dimension of \( J \) are not evenly divisible by the second item of \( W \).
Example:

```
 3 9 CVT 'ABZ' i CHARACTER NU.
 65 66 90
 67 91
 3 3 CVT 'AZ' i CONVERT TO OCTAL
 1 0 1 1 3 2
 3 36 CVT 12345678.015625
 1709378160 8589934592
```

**DL Function (Delay)**

**Syntax:**

```
I+DOL I
```

**Parameters:**

- `I` is a simple integer scalar.

**Description:**

The `DL` function requires at least `I` seconds to complete. The explicit result is the number of seconds of delay. The delay may be shorter than the number of seconds specified if it is interrupted by a break.

**Example:**

```
DL 6.75
```

Note that in the above example, requested delays of 6.75 and -60 seconds were actually delayed 7 and 0 seconds.

**EX Function (Expunge)**

**Syntax:**

```
V+DEX N
```

**Parameters:**

- `V` is a namelist.
- `N` is a simple integer vector.
Description:

The DEK function erases the user defined objects in namelist \( N \), except groups, labels, and active, pendent or suspended functions. The explicit result is a logical vector whose \( i \)’th item is 1 if the \( i \)’th name in \( N \) is now available for use (whether or not it was erased). For non-names or distinguished names or any names not erased, the result is 0.

Example:

\[ A+C+O \]
\[ \text{DEK } 4 \text{ Ip'AB7C'} \]
\[ 1 \ 1 \ 0 \ 1 \]

In the above example, the result of DEK indicates that the first, second and fourth names are now available for use (they have no active use) and that the third name is not.

\( \text{DEK} \) Function (Expunge Globals)

Syntax:

\[ V+\text{DEK} \ N \]

Parameters:

\( V \) is a namelist.

\( N \) is a simple integer vector.

Description:

Same as the DEK function except that only global referents are affected.

\( \text{DFI} \) Function (Fix Input)

Syntax:

\[ V+\text{DFI} \ T \]

Parameters:

\( T \) is a simple character scalar or vector.

\( V \) is a simple numeric vector.
Description:

The `OFI` function returns a numeric vector containing the value of all numeric constants found in `T` that are delimited by blanks. Non-blanks in `T` that are not legal numbers are indicated by a zero value.

Example:

```
  OFI '22 3x5 -100.5 1E999 1E6 0.0'
  22 0 -100.5 0 1000000 0
```

Possible Errors:

A `RANK ERR` is reported if:

- `T` is not a character scalar or vector.

A `DOMAIN ERR` is reported if:

- `T` contains an item that is not a character scalar.

OGRP Function (Return Group Members)

Syntax:

```
N*OGRP G
```

Parameters:

- `G` is a namelist containing the name of a group in the active workspace.
- `N` is a namelist.

Description:

The `OGRP` function returns a namelist containing the names associated with the group.

Example:

```
  OGRP 'STAT_GROUP'
  MEDIAN
  MODE
  REG
```

In this example, the name `STAT_GROUP` represents an APL group containing the names `MEDIAN`, `MODE`, and `REG`.
**IBEX Function (IBEX Expunge)**

Syntax:

\[ R+\text{IBEX} N \]

Parameters:

- \( N \) is a namelist containing the names of IBEX variables.
- \( R \) is a simple integer vector.

Description:

The \texttt{IBEX} system function is used to expunge IBEX variables. The right argument is a namelist, the result is a simple logical vector containing 1 for every IBEX name that is now available for re-use, or 0 for the corresponding name representing an unavailable name (illegal name).

Example:

\[ \text{IBEX 'STATUS'} \]

1

**IBLET Function (Set/Query IBEX Variable)**

Syntax:

\[ R+\text{IBLET} T \]

\[ R+T \text{ IBLET} T \]

Parameters:

- \( T \) is a simple character vector.
- \( R \) is a simple character vector.

Description:

The \texttt{IBLET} system function returns or sets the value of an IBEX variable. The right argument is the text of the name of an IBEX variable and the left argument when present is the value to be assigned to that variable. Monadically, \texttt{IBLET} returns the value of the named variable. Dyadically, the left argument becomes the new value of the variable.

This function can be useful when communicating with IBEX (outside of APL) or with other CP-6 programs. The left and right argument must be a scalar or vector or a \texttt{RANK ERR} is reported. A \texttt{LENGTH ERR} is reported if the name in the right argument contains more than 31 characters or if the length of the left argument is more than 511. A \texttt{DOMAIN ERR} is reported if either the left or right argument contains an item which is not a character scalar, or if the right argument contains an illegal name. An error is also reported if the monadic syntax is used and the named variable does not currently have a value.
Example:

'RATE=12, BALANCE=1246.42' DIBLET 'NAME'

DIBLET 'NAME'
RATE=12, BALANCE=1246.42

DIBLET 'NAME'
RATE=12, BALANCE=1246.42

\[ \text{IBNL Function (IBEX Namelist)} \]

Syntax:

\[ R = \text{IBNL} \]

Description:

The \text{IBNL} system function is used to return the names of all of the IBEX variables associated with this CP-6 session. The result is a simple character matrix with one IBEX variable name in each row.

Example:

\[ \text{IBNL} \]

\[ \text{NAME} \]

\[ \text{STATUS} \]

\[ \text{IDLOC Function (Identifier Location)} \]

Syntax:

\[ R = \text{IDLOC} \ N \]

Parameters:

\[ N \] is a namelist.
\[ R \] is a simple integer matrix having one row for each name in \( N \).

Description:

The \text{IDLOC} system function returns the local and global name classes for each of the names in the namelist at each level in the state indicator. The result contains a row whose length is \( 1 + \text{LOC} \) for each name. The name classes returned are:

\[ \begin{align*}
-1 & \text{ Not local at this level} \\
0 & \text{ Local but no value} \\
1 & \text{ Label} \\
2 & \text{ Variable} \\
3 & \text{ Function} \\
4 & \text{ Not Available}
\end{align*} \]
Example:

)`SINL
F2[2] * C A
F[4] X R D B A
)`

)`VARS
A C
)`

IDL0C 'A B C D F'
2 3 2
-1 2 0
-2 1 2
-1 0 0
-1 -1 3

The first row of the result of IDL0C contains the values 2 3 2 which indicate that the name A is a global variable, a function local to the execution instance of the function F and is a variable local to the function execution of F2. The second row indicates that the name B has no global usage, it is a variable local to the execution of F and is localized (but not yet used by) the execution of F2.

OLC Function (Line Chain)

Syntax:

V*OLC

Parameters:

V is a simple integer vector.

Description:

The OLC function returns an integer vector whose length indicates the number of entries in the state indicator and whose values are the line numbers of the functions in execution or 0 for state entries that are not defined functions. The result is ordered so that the most recently initiated function has the lowest index.

Example:

v F
[1] OLC
[2] x\'OLC'

F
1
0 2

In this example, the function F displays two lines of output. The first line displayed indicates that line 1 is in execution. The second line displayed indicates that line 2 of F is in execution followed by a state entry that is not a defined function (an execute state entry).
\textbf{\textit{OLGT} Function (Logon Time)}

Syntax:
\[ I \text{=} \text{OLGT} \]

Parameters:
\( I \) is an integer scalar.

Description:
The \textit{OLGT} function returns an integer scalar whose value is the number of milliseconds that have elapsed between midnight and the time of day that APL was invoked.

Example:
\[
0 \ 60 \ 60 \ 1000 \text{+OLGT}
\]
\[
45000250
\]
\[
12 \ 30 \ 0 \ 250
\]

In this example, APL was invoked at 12:30 PM.

\textbf{\textit{ONC} Function (Name Classification)}

Syntax:
\[ K \text{=} \text{ONC} \ N \]

Parameters:
\( N \) is a namelist.
\( K \) is a simple integer vector.

Description:
The \textit{ONC} function returns the type of object represented by each name in namelist \( N \). The \( I \)'th item of \( K \) corresponds to the \( I \)'th name in \( N \). The value of each item of the result is one of the following:

\begin{itemize}
\item 0 a name without an active referent
\item 1 a label
\item 2 a variable
\item 3 a function
\item 4 other (distinguished name, group name, or not a name.)
\end{itemize}
Example:

```
VFV
A+C+O
ONC 5 1p'AB7CF'
2 0 4 2 3
```

In the above example, the result of `ONC` indicates that the first and fourth names (A and C) are variables, the second name (B) has no current use. The third name is not available (actually 7 is not a legal name), and the fifth name (F) is a defined function.

**ONCG Function (Name Correspondence of Global)**

Syntax:

```
K+ONCG N
```

Parameters:

- `N` is a namelist.
- `K` is a simple integer vector.

Description:

The same as `ONC` except only Global referents are examined.

**ONL Function (Namelist)**

Syntax:

```
N+ONL K
N+T ONL K
```

Parameters:

- `K` is a simple numeric integer scalar or vector.
- `N` is a namelist.
- `T` is a simple character scalar or vector.

Description:

For monadic `ONL`, `K` is a simple numeric integer scalar or simple numeric vector with items containing the values 1, 2, or 3. The result is a namelist whose rows represent names whose active referents are of each of the indicated classes as defined for `ONC`.

Dyadic `ONL` is the same as the monadic case, except that only names beginning with one of the characters in `T` are included in the result.
Possible Errors:

A **DOMAIN ERR** is reported if:

- K contains an item that is not a simple integer value 1, 2 or 3.

A **RANK ERR** is reported if:

- K is not a scalar or vector.

Example:

```
A+AB+C+CX+O
AFUNCTION
FUNCTION
```

```
NL 3
AFUNCTION
FUNCTION
```

```
'AB' NL 2 3
```

```
A
AB
AFUNCTION
```

**DONL Function (Online)**

**Syntax:**

```
I<DONL
```

**Parameters:**

I is an integer scalar value.

**Description:**

The **DONL** function returns an integer scalar whose value is 1 if the current APL session is in timesharing mode or 0 if the session is in batch processing mode.

This function allows programs to determine whether to provide prompts for input or to allow a timesharing user to make corrective actions in some situations and provide default actions in batch.

Example:

```
DONL
```

```
1
```
**DOVH Function (Overhead Time)**

**Syntax:**

\[ I \cdot DOVH \]

**Parameters:**

\( I \) is an integer scalar.

**Description:**

The `DOVH` function returns an integer scalar containing the CPU execution time overhead since entering APL. The time returned is in units of milliseconds. Overhead time is defined as CPU time expended while executing within the CP-6 operating system and not while executing within the APL process.

**Example:**

\[ DOVH \circ DOVH, DOVH, DOVH, DOVH \]

227
231 231 231 231

In this example, the first line of output indicates that 227 milliseconds of CPU time overhead have been used since entering APL. In the second line of output, the overhead CPU time is constant since all four values are obtained without incurring any monitor service time. The different values reflect the monitor processing involved in writing the output to the terminal.

**QRM Function (Room)**

**Syntax:**

\[ V \cdot QRM \cdot N \]

**Parameters:**

\( N \) is a namelist.

\( V \) is a simple integer vector.

**Description:**

The `QRM` function returns an integer vector whose \( i \)'th value is equal to the number of bytes of workspace occupied by the \( i \)'th name in \( N \).

**Example:**

\[ QRM \circ QRM \cdot 2 \cdot 3 \]

\( A \)
\( C \)
\( F \)
16 16 144

In this example, the name \( A \) occupies 16 bytes, \( C \) occupies 16 bytes, and \( F \) occupies 144 bytes of workspace. Expunging these names does not necessarily return that amount of workspace because in CP-6 APL values can be shared with other names.
ORMG Function (Global Room)

Syntax:
\[ V \text{= ORMG } N \]

Parameters:
\( N \) is a namelist.
\( V \) is a simple integer vector.

Description:
Like ORM except that the size in bytes is of the global referents of the names in \( N \).

OSCT Function (Session Time)

Syntax:
\[ I \text{= OSCT} \]

Parameters:
\( I \) is an integer scalar.

Description:
The OSCT function returns an integer scalar whose value is the number of milliseconds that have elapsed since APL was invoked.

Example:
\[
\begin{align*}
0 & \ 60 \ 60 \ 1000 \text{OSCT} \\
1625740 \\
0 & \ 27 \ 5 \ 740
\end{align*}
\]

In this example, 27 minutes, 5 seconds, and 740 milliseconds have elapsed since APL was invoked.
OSI Function (State Indicator)

Syntax:

\[ X + \text{OSI} \]

Parameters:

\( X \) is a character vector.

Description:

The OSI function returns a character vector with the same contents as the display of the \( )\text{SI} \) command. Carriage return characters are used to separate each line of the state indicator display.

Example:

\[
\begin{align*}
\text{v} & \text{ F} \\
[1] & \text{1+1 a} \quad \text{A LINE TO STOP ON} \\
\text{v} & \\
1 & \text{STOP 'F' a STOP ON LINE 1} \\
\text{F(1)} & \text{a SUSPEND F} \\
\text{F(1)} & \text{ )SI} \\
\text{F(1)} & * \\
\text{pOSI} \\
\text{F(1)} & * \\
6 & \\
\text{F} & \text{a SUSPEND F AGAIN} \\
\text{F(1)} & \text{ )SI} \\
\text{F(1)} & * \\
\text{F(1)} & * \\
\text{pOSI} \\
\text{F(1)} & * \\
\text{F(1)} & * \\
13 & \\
\end{align*}
\]

In this example, the function \( F \) has been suspended by setting a stop on line 1. The result of the OSI function contains the same information as displayed by the \( )\text{SI} \) command.
**SITEID Function (Site ID)**

Syntax:

\[ T+\text{SITEID} \]

Description:

The `SITEID` niladic function returns the site-id of the current CP-6 system as a 6 item character vector.

Example:

```
SITEID
LX8001
```

**SITENAME Function (Site Name)**

Syntax:

\[ T+\text{SITENAME} \]

Description:

The `SITENAME` niladic function returns the CP-6 site name as a character vector.

Example:

```
SITENAME
LADC 66A
```

**STEPCC Function (Step Condition Codes)**

Syntax:

\[ \text{STEPCC} \]

Parameters:

\[ I \]

is a simple integer scalar.

Description:

The `STEPCC` function specifies the value for the step condition code when APL exits. The last value specified will be used. This value may be interrogated in IBEX statements that follow the execution of APL.
Example:
   OSTEPCC 4

SYSID Function (Sysid)

Syntax:
   I*SYSID

Parameters:
   I    is a simple integer scalar.

Description:
The SYSID niladic function returns the sysid of the current CP-6 user as a scalar integer. This number is used by the CP-6 system to identify output to devices (like line printer output) and to schedule and run batch jobs.

Example:
   SYSID
   38200

TS Function (Time Stamp)

Syntax:
   V*TS

Parameters:
   V    is a 7-item integer vector.

Description:
The TS function returns a 7-item integer vector whose individual items are the current year, month, day, hour, minute, second, and millisecond. The actual time returned depends on the setting of the time in the CPU that CP-6 APL is running on.

Example:
   TS
   1984 7 1 11 15 15 450
In this example, the current date and time is July 1, 1984 at 11:15 AM and 15.450 seconds.
OTT Function (Terminal Type)

Syntax:

\[ I \times OTT \]

Parameters:

\[ I \] is a simple integer scalar.

Description:

The OTT function returns an integer scalar whose value indicates the character set that APL uses to output to the terminal (or home device). The value returned by this function reflects the value determined when APL was invoked or the most recent value specified by the )TERMINAL system command. The possible values for terminal type are indicated by Table 11-2. When the output device is not capable of producing the full APL character set, ASCII mnemonics (defined in Appendix B) are used to output those characters which are not available. The choice of the mnemonics used for output depend upon whether the terminal type indicates support for lowercase and overstrikes.

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Full APL character set</td>
</tr>
<tr>
<td>2</td>
<td>ASCII character set, upper case only</td>
</tr>
<tr>
<td>3</td>
<td>ASCII character set, upper case only, overstrikes</td>
</tr>
<tr>
<td>4</td>
<td>ASCII character set, upper and lower case</td>
</tr>
<tr>
<td>5</td>
<td>ASCII character set, upper and lower case, overstrikes</td>
</tr>
<tr>
<td>13</td>
<td>Full APL character set</td>
</tr>
<tr>
<td>14</td>
<td>Full APL character set</td>
</tr>
</tbody>
</table>

Example:

\[ OTT \]

\[ 1 \]

OUA Function (User Account)

Syntax:

\[ T \times OUA \]

Parameters:

\[ T \] is a simple character vector of length 8.

Table 11-2. CP-6 APL Terminal Types
Description:
The OUA function returns a character vector containing the CP-6 account number under which the APL user is logged in.

Example:
```
p[}+OUA
123TEST
8
```

**OU Function (User Load)**

Syntax:
```
I+OU
```

Parameters:

*I* is a simple integer scalar.

Description:
The OUL function returns an integer scalar indicating the number of users that are currently using the CP-6 system.

Example:
```
OUL
115
```

**OVI Function (Verify Input)**

Syntax:
```
V+OVI T
```

Parameters:

*T* is a simple character scalar or vector.

*V* is a simple numeric vector.

Description:
The result has the same length as OFI T. Each item of V is either 1 meaning that the corresponding item in OFI T is a valid representation of a number or 0 meaning that the corresponding item of OFI T does not represent a number.
Example:

\[
INPUT+22 3E5 -100.5 1E999 1E6 0.0'
\]

\[
\text{DIVI INPUT}
1 0 1 0 1 1
\]

\[
(\text{DIVI INPUT})/\text{OFI INPUT}
22 -100.5 1000000 0
\]

Possible Errors:

A RANK ERR is reported if:
- \( T \) is not a scalar or vector.

A DOMAIN ERR is reported if:
- \( T \) contains an item that is not a character scalar.

\text{\textbf{\textsc{O}VERSION Function (Version)}}

Syntax:

\[
T+\text{\textsc{O}VERSION}
\]

Description:

The \text{\textsc{O}VERSION} niladic function returns the current version of APL as a character vector.

Example:

\[
\text{\textsc{D}O\textsc{O} \text{\textsc{O}VERSION}}
\]

\text{\textbf{\textsc{O}WA Function (Workspace Available)}}

Syntax:

\[
I+\text{\textsc{O}WA}
\]

Parameters:

- \( I \) is an integer scalar.

Description:

The \text{\textsc{O}WA} function returns an integer scalar whose value indicates the number of unused bytes in the active workspace. This space is available for the storage of data and defined functions.
Example:

```
T[WSID
```

**WSID Function (Workspace Identifier)**

Syntax:

```
T[WSID
```

Parameters:

- **T** is a character vector.

Description:

The WSID function returns a character vector containing the name of the active workspace.

Example:

```
? a[WSID
CLEAR WS
8 )LOAD APLANAR.X
APLANAR SAVED 12:18 NOV 10 '84
?a[WSID
APLANAR.X
9
```

**Shared Variable System Functions**

CP-6 APL provides the ability to share values between users of the system via the shared variable facility. A variable may only be shared by two users although each user can potentially share many (currently 16) variables. When a shared variable is used, it is indistinguishable from any other variable. It may be assigned a value and its value may be referenced. At any time, a shared variable has only one value, that is, the last value assigned by one of the partners.

All variables (including shared variables) have a degree of coupling associated with them which indicates the status of any shares associated with them. The degree of coupling indicates whether a variable is shared or not shared. The degrees of coupling are:

0. this name is not currently a shared variable
1. this name is a shared variable that has been offered but not yet accepted by another user.
2. this name is a shared variable that has been offered and matched (accepted) by another user.

The term processor is often used to describe each of the partners sharing a variable. In this respect, each processor is identified by the account it is logged on to and an optional string of 12 characters that enables multiple users logged onto the same account to simultaneously use the shared variable facility (see OSVN). Using the functions OSVQ or dyadic OSVO before a unique identification has been established results in a NO SHARES error being reported.
Namelists for the shared variable functions are slightly different than namelists used with other system functions. For shared variable functions, a vector is treated as a one row matrix. Each row of a shared variable function namelist may contain one or two names. The first (or only) name in each row designates the name to use for the shared variable in the active workspace. The second (or only) name in the row designates the name that is to be matched by the sharing process. This permits a single shared variable user to share the name \textit{A} with many processes where in fact each instance of a share actually references a unique (different) name in the user's workspace.

The following are the shared variable system functions.

\textbf{DSVC Function (Shared Variable Controls)}

Syntax:

\begin{verbatim}
R+DSVC N
R+C DSVC N
\end{verbatim}

Parameters:

\begin{itemize}
  \item \textbf{N} is a namelist.
  \item \textbf{R} is a simple integer matrix of shape \textbf{N}-by-4.
  \item \textbf{C} is a simple logical scalar, one-item vector, four-item vector or \textbf{N}-by-4 matrix.
\end{itemize}

Description:

For monadic \textbf{DSVC}, the explicit result is an array of shape \((1+pN),4\) giving, in each row, the current combined shared-variable access control vector for the corresponding rows of \textbf{N}. For a row which does not denote the name of a variable with a degree of coupling of at least one, zeros are given.

For dyadic \textbf{DSVC}, the effect is to set the access controls. The explicit result is an array whose shape is \((1+pN),4\) and whose value is the new combined shared variable access control for the corresponding rows of \textbf{N}. The \textbf{DSVC} function adds the active workspace contribution to the shared variable access control vector. Setting this vector permits two separate processes to coordinate (or synchronize) their use of a shared variable. The access control vector for a shared variable is a vector of four items whose values are 0 or 1 to turn specific controls off or on.

When a process is blocked from accessing or setting a shared variable by the access control vector, it will wait until the variable's state has changed to an unblocked state before proceeding with execution. The positions (in origin 1) of the access control vector and their meanings are:

1. If 1, then once the shared variable's value has been set in the active workspace, the partner (the other sharing process) must reference it before the variable can be set again in the active workspace.
2. If 1, then once the shared variable's value has been set by the partner, the active workspace must reference it before the partner can set the value again.
3. If 1, then once the shared variable's value has been referenced in the active workspace, the partner must set a value before the active workspace can reference it again.
4. If 1, then once the shared variable's value has been referenced by the partner, the active workspace must assign a value before the partner can reference it again.
NOTE: Both sharing partners contributions are combined to obtain the current settings of the access control vector.

Example:

```
OSV 3 3p'BA BJ SO '
0 0 0 0
1 1 0 0
0 0 1 1

1 OSV 3 3p'BA BJ SO '
0 0 0 0
1 1 1 1
1 1 1 1

0 0 1 1 OSV 2 3p'BJ SO '
0 0 1 1
0 0 1 1

(2 4p1 1 0 0 0 1 1) OSV 2 3p'BJ SO '
1 1 0 0
0 0 1 1
```

©SV Function (Shared Variable Offer)

Syntax:

```
R+©SV N
R+P ©SV N
```

Parameters:

- **N** is a namelist.
- **R** is a simple integer vector.
- **P** is a character scalar vector or matrix which identifies one or more accounts.

Description:

For monadic ©SV, the explicit result is a numeric vector giving the degree of coupling for each row of **N**: 2 if shared; 1 if there is an unmatched offer to another processor; 0 if not offered.

For each row of **N**, dyadic ©SV tenders an offer to the corresponding account if the first (or only) name in that row was not previously offered and is not already in use as the name of an object other than a variable. The explicit result is a vector giving the degree of coupling in effect after the offer for each name or pair. If a second name is used, the second name (surrogate name) is used only for matching offers. An empty vector **P** is used to denote a general offer: an offer to share a variable with any account whose offer otherwise matches.

The left argument must be a vector of length 0 through 20 or an N-by-20 matrix of processor identifications. The first 8 characters of a processor identification is the logon account and the remaining 12 characters are the name specified in the right argument of ©SVN.
Examples:

```
OSVO 2 3p'A B C'
0 0
'905APL' OSVO 2 3p'A B C'
1 1
   OSVO 'A'
1
   OSVO 'A X'
0
   OSVO 'A B'
1
```

The above example demonstrates the offer of two variables (A and C) to account 905APL. Account 905APL would see the offers of names B and C from this account.

Possible Errors:

A **DOMAIN ERR** is reported if:
- a row of N contains other than one or two variable names.

A **SV QUOTA EXHAUSTED** is reported if:
- more offers were made than the quota allotted by the system.

A **LENGTH ERR** is reported if:
- a processor identification has more than 20 characters.
- the number of processor identifications is not equal to 1 or the number of names being offered.

**OSVQ Function (Shared Variable Query)**

**Syntax:**

```
R=OSVQ P
```

**Parameters:**

- **P** is a character scalar or vector.
- **R** is a simple character matrix.

**Description:**

When **P** is non-empty, the result is a character matrix of names offered by account **P** to this user, either explicitly or generally, but not currently shared. If **P** is an empty vector, the result is a vector which identifies any accounts with unmatched offers to share variables with this user.
Example:

\[ \text{OSVQ} \]  a WHO IS OFFERING US SOMETHING

\[ \text{905APL ARES ERSTEST} \]

In this example, two accounts are found to be offering the current APL user variables to share. In the following example, the shares offered by account 905APL are matched using \[ \text{OSVO} \].

\[ \text{P+OSVQ} \]

\[ \text{P} \]

\[ \text{905APL ARES ERSTEST} \]

\[ \text{H+OSVQ P[1,]} \]

\[ \text{N} \]

\[ \text{STATUS DATA} \]

\[ \text{P[1,] OSVO N} \]

\[ 2 2 \]

\[ \text{OSVR Function (Shared Variable Retract)} \]

Syntax:

\[ \text{R+OSVR N} \]

Parameters:

\[ N \] is a namelist.

\[ R \] is a simple integer vector.

Description:

Ends sharing of any variables named in \( N \). The result is the degree of coupling before retraction (compare \[ \text{OSVO}, \] above). This function may cause a WS FULL error to occur obtaining the current value of the names being retracted.

Examples:

\[ \text{OSVO 'A' PRINT 2 IF A IS SHARED.} \]

\[ 2 \]

\[ \text{OSVR 'A'} \]

\[ 2 \]

\[ \text{OSVR 'A' IT IS NOT SHARED NOW.} \]

\[ 0 \]
DSVS Function (Shared Variable State)

Syntax:

\[ R^{+}\text{DSVS} \quad N \]

Parameters:

\( N \)  
- is a namelist.

\( R \)  
- is a simple integer matrix of shape \( N \)-by-4.

Description:

The result is a numeric array of shape \((-1.~N),4\) giving in each row the current shared variable state matrix for the names in \( N \). For variables that are not currently shared their state is given as all zeros.

Each row of the result of DSVS has four possible values:

0 0 0 0  
- this is not a shared variable

0 0 1 1  
- value set by one processor and has been referenced by the other.

0 1 0 1  
- value set by partner, but not yet referenced in the active workspace.

1 0 1 0  
- value set in active workspace, but not yet referenced by the partner.

Example:

\[ \text{DSVS} \quad 'A' \]

0 0 1 1  
- \( A+5 \)

1 0 1 0

DSVN Function (Shared Variable Process Name)

Syntax:

\[ I^{+}\text{DSVN} \quad T \]

Parameters:

\( T \)  
- is a simple character scalar or vector.

\( I \)  
- is the simple integer scalar containing the value 0 or 1.
Description:

If shared variables are to be used by multiple users on the same CP-6 account, then this function permits each user to uniquely identify their own process. T is a vector of up to twelve characters. If a unique identifier is established the result is 1. If there are currently any shares offered by this process or if the value specified in T does not create a unique identifier, the result is 0. If successful, this process is uniquely identified by the eight character CP-6 account followed by 12+T.

Example:

```
OSVN 'BRUCE'
1
'OSVO 'A'
1
OSVN 'HE'
0
```

In the example above, the second execution of OSVN returned 0 because a name (A) was currently shared.

Possible Errors:

A SV QUOTA EXHAUSTED error is reported if:

- an attempt is made to use shared variables before establishing a unique identifier (the default is blanks).

OSC Function (State Change)

Syntax:

```
I+OSC
```

Description:

The OSC function causes execution of the current line to halt until the state of one of this processes shared variables changes or an explicit offer is made to this process. The result is 1 if a unique processor identifier exists and zero if one does not.

Text Editing System Functions

CP-6 APL provides six text editing functions which facilitate the examination and modification of character vectors.
**OTIX Function (Text Index)**

**Syntax:**

\[ R = \text{OTIX} \ T \ SDV \ TDV \ DDV \]

**Parameters:**

- **T** must be a simple character vector containing the string to tokenize.
- **SDV** must be a simple character scalar or vector defining those characters that are token separators.
- **TDV** must be a simple character scalar or vector defining those characters that are single character tokens and token separators.
- **DDV** must be a simple character vector defining those character pairs that create delimited character strings.
- **R** is an N-by-2 integer matrix containing starting positions in the first column and lengths in the second column.

**Description:**

The **OTIX** function returns an integer matrix of \( N \) rows and 2 columns. The first column contains the starting index of each token in \( T \). The second column contains the corresponding length of each token in \( T \).

The definition of a token in \( T \) is governed by the arguments **SDV**, **TDV**, and **DDV**. The **SDV** items are token separators and are never tokens themselves (for example, blanks are skipped this way). The **TDV** items are token separators and are also single character tokens themselves (like + is in APL). The **DDV** items are token separators and also create a delimited token (like quote strings in APL). Finally, characters not appearing in **SDV**, **TDV**, and **DDV** are a single token when occurring consecutively (like identifiers in APL).

The scan of \( T \) starts at the first index position and continues until a character from the **SDV**, **TDV**, and **DDV** vectors is found or the last index position of \( T \) has been examined. The order of evaluation is as follows:

- Characters in \( T \) which occur in the **SDV** vector are simply skipped over when they are encountered.
- When the character encountered is not in the **SDV**, **DDV**, or **TDV** vectors, the vector \( T \) is scanned from this point until a character in one of those vectors is found. A new row is added to the result indicating the position of the first character not in **SDV**, **TDV**, or **DDV** and whose length includes the characters up to but not including the character found that are in **SDV**, **TDV**, or **DDV**.
- When the character encountered is in the **TDV** set, a token is added that indicates the character in **TDV** that was encountered.
- When the character encountered is in the **DDV** set, a delimited string token is added to the result. The delimited string is defined by treating the **DDV** vector as an \( N \) by 2 matrix and using the first character in each row as a delimited string starter and the corresponding second character in the same row as the terminator. If the delimited string starter and terminator are the same character, it may appear within the string by doubling it. All characters between the string start and end are treated as a single token. If the delimited string starter and terminator are separate characters, the first terminator character found terminates the delimited string.
- When the character encountered is in the **DDV** set, a delimited string token is added to the result. The delimited string is defined by treating the **DDV** vector as an \( N \) by 2 matrix and using the first character in each row as a delimited string starter and the corresponding second character in the same row as the terminator. If the delimited string starter and terminator are the same character, it may appear within the string by doubling it. All characters between the string start and end are treated as a single token.
- The scan of the vector \( T \) continues, searching for characters in the **SDV**, **DDV**, and **TDV** sets until the last index of the vector \( T \) is scanned.
DDV need not be specified if empty, and DDV and TDV need not be specified if both are empty.

Examples:

The following examples use the LIST function to display the tokens returned by the OTIX function. It works only in origin 1 and displays one token per row with the ".." character indicating characters which are not part of the actual token.

\[\text{VR}=\text{L} \text{IST} B_{,1} K \]
\[=1(\text{"R+-' \cdot A'\}[(B};1],J)0\cdot K0, \text{J='}^{-1}+1/ \text{K+B};1] \]

The first example demonstrates using blanks and commas as delimiters which are not themselves delimiters.

\[\text{L} \text{IST} \ \text{OTIX}(\text{L}+\text{\"A,TEST\") } ' ',' \]
\[\text{TEST} \]

The next example demonstrates using a dieresis character to indicate a delimited string.

\[\text{L} \text{IST} \ \text{OTIX}(\text{L}+\text{\"A TEST\"'}\text{S} \text{\"WOW,4\") } ' ',' ' ' ' ' \\
\text{TEST} \]

Notice that in the above example, the dieresis is doubled within the token to continue the production of the token. The following example demonstrates using token separators which are tokens themselves.

\[\text{L} \text{IST} \ \text{OTIX}(\text{L}+\text{\"A TEST\"'}\text{S} \text{\"WOW,4\") } ' ',' ' ' ' ' \\
\text{TEST} \]

In the above example, + and , are token separators and appear as tokens. The character " is a delimited token character in the above example.

Possible Errors:

A DOMAIN ERR is reported if:
- a terminating character cannot be found in the T string.
- a DDV or TDV character appears more than once in SDV, DDV or TDV vectors.
- a delimited string terminating character is found that is not within a delimited string.
- T, SDV, TDV, or DDV contains any item that is not a simple character scalar.

A RANK ERR is reported if:
- SDV or TDV is not a scalar or vector.
- T or DDV are not vectors.

A LENGTH ERR is reported if:
- the length of DDV is not a multiple of 2.
- the right argument to OTIX contains more than 4 items or fewer than two items.
OTLEX Function (Text Lexemes)

Syntax:

\[ R \circ OTLEX \ T \ SDV \ TDV \ DDV \]

Parameters:

\( T \) is a simple character vector containing the string to tokenize.

\( SDV \) is a simple character scalar or vector defining the token separator characters.

\( TDV \) is a simple character scalar or vector defining the single character tokens.

\( DDV \) is a simple character vector defining the character pairs that create delimited tokens.

\( R \) is a vector of character vectors.

Description:

This function tokenizes the string \( T \), returning a vector where each item was a token found in \( T \). The tokenization uses the same method as the \( OTIX \) function.

Example:

```r
R \circ OTLEX \ 'THIS IS A TEST' \ '
```

\( \) \( \) \( THIS IS A TEST \) \( 4 \)

```r
R \circ OTLEX \ 'TOMATOES=FRUIT, SALMON ARE FISHY' \ '=' \ '
```

\( \) \( \) \( TOMATOES = FRUIT, SALMON ARE FISHY \) \( 7 \)

OSSS Function (Substring Search)

Syntax:

\[ R \circ OSSS \ T \ SS \]

Parameters:

\( T \) is a simple character vector.

\( SS \) is a simple character vector.

\( R \) is a simple integer vector.

\( FCOL \) is a simple integer scalar index of \( T \).

\( LCOL \) is a simple integer scalar index of \( T \).
Description:
The result is a vector of the starting indices in T of each non-overlapping occurrence of SS. If the string SS does not occur in T then the result is an empty vector.

FCOL and LCOL frame the indices of T to be searched for occurrences of SS. FCOL is the first index of T and LCOL is the last index of T that will be searched for an occurrence of SS. When not specified FCOL defaults to 10 and LCOL defaults to (nT)-1+10.

Examples:
TV is a vector of length 100.
R=OSSS TV 'BOB' provides the starting indices of all occurrences of 'BOB' in TV.
R=OSSS TV 'BOB' 30 provides the starting indices of 'BOB' in TV from TV[30] to the end of TV.
R=OSSS TV 'BOB' 30 60 provides the starting indices of all occurrences of 'BOB' in TV from TV[30] to TV[60].
The result R, FCOL and LCOL are origin dependent.

Possible Errors:
A DOMAIN ERR is reported if:
- the right argument is not a 2, 3, or 4 item list.
- T or SS is not a character scalar or vector.
- FCOL or LCOL are not integer indices.

A LENGTH ERR is reported if:
- FCOL or LCOL are not scalars or one-item vectors.

An INDEX ERR is reported if:
- FCOL or LCOL are not valid indices of T.

OSSR Function (String Search and Replace)

Syntax:
```
R=OSSR T SS RS
R=OSSR T SS RS FCOL
R=OSSR T SS RS FCOL LCOL
```

Parameters:
- T is a character vector.
- RS is a character vector.
- SS is a character vector.
- R is a character vector.
- FCOL is a simple integer scalar index of T.
- LCOL is a simple integer scalar index of T.
Description:

The result is a character vector like T except that all non-overlapping occurrences of SS are replaced by RS. FCOL and LCOL indicate the range of indices of T subject to replacement. That is, only occurrences of SS in the range FCOL+1-LCOL-FCOL are replaced.

Examples:

TV is a character vector containing names separated by blanks.

RS+SSTV ' ' MV[13:10] replaces all blanks with carriage returns.


RS+SSR TV 'BOB' 'ROBERT' replaces all occurrences of 'BOB' with 'ROBERT'.

RS+SSR TV 'PIERRE' '' removes all occurrences of 'PIERRE' from TV.

OSRP Function (Substring Replace)

Syntax:

R+OSRP T RS FCOL LCOL

Parameters:

T is a character vector.

RS is a character scalar or vector.

FCOL is an index of T.

LCOL is an index of T.

R is a character vector.

Description:

The result is a character vector like T with the location T[LCOL] through T[LCOL] replaced by RS.

Examples:

TV+'THE PRICE OF PRODUCT-NAME IS'

RS+'WHEATIES'

R+OSRP TV RS 14 25

R THE PRICE OF WHEATIES IS
Possible Errors:

A DOMAIN ERR is reported if:

- the right argument is not a four item list.
- T is not a character vector.
- RS is not a character vector or scalar.
- LCOL or FCOL are not numeric scalars or 1-item vectors.

An INDEX ERR is reported if:

- FCOL > LCOL or if FCOL or LCOL are not valid indices of T.

SCP Function (String Compare)

Syntax:

\[ R = \text{SCP}(A;B) \]

Parameters:

- \( A \) is a character vector.
- \( B \) is a character vector.

Description:

The SCP function returns a two item numeric vector, the first item of which is 0 if \( A \) is equal to \( B \), or 1 if \( A \) is greater than \( B \), or 2 if \( A \) is less than \( B \). The second item of the result is the first index in \( A \) that \( A[R[2]] \neq B[R[2]] \) or if \( A \) is equal to \( B \), then \( R[2]+1 \). If \( A \) is longer than \( B \) and every item of \( B \) is equal to every item of \( A \), then \( R+2-1 \).

Possible Errors:

A DOMAIN ERR is reported if:

- the right argument is not a two item list.
- \( A \) or \( B \) is not a character vector.

Terminal I/O System Functions

These system functions return information about or control a terminal session.
**TIN Function** (Terminal Input)

Syntax:

\[ I \ TIN \ T \]

Parameters:

- \( T \) is a simple character vector or scalar.
- \( I \) is a simple integer scalar.

Description:

The right argument must be a character vector which replaces the current terminal re-read line. If the optional left argument is present when the re-read line is recalled, the value of the left argument is used as the column to position to.

**OTATTR Function** (Terminal Attributes)

Syntax:

\[ V+OTATTR \]

Description:

The \( OTATTR \) function returns a simple integer vector containing terminal status information. The vector may in a future release be extended to contain additional information. Currently the vector contains:

- 1 Line speed (CPS)
- 2 Parity (even=2, odd=1, none=0, one=3, zero=4)
- 3 Dial-up/hardwired/foreign net (0=dial-up, 1=hardwire, 2=NET)
- 4 Normal/multi-drop (0=normal, 1=multi)
- 5 Character set (0=ASCII, 1=bit paired, 2=type paired)
- 6 Lowercase=1
- 7 Screen width (characters)
- 8 Screen height (lines)
- 9 Blank erases (1=yes, 0=no, 2=not applicable)
- 10 Scroll (0=no, 1=yes)
- 11 Wrap (0=no, 1=yes)
- 12 Retypovr (0=no, 1=yes)
- 13 Editovr (0=no, 1=yes)
- 14 Echo (0=no, 1=yes)
**OTTIME Function (Terminal Timeout)**

Syntax:

```ottime n```

Parameters:

- `n` is a simple integer scalar.

Description:

The `OTTIME` function sets the timeout period in seconds for terminal reads. After a terminal read is issued, the terminal user must complete input in `n` seconds or an I/O error will be reported. The I/O error is, of course, sidetrackable. The read timeout may be reset by setting the timeout value to 0.

**OTECHO Function (Terminal Echo)**

Syntax:

```otecho l```

Parameters:

- `l` is the simple integer scalar value 0 or 1.

Description:

If `l` is zero, then terminal reads will not echo. If `l` is one, then characters typed at the terminal will echo.

**OTSQZ Function (Terminal Mnemonic Translation)**

Syntax:

```otsqz r l v```

Parameters:

- `l` is the simple numeric value 0 or 1.
- `v` must be a simple character scalar or vector.
- `r` is a simple character vector.
Description:
If the value of the left argument is 1 then the result of this function is a character vector containing the text in the right argument translated into internal APL text. This function resolves all valid overstrikes and mnemonics into single characters.

If the value of the left argument is 0, then the result of this function is a character vector containing the text in the right argument translated into external ASCII suitable for blind output. This function generates mnemonics for the internal APL characters that are not representable with the currently set terminal type.

This function is designed to aid in the use of blind I/O and APL characters with blind I/O.

\*\*TWINDW Function (Terminal Windows)\*

Syntax:

\[ H \cdot \text{TWINDW} \]

Parameters:

\( H \) is a matrix of shape N-by-8 containing information about each of the currently defined logical devices that refer to the terminal.

Description:

The result of the \*\*TWINDW function is a matrix which has one row for each logical device that refers to a terminal (device UC). The information returned indicates the positioning and size of each window associated with the device, and whether or not the window can be used to create another window.

Table 11-3 summarizes the contents of the result matrix. Note: A future release of CP-6 APL may return additional information by adding trailing columns to the result of this function.

The logical terminal devices 1, 98, and 99 always start a session referring to the same window. The system command \( \text{)}! \text{LDEV} \) may be used to create additional logical devices or to modify the definitions of existing devices. The \( \text{)} \text{SET} \) command may be used to direct APL input/output or blind I/O to any logical device. IBEX LDEV command options include the ability to specify a window size and position relative to the window being used to create the new window.

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Contains the logical device number. For example, if this value is 98, then the remaining columns of this row describe the device UC98.</td>
</tr>
<tr>
<td>2</td>
<td>Contains the line number on the screen of the top line of the window. The top-most line on the screen is 1.</td>
</tr>
<tr>
<td>3</td>
<td>Contains the column number on the screen of the left side of the window. The left-most column on the screen is 1.</td>
</tr>
<tr>
<td>4</td>
<td>Contains the number of lines in the window.</td>
</tr>
<tr>
<td>5</td>
<td>Contains the width of the window.</td>
</tr>
</tbody>
</table>
Table 11-3. Window Column Descriptions (cont.)

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Contains the minimum number of lines that must be available for this window. This value limits the number of lines that may be taken from this window to form a new window.</td>
</tr>
<tr>
<td>7</td>
<td>Contains the minimum width that must be available for this window. This value limits the number of columns that may be taken from this window to form a new window.</td>
</tr>
<tr>
<td>8</td>
<td>Contains either the value 0 indicating that the window is removable, or the value 1 indicating that the window is not removable.</td>
</tr>
</tbody>
</table>

Example:

```
αZ+WINDOW
```

```
4 8
Z
98 13 1 12 80 0 0 0
1 13 1 12 80 0 0 0
99 7 1 6 80 0 0 0
5 1 1 6 80 0 0 0
```

In the preceding example, the APL session has 4 logical devices known as UC98, UC01, UC99 and UC05. Logical devices 1 and 98 share the same window on the screen, beginning at row 13, column 1. The window is 12 lines long and 80 columns wide, have no minimum length or width, and are removable.
Section 12
CP-6 APL File I/O

CP-6 APL provides access to all CP-6 file types. Records within these files can be read or written as non-APL records, APL datablock records, or APL component records.

APL datablock records are read and written along with the data type, rank, and dimensions. This permits arrays to be written to a file and later read back as the same array.

APL component records (the default) are read and written with the data type, rank, dimensions, timestamp, and account identifier of the user that wrote the record. In addition to the capability associated with datablock records, there is a system function which operates on this record format to obtain the component information (timestamp and account identifier). Figure 12-1 shows the component record format used by APL.

A datablock record has similar format except that the first nine words of the component record format are omitted.

Non-APL records are typically files created by other CP-6 programs. Non-APL records may be read or written in a number of ways. The easiest method is to treat the record contents as a simple character vector when reading and writing the raveled data. This form excludes APL's internal type, rank, and shape information. Using this mode, datatype conversions are the programmer's responsibility. Other functions (such as OCVT and $) are available to aid in the datatype conversions.

The APL file I/O record types and descriptions are summarized in Table 12-1. The record type numbers indicated in this table are used to indicate the type of record to read or write.

When records are read or written, an encryption seed may be specified to protect the data in the file. If the wrong seed is provided on a read of a component or datablock record, APL informs the user that this is NOT AN APL FILE. If a non-APL record is read with an incorrect seed, the data returned is an encrypted version of the actual data.

Records within a file can be accessed (read or written) sequentially or by record identifier. The record identifier can be specified as an integer number in the range 1 through 134217728 or as a character vector of 1 to 255 characters. Record numbers need not be contiguous; record number 3 can be followed by record number 10099. New records can be inserted in the future and existing records may be deleted (or dropped).

Up to 31 files can be accessed simultaneously. Each file is known to APL by its stream number which is specified when opening (or tying) the file. Stream numbers are integer values in the range 1 through 34359738367. Once a file is opened, it remains open until it is closed using one of the functions OFCLOSE, OFCLEAR, OFERASE or until the APL session ends.

A file stream is not affected by changing the active workspace. In particular the system commands )LOAD and )CLEAR have no effect upon the files which have been opened.
CP-6 file management provides access controls to prevent unauthorized file access. Each file may be passworded and various levels of access are possible once the file is open. For example, READ access permits accounts to be specified that may only read records. WNEW access permits accounts to write new records. UPDATE allows accounts to replace existing records. For more information on file access see the OFSTAC and OFRDAC functions.

When CP-6 files are created, the system allocates an initial extent and as the file space is used up, the CP-6 system automatically extends the file until the file space limit for the account or packset is used up. Thus, in CP-6 APL there is little need to worry about file size when allocating files.

By default, APL users create keyed files, that is, files whose individual records are identified by a one to 255 item character vector. However, file access within APL is not restricted to this file type. Indexed files (most commonly created by COBOL), relative files, indexed-relational files, random files, unit record files, fixed files, and consecutive files are all accessible from APL. Each of these files have different capabilities (for more information see the CP-6 Host Monitor Services Reference Manual (CE74)).

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Component record. The record includes the APL datatype, rank, shape, date, time, account, user name and data in ravel order (default).</td>
</tr>
<tr>
<td>2</td>
<td>Datablock record. The record includes the APL datatype, rank, shape and data in ravel order.</td>
</tr>
<tr>
<td>3</td>
<td>Data record. Only the actual data is read or written. Reading always returns a character vector.</td>
</tr>
<tr>
<td>4</td>
<td>Record field description. If the file was created with a record field description, this is used to read or write the record. The data read or written is always a vector (possibly nested).</td>
</tr>
</tbody>
</table>
File Information Functions

The functions in this group provide information about the files that are currently being accessed.

DFNUMS Function (Numbers of Open Files)

Syntax:
    R·DFNUMS

Description:
The DFNUMS niladic function returns an integer vector containing the stream numbers for the files currently open.

Examples:
    DFNUMS
    1 314159

DFNAMS Function (Names of Open Files)

Syntax:
    R·DFNAMS

Description:
The DFNAMS niladic function returns a character matrix showing the names of files currently open.

Example:
    DFNAMS
    TEST
    TIMING
DFID Function (File Identifier)

Syntax:

DFID Y

Parameters:

Y is a simple integer scalar indicating a file I/O stream that is currently open.

Description:

The DFID system function returns the CP-6 file identifier for the file I/O stream specified.

Example:

DFID 1
*TEST
DFID 314159
TIMINGS.TESTAPL
DFID 1 314159
*TEST TIMINGS.TESTAPL

Opening, Closing, and Deleting Files

The file functions in this group are used to initiate and terminate access to files.

DFOPEN Function (Open File)

Syntax:

X DFOPEN T

Parameters:

T is a simple integer scalar indicating an available file I/O stream.

X is a simple character vector indicating the name of the file to open or a vector of nested arrays containing a simple text vector indicating the name of the file to open, and optionally a file access matrix, a record field matrix, and a key definition matrix.
Description:

The `OFOPEN` system function is used to initiate file access through a stream. The left argument is the file identifier and the right argument is the stream number to be associated with this file. The number used for the stream number must be an integer and not currently in use as a stream number.

If the left argument is a simple character vector containing a CP-6 file identifier, that file is opened for reading only. In order to create, update, or share a file, options are specified in the left argument following the FID and separated by commas. The options and their meanings are provided in Table 12-2.

<table>
<thead>
<tr>
<th>Option</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>UPDATE</td>
<td>Opens file so records can be read and written.</td>
</tr>
<tr>
<td>• IN</td>
<td>Opens file for reading only.</td>
</tr>
<tr>
<td>CREATE</td>
<td>Creates a file.</td>
</tr>
<tr>
<td>OLDFILE</td>
<td>For create, if file already exists use it.</td>
</tr>
<tr>
<td>• NEWFILE</td>
<td>For create, even if file already exists create new file.</td>
</tr>
<tr>
<td>ERROR</td>
<td>For create, if file already exists report error.</td>
</tr>
<tr>
<td>ALL</td>
<td>Share file (multiple updaters).</td>
</tr>
<tr>
<td>• NONE</td>
<td>If UPDATE, file open is for exclusive use.</td>
</tr>
<tr>
<td></td>
<td>If IN, file open shares with other readers only.</td>
</tr>
<tr>
<td>SHAREIN</td>
<td>Only readers can share file.</td>
</tr>
<tr>
<td>CTG</td>
<td>For create, catalogues file in directory upon open.</td>
</tr>
<tr>
<td>SCRATCH</td>
<td>File is not permanent.</td>
</tr>
<tr>
<td>• NAMED</td>
<td>File is permanent.</td>
</tr>
<tr>
<td>CONSEC</td>
<td>For create, specifies organization of new file.</td>
</tr>
<tr>
<td>• KEYED</td>
<td>For create, specifies organization of new file.</td>
</tr>
<tr>
<td>RANDOM</td>
<td>For create, specifies organization of new file.</td>
</tr>
<tr>
<td>UR</td>
<td>For create, specifies organization of new file.</td>
</tr>
<tr>
<td>RELATIVE</td>
<td>For create, specifies organization of new file.</td>
</tr>
<tr>
<td>INDEXED</td>
<td>For create, specifies organization of new file.</td>
</tr>
<tr>
<td>CG</td>
<td>For create, specifies organization of new file.</td>
</tr>
<tr>
<td>IREL</td>
<td>For create, specifies organization of new file.</td>
</tr>
<tr>
<td>• DIRECT</td>
<td>For create of alternate index file, build indices on file close.</td>
</tr>
<tr>
<td>SEQUEN</td>
<td></td>
</tr>
<tr>
<td>LOAD</td>
<td>CP-6 file management will compress records.</td>
</tr>
<tr>
<td>COMP</td>
<td>Uses IBEX ISET F$tie for additional options.</td>
</tr>
</tbody>
</table>

*denotes defaults

If one of the option fields is not a valid option and is exactly two characters in length, it is used as the file type. Additional information on the meanings of these options can be found in the CP-6 Host Monitor Services Reference Manual (CE74).

The left argument of the `OFOPEN` system function may also be a vector of nested arrays which permits the specification of file access controls, record-field definitions, and alternate key definitions. The topic named Specialized File Options (later in this section) contains information on this usage.
Examples:

'TEMP' OFOPEN 1
'COMMON,HISACCT,UPDATE,ALL' OFOPEN 99
APLSTUFF,DC,CREATE,ERROR,CTC OFOPEN 1234
'DP#PACK3/'MYSTUFF,UPDATE' OFOPEN 31415926

**OFCLOSE Function (Closing and Renaming Files)**

**Syntax:**

```
OFCLOSE TV
FID OFCLOSE Y
```

**Parameters:**

- **TV** is a simple integer vector indicating file I/O streams that are currently open.
- **Y** is a simple integer scalar indicating a file I/O stream that is currently open.
- **FID** is a simple character vector indicating the new name or new password by which this file will be known.

**Description:**

The **OFCLOSE** function closes the specified streams. For monadic **OFCLOSE**, the right argument is a scalar or vector of stream numbers.

A file's name can be changed at closing time using dyadic **OFCLOSE**. The right argument is the stream number. The left argument is the new file identifier.

Renaming a file requires DELF access in the file's access controls. The file's name, password, or both may be changed. The file's access controls (see File Access Controls) may also be modified at close time by specifying an access control matrix as the left argument. In general, the left argument to **OFCLOSE** may contain a fid, access control matrix or a nested vector containing both a fid and an access control matrix.

**Example:**

```
OFTNUMS
99 1234 31415926
OFCLOSE 1234 99
OFTNUMS
31415926
```
**FERASE Function (Close and Delete File)**

Syntax:

FERASE TV

Parameters:

TV is a simple integer vector indicating file I/O streams that are currently open.

Description:

The FERASE function closes the specified streams and deletes the files that were opened to them. The right argument is a scalar or vector of stream numbers. Note that once a stream has been closed, referencing it before opening it once again will result in a FILE TIE ERR.

Example:

- FNUMS
  - 99 1234 31415926
- FERASE 1234
- FNUMS
  - 99 31415926

**FCLEAR Function (Close All Open Files)**

Syntax:

FCLEAR

Description:

The FCLEAR system function causes all currently open streams to be closed. It is functionally equivalent to the expression:

FCLOSE FNUMS
Reading and Writing Records

The functions in this group provide access to records within the file. Records may be accessed either sequentially or directly by specifying record number or key. The absence of the record number or key is used to indicate a sequential operation.

OFAPPEND Function (Append Record to File)

Syntax:

\[ R+X \ \text{OFAPPEND} \ Y \]
\[ X \ \text{OFAPPEND} \ Y \]

Parameters:

\( X \) is the APL array that is to be written (appended) to the file.
\( Y \) is a vector of up to 3 items. The first item must be a simple integer scalar indicating a file I/O stream that is currently open. The optional second item is a simple integer encryption seed (or a 4-element character vector). The optional third item is a simple integer scalar record type number as described in Table 12-1 (or a record field matrix).
\( R \) is the key of the record that was appended.

Description:

The OFAPPEND function writes the data object to the file at the position of the last record in the file plus the key interval of the file. The key interval can be set or obtained by using the OFKEYINT function. The key interval for files other than keyed files is always 1. The file must have been open in UPDATE or CREATE mode.

The right argument consists of the stream number, the optional encryption seed, and the optional type of record to be written. Only the stream number is required. If the encryption seed is zero or not present then the record will not be encrypted. If the third item of the right argument is omitted or 1, then an APL component record is written. If it is 2, then an APL datablock is written. If it is 3, then the ravel of the data is written. Finally, if it is 4, the record field description associated with the file is used to format the record before writing. The left argument is any APL array.

OFAPPENDR is identical in operation to OFAPPEND, and additionally returns the numeric key of the record written.

Examples:

'FAR OUT' OFAPPENDR 31415926
1

'EXTERNAL RECORD TYPE' OFAPPEND 1 0 3

'ENCRYPTED RECORD' OFAPPEND 1 998
OFREAD Function (Read a Record)

Syntax:

\[ R \leftarrow \text{OFREAD} \ Y \]

Parameters:

\( Y \) is a vector of 1 to 4 items in length (stream, key, seed, type).

\( R \) is the contents of the requested record.

Description:

The \( \text{OFREAD} \) function is used to read records. The right argument contains the stream number and optionally the record number or key, the encryption seed and the record type. If the key is a character vector, the argument must be a nested array with the key as the second item. If the key is an empty vector, then a sequential read is performed. If a record with the specified key does not exist or if a sequential read reaches the end of the file, \( \text{FILE INDEX ERR} \) is reported.

As in \( \text{OFAPPEND} \), the encryption seed can be non-zero to request encryption and record types 1 (the default), 2, 3, or 4 may be requested. The result is the record with the specified key or the next sequential record if READ access permission has been granted.

Reading when a record type of 3 is specified always results in a character vector result.

Examples:

\[ \text{OFREAD} \ 31415926 \ 1 \]

FAR OUT

\[ \text{OFREAD} \ 1 \ 2 \ 0 \ 3 \]

EXTERNAL RECORD TYPE

\[ \text{OFREAD} \ 1 \ 3 \ 998 \]

ENCRYPTED RECORD

\[ \text{OFREAD} \ 1 \ '\text{TEXTKEY}' \]

RECORD WITH TEXT KEY

Reading Sequentially

A sequential read may be performed by not specifying a key. For example:

\[ \text{OFREAD} \ 5 \]

where 5 is the stream number in this case. In order to read a non-APL file sequentially the following expression is used:

\[ \text{OFREAD} \ 9 \ '\ 0 \ 3 \]

where 9 is the stream number in this example.
DFWRITE Function (Write or Replace a Record)

Syntax:

\[ X \text{ DFWRITE } Y \]

Parameters:

- \( Y \) is a vector of 1 to 4 items in length (stream, key, seed, type).
- \( X \) is the APL array that is to be written to the file.

Description:

The DFWRITE system function causes a record to be written (new or replaced) in the file with the specified key.

The right argument contains the stream number and optionally a record number or key, an encryption seed and a record type.

If the record identifier is a character key, the right argument must be a nested array with the key as the second item. If the key is not specified and this is not an indexed or irel file, then the record last read by this stream is replaced.

A non-zero value for the encryption seed will cause the record to be encrypted before writing it. The same encryption key must be used to subsequently read it.

The record type is 1 for a component record, 2 for a datablock record, 3 for an external record, and 4 for the file's record field definition.

The file must have been opened with either the UPDATE or CREATE options and WNEW or UPDATE permission must be granted.

Examples:

- 'REPLACEMENT' DFWRITE 31415926 1
- 'TEXT KEY' DFWRITE 1 'OJ SIMPSON' 27165
- 'EXTERNAL WRITE' DFWRITE 1 3330 0 3

DFDROP Function (Delete Record from File)

Syntax:

\[ \text{DFDROP } Y \]

Parameters:

- \( Y \) is a vector of length 2 (stream, key).
Description:
The OFDROP system function deletes specific records from a file. The right argument identifies the stream and the record number or key of the record to delete.

Examples:

```
OFDROP 1 2
```

deletes record number 2. The file must be opened in either UPDATE or CREATE mode to use this function and DELR access permission must be granted.

**OFRDCI Function (Return Component Information)**

Syntax:

```
R=OFRDCI Y
```

Parameters:

- **Y** is a 1, 2, or 3 item vector (stream, key, seed).
- **R** is a simple character vector of length 36.

Description:

The OFRDCI function returns a character vector of 36 items containing the date in the format YYMMDD (e.g., 841030) in the first six items, the time in the format HHMMSSSS (e.g., 12300000 for 12:30 PM) after the blank following the date. The remaining characters are the account and user name fields (see Figure 12-1).

The right argument is the same as for OFREAD except that the record type is not specified (this function only works on component records).

If the record was not written as a component record, then the error NOT AN APL FILE is reported. For example:

```
OFRDCI 1 2
840922 16410818MAGAPL 201GONE
```

**File Access Controls**

The functions in this group set and retrieve the current file access controls for files that are currently open. Access controls may also be set when the file is created by the OFOPEN system function, or modified when closing the file by the OFCLOSE system function.
File Access Matrix

An APL file access matrix is used to indicate the file access controls. Access controls permit or prevent access to files by users. Permissions are indicated in terms of accounts (which may be wild-carded) and file access permissions granted to those accounts. Table 12-3 contains the file access permissions which are available.

An APL file access matrix is a simple N-by-17 character matrix. The first eight columns contain an account identifier. The ninth column must always be blank. The remaining columns contain either the character 'Y' to permit the corresponding access or the character 'N' to restrict the access.

Example:

```
AC=1 17p(8*'905APL'),' YYYYNNNN'
BC=1 17p(8*'TEST?'),' YNYNNNNN'
CC=AC,([10]BC
```

In the example, AC is a file access matrix which permits the account 905APL to read, delete, update, write new records and see the file name in the file directory (or account).

The file access matrix BC permits any account beginning with the characters 'TEST' to read, write new records, and see the file name in the file directory.

The file access matrix CC provides the permissions associated with AC and BC to their respective accounts.

<table>
<thead>
<tr>
<th>Column</th>
<th>Permission</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>READ</td>
<td>can use OFREAD, OFRDIC, OFRDAC, OFENQ, OFDEQ</td>
</tr>
<tr>
<td>11</td>
<td>DELR</td>
<td>can use OFDROP to delete records</td>
</tr>
<tr>
<td>12</td>
<td>WNEW</td>
<td>can use OFAPPEND, OFWRITE to write new records</td>
</tr>
<tr>
<td>13</td>
<td>UPDATE</td>
<td>can use OFWRITE to replace records</td>
</tr>
<tr>
<td>14</td>
<td>DELF</td>
<td>can use OFSTAC, OFERASE or dyadic OFCLOSE</td>
</tr>
<tr>
<td>15</td>
<td>NOLIST</td>
<td>can use OFLIB will not list file name</td>
</tr>
<tr>
<td>16</td>
<td>REATTR</td>
<td>can use OFSTAC</td>
</tr>
<tr>
<td>17</td>
<td>EXEC</td>
<td>not meaningful to APL files</td>
</tr>
</tbody>
</table>

**OFRDAC Function (Return File Access Matrix)**

Syntax:

```
R=OFRDAC Y
```
Parameters:

$Y$ is a simple integer scalar indicating a file I/O stream that is open.

$R$ is a simple character matrix of shape $N$-by-17.

Description:

The OFDAC function returns the APL file access matrix for the specified file. Each row of the matrix contains an account identifier (which can be wild-carded) and the corresponding file permissions. The right argument is a stream number. If the file was opened with the create option, then it must also have been opened with the CTG option.

Examples:

```
OFRDAC 1

? HNNNNNN
```

OFSTAC Function (Store File Access Controls)

Syntax:

```
OFSTAC Y
```

Parameters:

$Y$ is a simple integer scalar indicating a file I/O stream that is open.

$H$ is a file access matrix, that is, a simple character matrix of shape $N$-by-17.

Description:

When the OFSTAC function is executed, the file opened to stream $Y$ has its access controls revised to reflect the permissions specified in $H$. The right argument is the stream number of a currently open file. The left argument is a file access matrix.

Examples:

```
((('ACCOUNT','YNNNNNN'),(1)OFRDAC 1))OFSTAC 1
```

This example will allow the account named in the variable `ACCOUNT` to read and delete records and to change the access permissions of the file.
Coordinating Shared Files

The functions in this group are intended to be used when more than one user is accessing a file, and it is being updated by at least one user. The enqueuing protocol should be agreed upon for all applications using the file; its use is not enforced by the system.

**OFENQ Function** (Hold a Record)

**Syntax:**

\[ R+OFENQ \ Y \]

**Parameters:**

\( Y \) is a vector of length 2 (stream, key).

**Description:**

After the OFENQ function has executed, another user executing OFENQ on the same file and resource name will be halted until the user currently holding the resource releases it with the OFDEQ function.

The right argument contains the tie number and resource name. The resource name is an integer or character value, most commonly a record key.

**OFDEQ Function** (Release Record or File)

**Syntax:**

\[ R+OFDEQ \ Y \]

**Parameters:**

\( Y \) is a vector of length 2 (stream, key).

**Description:**

When the OFDEQ function is executed, the resource specified is released permitting another user currently waiting for this resource to continue.

The right argument contains the tie number and optional resource name.

If the resource is not specified, then all resources currently held by this user are released for this file.
File Status Functions

The following functions give additional information about a specific currently open file.

OFRKEY Function (Return Key Values)

Syntax:

\[ R + \text{OFRKEY } YS \]

Parameters:

- \( YS \) is a vector of length 2 or 3 (stream, keytype, altkey).
- \( R \) is the key.

Description:

The \( \text{OFRKEY} \) function returns specific key values depending upon the second item in \( YS \).

If \( YS[2] = 1 \), \( \text{OFRKEY} \) returns the key of the first record in this file. If \( YS[2] = 2 \), \( \text{OFRKEY} \) returns the key of the record most recently read or written. If \( YS[2] = 3 \), \( \text{OFRKEY} \) returns the key of the last record in the file. If \( YS[2] = 0 \), \( \text{OFRKEY} \) returns the key of the record last accessed when reading or writing on the specified key index. (For non-IREL files, the difference between 0 and 2 is that file position is maintained independently for every key index and 2 is the key contained in the most recently read or written record. 0 indicates the position at which a sequential read along a particular key index would commence; for IREL files they are equivalent).

The right argument is a simple integer vector of two or three items. The first item is the stream number and the second item is the integer 0, 1, 2 or 3. The third (optional) item is the key index. If the third item is not present, 1 (primary key) is assumed. The key index is not \( 0 \) dependent.

If the file is currently empty, an empty vector is returned.

For keyed files, a key length of three characters is treated as a numeric key, for all other key lengths the keys are returned as a character vector.

Examples:

\[ \text{FLIM} = (\text{OFRKEY } 1 \ 1), \text{OFRKEY } 1 \ 3 \]

If this is a keyed file with numeric keys or any other file type other than INDEXED or IREL, then this expression results in \( \text{FLIM} \) being assigned an integer vector of length 2. The first item of \( \text{FLIM} \) is the record number of the first record in the file, the second item is the record number of the last record in the file. For example:

\[ \text{OFRKEY } 1 \ 1 \ 0 \ \text{OFRKEY } 1 \ 2 \ 0 \ \text{OFRKEY } 1 \ 3 \]

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20

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OFRKEY Function (Return Key Values)
**FSIZE Function (File Size)**

Syntax:

```plaintext
R = FSIZE Y
```

Parameters:

- `Y` is a simple integer scalar indicating a file I/O stream that is open.

Description:

The `FSIZE` function returns the number of bytes of storage allocated to the file opened to stream `Y`.

**FKKEYINT Function (Set Key Interval)**

Syntax:

```plaintext
R = FKKEYINT YS
```

Parameters:

- `YS` is a simple 1 or 2 element integer vector.

Description:

The `FKKEYINT` function sets the increment to be used when appending a record to a keyed file. The right argument is a stream number and an optional integer value.

The result is the previous increment or the current increment depending on whether the current increment has been replaced. The default value (after `FOPEN`) is 1000 for keyed files.

**FKKEYS Function (Return File Keys)**

Syntax:

```plaintext
R = FKKEYS Y
```

Parameters:

- `Y` is a simple integer scalar indicating a file I/O stream that is open.
- `R` is a key definition matrix.
Description:

The OFKEYS system function returns the key list for the specified stream.

For INDEXED files, this is a matrix of shape N-by-3 containing the starting position, length, and duplicate indicator. The first column contains the index in character positions of the first character of the key (the first index position is 0). The second column contains the length in characters of the key. The third column contains 1 if the key must be unique or 0 if the duplicate key values are permitted. Each row defines a key, the first row is the primary key (this key must always be unique). Any subsequent rows are alternate keys (may be unique).

For IREL files, this is a matrix of shape N-by-2 containing field numbers in the first column and key unique/key-end flags in the second column. The second column values and their associated meanings are as follows: 0, a non-unique key; 1, a unique key; 2, the last field of a non-unique key; and 3, the last field of a unique key.

For other file types, the result is:

Example:

An example of OFKEYS with an indexed file is:

\[
\begin{array}{ccc}
10 & 4 & 1 \\
14 & 20 & 0 \\
1 & 5 & 0 \\
\end{array}
\]

In this example, the file open to stream 4 has 3 keys. The primary key is 4 characters long beginning at position 10. The secondary keys are 20 and 5 characters long and begin at positions 14 and 1 respectively. Only key values for the primary key must be unique.

An example of OFKEYS with an IREL file is:

\[
\begin{array}{ccc}
3 & 3 & 0 \\
4 & 2 & 0 \\
8 & 1 & 0 \\
9 & 3 & 0 \\
\end{array}
\]

In this example, the file open to stream 9 has 3 keys. The primary key is field 3. The first alternate key is field 5 followed by field 4. The first alternate keys do not have to be unique. The last alternate key is field 8 followed by field 9. The last key values must be unique.

OFCRPT Function (Set File Encryption Seed)

Syntax:

\[
X \text{ OFCRPT } Y
\]
Parameters:

$Y$ is a simple integer scalar indicating a file I/O stream that is open.
$X$ is a simple integer scalar encryption seed.

Description:

The $\text{OFCRPT}$ function changes the seed that is used by default for subsequent read and write operations to this stream. The initial default encryption seed is zero when a stream is opened. The right argument is the stream number. The left argument is an encryption seed.

A seed can be specified on the $\text{OFREAD}$, $\text{OFWRITE}$, $\text{OFAPPEND}$ and $\text{OFRCRT}$ functions which overrides this default seed. There is no explicit result to this function.

Library or Account Information

The functions in this group return information about the files in an account.

$\text{OFMA}$ Function (Return File Management Account)

Syntax:

\[ R+\text{OFMA} \]

Description:

The $\text{OFMA}$ system function returns a character vector of length 8 containing the current default file management account which is used whenever a file identification does not contain an account identifier. This would typically be the same as the current logon account but can be changed by a $\text{DIR}$ command (for example).

$\text{OFLIB}$ Function (Return File Names)

Syntax:

\[ R+\text{OFLIB} A \]

\[ R+X \text{OFLIB} A \]

Parameters:

$A$ is a simple character vector containing an account or a wild-carded file name and account.

$R$ is a simple character matrix of shape $N$-by-$40$.

$X$ is a simple character vector of length 2 or a simple character matrix of shape $N$-by-2.
Description:

The `OFLIB` function returns a character matrix of shape N-by-40 containing names of the files in the specified account. If a wild-carded file name is specified, the result includes only those names which contain all of the characters in the wild-card with any characters (zero or more) in place of the '?' character.

The right argument is either a CP-6 account identifier or a wild-carded file identifier.

An account name is 0 to 8 characters in length. A wild-carded file identifier is 1 to 31 characters in length containing a single '?' character and any other characters, followed by a period, and an (optional) account name.

Monadically, the result is a character matrix of shape N-by-40 where each row contains the account in the first 8 characters (or blanks for the default file management account), a blank, and the file name left justified in the remaining 31 characters.

Dyadically, only those files which have a file type listed in the left argument are returned. If the left argument is empty (a 0-by-2 matrix), all file types are selected. Note that dyadically, `OFLIB` returns a CP-6 FID which can be used directly by the `OFOPEN` system function.

Examples:

```apl
OFLIB 'TESTAPL'
TESTAPL APLPCF TESTAPL MAIL_CENTRAL TESTAPL IDSWS TESTAPL GRAFX TESTAPL TESTWS
```

```apl
OFLIB '?TESTAPL'
TESTAPL APLPCF TESTAPL MAIL_CENTRAL
```

```apl
OFLIB '?WS.TESTAPL'
TESTAPL IDSWS TESTAPL
```

```apl
OFLIB '*?.'
*A *N *S

'WA' OFLIB 'TESTAPL' a WORKSPACES.
IDSWS.TESTAPL TESTWS.TESTAPL

'*OFLIB 'TESTAPL' a ALL FILES.
:APLPCF.TESTAPL :MAIL_CENTRAL.TESTAPL IDSWS.TESTAPL GRAFX.TESTAPL TESTWS.TESTAPL
```

Possible Errors:

A `RANK ERR` is reported if:

- A is not a scalar or vector.

A `DOMAIN ERR` is reported if:

- A is not simple or contains an item that is not a character.

- A is not a wild-carded file name containing a legal CP-6 account.
The account name is longer than 8 characters.

Record Field Descriptions

When a file is created, a record field matrix may be specified. This matrix defines the contents of the records in a file in terms of fields. Each field (or row of the record field matrix) defines the datatype, location within the record and the field size.

A record field matrix is a simple integer matrix of shape N-by-4 or N-by-5. The record field matrix column numbers (in origin 1) and their definitions are:

1. Datatype. This is an integer indicating the type of data which is in this field. Table 12-4 contains the numbers of the valid datatypes.

2. Length. For decimal fields, this is the number of digits (minus possible overhead); for floating point and character fields, this is the number of bytes; for integer fields, this is the number of bits. Table 12-4 indicates the rules for the field lengths.

3. Scale. A scale value may be specified for some decimal datatypes. The scale value must be in the range -32 to 31 and it indicates the number of digits after the decimal point. Table 12-4 indicates whether the scale is permitted for each datatype.

4. Vector. Numeric fields may be vectors of numbers. A vector value of 0 indicates that this field is a scalar. A negative vector value indicates a fixed length vector whose length is the absolute value. A vector value greater than zero indicates the field number whose value indicates the length of the vector.

5. Logical Order. This optional value may be used to reorder the physical record contents into a logical order. If all logical order values are 0, then the physical order of fields directly corresponds to the logical order. Otherwise, the logical record corresponds to those fields whose logical order is greater than 0 sorted by increasing logical order number. Logical order values are only used to communicate with other CP-6 processors.

The physical order of fields in a record is always the order in which the fields are defined. That is, the first physical field is the first row of the record field matrix.

When accessing records in a file, the use of the file's record field matrix may be requested by specifying a record type 4. In this case, APL will automatically perform datatype conversions between the internal APL datatypes and those in the record field matrix datatypes.

When reading records using a record field matrix, the result is a vector with as many items as the record contains (usually the number of fields defined). A DOMAIN ERR is reported if the contents of a field are not legal for the datatype indicated by the record field matrix. This occurs if a decimal field (for example) contains a '(': character in a digit position.

When writing records using the record field matrix, the value to write must be a vector that is not longer than the number of fields (rows) in the record field matrix. A DOMAIN ERR is reported if:

- a numeric item to be written has a character datatype in the corresponding row of the record field matrix.
- a character item to be written has a numeric datatype in the corresponding row of the record field matrix.
- the value overflows (or underflows) when converted to the type in the corresponding row of the record field matrix.

When creating a file with a record field matrix, the matrix is specified as an item of the left argument of the OFOPEN system function. During the execution of the OFOPEN function, the system verifies the contents of the record field matrix and reports any inconsistencies as a DOMAIN ERR or a FILE I/O ERR.
<table>
<thead>
<tr>
<th>Datatype</th>
<th>Type</th>
<th>Decimal</th>
<th>Size</th>
<th>Scale</th>
<th>Digits</th>
<th>Overhead</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undefined</td>
<td>0</td>
<td>Decimal</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Integer</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Single Floating</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Double Floating</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Packed decimal leading sign</td>
<td>9</td>
<td>YES</td>
<td>2</td>
<td>YES</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Floating packed decimal</td>
<td>10</td>
<td>YES</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Fixed length character</td>
<td>21</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Varying length character</td>
<td>22</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Unsigned integer</td>
<td>24</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Packed decimal trailing sign</td>
<td>25</td>
<td>YES</td>
<td>2</td>
<td>YES</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Packed decimal EBCDIC sign</td>
<td>31</td>
<td>YES</td>
<td>2</td>
<td>YES</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Packed decimal unsigned</td>
<td>40</td>
<td>YES</td>
<td>2</td>
<td>YES</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Decimal unsigned</td>
<td>41</td>
<td>YES</td>
<td>3</td>
<td>YES</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Decimal leading sign</td>
<td>42</td>
<td>YES</td>
<td>3</td>
<td>YES</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Decimal trailing sign</td>
<td>43</td>
<td>YES</td>
<td>3</td>
<td>YES</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Leading overpunch sign</td>
<td>44</td>
<td>YES</td>
<td>3</td>
<td>YES</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Trailing overpunch sign</td>
<td>45</td>
<td>YES</td>
<td>3</td>
<td>YES</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Floating decimal</td>
<td>50</td>
<td>YES</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td>54</td>
<td>YES</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>UTS</td>
<td>55</td>
<td>1</td>
<td>5</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TEXTTH</td>
<td>56</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>57</td>
<td>YES</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

where

Size rules:

1. The field can be of any length up to 36 bits starting at any bit.
2. The field length is in nibbles and starts on a nibble or character boundary.
3. The field length is in characters and starts on a character boundary.

Digits Rules:

The number of decimal digits in the field is:

0. none
1. \(1002+\text{SIZE}-\text{OVERHEAD}\)
2. \((\text{SIZE}+3)\)-OVERHEAD
3. \(\text{SIZE}+3\)-OVERHEAD
4. Length must be 16 (nibbles).
5. Length must be 36 (bits).

Note: Decimal fields cannot contain more than 63 digits.

Overhead Rules:

0. 0 (none)
1. 1 (bits for integer, digits for decimal)
2. 9 (bits)
3. 2 3[60+TYPE=10] (digits)
OFFLDS Function (Return Record Fields)

Syntax:

\[ R^{+}\text{OFFLDS} \ Y \]

Parameters:

\( Y \) is a simple integer scalar indicating a file I/O stream that is open.

Description:

The OFFLDS system function returns the record field description for the specified file. The result is an integer matrix of shape \((N,5)\). If the file tied to the specified stream has no record field list defined, the result is a matrix of shape \((0,5)\).

Example:

\[
\text{OFFLDS 29} \\
1  36 0 0 0 \\
21 12 0 0 0 \\
10 12 0 0 0 \\
44  6 2 0 0 \\
50 32 0 0 0 \\
22  0 0 0 0 \\
\]

In this example, file stream 29 is open to a file whose records contain 6 fields. The field numbers and their corresponding types are:

1. Integer. Values in the range \((-2^{35})\) to \((-1+2^{35})\).
2. Text vector. 12 characters in length.
3. Floating packed decimal. 9 decimal digits in the range \(-1E136\) to \(1E136\) exclusive. The smallest non-zero numbers in magnitude are \(-1E^{-128}\) and \(1E^{-128}\).
4. Leading overpunched signed decimal. 6 decimal digits (2 after the decimal point). The largest values are \(9999.99\) and \(-9999.99\).
5. Floating decimal. 30 decimal digits in the range \(-1E157\) to \(1E157\) (exclusive). Note that APL will provide an approximation to these values accurate to the 18 most significant digits.
6. Variable length text vector. The maximum length of this field is 511 characters.

The following examples demonstrate writing records to this file using APL's automatic data conversion capability (record type 4).

\[ X\leftarrow123 \ 'CHAR(12)' \ (*1) \ 12.345 \ (01) \ 'VARYING' \]

\[ X \ \text{OWRITE} \ 29 \ 1 \ 0 \ 4 \]

\[ X \]

\[ 123 \ 'CHAR(12)' \ 2.718281828 \ 12.345 \ 3.141592654 \ 'VARYING' \]

In the above example, X is written to the file. APL will pad field 2 with blanks to fill it out to 12 characters in length. The value written for fields 3 and 4 will be rounded to the number of digits defined for the field.

\[ \text{OFREAD} \ 29 \ 1 \ 0 \ 4 \]

\[ 123 \ 'CHAR(12)' \ 2.71828 \ 12.35 \ 3.141592654 \ 'VARYING' \]

Notice that field 2 has been padded with blanks and that field 4 has been rounded to 2 digits after the decimal point.
Alternate Indexed Files

The following file I/O functions permit the specification of an alternate index: \texttt{OFREAD, OFRDCI, OFDROP, OFKEY}. The alternate key list can be obtained via the \texttt{OFKEYS} function.

An alternate key is specified as a nested 2-item argument in the position in which the key is found. The first item is the key index number. The second item is the key value. An empty vector for the key value causes a sequential read along the specified alternate key to occur. For example:

\begin{verbatim}
OFREAD 9 (3 ('SMITH')) 0 3
\end{verbatim}

In this example, stream 9 is read. The third key is searched for the value 'SMITH' (trailing blanks are supplied by APL if the key is shorter than the key length). If multiple records with that key exist, the first record with that key is returned. Subsequent reads on this stream that do not specify a key index or specify index 0 will use the third key index.

In the following example, all records with the value 'MARTIN' for the third key index are removed from the file:

\begin{verbatim}
OFDROP 9 (3 'MARTIN')
\end{verbatim}

If only one particular 'MARTIN' record is to be deleted, the key value for a unique key (there is always one) must be provided.

For IREL files, the key index must always be provided and the key value must be a vector of field values. For example:

\begin{verbatim}
OFREAD 4 (2 (,5)) 0 4
\end{verbatim}

In this example, the second key index is used. The key value that will be found is 5.

Specialized File Options

The left argument of the \texttt{OFOPEN} and \texttt{OFCLOSE} system functions can be:

- a simple character vector containing the CP-6 file identifier and options,
- a vector of arrays, where each item in the vector can be: a character vector with the CP-6 fid, an access control matrix as described in \texttt{OFREAD}, a record field matrix, or an indexed key list as described in \texttt{OFKEYS}. The access control matrix and indexed key list are only used for \texttt{CREATE} opens. If \texttt{OLDFILE} is specified and the file exists, the access controls and index keys are not used. The character vector containing the file identifier must appear before the alternate keys in the list of items.

Examples:

To create a file which permits any CP-6 user to read with a 5 character primary key starting at index 1, a 4 character alternate key starting at index position 6, a 20 character alternate key starting at index position 10, and another 20 character alternate key starting at index position 30, the following is entered:

\begin{verbatim}
ALTKEYS+4 3p 1 5 1 6 4 0 10 200 30 20 0
AC+1 17p'(9*P'?),Y',7p'N'
FID+('ALTFILE,CREATE,NEWFILE,INDEXED,LOAD,CTG')
( FID ALTKEYS AC)OFOPEN 1
\end{verbatim}
All of the options available through the IBEX !SET command are also available to users wishing to open a file. For information on the SET command, see the CP-6 Programmers Reference Manual (CE40).

To create an INDEXED file in APL with the name INDEX01 and with the key starting in the 73rd character and being 8 characters in length, the following APL expressions can be used:

\[
\begin{align*}
\text{INDEX01} & \equiv \text{INDEX} \cdot \text{SET} \cdot \text{INDEXX} = 72, \text{KEYL} = 8' \\
\text{NEWFILE} & \equiv \text{REASSIGN}, \text{INDEXED}, \text{CREATE}, \text{NEWFILE}' \\
\text{OFOPEN} & \equiv 31
\end{align*}
\]

The options that APL permits on the OFOPEN all have defaults that will override the SET options. That is, the SET options EXIST=, SHARE=, FUN=, ORG= and ACS= will be ignored on the )SET command and so they must be specified on the OFOPEN if different from APL's default options.

Possible Errors:
A RANK ERR is reported if:
- the left argument of OFOPEN or OFCLOSE is not a scalar or vector.

A LENGTH ERR is reported if:
- the left argument is not simple and it contains zero or more than four items.

A RANK ERR is reported if:
- any item of the left argument is not a scalar, vector or matrix.

A DOMAIN ERR is reported if:
- any item of the left argument is not simple.

A LENGTH ERR is reported if:
- a matrix item of the left argument is not of shape N-by-17 (access control matrix), or an N-by-3 (alternate key matrix) matrix.
Section 13
CP-6 APL I-D-S/II System Functions

CP-6 APL contains system functions which provide access to I-D-S/II databases. All of the COBOL language DML (Data Manipulation Language) statements have equivalent APL functions. In addition to these standard DML functions, the APL interface contains a number of unique functions which may be used to obtain detailed information about the database being accessed.

In order to make use of this facility an APL subschema must be generated. The creation of I-D-S/II databases and subschema generation is achieved through the execution of various I-D-S/II utility programs.

```
R+DDBSUB 'sub-schema-name,privacy-lock,SHARE'
```

This function must always be the first I-D-S/II function to be executed during an APL session. It informs I-D-S/II of the name of the subschema to be used and the result of its execution is the name of the associated schema. If the subschema, schema or areas reside in an account other than the current file management account, or if their file management name is different than their schema name or the CP-6 file containing the subschema is passworded, a SET command is required to direct I-D-S/II to the correct file. For example, if the subschema name is SSCHFILE and it resides in the file: SSCHFILE.7A.123TEST, the schema file name is SCHFILE and it resides in the file SCHFILE.123APL.PSSWD and the area to be used in this subschema is AREA0 in the CP-6 file MAGAREA.123IDS. The SET commands required to use this database in APL are:

```
)SET SSCHFILE SSCHFILE.7A.123TEST
)SET SCHFILE SCHFILE.123APL.PSSWD
)SET AREA0 MAGAREA.123IDS
```

The optional positional parameter SHARE when present causes all of the items in the database to become automatically shared between the user work area and the APL workspace. This allows the functions DDBFROM and DDBTO to be performed automatically upon assignment or a reference to a workspace variable with the same name as the corresponding database item. Note however, item names containing underscores will appear in the workspace with deltas replacing the underscores.

The following errors are possible when executing the DDBSUB system function:

**I-D-S/II LIBRARY NOT AVAILABLE**

The alternate shared library named I-D-S/II either does not exist or another alternate library is currently associated. This error may be sidetracked as error number 201.

**INVALID SUBSCHEMA**

The file indicated as the subschema is not an I-D-S/II subschema file. This error may be sidetracked as error number 202.

**FILE TBL FULL**

The maximum number of files that an APL user may open are currently open. In order to use I-D-S/II, some files must be closed. This may be sidetracked as error number 203.

**SUBSCHEMA NAME ERR**

Either the subschema name and privacy key is ill-formed or the subschema name in the file does not match the name supplied. This may be sidetracked as error number 205.
SUBSCHEMA ACCESS ERR

Access to the subschema has been denied because the file does not exist, it is passworded, or the privacy locks do not match. This may be sidetracked as error number 206.

Subschema Information Functions

The following functions give information about subschema names and subschema name types.

DBNAMES Function (List Subschema Names)

Syntax:

R+ODBNAHES

Description:

The ODBNAHES niladic system function returns the names of all of the realms, sets, records, items, and I-D-S/II keywords available through the current subschema. The shape of the result is N by M where N is the number of names and M is the length of the longest name.

DBTYPES Function (Subschema Name Types)

Syntax:

R+ODBTYPES

Description:

The ODBTYPES niladic system function returns a numeric array of shape N-by-6 indicating the attributes of each corresponding name in ODBNAHES. The first item of each row indicates the type of object represented by that name. The second item of each row contains usage or mode information, the third item of each row contains encoded flags that are type specific, the fourth item of each row contains the index in ODBNAHES of the object that owns this object, the fifth item of each row contains sub-type information and the sixth item of each row contains the length of the object.

Column one contains:

OBJECT TYPE
1 REALM
2 RECORD
3 FIELD
4 SET
5 PARAMETER
6 unused
7 I-D-S/II KEYWORD
8 Record Key
Record Type Information

For records, column two contains the location mode for this record:

- 0 DIRECT
- 1 CALC
- 2 VIA SET
- 3 SEQUENTIAL
- 4 INDEXED

Column three contains flags decoded as:

\[ F^\ast(35p2)\tau \mathrm{DBTYPES}(R;3) \]

where (in index origin 1):

- \( R[1] \) name is in SUBSCHEMA
- \( R[2] \) name understood by I-O-S/II
- \( R[3] \) STORE is allowed
- \( R[4] \) MODIFY is allowed
- \( R[5] \) DELETE is allowed
- \( R[6] \) ERASE is allowed
- \( R[7] \) variable length
- \( R[8] \) in multiple areas
- \( R[9] \) has alternate keys
- \( R[10] \) an elementary item
- \( R[11] \) item is signed
- \( R[12] \) item is scaled

Field Type Information

The second column for fields contains usage information. The range of possible values are:

- 0 DATA ITEM
- 1 DATA BASE PARAMETER
- 2 LOCATION MODE DIRECT FIELD
- 3 AREA-ID FIELD
- 4 CALC KEY SYNONYM FIELD
- 5 SCAN KEY SYNONYM FIELD

The third column for fields contains flags that may be decoded with the expression:

\[ F^\ast(35p2)\tau \mathrm{DBTYPES}(F;3) \]

where the meanings are the same as for the record flags.

The fourth column contains the record number in DBNAMES that this field belongs to.

The fifth column contains the data type of this field. Values are:

- 0 CHARACTER
- 1 INTEGER DB KEY
- 2 INTEGER
- 13 SINGLE PRECISION FLOATING POINT
- 14 DOUBLE PRECISION FLOATING POINT

The sixth column is used for character data items to indicate the length of the string.
Set Type Information

The second column for sets indicates the mode of this set. Valid values of mode are:

0  CHAIN
1  RECORD ARRAY
2  POINTER ARRAY

The fourth column for sets indicates the index in ODBNAMES of the record that owns this set. The fifth column indicates the type of set this is. Values of set type are:

0  USER SET
1  CALC SET
2  PRIMARY KEY
3  SECONDARY KEY

The sixth column indicates how this set is ordered. Values of order are:

0  FIRST
1  LAST
2  NEXT
3  PRIOR
4  SORTED BY KEY

Parameter Type Information

Column four contains the index in ODBNAMES of the record related to this database parameter.

I-D-S/II Function Arguments

In the following description of the APL language interface to I-D-S/II, the functions are described in terms of the database objects known to I-D-S/II. The database objects are indicated in APL by either the text of the object's name or by the numeric index of the object's name in ODBNAMES.

A series of database objects and keyword names may be indicated by separating the names by blanks in a character vector, as an integer vector of object indices (in ODBNAMES), or as a series of object values (including character and/or numeric indices), separated by semi-colons and enclosed in parentheses as in arguments to OFHT. This means that all of the following I-D-S/II calls are equivalent:

R+ODBFIN 'STUREC WITHIN COURSET CURRENT STUNAME'
R+ODBFIN ('STUREC';'WITHIN';'COURSET';'CURRENT';'STUNAME')
R+ODBFIN ('STUREC WITHIN COURSET CURRENT';'STUNAME')
R+ODBFIN (5 42 3 34;'STUNAME')

where in the last example, the fifth row of ODBNAMES contains the text STUREC, the 42nd row contains WITHIN, etc.
Name and Set Information

The following functions give information about subschema names and sets.

**DDBANLZ Function (Analyze Subschema Names)**

Syntax:

```
R + DDBANLZ A
```

Description:

The right argument to this function is a simple character vector containing subschema names and keywords. The result is an integer vector containing the index in ODBNAMES of each name in A.

**DDBOWNER Function (Set Owner)**

Syntax:

```
R + DDBOWNER B
```

Parameters:

- `B` is a character vector containing the name of a set or record. Optionally, it may be the index in ODBNAMES of the name of a set or record.

Description:

The right argument to this function is either the name of a set or record. The result for a set is the index of the record that owns this set in ODBNAMES. The result for a record is a vector of the indices of the sets that this record may own.

**DDBMEMBER Function (Set Member)**

Syntax:

```
R + DDBMEMBER B
```

Parameters:

- `B` is a character vector containing the name of a set or record. Optionally, it may be the index in ODBNAMES of the name of a set or record.
Description:

The right argument to this function is either the name of a set or record. The result is always an N-by-3 matrix indicating in column one the sets or records that the supplied record or set may be a member of. The second column contains zero if membership is manual or one if membership is automatic. The third column is zero if membership is optional or one if membership is mandatory.

**DBINFORM** Function (Database Register)

Syntax:

\[ R = \text{DBINFORM} \ B \]

Parameters:

\( B \) is a simple character vector.

Description:

The **DBINFORM** function returns the contents of the specified database register. The registername is specified as one of the following:

- **DBSTATUS**
- **DBREIM**
- **DBSET**
- **DBRECORD**
- **DBPRIVACY**
- **DBDATANAME**
- **DBKEYNAME**
- **DIRECTREFERENCE**

Accessing Data

The values of record items may be set and obtained by either sharing variables in the workspace with I-D-S/II or by the functions **ODBFORH** and **ODBTO**. Sharing of all database items may be requested when the database is opened (see **ODBSUB**) or by using the Shared Variable system functions. For example, if **USERNAME** is the name of an item in the database then the expression:

\[ 'IDS.:SYS' OSVO 'USERNAME' \]

returns 2 indicating that the variable **USERNAME** in the active workspace may be referenced or assigned is a surrogate for the value in the UWA. Note that erasing **USERNAME** or retracting **USERNAME** by the **OSVR** system function will discontinue sharing.
**ODBFROM Function** (Retrieving Data)

Syntax:

\[ R+\text{ODBFROM } B \]

Description:

The `ODBFROM` function returns the values of the specified items in the UWA (User Work Area). The items in the `itemlist` must all be of type numeric or all character or a `DOMAIN ERR` will occur. Character values in the result are separated by carriage return characters.

**ODBTO Function** (Storing Data)

Syntax:

\[ R+\text{ODBTO} \ (\text{itemlist};\text{valuelist}[:]\text{valuelist}:...) \]

Parameters:

- **itemlist**: is a simple character vector containing the names of I-D-S/II items. Optionally, this may be a simple integer vector containing the indices of items in `ODBNAHES`.
- **valuelist**: are simple scalar numbers or vectors of numbers to be assigned to the corresponding item named in `itemlist`. Character values are included as separate items in the list.

Description:

The right argument to this monadic system function is a list, the first item of which is either the character vector of the itemnames or a numeric vector of the name indices in `ODBNAHES`. The remaining items in the argument list consist of the values to be moved into the UWA for each corresponding item name. A `valuelist` consists of character or numeric scalars or vectors. If a character vector is supplied, separate values may be separated by carriage return characters.

**Standard I-D-S/II Functions**

Brief descriptions of syntax for APL calls on the I-D-S/II data manipulation functions are listed below. For information on their meaning and use, see the I-D-S/II Programmers Reference Manual (CE35).

\[ R+\text{ODBACEPT} \ (\text{FROM}) \text{[recordname]} \text{CURRENCY} \]
\[ R+\text{ODBACEPT} \ (\text{FROM}) \text{[recordname]} \text{REALMNAME} \]
\[ \text{dbkey} \]

If the first parameter is a setname or recordname, this function requires that the text of the name be supplied and not the name's index in `ODBNAHES`.
If the first parameter is a keyword, this function requires that the text of the name be supplied.

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If the first parameter is a keyword, this function requires that the text of the name be supplied.
I-D-S/II Error Reporting and Handling

The execution of I-D-S/II data manipulation functions always cause a code to be returned in the DBSTATUS cell. Values of DBSTATUS greater than zero signify that an exception condition has occurred. Successful completion of the data management function is indicated by a DBSTATUS of zero.

Control over exception conditions may be obtained by APL use procedures.

**DBUSE Function (Use Procedures)**

Syntax:

```
code DBUSE name
```

Description:

The `DBUSE` function returns the name of the use procedure associated with the specified code.

APL use procedures are specified and interrogated by the `DBUSE` system function. To specify a use procedure, the left argument to `DBUSE` contains the DBSTATUS value. The right argument contains the name of a niladic function or character vector to be executed when the DBSTATUS value returned by I-D-S/II is equal to the left argument. If an empty vector is supplied for the right argument, the use procedure for the DBSTATUS value in the right argument is deleted. More generally, the left argument to `DBUSE` may be a vector of status codes, in which case, the specified niladic function becomes the use procedure for all of the status codes specified. If the right argument is empty, use procedures for all of the specified codes are removed. Finally, the left argument may be a namelist, in which case, there must be exactly as many status codes specified as there are names in the use procedure list.
Monadically, \texttt{ODBUSE} is used to determine the status codes for which there exists an active use procedure or the names of procedures attached to particular status codes.

Examples:

\texttt{ODBUSE \texttt{t}0}

This function returns all of the status codes for which there exists a use procedure.

\texttt{ODBUSE ODBUSE \texttt{t}0}

This function returns the names of all of the use procedures.

A status code of zero may be specified for a use procedure in which case that procedure will gain control whenever an exception condition occurs for which there exists no explicitly named use procedure for that code. The use procedure table is of limited size, there will however always be room for 75 use procedures. Whenever the current workspace is cleared or a new workspace is loaded, the use procedure table is lost and must be set up once again.
Section 14

Packages

A package is used to hold the definition of one or more functions, or the value of one or more variables. A package contains a set of names which are distinct from each other. However, the names within a package need not be distinct from names used outside the package or from the name of the package itself. A name must be extracted from the package before it can be referenced in the active workspace. Packages can be written to or read from files, passed as the argument of a defined function, or returned as the result of a defined function. Packages within saved workspaces can be copied.

The package name is displayed by the system command \texttt{VERS} or as the result of \texttt{CML}. The function \texttt{CNC} reports the nameclass of the package as "variable", the function \texttt{CRM} reports the number of bytes required to store the package and the function \texttt{DEX} may be used to expunge a package. The \texttt{ERASE} command can also be used to expunge a package if the package is defined globally.

The following restrictions apply to the use of packages:

1. A package is outside the domain of arithmetic, relational, and structural functions.
2. A package is outside the domain of \texttt{t}, \texttt{c}, and \texttt{[ ].
3. A package cannot be:
   - an item of another array.
   - catenated.
   - inserted into an array via indexed assignment.
4. The contents of a package cannot be directly displayed.

The function \texttt{OPWAMES} can be used to distinguish a variable that is a package from a variable that is not a package. For example, the expression \texttt{OPWAMES X} returns a matrix when \texttt{X} is a package and returns an empty vector when \texttt{X} is not a package.

Package System Functions

The following system functions are used to create and manipulate packages. When two syntax formats are listed for a function, "Monadic Syntax:" refers to the monadic function and "Dyadic Syntax:" refers to the dyadic function.
\(\text{OPACK} \) Function (Package Create)

Syntax:
\[
R + \text{OPACK} \ X \\
R + Y \ [\text{OPACK} \ X]
\]

Parameters:
- \(X\) is a namelist.
- \(R\) is a package.
- \(Y\) is a name list.

Description:
Using monadic \(\text{OPACK}\), the argument is a namelist which contains the names to be included in the resulting package. The result is a package containing each of the distinct names included in the argument and the object, if any, to which that name refers. If the name in \(X\) is the name of a shared variable, the value included in the package is the last visible value in the active workspace. (Referring to a shared variable with monadic \(\text{OPACK}\) does not count as a "use" of the shared variable.)

Dyadically, the \(\text{OPACK}\) function packages the value \(X\) with the name in \(Y\). The right argument is any data object (an array or package, but not a function). The left argument is a character vector, scalar or 1-row matrix which contains a single name. The result is a package which contains the name in the left argument and the data in the right argument.

Note:
1. If the same name is included more than once in the right argument \(X\), the extra occurrences have no effect.
2. A misspelled name in the argument does not cause an error message and the intended object will be missing from the package.

\(\text{OPINS} \) Function (Package Insert)

Syntax:
\[
R + Y \ [\text{OPINS} \ X]
\]

Parameters:
- \(X\) is a package.
- \(Y\) is a package.
- \(R\) is a package.

\(\text{OPINS} \) Function (Package Insert)
Description:

The OPINS function inserts the package X into the package Y. Both X and Y must be packages. The result is a package which contains all the names along with their referents from package X, and, in addition those names that occur in Y but do not occur in X, and the objects which are referred to in package Y.

The resulting package contains all of the names from both of the packages. However, when a name in X is the same as a name in Y, it's referent from X is included as the referent in the result.

Note: The names in a package are reported in arbitrary order. The package resulting from OPINS need not have names in the identical order as the names which appear in Y.

OPNAMES Function (Package Names)

Syntax:

R+OPNAMES X

Parameters:

X is a package.
R is a namelist.

Description:

The OPNAMES function returns the names in a package X. The argument is any array or package. The result is an empty vector whenever the argument is not a package, otherwise the result is a character matrix containing the names in the package. The matrix has one row for each name, and the longest name determines the number of columns. Names are left-justified, with following blanks.

Note: APL reports the names within a package in arbitrary order.

OPNC Function (Package Name Correspondence)

Syntax:

R+ OPNC X
R+Y OPNC X

Parameters:

X is a package.
Y specifies an optional argument which is a namelist.
R is a simple integer vector.
Description:

Monadically, OPNC returns the nameclass of each of the names in the package.
Dyadically, OPNC returns the nameclass of each of the specified names in a package.

The right argument is a package. The left argument is an optional namelist. It is not necessary that a name included in the left argument also be present in the package, or that the names are well formed. The result is an integer vector which indicates the nameclass of package X names. Whenever OPNC is used with a left argument, the result contains one item corresponding to each name in the left argument.

Monadically, the result of the OPNC function contains one item for each name included within the package X in the same order as the names reported by OPNAMES X, leading to the following identity:

\[ \text{OPNC } X \leftrightarrow (\text{OPNAMES } X) \text{ OPNC } X \]

The class of object to which the name refers is indicated by an item of the result. The following table shows the relationship:

<table>
<thead>
<tr>
<th>CODE</th>
<th>NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1</td>
<td>No referent</td>
</tr>
<tr>
<td>0</td>
<td>Not present in the package</td>
</tr>
<tr>
<td>2</td>
<td>Refers to a variable</td>
</tr>
<tr>
<td>3</td>
<td>Refers to a function</td>
</tr>
<tr>
<td>4</td>
<td>Is not well-formed</td>
</tr>
</tbody>
</table>

The code used in the result of OPNC determines the code in the result of OPNC. The value 1 cannot appear in the result of OPNC because a package cannot contain a label. The value -1 does not occur in the result of OPNC.

OPVAL Function (Package Value)

Syntax:

\[ R \leftarrow Y \text{ OPVAL } X \]

Parameters:

- **X** is a package.
- **Y** is a namelist containing one name.
- **R** is an APL value.

Description:

The OPVAL function returns the value of the variable named in Y from the package X. The left argument is a character vector, scalar, or matrix. The referent in X must be a variable and the left argument must contain one name. APL reports a DOMAIN ERR message when Y does not meet those requirements. The result is the value of the variable which is named in Y.
**OPDEF Function (Package Definition)**

Syntax:

\[ \text{OPDEF } X \]
\[ Y \text{ OPDEF } X \]

Parameters:

- \(X\) is a package.
- \(Y\) is a namelist.

Description:

**Monadically.** \(\text{OPDEF}\) defines all of the names in the package right argument. Dyadically, \(\text{OPDEF}\) defines those names in the package right argument that appear in the left argument.

Each name in the left argument must:

- Be well formed.
- Be contained in package \(X\).
- Not have an active function which is a visible referent in the workspace. (Its referent may not appear on the state indicator.)

**Monadically.** the \(\text{OPDEF}\) function defines every name in package \(X\) in the active workspace with the referent from the package. Dyadically, the \(\text{OPDEF}\) function defines each name in the namelist \(Y\) in the active workspace with the referent from the package \(X\). A name existing in the package without a referent is expunged when \(\text{OPDEF}\) is used to bring the name into the workspace.

**Possible Errors:**

A **DOMAIN ERR** is reported if:

- any of the names in \(Y\) do not meet requirements stated in description.

**OPPDEF Function (Protected Package Definition)**

Syntax:

\[ R+ \text{ OPPDEF } X \]
\[ R=Y \text{ OPPDEF } X \]
Parameters:

X is a package.
Y is a name list.
R is a name list.

Description:

Monadically, \texttt{PPDEF} defines all of the names in the package right argument that currently have no value. Dyadically, \texttt{PPDEF} defines those names that appear in the package right argument, are named in the left argument, and do not currently have a value. The explicit result for both cases is a name list containing names of objects not defined because they had values.

\texttt{PPDEF} assigns a new meaning to a name with no current use and never expunges or changes an existing name's referent. (It can be compared to the system command \texttt{PCOPY}, except that \texttt{PCOPY} refers to the global and not to the visible meaning of each name.)

When \texttt{PPDEF} is used dyadically, the left argument \texttt{Y} is a name list that specifies the names which are to be defined. Each name in \texttt{Y} must be included as a name in package \texttt{X}.

When \texttt{PPDEF} is used with two arguments, each name in \texttt{Y} (or when \texttt{PPDEF} is used with one argument, each name in \texttt{X}) which has no visible referent in the workspace, is given the value which it has in the package.

The result is a name list containing the names in the package which were not defined because they already exist in the active workspace.

\texttt{OPSEL} Function (Package Select)

Syntax:

\[ R+Y \texttt{OPSEL} X \]

Parameters:

\( X \) is a package.
\( Y \) is a name list.
\( R \) is a package.

Description:

The \texttt{OPSEL} function returns a package containing those names from the package right argument that appear in the name list left argument. Each name specified in the name list must be contained within the package.
OPEX Function (Package Expunge)

Syntax:
\[ R+Y \text{ OPEX } X \]

Parameters:
- \( X \) is a package.
- \( Y \) is a namelist.
- \( R \) is a package.

Description:
The \text{OPEX} function returns a copy of the package right argument excluding the names specified in the namelist left argument.

OPLOCK Function (Package Lock)

Syntax:
\[ R+Y \text{ OPLOCK } X \]
\[ R+ \text{ OPLOCK } X \]

Parameters:
- \( X \) is a package.
- \( Y \) is an optional namelist.
- \( R \) is a package.

Description:
Monadically, \text{OPLOCK} returns a package identical to the right argument except that all of the defined functions are locked. Dyadically, \text{OPLOCK} returns a package identical to the right argument except that all of the defined functions named in the left argument are locked.

Each of the names must be well formed and must be a name which is present in package \( X \) and is used there as the name of a function. The function in \( X \) need not be previously unlocked.

The result is a package which contains the same names with the same referents as package \( X \). The exceptions are as follows:

- When \text{OPLOCK} has two arguments, the functions which are unlocked in \( X \) and named in \( Y \) are locked in the resulting package.
- When \text{OPLOCK} is used with one argument, all functions are locked in the resulting package.
Section 15
CP-6 APL Graphics

CP-6 APL provides four system functions which produce device independent graphics output. Additional system functions and variables are also provided which may be used to control the graphics device or the appearance of the graphics output. The CP-6 DIGS Reference Manual (CE72) provides a more detailed definition of the general capabilities and functionality available. This section contains a simple overview of the graphics capability available within APL.

The APL graphics capabilities are sub-divided into the five areas:

- Output Functions
- Segment Primitives
- Attribute Variable
- Viewing Variables
- Control Primitives

The graphics output primitives include the ability to draw lines, draw and optionally fill polygons, draw markers and generate text. Graphics output is subject to the controls provided by the other graphics capabilities and the device on which it is displayed.

All graphics output appears in either a temporary or a retained segment. CP-6 APL provides the ability to create segments, delete segments, rename segments, select segments, and to inquire about the attributes of segments. A retained segment defines an image which is a part of the whole picture displayed on a view surface. Attributes of a retained segment may be dynamically modified, thereby changing the image on the view surface.

The capabilities provided by the graphics attribute variables allow control over the appearance of graphics output primitives. The appearance includes such items as the color, intensity, line widths, marker symbols, and the text font. The graphics viewing variables control the location, size and rotation of graphics output. The viewing variables include such items as the graphics window, the viewport, and the image transformation variables.

The graphics control primitives provide the capabilities required to initiate an APL graphics session, select a graphics device, determine the device capabilities, and define the mappings between certain attribute settings and the corresponding device color or intensity.

The following APL program demonstrates the use of APL graphics. It does all that is necessary within APL to produce graphics output on a graphics terminal.

```

```

CE38-04 CP-6 APL Graphics 15-1
This example demonstrates the necessary preparations before graphics output may be created. The `OCRINIT`, `OCRINTSURF` and `CRSURFACE` functions must all be executed before any graphics output is created. The use of these functions is described under the topic Graphics Control Functions and Variables.

The function `CGRTEGO` is used to indicate that the following output is temporary (not to be retained across screen clears for example). This function is described under the topic Graphics Segment Functions. A graphics segment (temporary or retained) must also be in use before graphics output may commence.

The function `CGRLINE` is one of the five graphics output functions available in CP-6 APL. This function connects each of the points specified with a line. The type of line drawn may be controlled by variables that are described under the topic Graphics Attribute Variables.

**Graphics Output Functions**

Five system functions in CP-6 APL are used to produce graphics output. Each of the functions supply a different type of graphics output from a similar graphics argument. The data to be displayed graphically is provided as either an N-by-2 or N-by-3 array. The columns are treated as X, Y, and optional Z components of a graphical position. If the data to be displayed is not a matrix, a RANK ERR is reported. If the data to be displayed is not an N-by-2 or N-by-3 array, a LENGTH ERR is reported. If the data to be displayed is not a simple numeric array, a DOMAIN ERR is reported.

If an APL graphics session has not been initiated by executing the `GRINIT` system function, or if a device has not been initialized and selected, or there is not a currently open segment, a DOMAIN ERR is reported. (Entering a '?' command indicates which error has occurred).
DGRLINE Function (Draw Line)

Syntax:

DGRLINE DATA

Parameters:

DATA is a simple array of shape N-by-2 or N-by-3 containing only scalar numbers.

Description:

The DGRLINE function defines the simplest form of graphical output. A line is drawn connecting each of the positions in the data array provided.

Example:

\[ \text{HOUSE} = \begin{bmatrix} 7 & 2.6 & .1 & .9 & .5 & .6 & .9 & .1 & .1 & .6 & .1 & .6 & .9 \\ \end{bmatrix} \]

DGRLINE HOUSE

This example creates a simple stick house on the currently selected view surface.

Possible Errors:

A RANK ERR is reported if:

- the right argument is not a matrix

A LENGTH ERR is reported if:

- the right argument is not an N-by-2 or N-by-3 matrix

A DOMAIN ERR is reported if:

- the right argument is not simple or all numeric
- APL graphics is not initialized
- there is not an open segment
- the current value of DGRLF is not supported
- the current value of DGRLS is not supported
- the current value of DGRLM is not supported
- the current value of DGRPN is not supported

DGRMARK Function (Draw Marker Symbols)

Syntax:

DGRMARK DATA
Parameters:

DATA is a simple array of shape N-by-2 or N-by-3 containing only scalar numbers.

Description:

The OGRMARK function produces a marker symbol (as selected by the OGRMARKER system variable) at each of the positions indicated by the data array.

Example:

```
CURVE+7 2p0 .2 .1 .3 .4 .5 .7 .4 .8 .1 .9
OGRMARK CURVE
```

Possible Errors:

A RANK ERR is reported if:
- the right argument is not a matrix

A LENGTH ERR is reported if:
- the right argument is not an N-by-2 or N-by-3 matrix

A DOMAIN ERR is reported if:
- the right argument is not simple or not all numeric
- APL graphics is not initialized
- there is not an open segment
- the current value of OGRLI is not supported
- the current value of OGRMARKER is not supported.
- the current value of OCRPEN is not supported

OGRPOLYGON Function (Draw Polygon)

Syntax:

```
OGRPOLYGON DATA
```

Parameters:

DATA is a simple array of shape N-by-2 or N-by-3 containing only scalar numbers.

Description:

The OGRPOLYGON function produces a polygon whose vertices are the positions provided in the data array. The appearance of the polygon can be controlled through assignment to the attribute variables.

Example:

```
PARALLELS+4 2p.2 .3 .4 .7 .8 .7 .6 .3
OGRPOLYGON PARALLELS
```
Possible Errors:

A RANK ERR is reported if:
  o the right argument is not a matrix

A LENGTH ERR is reported if:
  o the right argument is not an N-by-2 or N-by-3 matrix

A DOMAIN ERR is reported if:
  o the right argument is not simple or not all numeric
  o APL graphics is not initialized
  o there is not an open segment
  o the current value of OCRPEN is not supported
  o the vertices are not coplanar
  o the current value of OCRFILL is not supported
  o the current value of OCRVERTEX is not supported
  o the length of OCRVERTEX is not equal to the first dimension of the right argument
  o the current value of OCRFL is not supported

Function (Draw Picture)

Syntax:

  I OCRDRAW DATA

Parameters:

  I is the integer scalar value 0, 1, or 2.

  DATA is a simple numeric array of shape N-by-3 or N-by-4. The first column contains
  the values 0 or 1 only. The last 2 or 3 columns the X, Y or X, Y, and Z world
  coordinates.

Description:

The OCRDRAW function provides a mechanism to define a sequence of strokes or
polygons. A new stroke begins when a row of the data in the right argument contains
the value 1 in the first column. A stroke ends when all positions in the remaining
rows have been connected or before the next row which contains a 1 in the first
column.

If I is 0, each stroke is joined by a line. If I is 1, each point is marked. If I
is 2, each stroke is treated as a polygon.

Example:

In the following example, the picture of the house created in the example at the
beginning of this section is produced by a single use of the OCRDRAW function rather
than executing the function OCRLINE four separate times.

  \$ DRAW_EXAMPLE
  [1] H=((3+1),HOUSE),[1(4+1),DOOR],[1(5+1),WINDOW2
  [2] I OCRDRAW H
  \$
Possible Errors:

A **RANK ERR** is reported if:
- the left argument is not a matrix.
- the left argument is not a scalar.

A **LENGTH ERR** is reported if:
- the right argument is not an N-by-3 or N-by-4 matrix.
- the left argument is not a single value.

A **DOMAIN ERR** is reported if:
- the right argument is not simple or all numeric.
- the left argument is not simple or not numeric.
- APL graphics is not initialized.
- there is not an open segment.
- the current value of OCRLI is not supported.
- the current value of OCRGEN is not supported.
- the current value of OCRLS is not supported.
- the current value of OCRLOW is not supported.
- the current value of OCRMARKER is not supported.
- the current value of OCRFILL is not supported.
- the current value of OCRVERTEX is not supported.
- the length of OCRVERTEX is not equal to the number of points in the stroke.
- the vertices are not coplanar.

**OCRTEXT Function (Draw Text)**

Syntax:

```
POSITION OCRTEXT STRING
```

Parameters:

- **POSITION** is a simple numeric vector of 2 or 3 items which indicate a graphical position.
- **STRING** is a simple character vector containing the characters to be displayed on the graphics device.

Description:

The **OCRTEXT** function causes the character vector to appear on the graphics device starting at the position indicated. The appearance of the text depends on the current definition of the text graphics attribute variables.

Example:

```
.125 .25 OCRTEXT 'HERMOSA'
```

This example displays the text 'HERMOSA' at the world coordinate position (0.125,9.25).
Possible Errors:

A **RANK ERR** is reported if:
- the left argument is not a vector
- the right argument is not a vector or scalar

A **LENGTH ERR** is reported if:
- the left argument does not contain 2 items

A **DOMAIN ERR** is reported if:
- the right argument is not simple and all character scalars
- the left argument is not simple and all numeric
- APL graphics is not initialized
- there is not an open segment
- the current value of OCRPEN is not supported
- the current value of OCRTEXT is not supported
- the string contains illegal characters
- the vectors established by OCRPLANE and OCRCHUP are parallel
- the string contains more than 256 characters
- OCRPLANE and OCRCHUP matrix cannot be inverted

**OCRWORLD** Function (Map to World Coordinates)

Syntax:

\[
\text{DATA0} \cdot \text{OCRWORLD} \cdot \text{DATA1}
\]

Parameters:

- **DATA0** is a simple array of shape N-by-2 or N-by-3 containing only scalar numbers.
- **DATA1** is a simple array of shape N-by-2 or N-by-3 containing only scalar numbers.

Description:

The **OCRWORLD** function returns the world coordinates associated with the normalized device coordinates supplied as the right argument.

Example:

\[
\text{OCRWORLD} \quad 4 \quad 2 \quad 0.2 \quad 0.3 \quad 0.4 \quad 0.7 \quad 0.8 \quad 0.7 \quad 0.6 \quad 0.3
\]

Since the default image transformation is an identity matrix, the positions supplied to this function are mapped to themselves.
Possible Errors:

**A RANK ERR** is reported if:
- the right argument is not a matrix

**A LENGTH ERR** is reported if:
- the right argument is not an N-by-2 or N-by-3 matrix

**A DOMAIN ERR** is reported if:
- a specified NDC position is outside the current viewport
- the world coordinate transformation is not invertible
- the view plane normal and view up direction are parallel
- APL graphics is not initialized
- the projection and view parameters are inconsistent
- the clipping planes are inconsistent

**GRNDC Function** (Map to NDC)

Syntax:

\[ DATA0 + OGRNDC DATA1 \]

Parameters:

- **DATA0** is a simple array of shape N-by-2 or N-by-3 containing only scalar numbers.
- **DATA1** is a simple array of shape N-by-2 or N-by-3 containing only scalar numbers.

Description:

The \( OGRNDC \) function returns the normalized device coordinates associated with the world coordinates supplied as the right argument.

Example:

\[ OGRNDC 4 2 .2 .3 .4 .7 .8 .7 .6 .3 \]

0.2 0.3
0.4 0.7
0.8 0.7
0.6 0.3

Possible Errors:

**A RANK ERR** is reported if:
- the right argument is not a matrix

**A LENGTH ERR** is reported if:
- the right argument is not an N-by-2 or N-by-3 matrix

**A DOMAIN ERR** is reported if:
- a specified world position is outside the current window and clipping is enabled
- the view plane normal and view up direction are parallel
- APL graphics is not initialized
- the projection and view parameters are inconsistent
OGRTEXTX Function (Inquire Text Extent)

Syntax:

\[ \text{POSO} + \text{POS1} \circ \text{OGRTEXTX} \circ \text{STRING} \]

Parameters:

\( \text{POSO} \) is a simple numeric vector of 2 or 3 items which indicate a graphical position in world coordinates.

\( \text{POS1} \) is a simple numeric vector of 2 or 3 items indicating a graphical position in world coordinates.

\( \text{STRING} \) is a simple character vector containing the characters to be displayed on the graphics device.

Description:

The OGRTEXTX function is used to return the extent of the specified character string on the specified view surface, if the character string is drawn, unjustified, beginning at the position indicated by the left argument.

Example:

\[ .125 .25 \circ \text{OGRTEXT} \, \circ \text{'HERMOSA BEACH'} \]

\[ 0.13 \, 0 \]

Possible Errors:

A RANK ERR is reported if:

- the left argument is not a vector
- the right argument is not a vector or scalar

A LENGTH ERR is reported if:

- the left argument does not contain 2 items

A DOMAIN ERR is reported if:

- the right argument is not simple and all character scalars
- the left argument is not simple and all numeric
- APL graphics is not initialized
- there is not an open segment
- the current value of OCRFONT is not supported
- the string contains illegal characters
- the vectors established by OGRCHPLANE and OGRCHUP are parallel
- the string contains more than 256 characters
- the OGRCHPLANE and OGRCHUP matrix cannot be inverted
GRCP Function (Current Position)

Syntax:

POS=GRCP

Parameters:

POS is a simple numeric vector of 2 or 3 items which indicate a graphical position in world coordinates.

Description:

The GRCP niladic function is used to return the current drawing position in world coordinates.

Example:

GRCP 0.125 0.25

Possible Errors:

A DOMAIN ERR is reported if:

- APL graphics is not initialized

Graphics Segment Functions

All graphics output occurs in graphical segments. The segments partition the output primitives such that the output of each primitive occurs in one and only one segment and each segment contains only graphic primitive output. Two types of segments may be used: retained segments and temporary segments.

Graphic output directed to a temporary segment exists for the life of the current frame. Output directed to a retained segment may appear in multiple frames depending on its visibility attribute. Many retained segments may be used to represent the image on the view surface. Retained segments are identified by their names which must be an integer number in the range 1 to 65535.

GRSEGOPEN Function (Create a Retained Segment)

Syntax:

GRSEGOPEN SEG
Parameters:

\texttt{SEC} \quad \text{is a simple numeric scalar containing the number of the segment to be created.}

Description:

The \texttt{OGRSECOPEN} function creates a new empty retained segment. The dynamic attributes for the new segment are determined by the current attribute values for the retained segment dynamic attributes. The set of currently selected view surfaces is recorded with the newly created retained segment. Throughout the life of the retained segment, the image it defines appears on each view surface in this list.

The newly created segment becomes the currently open segment. Subsequent execution of graphics output functions are recorded in this retained segment. If the retained segment visibility attribute is visible, the execution of graphics output functions also results in new information appearing on the view surfaces selected by the segment. While a segment is open, the viewing parameters may not be altered and view surfaces may not be selected or deselected.

Example:

\texttt{OGRSECOPEN 314}

Possible Errors:

A \texttt{LENGTH ERR} is reported if:

- the right argument does not contain exactly one item

A \texttt{DOMAIN ERR} is reported if:

- the right argument is not simple or numeric
- there is no currently selected view surface
- an open segment already exists
- the specified retained segment already exists
- there is an illegal image transformation
- the view plane normal and view up direction are parallel
- the viewing parameters are inconsistent
- the clipping parameters are inconsistent
- APL graphics is not initialized

\texttt{OGRSECCLOSE} Function (Close Retained Segment)

Syntax:

\texttt{OGRSECCLOSE}

Description:

The \texttt{OGRSECCLOSE} function closes currently open retained segments. Output primitives can no longer be executed. Closing a retained segment has no effect on its visibility or other segment attributes.
Example:

\texttt{GRSEGCLOSE}

Possible Errors:

A \texttt{DOMAIN ERR} is reported if:

- no open retained segment exists
- APL graphics is not initialized

\texttt{GRSEGDEL} Function (Delete Retained Segment)

Syntax:

\texttt{GRSEGDEL SEGS}

Parameters:

\texttt{SEGS} is a simple integer vector containing the numbers of the segments to be deleted.

Description:

The \texttt{GRSEGDEL} function deletes the specified retained segment. If the retained segment's visibility attribute is visible, its image is removed from each view surface on which it appears. After a retained segment is deleted, it is as if the segment had never existed.

Example:

\texttt{GRSEGDEL 314 1}

This example causes segments 314 and 1 to be deleted.

Possible Errors:

A \texttt{RANK ERR} is reported if:

- the right argument is not a scalar or vector

A \texttt{DOMAIN ERR} is reported if:

- the right argument is not simple or does not have integer values
- APL graphics is not initialized
- the specified retained segment does not exist
OCRSEGREN Function (Rename Retained Segment)

Syntax:

OCRSEGREN SEC2

Parameters:

SEC2 is a simple integer vector containing 2 items which are the current segment number and the new number by which that segment is to be known.

Description:

The OCRSEGREN function renames the specified segment. The original retained segment name can no longer be referenced. This function has no visible effect.

Example:

OCRSEGREN 2 314

This example changes the name (segment number) of segment 2 to number 314.

Possible Errors:

A RANK ERR is reported if:

- the right argument is not a scalar or vector

A LENGTH ERR is reported if:

- the right argument is not of length 2

A DOMAIN ERR is reported if:

- the right argument is not simple or not near integer
- the first item of the right argument is not a retained segment number
- the second item of the right argument is a currently existing segment number
- APL graphics is not initialized

OCRSEGSURFS Function (Inquire Segment Surfaces)

Syntax:

SURFS*OCRSEGSURFS SEG

Parameters:

SEG is a simple numeric scalar containing the number of an existing segment.

SURFS is a simple integer vector of view surface numbers.
Description:

The OCRSEGSURFS function returns the number of the view surfaces which were selected when the retained segment was created.

Example:

```
OCRSEGSURFS 314
1
```

This example demonstrates that graphics output to segment 314 appears on view surface 1.

Possible Errors:

A LENGTH ERR is reported if:

- the right argument does not contain exactly one item

A DOMAIN ERR is reported if:

- the right argument is not simple or near integer
- the specified segment does not exist
- APL graphics is not initialized

OCRSEGS Function (Inquire Retained Segment Names)

Syntax:

```
SEGS$OCRSEGS
```

Parameters:

SEGS is a simple integer vector result.

Description:

The OCRSEGS function returns the numbers of all of the current retained segments.

Example:

```
OCRSEGS
3 314
```

This example displays the number of current retained segments, in this case there are currently two retained segments numbered 3 and 314.

Possible Errors:

A DOMAIN ERR is reported if:

- APL graphics is not initialized
**OCRSEGCURR Function (Inquire Open Segment)**

Syntax:

```
SEC*OCRSEGCURR
```

Parameters:

- **SEC**: A simple integer scalar result.

Description:

The result of the OCRSEGCURR function is 0 if there is not a currently open retained segment, or it is the number of the currently open retained segment.

**OCRSTSEGO Function (Create Temporary Segment)**

Syntax:

```
OCRSTSEGO
```

Description:

The OCRSTSEGO creates an open temporary segment. Subsequent execution of output primitives result in information appearing on the currently selected view surfaces. While a temporary segment is open, the viewing parameters may not be altered and view surfaces may not be selected or deselected.

Example:

```
OCRSTSEGO
```

Possible Errors:

A **DOMAIN ERR** is reported if:

- APL graphics is not initialized
- the set of selected view surfaces is empty
- an open segment already exists
- the viewing parameters are inconsistent
- the clipping parameters are inconsistent


\[\texttt{OCRTSEGC}\] Function (Close Temporary Segment)

Syntax:

\[
\texttt{OCRTSEGC}
\]

Description:
The [\texttt{OCRTSEGC}] function closes the currently open temporary segment. Output primitives may no longer be executed.

Example:

\[
\texttt{OCRTSEGC}
\]

Possible Errors:
A \texttt{DOMAIN ERR} is reported if:
- APL graphics is not initialized
- there is no open temporary segment

\[\texttt{OCRTSEG}\] Function (Inquire Open Temporary Segment)

Syntax:

\[
\texttt{LOGL+OCRTSEG}
\]

Parameters:

\texttt{LOGL} is a scalar logical value 0 or 1.

Description:
The result of executing the [\texttt{OCRTSEG}] function is the value 1 if there is a temporary segment currently open, otherwise the result is 0.

Example:

\[
\texttt{OCRTSEG}
\]

0

Possible Errors:
A \texttt{DOMAIN ERR} is reported if:
- APL graphics is not initialized
\textbf{OGRSEGVISIBILITY} Function (Segment Visibility)

Syntax:

\begin{verbatim}
   LOGLO+LOGLI OGRSEGVISIBILITY SEGS
   LOGLO- OGRSEGVISIBILITY SEGS
\end{verbatim}

Parameters:

\begin{itemize}
   \item \texttt{LOGLO} is a simple logical vector.
   \item \texttt{SEGS} is a simple integer vector containing the numbers of retained segments.
   \item \texttt{LOGLI} is a simple logical vector of the same length as \texttt{SEGS}. Or, it is a single logical value to be used for each item in \texttt{SEGS}.
\end{itemize}

Description:

The \texttt{OGRSEGVISIBILITY} function is used to modify or inquire about the current value of the segment visibility attribute for each segment number in the right argument. If the left argument is not provided, the result has the same length as the right argument. In this case, each result value is 1 if the segment visibility attribute is 'VISIBLE' or 0 if the segment visibility attribute is 'INVISIBLE'.

If the left argument is provided, the values specified by the left argument are used as the new segment visibility dynamic attribute for each of the segments specified in the right argument; the result is an empty vector. The value 1 is used to set the segment visibility to 'VISIBLE' and the value 0 is used to set the segment visibility to 'INVISIBLE'.

Example:

\begin{verbatim}
   1 OGRSEGVISIBILITY 3 314
   OGRSEGVISIBILITY 3 314
   1 1
\end{verbatim}

Possible Errors:

A \texttt{RANK ERR} is reported if:
\begin{itemize}
   \item the left or right arguments are not vectors or scalars
\end{itemize}

A \texttt{LENGTH ERR} is reported if:
\begin{itemize}
   \item the left argument is not the same length as the right argument and the left argument is not a single item.
\end{itemize}

A \texttt{DOMAIN ERR} is reported if:
\begin{itemize}
   \item the right argument contains an item that is not a simple integer value
   \item the left argument contains an invalid value
   \item the right argument contains a number which is not the number of a retained segment
   \item APL graphics is not initialized
\end{itemize}
OGRESEG-HIGHLIGHT Function (Segment Highlight)

Syntax:

\[ \text{LOGLO}+\text{LOGL1} \] OGRESEG-HIGHLIGHT \text{SEGS} \\
\text{LOGLO}+ \] OGRESEG-HIGHLIGHT \text{SEGS}

Parameters:

\text{LOGLO} \quad \text{is a simple logical vector.} \\
\text{SEGS} \quad \text{is a simple integer vector containing the numbers of retained segments.} \\
\text{LOGL1} \quad \text{is a simple logical vector of the same length as SEGS. Or, it is a single logical value to be used for each item in SEGS.}

Description:

The OGRESEG-HIGHLIGHT function is used to modify or inquire on the current value of the segment highlighting attribute for each segment number in the right argument. If the left argument is not provided, the result has the same length as the right argument. In this case, each result value is 1 if the segment highlighting attribute is 'HIGHLIGHTED', or 0 if the segment highlighting attribute is 'NON-HIGHLIGHTED'.

If the left argument is provided, the values specified by the left argument are used as the new segment highlighting dynamic attribute for each of the segments specified in the right argument; the result is an empty vector. The value 1 is used to set the segment highlighting to 'HIGHLIGHTED', and the value 0 is used to set the segment highlighting to 'NON-HIGHLIGHTED'.

Example:

\[ \begin{align*}
1 & \text{ OGRESEG-HIGHLIGHT 3 314} \\
1 & \text{ OGRESEG-HIGHLIGHT 3 314}
\end{align*} \]

1 1

Possible Errors:

A \textit{RANK ERR} is reported if:
- the left or right arguments are not vectors or scalars

A \textit{LENGTH ERR} is reported if:
- the left argument is not the same length as the right argument and the left argument is not a single item

A \textit{DOMAIN ERR} is reported if:
- the right argument contains an item that is not a simple integer value
- the left argument contains an invalid value
- the right argument contains a number which is not the number of a retained segment
GRVISIBILITY Variable (Set/Inquire Visibility)

Syntax:

GRVISIBILITY+LOGL

Parameters:

LOGL is either a scalar numeric value 0 or 1. Or, it is a simple vector containing the characters 'VISIBLE' or 'INVISIBLE'.

Description:

The GRVISIBILITY system variable is used to define the default segment visibility attribute. This value is used when a new segment is created by the OCRSEGO or OCRSECOEN system functions.

Example:

GRVISIBILITY+1
GRVISIBILITY 1

Possible Errors:

A RANK ERR is reported if:
- a character value assigned is not a scalar or vector

A LENGTH ERR is reported if:
- a numeric value assigned contains more than one item

A DOMAIN ERR is reported if:
- the value assigned is not simple.
- a numeric value assigned is not 0 or 1
- a character value assigned is not a legal keyword

GRHIGHLIGHT Variable (Set/Inquire Highlighting)

Syntax:

GRHIGHLIGHT+LOGL

Parameters:

LOGL is either a scalar numeric value 0 or 1. Or, it is a simple vector containing the characters 'HIGHLIGHTED' or 'NON-HIGHLIGHTED'.

GRHIGHLIGHT Variable (Set/Inquire Highlighting)
Description:

The OGRHIGHLIGHT system variable is used to define the default segment highlighting attribute. This value is used when a new segment is created by the OGRTSEGO or OGRSEGOPEN system functions.

Example:

   OGRHIGHLIGHT+1
   OGRHIGHLIGHT
   1

Possible Errors:

A RANK ERR is reported if:
- a character value assigned is not a scalar or vector

A LENGTH ERR is reported if:
- a numeric value assigned contains more than one item

A DOMAIN ERR is reported if:
- the value assigned is not simple.
- a numeric value assigned is not 0 or 1
- a character value assigned is not a legal keyword

Graphics Attribute Variables

The graphics output functions use the current values of the graphics attribute system variables to determine the actual appearance of the graphics output. These system variables may be referenced to obtain their current value, assigned new values, or localized within functions. When localized, these system variables maintain their previous value unless reassigned.

Values assigned to these attributes affect future use of their associated graphics output functions.

The assignment of these attribute variables can result in a DOMAIN ERR report from APL for the following reasons:
- the attribute value is invalid
- APL graphics is not initialized

Other errors can include RANK ERR, LENGTH ERR, and DOMAIN ERR when requirements set out by the parameter definition for the variable are not met.
**OGRMARKER Variable (Marker Symbol)**

Syntax:

```
OGRMARKER+KEYWORD
```

Parameters:

`KEYWORD` is a scalar integer value which indicates the number of the desired marker symbol.

Description:

The `OGRMARKER` variable is used by the `OCRMARK` system function to specify a marker symbol. The valid values are integers in the range 1 through the device driver defined maximum. The values 1 through 5 always produce the symbols: dot, star, capital letter O and capital letter X. Legal values greater than 5 produce symbols determined by the device. The default value is 1.

Example:

```
3
```

**OGRPINS Variable (Polygon Interior Style)**

Syntax:

```
OGRPINS+KEYWORD
```

Parameters:

`KEYWORD` is a simple character vector containing one of the keyword values: 'PLAIN', 'SHADED', or 'PATTERNED'.

Description:

The `OGRPINS` variable is used by the `OCRPOLYGON` system function to determine the method for filling the image of the interior of a visible polygon. The default value is 'PLAIN'.

Example:

```
SHADED
```

CE38-04
**GRPES Variable (Polygon Edge Style)**

Syntax:

\[ \text{GRPES}+\text{KEYWORD} \]

Parameters:

**KEYWORD** is a simple character vector containing one of the keyword values: 'SOLID' or 'INTERIOR'.

Description:

The **GRPES** variable is used by the **GRPOLYGON** system function to determine the method for forming the image of the border (edges) of a visible polygon. The default value is 'SOLID'.

Example:

\[ \text{GRPES} \text{'}SOLID\text{' \text{GRPES}} \]

**GRLW Variable (Line Width)**

Syntax:

\[ \text{GRLW}+N \]

Parameters:

\( N \) specifies the relative width of the image of a visible line.

Description:

The **GRLW** variable specifies the relative width of the image of a visible line generated by the **GRLINE** system function. The specified value must be in the range from 0 to 1 inclusive. The default value is 0.

Example:

\[ \text{GRLW} \text{'.0625 \text{GRLW}} \]

0.0625
\textbf{OCRLI Variable (Line Index)}

Syntax:

\texttt{OCRLI+I}

Parameters:

\( I \) is a simple integer scalar value.

Description:

The \texttt{OCRLI} variable specifies the index used to select the color or intensity of the image of a visible line, marker, or polygon edge (whose \texttt{OCRPES} is 'SOLID'). This value only applies to the system functions \texttt{OCRLINE}, \texttt{OCRMARKER}, and \texttt{OCRPOLYGON}. The default value is 1.

Example:

\begin{verbatim}
OCRLI+2
OCRLI
\end{verbatim}

\textbf{OCRLS Variable (Line Style)}

Syntax:

\texttt{OCRLS+I}

Parameters:

\( I \) is a scalar integer value.

Description:

The \texttt{OCRLS} variable is used by the \texttt{OCRLINE} function to determine the style of the image of a visible line (e.g., solid, dashed). The default value is 1 which corresponds to a solid line.

Example:

\begin{verbatim}
OCRLS+4
OCRLS
\end{verbatim}
OGRPEN Variable (Pen)

Syntax:

\[ \text{OGRPEN}+I \]

Parameters:

\[ I \] is a scalar integer value.

Description:

The OGRPEN variable may be used by all output primitives to distinguish the image of their output. The particular values of OGRLI, OGRLS, OGRLW, and OGRTEXT which correspond to a particular pen value are implementation and device dependent. The default value of 0 corresponds to the current settings or OGRLI, OGRLS, OGRLW, and OGRTEXT. All other OGRPEN values override these values.

Example:

\[ \text{OGRPEN}+2 \]
\[ \text{OGRPEN} \]

OFROFONT Variable (Font)

Syntax:

\[ \text{OFROFONT}+I \]

Parameters:

\[ I \] is a scalar integer value.

Description:

The OFROFONT variable is used by the OFROTO function to specify the style of a visible character. Values range from 1 to a device dependent maximum. The default value of 1 corresponds to ASCII.

Example:

\[ \text{OFROFONT}+29 \quad \text{a SELECT APL FONT} \]
\[ \text{OFROFONT} \]
\[ 29 \]
\textbf{\texttt{DGRTEXTI}} Variable (Text Index)

Syntax:
\[
\texttt{DGRTEXTI+I}
\]

Parameters:

\(I\) is a scalar integer value.

Description:

The \texttt{DGRTEXTI} variable is used by the \texttt{DGRTEXT} function to select the color or intensity of the images of a visible character. The default value is 1.

Example:
\[
\texttt{DGRTEXTI+3}
\]
\[
\texttt{DGRTEXTI}
\]
\[
3
\]

\textbf{\texttt{DGRCHSIZE}} Variable (Character Size)

Syntax:
\[
\texttt{DGRCHSIZE+NN}
\]

Parameters:

\(NN\) is a simple two item numeric vector.

Description:

The \texttt{DGRCHSIZE} variable is used by the \texttt{DGRTEXT} function to select the desired size (in world coordinate units) of a character. The pair of values is used to select both the width and height of a character. The values must be in the range of 0 to 1 inclusive. The default value is (0.01 0.01).

Example:
\[
\texttt{DGRCHSIZE+.0625 .0625}
\]
\[
\texttt{DGRCHSIZE}
\]
\[
0.625 0.625
\]
**DGRCHPLANE Variable (Character Plane)**

Syntax:

DGRCHPLANE+NNN

Parameters:

NNN is a simple numeric vector of length 3.

Description:

The DGRCHPLANE variable is used by the DGRTEXT function to select the orientation in the world coordinate system of the plane on which the characters will appear. The three values contain an X, Y, and Z component. The default value is (0 0 -1).

Example:

DGRCHPLANE=0 2 1
DGRCHPLANE
0 2 1

**DGRCHUP Variable (Character Up)**

Syntax:

DGRCHUP+NNN

Parameters:

NNN is a simple numeric vector of length 3.

Description:

The DGRCHUP variable is used by the DGRTEXT system function selects the principal up direction in the plane on which the characters will appear. The component of DGRCHUP perpendicular to DGRCHPLANE points up. The value is made up of (X, Y, Z) components. The default value is (0 1 0).

Example:

DGRCHUP=0.25
DGRCHUP
1 0.25
DGRCHPATH Variable (Character Path)

Syntax:

DGRCHPATH+KEYWORD

Parameters:

KEYWORD is a simple character vector containing one of the keyword values: 'RIGHT', 'LEFT', 'UP', or 'DOWN'.

Description:

The DGRCHPATH variable is used by the DGRTEXT function to determine the direction within the plane on which the characters will appear. The default value is 'RIGHT'.

Example:

DGRCHPATH+ 'DOWN'

DGRCHPATH

DGRCHSPACE Variable (Character Space)

Syntax:

DGRCHSPACE+N

Parameters:

N is a scalar numeric value in the range 0 to 1.

Description:

The DGRCHSPACE variable is used by the DGRTEXT system function to determine additional spacing between adjacent characters in a string. The value represents the fraction of the DGRCHSIZE attribute. The default value is 0.

Example:

DGRCHSPACE+.03125
DGRCHSPACE

0.03125
**OGRCHJUST Variable (Character Justification)**

Syntax:

```
OGRCHJUST + KEYWORDS
```

Parameters:

`KEYWORDS` is a simple character vector containing two keywords separated by a blank. The first keyword value must be either 'OFF', 'LEFT', 'RIGHT', or 'CENTER'. The second keyword value must be either 'OFF', 'TOP', 'BOTTOM', or 'CENTER'.

**Description:**

The `OGRCHJUST` variable is used by the `OGRTEXT` system function to determine the mode of string justification. It has two components specifying the horizontal and vertical justifications. The default value is 'OFF OFF'.

**Example:**

```
OGRCHJUST + 'LEFT TOP'
OGRCHJUST
```

**OGRCHPREC Variable (Character Precision)**

Syntax:

```
OGRCHPREC + KEYWORD
```

Parameters:

`KEYWORD` is a simple character vector containing one of the keyword values: 'STRING', 'CHARACTER', or 'STROKE'.

**Description:**

The `OGRCHPREC` is used by the `OGRTEXT` system function to determine the precision of the appearance of text output. The default value is 'STRING'.

**Example:**

```
OGRCHPREC + 'STROKE'
OGRCHPREC
```

STROKE
GRFILL Variable (Fill Index)

Syntax:

GRFILL+I

Parameters:

I is a simple integer scalar value.

Description:

The GRFILL variable specifies the index used to select the color or intensity used to fill the image of a visible polygon.

Example:

GRFILL+3
GRFILL 3

GRVERTEX Variable (Vertex Indices)

Syntax:

GRVERTEX+IV

Parameters:

IV is a simple integer vector containing at least 3 values.

Description:

The GRVERTEX variable is used by the GRPOLYGON function to specify the set of index values used to shade the image of a visible polygon (whose GRPINS is 'SHADED'). The default value is (1 1 1).

Example:

GRVERTEX+3 2 1 4 5
GRVERTEX 3 2 1 4 5
Graphics Viewing Variables

APL graphics provides system variables to define the viewing operations and the coordinate transforms to be made when graphics output is generated. These system variables may be referenced to obtain their current value, assigned to modify their value or localized within user-defined functions. The most recently specified values of the viewing parameters (or their defaults) are used to determine the viewing.

Viewing parameters may not be specified while a graphics segment is open (or being created). If the termination of a defined function causes a viewing variable to be surfaced while a segment is open, then the surfaced value is lost.

The valid values of a viewing variable may depend on whether the graphics system is initialized as 2D or 3D. At graphics initialization time, all values of graphics viewing variables are respecified and set to their defaults.

GRWINDOW Variable (Window)

Syntax:

GRWINDOW+NNNN

Parameters:

NNNN is a simple numeric vector of length 4.

Description:

The GRWINDOW variable specifies a rectangle in world coordinates. The values define the X-minimum, X-maximum, Y-minimum, and Y-maximum extents of the window. The default window is (0 1 0 1).

Example:

GRWINDOW+0 .75 .25 1
GRWINDOW
0 0.75 0.25 1

Possible Errors:

A RANK ERR is reported if:

- the assigned value is not a vector.

A LENGTH ERR is reported if:

- the assigned value is not of length 4

A DOMAIN ERR is reported if:

- the assigned value is not simple or all numeric
- a segment is currently open
- the first item is greater than the second or the third item is greater than the fourth
- APL graphics is not initialized
$\textbf{GRUP} \text{ Variable \ (View Up)}$

Syntax:

$\text{GRUP} + N23$

Parameters:

$N23$ is a simple numeric vector of 2 items for 2D graphics or 3 items for 3D graphics.

Description:

The $\text{GRUP}$ variable defines the world coordinate up direction so that the world coordinate Y-axis need not be upright on the view surface. The default value for 2D graphics is $(0 \ 1)$ and $(0 \ 1 \ 0)$ for 3D graphics.

Example:

```
1 0

\text{GRUP}
```

Possible Errors:

A $\text{RANK ERR}$ is reported if:

- the assigned value is not a vector

A $\text{LENGTH ERR}$ is reported if:

- the assigned value is not of length 2 or 3

A $\text{DOMAIN ERR}$ is reported if:

- the assigned value is not simple or all numeric
- APL graphics is not initialized
- a segment is currently open
- all assigned values are zero

$\textbf{GRSPACE} \text{ Variable \ (NDC Space)}$

Syntax:

$\text{GRSPACE} + N23$

Parameters:

$N23$ is a simple numeric vector of 2 items for 2D graphics or 3 items for 3D graphics.
Description:

The OGRSPACE variable defines the size of the normalized device coordinate space which can be addressed on the view surface of all display devices and within which viewports are specified. All values must be in the range 0 to 1 inclusive and at least one value must be 1. This value may be specified at most once per initialization. The default value for 2D is (1 1) and (1 1 0) for 3D graphics.

Example:

\[OGRSPACE\]
1 1

Possible Errors:

A RANK ERR is reported if:

- the assigned value is not a vector

A LENGTH ERR is reported if:

- the assigned value is not 2 or 3 items in length

A DOMAIN ERR is reported if:

- the assigned value is not simple or not all numeric
- APL graphics is not initialized
- the NDC space is already established
- a value is not in the range of 0 to 1
- neither value is 1
- the first or second value is 0

\[OGRVIEWPORT\] Variable (Viewport)

Syntax:

\[OGRVIEWPORT+NNNN\]

Parameters:

NNNN is a simple numeric vector of length 4.

Description:

The OGRVIEWPORT variable specifies a rectangle in normalized device coordinate space. The viewport cannot exceed the bounds defined for the variable OGRSPACE. The values define (in order) the X-minimum, X-maximum, Y-minimum, and Y-maximum limits of the viewport. The default value of this variable is the value of OGRSPACE.

Example:

\[OGRVIEWPORT+0.125 0.875 0 1\]
\[OGRVIEWPORT\]
0.125 0.875 0 1
Possible Errors:

A RANK ERR is reported if:

- the assigned value is not a vector

A LENGTH ERR is reported if:

- the assigned value is not of length 4

A DOMAIN ERR is reported if:

- the assigned value is not simple or all numeric
- APL graphics is not initialized
- a segment is open
- the first item is greater than the second item or
  the third item is greater than the fourth item
- the viewport is outside of NDC space

GRVREFPT Variable (View Reference Point)

Syntax:

GRVREFPT + NNN

Parameters:

NNN is a simple numeric vector of length 3.

Description:

The GRVREFPT variable specifies the view reference point in world coordinates. The value specified defines (in order) the X, Y, and Z location of the reference point. The default value is (0 0 0). This value is only used in 3D viewing.

Example:

GRVREFPT + 1 2 3
GRVREFPT 0 0 0

Possible Errors:

A RANK ERR is reported if:

- the assigned value is not a vector

A LENGTH ERR is reported if:

- the assigned value is not 3 items in length

A DOMAIN ERR is reported if:

- the assigned value is not simple or all numeric
- APL graphics is not initialized
- a segment is open
**GRVPLNORM** Variable (View Plane Normal)

Syntax:

\[ \text{GRVPLNORM}+\text{NNN} \]

Parameters:

- **NNN** is a simple numeric vector of length 3.

Description:

The **GRVPLNORM** variable specifies the view plane normal. The value specified determines a vector in world coordinates relative to the view reference point. The value specified defines (in order) the X, Y, and Z location of the view plane normal. The default value is \((0 \ 0 \ -1)\). This value is only used in 3D viewing.

Example:

\[ \text{GRVPLNORM}+1 \ 0 \ 1 \]

Possible Errors:

- A **RANK ERR** is reported if:
  - the assigned value is not a vector
- A **LENGTH ERR** is reported if:
  - the assigned value is not of length 3
- A **DOMAIN ERR** is reported if:
  - the assigned value is not simple or all numeric
  - APL graphics is not initialized
  - all three values are zero

**GRVPLNDIS** Variable (View Plane Distance)

Syntax:

\[ \text{GRVPLNDIS}+N \]

Parameters:

- **N** is a simple numeric scalar value.

15-34
Description:
The `OGRVPLNDIS` variable specifies the distance of the view plane. The default value is 0 which signifies that the view plane is located at the view reference point.

Example:

```
OGRVPLNDIS+2
OGRVPLNDIS
2
```

Possible Errors:

A `LEN`gh ERR is reported if:
- the assigned value is not exactly one item

A `DOMA`in ERR is reported if:
- the assigned value is not simple or numeric
- APL graphics is not initialized
- a segment is open

`OGRVDEPTH` Variable (View Depth)

Syntax:

```
OGRVDEPTH+NN
```

Parameters:

- `NN` is a simple numeric vector of length 2.

Description:
The `OGRVDEPTH` variable specifies the clipping depth planes but does not affect whether depth clipping is performed. The first item is the front distance from the view reference point. The second item is the back distance from the view reference point. The default value is (0 -1).

Example:

```
OGRVDEPTH+-2 2
OGRVDEPTH
-2 2
```

Possible Errors:

A `RANK` ERR is reported if:
- the assigned value is not a vector

A `LEN`gh ERR is reported if:
- the assigned value is not of length 2
A DOMAIN ERR is reported if:
  o the assigned value is not simple or all numeric
  o APL graphics is not initialized
  o a segment is open
  o the first item is greater than or equal to the second

\begingroup
\textbf{\texttt{\textsc{ogrprojection}} Variable (Projection Type)}
\endgroup

Syntax:

\begingroup
\texttt{\texttt{\textsc{ogrprojection}}+\texttt{\texttt{\textsc{proj}}}}
\endgroup

Parameters:

\texttt{\texttt{\textsc{proj}}} is a 4 item vector. The projection keyword is an enclosed character vector representing the first item. The X, Y, and Z positions in world coordinates are the final 3 items. The projection keyword value must be either 'PARALLEL' or 'PERSPECTIVE'.

Description:

The \texttt{\textsc{ogrprojection}} variable specifies the type of projection used in the 3D viewing operation. If a parallel projection is specified, the world coordinate position indicates the lines are parallel to a line through the view reference point and this point. If a perspective projection is selected, the world coordinate position specifies the center of the projection. The default value is ('PARALLEL' 0 0 1).

Example:

\begingroup
\begin{verbatim}
\texttt{\texttt{\textsc{ogrprojection}}+'\texttt{\texttt{\textsc{perspective}}} 0 0 2
\texttt{\texttt{\textsc{ogrprojection}}
  \texttt{\texttt{\textsc{perspective}} 0 0 2}
\end{verbatim}
\endgroup

Possible Errors:

A RANK ERR is reported if:
  o the assigned value is not a vector
  o the first item of the assigned value is not a scalar or a vector

A LENGTH ERR is reported if:
  o the assigned value is not of length 4

A DOMAIN ERR is reported if:
  o the first item of the assigned value is not character or the remaining items not scalar numbers
  o the first item of the assigned value is not a valid keyword
  o a segment is open
  o the assigned value is ('PARALLEL' 0 0 0)
  o APL graphics is not initialized
Window Clipping Variables

APL automatically provides a window clipping capability if clipping is enabled. The clipping is controlled by specifying values for the three clipping variables: OGRCLIP, OGRFCLIP, and OGRBCLIP.

OGRCLIP Variable (Window Clipping)

Syntax:
OGRCLIP+L

Parameters:
L specifies a value which can be the simple numeric scalar 0 or 1, or the keyword value 'ON' or 'OFF'.

Description:
The OGRCLIP variable specifies whether window clipping is enabled. The values 'ON' or 1 may be used to turn window clipping on. The values 'OFF' or 0 may be used to turn window clipping off. When referenced, the value is 0 or 1. The default value is 1.

Example:
OGRCLIP+'OFF'
0

Possible Errors:
A RANK ERR is reported if:
o the character value assigned is not a scalar or vector

A LENGTH ERR is reported if:
o the numeric value assigned is not a singleton

A DOMAIN ERR is reported if:
o a character value assigned is not a clipping keyword
o a numeric value being assigned is not 0 or 1.
o APL graphics is not initialized
o a segment is open
**GRFCLIP Variable (Front Plane Clipping)**

Syntax:

OGRFCLIP+L

Parameters:

L specifies a value which can be the simple numeric scalar 0 or 1, or the keyword value 'ON' or 'OFF'.

Description:

The OGRFCLIP variable specifies whether front plane clipping is enabled. The values 'ON' or 1 may be used to turn front plane clipping on. The values 'OFF' or 0 may be used to turn front plane clipping off. When referenced, the value is 0 or 1. The default value is 0.

Example:

OGRFCLIP+0
OGRFCLIP
0

Possible Errors:

A RANK ERR is reported if:
- the character value assigned is not a scalar or vector

A LENGTH ERR is reported if:
- the numeric value assigned is not a singleton

A DOMAIN ERR is reported if:
- a character value assigned is not a clipping keyword
- a numeric value being assigned is not 0 or 1
- APL graphics is not initialized
- a segment is open

**GRBCLIP Variable (Back Plane Clipping)**

Syntax:

OGRBCLIP+L

Parameters:

L specifies a value which can be the simple numeric scalar 0 or 1, or the keyword value 'ON' or 'OFF'.

15-38
Description:
The \texttt{OCRBCLIP} variable specifies whether back plane clipping is enabled. The values 'ON' or 1 may be used to turn back plane clipping on. The values 'OFF' or 0 may be used to turn back plane clipping off. When referenced, the value is 0 or 1. The default value is 0.

Example:
\begin{verbatim}
\verb|OCRBCLIP+1|
\verb|OCRBCLIP|
\verb|1|
\end{verbatim}

Possible Errors:
A \texttt{RANK ERR} is reported if:
\begin{itemize}
\item the character value assigned is not a scalar or vector
\end{itemize}
A \texttt{LENGTH ERR} is reported if:
\begin{itemize}
\item the numeric value assigned is not a singleton
\end{itemize}
A \texttt{DOMAIN ERR} is reported if:
\begin{itemize}
\item a character value assigned is not a clipping keyword
\item a numeric value being assigned is not 0 or 1
\item APL graphics is not initialized
\item a segment is open
\end{itemize}

\texttt{DGRCOORD} Variable (Coordinate System Type)

Syntax:
\begin{verbatim}
\verb|DGRCOORD=KEYWORD|
\end{verbatim}

Parameters:
\texttt{KEYWORD} is a simple character vector containing one of the keyword values: 'LEFT' or 'RIGHT'.

Description:
The \texttt{DGRCOORD} variable is used to specify whether the world coordinate system is left-handed or right-handed. The default value is 'RIGHT'.

Example:
\begin{verbatim}
\verb|DGRCOORD|
\verb|RIGHT|
\end{verbatim}
Possible Errors:

A RANK ERR is reported if:
- the character value assigned is not a scalar or vector

A LENGTH ERR is reported if:
- the numeric value assigned is not a singleton

A DOMAIN ERR is reported if:
- a character value assigned is not a clipping keyword
- a numeric value being assigned is not 0 or 1
- APL graphics is not initialized
- a segment is open

OCRWORLD Variable (World Transformation)

Syntax:

OCRWORLD+MAT

Parameters:

MAT is a simple numeric matrix of shape (3 3) for 2D transformations or shape (4 4) for 3D transformations.

Description:

The OCRWORLD variable is used to transform world coordinate positions. This matrix is used in a matrix multiplication which can effect scaling, translation, and rotation of the position.

Example:

OCRWORLD

1 0 0
0 1 0
0 0 1

Possible Errors:

A RANK ERR is reported if:
- the value assigned is not a matrix

A LENGTH ERR is reported if:
- the value assigned is not shape 3-by-3 or shape 4-by-4

A DOMAIN ERR is reported if:
- the value assigned is not simple and all numeric
- APL graphics is not initialized
Graphics Control Functions and Variables

CP-6 APL provides several functions and variables which control the picture generation process. These capabilities are provided for:

- Initiating and terminating APL graphics
- View surface (device) control
- Picture change control
- Frame control
- Color specification
- Color and intensity binding
- Pixel array definition

Before graphics output can occur, APL graphics must be initialized and a view surface must be initialized and selected.

**OCRINIT Function (Initialize APL Graphics)**

Syntax:

```
OCRINIT STRING
```

Parameters:

`STRING` is a simple character vector containing initialization keywords separated by blanks or a single comma. Any keyword that is all blank is defaulted.

Description:

The `OCRINIT` function is used to initialize APL graphics. The right argument may contain up to four keywords which define (in order) the graphics output level, the input level, the number of dimensions, and the hidden surface removal level. The values for output level are: 'BASIC', 'BUFFERED', 'DYNAMIC-A', 'DYNAMIC-B', and 'DYNAMIC-C'. The value for the input level is: 'NONE'. The values for the number of dimensions are: '2D' or '3D'. The value for the hidden surface removal level is: 'NONE'.

This function must be executed before any other graphics function is executed or any graphics variable is referenced or assigned. It causes all graphics variables to be initialized to their default values.

Example:

```
OCRINIT 'BUFFERED,2D'
```

In this example, APL graphics is initialized with the output level 'BUFFERED', the input level 'NONE', a dimensionality of '2D', and a hidden surface removal level of 'NONE'. The default right argument (if an empty or all blank value is specified) is 'BUFFERED,NONE,2D,NONE'.

Possible Errors:

A RANK ERR is reported if:

- the right argument is not a vector or scalar
A **DOMAIN ERR** is reported if:

- Graphics is already initialized
- The output level is not supported
- The input level is not supported
- The dimension level is not supported
- The hidden surface level is not supported
- An undefined keyword is provided
- Too many keywords are provided
- APL graphics capability is not available

**GRDONE Function (Terminate APL Graphics)**

Syntax:

```apl
GRDONE
```

Description:

The `GRDONE` function closes any open segments, terminates all initialized view surfaces, and releases all resources used by APL graphics. After this function is executed, APL graphics may be reinitialized by executing the `GRINIT` function.

Example:

```apl
GRDONE
```

Possible Errors:

A **DOMAIN ERR** is reported if:

- APL graphics is not initialized

**GRINITSURF Function (Initialize View Surface)**

Syntax:

```apl
STRING GRINITSURF SURF
```

Parameters:

- `STRING` is a simple character vector containing options separated by commas.
- `SURF` is a simple integer scalar indicating a view surface number.

Description:

The `GRINITSURF` function obtains access to the specified view surface and clears it. The right argument is a view surface number. The left argument specifies attributes of the view surface. The left argument is composed of the keyword 'INTENSITY' or 'COLOR', followed by the CP-6 fid indicating the location of the view surface (default is 'HE'). This is followed by the CP-6 device profile name (default is current profile if online or super-graphics device if batch). Each of these parameters is separated by blanks or commas. The default left argument (if it is empty) is 'INTENSITY,HE'.
Example:

'INTENSITY' ORDINITSURF 1

In this case, the view surface is cleared and the device is prepared for graphics output on the terminal.

Possible Errors:

A RANK ERR is reported if:
- the left argument is not a scalar or vector

A LENGTH ERR is reported if:
- the right argument contains more than one item

A DOMAIN ERR is reported if:
- the view surface is already initialized
- all possible view surfaces are initialized
- an unknown keyword value is specified
- color is not provided on this surface
- the left argument is not all character scalar items
- the right argument is not an integer scalar
- too many keywords in the left argument

**OCRTERMSURF Function (Terminate View Surface)**

Syntax:

**OCRTERMSURF** SURFS

Parameters:

**SURFS** is a simple integer vector of view surface numbers.

Description:

The **OCRTERMSURF** function terminates access to the view surface. Segments whose images appear only on this view surface are deleted.

Example:

**OCRTERMSURF** 1

In this case, the view surface number 1 is terminated.

Possible Errors:

A RANK ERR is reported if:
- the right argument is not a scalar or vector

A DOMAIN ERR is reported if:
- the view surface is not initialized
- APL graphics is not initialized
- an item of the right argument is not an integer
OGRCAPABILITIES Function (Inquire Capabilities)

Syntax:

\[
\text{CAP} \cdot \text{OGRCAPABILITIES} \text{ SURF}
\]

Parameters:

\text{SURF} \quad \text{is a simple integer scalar indicating a view surface number.}
\text{CAP} \quad \text{is a 6-item nested array indicating the device capabilities.}

Description:

The OGRCAPABILITIES function returns the device capabilities associated with the specified view surface. Each item of the result indicates attributes of the device. They are separated into 6 classes of information which are:

1. the highest initialization levels supported by the device.
2. an indication of whether the device is physically there or is a pseudo device.
3. the size of the view surface (in centimeters).
4. the level of support available for the primitive attributes.
5. an indication of how the segment attributes are supported.
6. an indication of the effect of batching functions.

The result is a 6 item vector containing:

1. LEVELS
   
   A 3 item nested vector containing three character vectors:
   
   1. highest output level supported
   2. highest dimension level supported
   3. highest hidden surface level supported

2. PHYSICAL
   
   A character vector containing the value 'PSEUDO' or 'REAL'.

3. SIZES
   
   A 6 item numeric vector containing:
   
   1–2 width and height of view surface in centimeters
   3–4 width and height of NDC space area in centimeters
   5–6 horizontal and vertical resolution per centimeter

4. PRIMITIVE_ATTRIBUTES
   
   A 22 item numeric vector containing:
   
   1. Line index color count
   2. Line index intensity count
   3. Line index global color count
   4. Line index global intensity count
   5. Line index intensity hard/soft
   6. Line index color type
   7. Line index intensity type
   8. Line style hardware count
9 Line style software count
10 Line width count
11 Line width hard/soft
12 Line width minimum NDC
13 Line width maximum NDC
14 PEN hardware count
15 PEN software count
16 FONT count
17 Charsize count
18 Charsize hard/soft
19 Charsize minimum size in NDC
20 Charsize maximum size in NDC
21 Marker hardware count
22 Marker software count

5. SEGMENT_ATTRIBUTES
   A vector containing two character vectors:
   1 highlighting support
   2 image transformation support

6. BATCHING
   A character vector indicating the strategy used by the device for batching of updates.

Example:
   pCAP+OGRCAPABILITIES 1

Possible Errors:
A LENGTH ERR is reported if:
   o the right argument is not a single value

A DOMAIN ERR is reported if:
   o the right argument value is not an integer
   o the right argument value is not a valid view surface
   o APL Graphics is not initialized

OGRSURFACE Function (Select View Surface)

Syntax:
   OGRSURFACE SURFS

Parameters:
SURFS is a simple integer vector of view surface numbers.
Description:

The `GRSURFACE` function adds the specified view surfaces to the list of currently selected view surfaces. When a subsequent segment is created, the graphics output will appear only on those surfaces that are currently selected.

Example:

```
GRSURFACE 1
```

This example selects view surface 1.

Possible Errors:

A `RANK ERR` is reported if:

- the right argument is not a scalar or vector

A `DOMAIN ERR` is reported if:

- the right argument values are not integer
- a segment is currently open
- the specified view surface is not initialized
- the specified view surface has been selected
- APL Graphics is not initialized

`GRUNSURFACE` Function (Deselect View Surface)

Syntax:

```
GRUNSURFACE SURFS
```

Parameters:

- `SURFS` is a simple integer vector of view surface numbers.

Description:

The `GRUNSURFACE` function removes the view surface specified from the set of selected view surfaces. Subsequent segment creations and `GRFRAME` function execution will not affect this view surface until it is reselected.

Example:

```
GRUNSURFACE 1
```

This example deselects view surface 1.

Possible Errors:

A `RANK ERR` is reported if:

- the right argument is not a scalar or vector

A `DOMAIN ERR` is reported if:

- the right argument contains a non-integer value
- a segment is open
- the view surface has not been selected
- APL Graphics is not initialized
GSRFACES Function (Inquire Selected Surfaces)

Syntax:

```
SURFS←GSRFACES
```

Parameters:

- `SURFS` is a simple integer vector of view surface numbers.

Description:

The `GSRFACES` function returns a vector containing the numbers of the selected view surfaces.

Example:

```
GSRFACES
1
```

In this example, the result is the vector 1 indicating that view surface 1 has been selected.

Possible Errors:

- A `DOHAIN ERR` is reported if:
  - APL graphics is not initialized

GMMVISIBILITY Function (Immediate Visibility)

Syntax:

```
GMMVISIBILITY LOGL
```

Parameters:

- `LOGL` is the simple scalar number 0 or 1. Optionally, the keyword 'ON' or 'OFF' may be used.

Description:

Specifying the value 1 as the right argument causes all delayed visible picture changes to take effect unless they are deferred as a result of batching.

Example:

```
GMMVISIBILITY 1
```
Possible Errors:
A RANK ERR is reported if:
  o the right argument is character and is not a scalar or vector
A LENGTH ERR is reported if:
  o the right argument is numeric and contains more than one item
A DOMAIN ERR is reported if:
  o the right argument is not the number 0 or 1 or the character vector is not 'ON' or 'OFF'.
  o APL graphics is not initialized

GRCURRENT Function (Make Picture Current)

Syntax:

  GRCURRENT

Description:
The GRCURRENT function has no effect if immediate visibility is 1. If immediate visibility is 0, all delayed visible picture changes take effect subject to batching.

Example:

  GRCURRENT

Possible Errors:
A DOMAIN ERR is reported if:
  o APL graphics is not initialized

GRBATCH Function (Control Batching of Updates)

Syntax:

  GRBATCH LOGL

Parameters:

  LOGL is the simple numeric scalar value 0 or 1.
Description:

If the right argument is 1, a batch of updates is started. The end of the batch of updates is indicated by executing the OGRBATCH function with a right argument value of 0. While batching of updates is in effect, visible picture changes are deferred.

Example:

```
OGRBATCH 1
OGRLINE 7 2p .1 .6 .5 .9 .6 .9 .1 .9 .1 .6 .1 .6 .9
OGRBATCH 0
```

Possible Errors:

A LENGTH ERR is reported if:
- the right argument contains more than one item

A DOMAIN ERR is reported if:
- the right argument value is not 0 or 1
- APL graphics is not initialized
- the right argument value is 1 and already batching updates
- the right argument value is 0 and not batching updates

OGRCSTATUS Function (Inquire Control Status)

Syntax:

```
LOGL2*OGRCSTATUS
```

Parameters:

LOGL2 is a simple vector of 2 items containing the values 0 or 1.

Description:

The OGRCSTATUS function indicates the current status of immediacy and batching of updates. The first item is 1 if updates are immediately visible, otherwise it is 0. The second item is 1 if within a batch of updates, otherwise it is 0.

Example:

```
OGRCSTATUS
1 0
```

This result indicates that immediate visibility is in effect and that no batching of updates is being performed.

Possible Errors:

A DOMAIN ERR is reported if:
- APL graphics is not initialized
**GRFRAME Function (New Frame)**

Syntax:

```
GRFRAME
```

Description:

The **GRFRAME** function causes a new frame action to occur. The result on each affected view surface is that the surface is erased and all visible retained segments are redrawn.

Possible Errors:

A **DOMAIN ERR** is reported if:

- the set of currently selected view surfaces is empty
- APL graphics is not initialized

**GRCOLMODEL Function (Color Model)**

Syntax:

```
GRCOLMODEL KEY
```

Parameters:

- **KEY** is a simple character vector containing the keyword value 'HLS', 'RGB' or ' '.

Description:

The **GRCOLMODEL** function is used to establish or inquire about the current color model. If the right argument is empty or contains only blanks, the result is the current color model type ('RGB' or 'HLS'). If the right argument contains non-blank characters, they are used to specify the color model. The color model may be established once after APL graphics is initialized before any view surfaces are initialized.

Example:

```
GRCOLMODEL ''
```

This example demonstrates obtaining the current color model.

Possible Errors:

A **RANK ERR** is reported if:

- the right argument is not a scalar or vector.

A **DOMAIN ERR** is reported if:

- the keyword specified is not 'RGB' or 'HLS'
- a keyword is specified and a view surface has been initialized
- APL graphics is not initialized
**GRCOLINDEX Function (Set/Inquire Color Indices)**

Syntax:

- `COLS~COLS GRCOLINDEX SURF`
- `COLS~ GRCOLINDEX SURF`

Parameters:

- `SURF` is a simple integer scalar indicating a view surface number.
- `COLS` is a simple N-by-3 numeric array whose values range from 0 to 1.

Description:

Dyadically, the `GRCOLINDEX` function sets all of the color entries for the specified view surface to the color components specified by the left argument and returns an empty vector. Monadically, the `GRCOLINDEX` function returns the currently defined color entries for the specified view surface.

Example:

```
(4 3p 0 0 1 0 1 0 0 1 1 1) GRCOLINDEX 1
GRCOLINDEX 1
0 0 1
0 1 0
1 0 0
1 1 1
```

Possible Errors:

- A **RANK ERR** is reported if:
  - the left argument is not a matrix
- A **LENGTH ERR** is reported if:
  - the right argument is not exactly one item
  - the second dimension of the left argument is not 3
- A **DOMAIN ERR** is reported if:
  - the right argument is not an integer
  - the left argument is not numeric
  - the specified view surface is not initialized
  - the view surface is not of type 'COLOR'
  - too many indices are specified
  - one or more of the color parameters is invalid
  - APL graphics is not initialized
OGRINTINDEX Function (Set/Inquire Intensity Indices)

Syntax:

\[ \text{INTS} \times \text{INTS} \] OGRINTINDEX \( \text{SURF} \)
\[ \text{INTS} \times \] OGRINTINDEX \( \text{SURF} \)

Parameters:

\( \text{SURF} \) is a simple integer scalar indicating a view surface number.

\( \text{INTS} \) is a simple numeric vector whose values range from 0 to 1.

Description:

Dyadically, the OGRINTINDEX function sets all of the intensity entries for the specified view surface to the intensity values specified by the left argument and returns an empty vector. Monadically, the OGRINTINDEX function returns the currently defined intensity entries for the specified view surface.

Example:

\[ .1 .2 .3 .4 .5 .6 .7 \] OGRINTINDEX 1
\[ \text{OCRCOLINDEX} 1 \]
\[ 0.1 0.2 0.3 0.4 0.5 0.6 0.7 \]

Possible Errors:

A RANK ERR is reported if:

- the left argument is not a vector or scalar

A LENGTH ERR is reported if:

- the right argument is not exactly one item

A DOMAIN ERR is reported if:

- the right argument is not an integer
- the left argument is not numeric
- the specified view surface is not initialized
- the view surface is not of type 'INTENSITY'
- too many indices are specified
- one or more of the intensity values are invalid
- APL graphics is not initialized
**DGRBACKGROUND Variable (Background Index)**

Syntax:

\[ \text{DGRBACKGROUND+I} \]

Parameters:

\( I \) is a simple integer scalar.

Description:

The \text{DGRBACKGROUND} variable controls the current background index. During a new-frame action, the background is set to the color or intensity specified by the value of this variable.

Example:

\[ \text{DGRBACKGROUND+1} \]

\[ \text{DGRBACKGROUND} \]

\[ 1 \]

Possible Errors:

A \text{LENGTH ERR} is reported if:

- the value being assigned contains more than one item

A \text{DOMAIN ERR} is reported if:

- the specified index value is not supported by a view surface
- APL graphics is not initialized

**DGRPIXEL Variable (Pixel Array)**

Syntax:

\[ \text{DGRPIXEL+HAT} \]

Parameters:

\( HAT \) is a simple integer matrix.

Description:

The \text{DGRPIXEL} variable specifies the pixel array that is used when a polygon is drawn, and the \text{DGRPINS} variable has the value 'PATTERNED'.

CE38-04 DGRPIXEL Variable (Pixel Array) 15-53
Example:

```
OCRPIXEL+2 2p 2 3 14
OCRPIXEL
```

2 3
1 4

Possible Errors:

A RANK ERR is reported if:
- the assigned value is not a matrix

A DOMAIN ERR is reported if:
- the matrix is too large
- the matrix is empty
- APL graphics is not initialized

OCRPIXELORG Variable (Pixel Pattern Origin)

Syntax:

```
OCRPIXELORG+XY
```

Parameters:

- `XY` is a simple 2 item vector containing a position in normalized device coordinate space. The default value is 0 0.

Description:

The `OCRPIXELORG` variable is used to specify the origin for the transfer of the pixel array to the view surface. The origin specifies the position of the item in the lower left-hand corner of the current pixel array.

Example:

```
OCRPIXELORG+0.25 0.125
OCRPIXELORG
```

0.25 0.125

Possible Errors:

A RANK ERR is reported if:
- the assigned value is not a vector

A LENGTH ERR is reported if:
- the assigned value is not exactly 2 items

A DOMAIN ERR is reported if:
- the value specified is outside of NDC space
- the value specified is not numeric
- APL graphics is not initialized
Section 16

Blind I/O

Blind I/O is a capability which is of use in a number of specialized cases. The major uses of blind I/O include:

- Sending or receiving data to CP-6 devices or files without undergoing any translation or validity checking by APL.
- Exercising more control over a CP-6 device than is possible with normal APL input and output.
- Accessing multiple input and output streams (or devices) simultaneously.
- Creating a terminal independent CP-6 FORM which permits reading, writing and clearing specified fields in a screen-oriented fashion.

For example, blind input permits the entry of overstrikes (or any other characters) which would result in a BAD CHAR error if normal APL input were used. Blind output may be used to output special character sequences (including ASCII control characters) to perform special device functions such as controlling a plotter.

Using Blind I/O

APL provides ten DCBs – F$Q0 through F$Q9 to be used for blind I/O, but performs no special set-up on them. It is assumed that the DCB will be assigned to devices or files, using the )SET command (section 8). If a )SET command has not been issued, the blind I/O streams default to the standard APL input (and output) streams (the CP-6 ME device, which is the terminal if online or the card-reader if batch).

Within APL, the characters 1 through 8 (quad overstruck with 0 through 9) supplement the quad and quote-quad characters. They are used to access the DCBs when blind input or output is desired.

There is no limit on the size of a record input via blind I/O. Input from blind DCBs creates a character vector result. If the data actually contains logic values, integer values, or floating point values, then the OCVT function may be used to correct the data type after input.

Blind output may only be used to output simple APL arrays. It should be noted, however, that large output records routed to physical devices with maximum length constraints will be truncated on output. In particular, records output to the user's console should be limited to 511 bytes, and records output to a line printer to 132 bytes. Note also that blind output of non-character data to a printing device may lead to unpredictable results.

APL bypasses all of its translation sequences (overstrike resolution and mnemonic substitution) for blind input. If an end-of-file condition is encountered by a blind-input request, APL returns an empty numeric vector result.
Blind I/O on a Device

In the following examples, B is assigned to the user's console (if the session is online) after calling APL, as follows:

)SET B ME, ORG=TERMINAL, FUN=UPDATE

Quad-2 may then used for blind input and for blind output to the terminal. In the example below, blind input functions much the same as a quote-quad input, since the terminal itself is the input device.

A+B

NOW IS THE TIME FOR ALL GOOD MEN.

A

NOW IS THE TIME FOR ALL GOOD MEN.

Blind input can be used to input illegal overstrike characters, which cannot be done with quote-quad input. Note, however, that the characters entered appear in the result, including backspaces, and that overstrikes are not mapped into single APL characters.

The examples below illustrate blind output to the terminal. Only simple arrays containing all character or all numeric data may be written with blind I/O. Note that the data to be output was specified as a literal. When the RETURN key is struck, the data is output the terminal exactly as it was input.

B+"1234567890+QWERTYUIOP+ASDFGHJKL[]ZXCVBNM,./"

1234567890+QWERTYUIOP+ASDFGHJKL[]ZXCVBNM, ./

B+"'-<S=><Ep-++tO*~arL-V60'O()'c~nu'TI

"'-<s=~>~VA-+?~Ep-++tO*~arL-V60'O()'c~nu'TI

B+"ASDF"

ASDF

Note that the OBTRANS function may be used to request transparent input. Transparent input from a terminal (with ORG=TERMINAL specified on the SET command) should only be specified when all of the control characters entered are of interest to the APL program. In this mode, the terminal read is not terminated until the number of characters specified by the read (511 by default, or see OBSIZE) have been received. The command:

)SET B ME, FUN=CREATE

is used to set B to the terminal (or lineprinter in batch). In this case, unit record oriented functions may be performed on the stream. This includes the ability to specify a page heading on the SET command and to use the OBBLINES function to determine the number of lines per page and the number of lines remaining on the current page. The OBVFC function may be used to indicate that the first character of each output line is to be used to control line spacing.

The OTSQZ system function may be used to map legal APL overstrikes and mnemonics into their internal representations or to map the internal APL characters into mnemonics and overstrikes appropriate for the current APL terminal (as indicated by the current terminal type).
Accessing Files with Blind I/O

In the following examples, m is assigned to a test input file which is built using CP-6 EDIT:

```
EDIT
EDIT C00 HERE
*BUILD BLINDIN
  1.000 BLINDIN, RECORD 1.
  2.000 RECORD 2. TEST BACKSPACING.
  3.000 LAST RECORD
  4.000
*END
```

Record 2 of the file contains a series of blanks and backspaces such that the total number of characters in the record is considerably more than the example shows.

After APL is called:

```
)SET m BLINDIN,FUN=IN
```

In the next example, blind input is used to input records from the file. Note that an attempt to use blind I/O to access the non-existent fourth record results in an empty integer vector.

```
A=-m
B=-m
C=-m
D=-m
```

A, B, C, and D now contain the data from the file records, as shown below. Note that the length of B reflects the blanks and backspace characters that were part of the file record.

```apl
pA 18
A BLINDIN, RECORD 1.
pB 81
B RECORD 2. TEST BACKSPACING.
pC 15
C LAST RECORD.
pD 0
```

When blind output to a file is used, records are output as character data — scalars, vectors, and arrays are written without any sort of header data.

The blind I/O system functions OBPRECORD, OBPFIELD, and OBREV may be used to position to a specific record within the file. The system functions OBSEED and OBREWRITE may be used to set record encryption or to indicate that the last record read is to be replaced.

When writing records to a keyed, random or relative file, the record identifier (number or key) may be specified by assigning a nested array whose first item is a simple non-negative scalar integer less than 134217726 or a simple character vector. The second item is a non-scalar array to be written.

For example:

```
m+5000 'EDIT KEY FIVE'
m+'TEXT KEY' 'RECORD ASSOCIATED WITH KEY:' 'TEXT KEY'
```
In the first example, the integer key 5000 is used to write the record. In the second statement, the character key 'TEXT KEY' is used to write the record. Note that blind I/O does not permit records to be read by their key as does APL File I/O (see Section 12).

Blind I/O System Functions

CP-6 APL allows options to be specified for reading and writing with blind I/O. These capabilities include specification and interrogation of VFC, TRANSPARENCY and BINARY modes, setting the encryption seed for reading and writing, and setting the size of the record to read.

The right argument to the blind I/O system functions must be a scalar or vector or a RANK ERR is reported. If a vector argument is provided, there must be one or two items or a LENGTH ERR is reported. The right argument must be simple and contain only scalar integers or a DOMAIN ERR is reported.

When a scalar or one-item vector argument is provided, the current status of an I/O option is returned. When a two item vector argument is provided, the I/O option is set for a subsequent read or write. The first item of the argument is the blind I/O stream number to be affected.

BBIN Function (Set and Query Binary Mode)

Syntax:

$I+$BBIN $N,L$

Parameters:

$N$ is a simple integer scalar representing the blind I/O channel number.

$L$ is an optional simple integer scalar value 0 or 1.

$I$ is a simple integer scalar value 0 or 1.

Description:

The $BBIN$ function sets or resets binary mode. If $L$ is equal to one, then subsequent reads and writes through channel $N$ will be in binary mode. If $L$ is zero, then subsequent reads and writes will not specify binary mode. If $L$ is not present, the result indicates whether the last operation was BINARY.

When querying binary mode, this function indicates whether the last record read or written was with BINARY.
**BSIZE Function (Read Size)**

Syntax:

\[ I + \text{BSIZE} N, I \]

Parameters:

- **N** is a simple integer scalar representing the blind I/O channel number.
- **I** is an optional simple integer scalar value greater than or equal to 0.

Description:

When a blind I/O stream is SET or opened for the first time, APL determines a default read size that is sufficient for any record in the file. This function is used to override the default input record size. The integer value **I** is subsequently used for the record size. If **I** is zero, then APL reverts back to the default read size for the stream. If **I** is not specified in the right argument, the result is the current default read record size; otherwise, an empty vector is returned.

**BVFC Function (Set and Query VFC)**

Syntax:

\[ I + \text{BVFC} N, L \]

Parameters:

- **N** is a simple integer scalar representing the blind I/O channel number.
- **L** is an optional simple integer scalar value 0 or 1.
- **I** is the simple integer scalar value 0 or 1.

Description:

If **L** is not present, then this function indicates whether the last record read was originally written with VFC.

If **L** is one, subsequent writes through channel **N** will specify VFC. If **L** is zero, then subsequent writes will not specify VFC.
OBTRANS Function (Set and Query Transparency)

Syntax:

\[ \text{I+OBTRANS N,L} \]

Parameters:

N is a simple integer scalar representing the blind I/O channel number.
I is the simple integer scalar value 0 or 1.
L is an optional simple integer scalar value 0 or 1.

Description:

If L is not present, then this function indicates whether the last record read or written was with transparency.

If L is one, subsequent blind I/O reads and writes through channel N will specify TRANSPARENCY. If L is zero, then subsequent writes will not specify transparency.

OBLINES Function (Lines Remaining)

Syntax:

\[ \text{I+OBLINES N} \]

Parameters:

N is a simple integer scalar representing the blind I/O channel number.
I is a simple 2-item integer vector.

Description:

This function returns a two item integer vector containing the number of lines per page, and the number of lines currently remaining on the page printed through channel N.

OBKEY Function (Return Key)

Syntax:

\[ \text{K+OBKEY N} \]
Parameters:

$N$ is a simple integer scalar representing the blind I/O channel number.

$K$ is a record key returned as an integer or character vector.

Description:

The result is the key of the next record to be read, or, if the file is not keyed or indexed, the record number of the next record to be read. Three byte keys and record numbers are returned as integers, all other keys are returned as character vectors. This function operates on tape or disk files only.

**OBPRECORD Function** (Position Record)

Syntax:

```
K = OBPRECORD N, I
```

Parameters:

$N$ is a simple integer scalar representing the blind I/O channel number.

$I$ is a simple integer scalar.

$K$ is a record key returned as an integer or character vector.

Description:

If $I$ is positive, the file or device is positioned $I$ records ahead. If $I$ is negative, the file or device is backspaced $I$ records. The result is the key of the record positioned to (or record number for sequential files).

**OBFILE Function** (Position File)

Syntax:

```
OBFILE N, L
```

Parameters:

$N$ is a simple integer scalar representing the blind I/O channel number.

$L$ is a simple integer scalar.

Description:

If $L$ is zero, then the file or device is positioned to the beginning of the file. If $L$ is one, then the file or device is positioned to the end of the file.
**OBREW Function (Rewind)**

Syntax:

```
OBREW N
```

Parameters:

- $N$ is a simple integer scalar representing the blind I/O channel number.

Description:

The file associated with stream $N$ is positioned to the beginning of file or the device associated with stream $N$ is rewound.

**OBREWRITE Function (Rewrite Record)**

Syntax:

```
OBREWRITE N,L
```

Parameters:

- $N$ is a simple integer scalar representing the blind I/O channel number.
- $L$ is a simple integer scalar.

Description:

If $L$ is one, then subsequent writes will specify the REWRITE option. If $L$ is zero, then the REWRITE option is not specified. If $L$ is not specified, the result is the current setting of rewrite for this stream.

**OBSEED Function (Encryption Seed)**

Syntax:

```
OBSEED N,I
```

Parameters:

- $N$ is a simple integer scalar representing the blind I/O channel number.
- $I$ is a simple integer scalar.
Description:
The integer value $I$ is used on all succeeding reads and writes as the encryption seed for channel $N$.

**OBRR Function (Re-Read Mode)**

Syntax:

$$R + OBRR IV$$

Parameters:

$I$ is a simple 1 or 2-item integer vector containing as the first item a blind I/O stream number. The second item must be the value 0 or 1.

$R$ is a simple integer scalar containing the previous re-read setting.

Description:
The OBRR function permits the specification of re-read on blind input for each blind I/O stream. This function may be used in conjunction with the OTTIN system function which sets the re-read line. If the second item of $IV$ is not present, then the result indicates whether re-read will be specified on the next read. If the second item of $IV$ is 1, re-read will be specified on the next read. If the second item of $IV$ is 0, then re-read will not be specified on the next read.

**OBRS Function (Record Size)**

Syntax:

$$R + OBRS I$$

Parameters:

$I$ is a simple integer scalar containing a blind I/O stream number.

$R$ is a simple integer scalar representing the value of the ARS$#$ field of the DCB associated with the specified stream.

Description:
The OBRS system function is used to return the setting of the DCB field F$DCB.ARS$#. This is intended to be used with screen edit access mode which provides information via this DCB field.
OBKR Function (Key Returned)

Syntax:

\[ R + \text{OBKR} \ 1 \]

Parameters:

- \( I \) is a simple integer scalar whose value is used to indicate a blind I/O stream to be affected.
- \( R \) is a simple character vector.

Description:

The OBKR system function is used to return the key specified by the most recent M$READ or M$WRITE associated with a blind I/O stream whose ORG is SE or FORM.

OBCLOSE Function (Close Blind I/O Channel)

Syntax:

\[ \text{OBCLOSE} \ N \]
\[ \text{OBCLOSE} \ N, L \]

Parameters:

- \( N \) is a simple integer scalar representing a blind I/O channel number.
- \( L \) is a simple integer scalar value 0 or 1.

Description:

The OBCLOSE function closes the specified blind I/O channel. If \( L \) is 1 or not specified, the channel is closed with SAVE. If \( L \) is 0, the channel is closed with RELEASE. The RELEASE option is used to delete files or make windows created by a )SET command disappear.

If this function is not executed, an automatic close is performed whenever a )SET command is issued to a channel, or when the APL session ends.
\section*{\texttt{DBPAGE} Function (Skip to New Page)}

Syntax:
\begin{verbatim}
\texttt{DBPAGE \textit{N}}
\texttt{DBPAGE \textit{N, L}}
\end{verbatim}

Parameters:
\begin{itemize}
\item \textit{N} is a simple integer scalar representing a blind I/O channel number.
\item \textit{L} is a simple integer scalar value 0 or 1.
\end{itemize}

Description:
The \texttt{DBPAGE} function is used to eject the current page of a unit record device.

If the blind I/O channel is open to the terminal with \texttt{ORG=FORM}, the argument \textit{L} is used to control the display. For screens, if \textit{L}=0, then this function causes the screen to be updated. If the device is not a screen and \textit{L}=0, then nothing is printed. If \textit{L}=1, then the screen is updated or the form is printed.

\section*{\texttt{DBDELREC} Function (Delete Record)}

Syntax:
\begin{verbatim}
\texttt{DBDELREC \textit{N}}
\texttt{DBDELREC \textit{N,K1}}
\texttt{DBDELREC \textit{N,K1,K2}}
\end{verbatim}

Parameters:
\begin{itemize}
\item \textit{N} is a simple integer scalar representing the blind I/O channel number.
\item \textit{K1} is a simple integer scalar.
\item \textit{K2} is a simple integer scalar.
\end{itemize}

Description:
The \texttt{DBDELREC} function is used to delete a record (or records) from a file. If \textit{K1} is not specified, the last record read or written is deleted. Otherwise, \textit{K1} indicates the key of the record to delete. If \textit{K2} is specified, all records between \textit{K1} and \textit{K2} (inclusive) are deleted.
OUNSET Function (Unset DCB)

Syntax:

\[ V+\text{OUNSET} \ n \]

Parameters:

\( N \) is a simple integer scalar representing the blind I/O channel number or a simple character scalar or vector.

Description:

If \( N \) is an integer channel number, the result is a character string containing the \textit{fid} and )\textit{SET} options for this blind I/O channel. If \( N \) is a character vector, the result is the setting for the DCB named.

Forms Mode

Forms mode is a terminal independent method of defining a screen (form) consisting of a number of fields and accessing specific fields for the purpose of reading, writing and erasing. In forms mode, a field is a variable length string of characters which are on a specific line, start in a specific column and occupy \( N \) columns (where \( N \) is the length of the field). Multiple fields may appear on the same line, but fields may not overlap. Forms mode permits form definition, field selection, field input, field output and selective erasure.

When a blind I/O channel is open with \textit{ORC=FORH}, the result of a read and the value to write is a matrix of two columns. The first column is an integer key or field number. The second column contains enclosed character vectors.

When forms mode is required, the blind I/O channel that is used should be )\textit{SET} to the terminal with the option \textit{ORC=FORH}. If a CRT terminal is in use, a window for the form should also be defined with the \textit{WWIDTH=} and \textit{WLENGTH=} options. Next, the fields for that form must be defined by executing the )\textit{DBFLD} system function. This system function defines the position, length, initial contents, and attributes of the fields on the screen. Attributes and contents of currently defined screen fields can be modified by the )\textit{DBXFLD} system function.

Before reading from an \textit{ORC=FORM} blind I/O channel, the fields that are to be input must be selected by the )\textit{DBSFLD} system function. Only those input fields that are currently selected may have values input for them. The )\textit{DBRFLD} system function is used to release currently selected fields. The )\textit{DBXFLD} system function selectively erases fields.

Finally, the )\textit{DBSPACE} system function is used to make changes to the form visible. Normally, when a field value is written or an attribute is changed, the changes do not appear until a read is issued to the form. The )\textit{DBSPACE} system function is used to force changes to appear. The right argument of )\textit{DBSPACE} may be a 1 or 2-item integer vector. The first item is the blind I/O stream and the second item is 0 or 1 to force changes to the current screen or (if the device is not a screen) 1 to force a copy of the form to be displayed on the terminal. If the terminal device is not a screen, then changes to the form are not displayed unless the second item of the right argument is 1 or is omitted.
Field Definition Matrix

The form is initially defined using the OBFLD system function. After definition, the attributes and values of the fields can be modified by the OBHFLD system function. The left argument for both of these functions must be a field definition matrix.

This matrix must have at least four columns and no more than seven columns. The first six columns always contain integer values; the seventh column must always contain character vectors. Each row of the matrix defines a field.

Field Definition Matrix Columns

1. Field Number. This number is used to refer to the field when selecting, erasing, modifying or writing. Field numbers are integer scalars in the range 0 through 65535. When modifying a field definition, a field number value of -1 is used to modify the definition of all currently selected fields.

2. Row Number. This number locates the row on the screen in which a field will appear. Row numbers are integer scalars in the range 1 through 254. When modifying a field definition, a value of -1 must be specified for the row number.

3. Column Number. This number locates the column on the screen in which a field begins. Column numbers are integer scalars in the range 1 through 254. When modifying a field definition, a value of -1 must be specified for the column number.

4. Length. This number determines the number of character positions that the field takes up. Field lengths are integer scalars in the range 1 through 254. When modifying a field definition, a value of -1 must be specified for the field length.

5. Field Rendition Attributes. Rendition attributes are scalar integers whose values are the sums of the inclusion values listed in Table 16-1. The default attributes are obtained (when defining a field) by using the value -1 or 0. When modifying a field definition, a value of -1 for the rendition attribute is used to indicate no change to the current rendition attributes. The value 0 indicates the default attributes.

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>reserved for future use</td>
</tr>
<tr>
<td>2</td>
<td>reverse video</td>
</tr>
<tr>
<td>4</td>
<td>fast blink</td>
</tr>
<tr>
<td>8</td>
<td>slow blink</td>
</tr>
<tr>
<td>16</td>
<td>underscore</td>
</tr>
<tr>
<td>32</td>
<td>decreased intensity</td>
</tr>
<tr>
<td>64</td>
<td>increased intensity</td>
</tr>
<tr>
<td>128</td>
<td>hidden</td>
</tr>
</tbody>
</table>

6. Field Input Attributes. Field input attributes are scalar integers whose values are the sums of the inclusion values listed in Table 16-2. The default input attributes are obtained by using the value -1 or 0. When modifying a field definition, a value of -1 for the input attribute is used to indicate no change to the current input attributes.
Table 16-2. Blind I/O Field Input Attributes

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>reserved for future use</td>
</tr>
<tr>
<td>2</td>
<td>constant</td>
</tr>
<tr>
<td>4</td>
<td>input required</td>
</tr>
<tr>
<td>8</td>
<td>protected</td>
</tr>
<tr>
<td>16</td>
<td>letters permitted</td>
</tr>
<tr>
<td>32</td>
<td>numbers permitted</td>
</tr>
<tr>
<td>64</td>
<td>graphic characters permitted</td>
</tr>
<tr>
<td>128</td>
<td>protect and guard field</td>
</tr>
<tr>
<td>256</td>
<td>all characters permitted</td>
</tr>
</tbody>
</table>

Attributes that are not supported by the device in use are not available.

7. Value. Field values are simple character vectors. When modifying a field definition, an empty vector is used to indicate that the current field value is not to be changed.

**OBFLD Function (Field Definition)**

Syntax:

\[ \text{OBFLD} \]

Parameters:

- \( H \) is a field definition matrix (see below).
- \( I \) is a simple integer scalar representing a valid blind I/O channel.

Description:

The **OBFLD** system function defines the fields indicated by the left argument field definition matrix. The field definition matrix contains definitions of the location and size of each field, input attributes, rendition attributes, and the current (or initial) value of the field.

Examples:

The following example demonstrates the creation of a form for entry of names and addresses. Figure 16-1 shows the screen image that results from the form definition example.

```
FIELDS+2 7Pl 130 15 0 0 'ADDRESS SCREEN' 2 3 2 5 0 0 'NAME':
FIELDS+FIELDS, (1) 3 11 35 0 0 'JOE WHO'
FIELDS+FIELDS, (1) 4 2 8 0 0 'ADDRESS:
FIELDS+FIELDS, (1) 5 11 35 0 0 'SUSSEX DRIVE,'
FIELDS+FIELDS, (1) 6 11 35 0 0 'CALGARY, ALBERTA'
```

\[ \text{DISPLAY THE FIELD DEFINITION MATRIX} \]

```
FIELDS 1 1 30 15 0 0 'ADDRESS SCREEN'
2 3 2 5 0 0 'NAME:
3 3 11 35 0 0 'JOE WHO'
4 4 2 8 0 0 'ADDRESS:
5 4 11 35 0 0 'SUSSEX DRIVE,'
6 5 11 35 0 0 'CALGARY, ALBERTA'
```

\[ \text{SET THE BLIND I/O CHANNEL TO BE USED} \]

```
SET UC05, ORG=FORM, FUN=UPDATE
```
Possible Errors:

A **RANK ERR** is reported if:

- the left argument is not a matrix or vector.
- the seventh column of the left argument does not contain scalars or vectors.

A **LENGTH ERR** is reported if:

- the right argument contains more than one item.
- the left argument contains more than 7 or fewer than 4 columns.

A **DOMAIN ERR** is reported if:

- the right argument is not a simple scalar integer in the range 0 through 9 inclusive.
- the first six columns of the left argument are not scalar integers.
- the seventh column of the left argument is not simple character vectors or scalars.
- the first column of the left argument contains a value (field number) greater than 65535 or less than 0.
- the second column of the left argument contains a value (row number) greater than 254 or less than 0.
- the third column of the left argument contains a value (column number) greater than 254 or less than 0.
- the fourth column of the left argument contains a value (field length) greater than 254 or less than 0.
- the fifth column of the left argument contains a value (field rendition) greater than 1023 or less than -1.
- the sixth column of the left argument contains a value (input attributes) greater than 1023 or less than -1.

An **I/O ERR** is reported if:

- the field definition is not consistent with CP-6 requirements.
OBMFLD Function (Modify Field)

Syntax:

\[ H \text{ OBHFLD} I \]

Parameters:

- \( H \): a field definition matrix.
- \( I \): a simple integer scalar representing a valid blind I/O channel.

Description:

The left argument is a field definition matrix as described for the OBFLD system function. Because the field location and length may not be modified, the value specified for them must be 0. A value of -1 for either the field rendition attributes or the field input attributes is used to indicate no change in this attribute. An empty vector is used to indicate no change in the current field value.

Examples:

In the following example, fields 3, 5, and 6 of the current form are selected and their attributes are modified to reverse video and input required:

\[ 3 \ 5 \ 6 \text{ OBHFLD} \ 1 \quad \text{SELECT OUR INPUT FIELDS} \]

A THE FOLLOWING EXECUTION OF THE OBHFLD SYSTEM
FUNCTION WILL CAUSE ALL CURRENTLY SELECTED
FIELDS TO BE MODIFIED TO THE RENDITION ATTRIBUTE
OF REVERSE VIDEO AND THEIR INPUT ATTRIBUTES TO
INPUT REQUIRED.

\[-1 \ -1 \ -1 \ -1 \ 2 \ 4 \text{ OBHFLD} \ 1 \]

Possible Errors:

A **RANK ERR** is reported if:

- the left argument is not a matrix or vector.
- the seventh column of the left argument does not contain scalars or vectors.

A **LENGTH ERR** is reported if:

- the right argument contains more than one item.
- the left argument contains more than 7 or fewer than 4 columns.

A **DOMAIN ERR** is reported if:

- the right argument is not a simple scalar integer in the range 0 through 9 inclusive.
- the first six columns of the left argument are not scalar integers.
- the seventh column of the left argument is not simple character vectors or scalars.
- the first column of the left argument contains a value (field number) greater than 65535 or less than -1.
- the second column of the left argument contains a value (row number) other than -1.
- the third column of the left argument contains a value (column number) other than -1.
the fourth column of the left argument contains a value (field length) other than -1.

- the fifth column of the left argument contains a value (field rendition) greater than 1023 or less than -1.

- the sixth column of the left argument contains a value (input attributes) greater than 1023 or less than -1.

An I/O ERR is reported if:

- the field definition is not consistent with CP-6 requirements.

**OBSFLD Function (Select Field)**

**Syntax:**

```
IV OBSFLD I
```

**Parameters:**

- **IV** is a simple integer vector of field numbers.
- **I** is a simple integer scalar representing a valid blind I/O channel.

**Description:**

The OBSFLD function is used to select fields that are to be affected by subsequent field operations. For example, in order to input a field value, it must have been selected previous to the read. A field number of -1 is used to select all currently defined fields.

**Examples:**

In the following example, fields 3, 5, and 6 are selected:

```
3 5 6 OBSFLD 1
```

**Possible Errors:**

- A RANK ERR is reported if:
  - the left argument is not a vector or scalar.

- A LENGTH ERR is reported if:
  - the right argument contains more than one item.

- A DOMAIN ERR is reported if:
  - the right argument is not a simple integer value representing a valid blind I/O channel (0 through 9 inclusive).
  - the left argument is not a simple integer vector of valid field numbers or -1.

An I/O ERR is reported if:

- the operation is not consistent with CP-6 requirements.
**OBRFLD Function (Release Field)**

Syntax:

\[
IV \text{ OBRFLD } I
\]

Parameters:

\[IV\] is a simple integer vector of field numbers.

\[I\] is a simple integer scalar representing a valid blind I/O channel.

Description:

The OBRFLD system function is used to release (or deselect) a previously selected screen field. A field number of \(-1\) is used to release all currently selected fields.

Examples:

In the following example, fields 5 and 6 are deselected:

\[
5 \text{ 6 OBRFLD } I
\]

Possible Errors:

A **RANK ERR** is reported if:
- the left argument is not a vector or scalar.

A **LENGTH ERR** is reported if:
- the right argument contains more than one item.

A **DOMAIN ERR** is reported if:
- the right argument is not a simple integer value representing a valid blind I/O channel (0 through 9 inclusive).
- the left argument is not a simple integer vector of valid field numbers or -1.

An **I/O ERR** is reported if:
- the operation is not consistent with CP-6 requirements.

**OBXFLD Function (Expunge Field)**

Syntax:

\[
IVO \text{ OBXFLD } IVI
\]
Parameters:

IV0 is a simple integer vector of field numbers.

IV1 is a simple integer vector of length two, containing a valid blind I/O channel number and an erase level code value of 0, 1, 2, or 3.

Description:

The OBXFLD system function is used to erase (or expunge) the specified fields. The second item of the right argument controls the extent of the erase. A value of 0 erases input fields, 1 erases input fields and protected fields, 2 erases input fields and constant fields, and 3 erases input fields, constant fields and protected fields. A field number of -1 is used to erase all currently selected fields.

Examples:

In the following example, fields 3, 5, and 6 are erased:

3 5 6 OBXFLD 1 1

Possible Errors:

A RANK ERR is reported if:

- the left argument is not a vector or scalar.

A LENGTH ERR is reported if:

- the right argument contains more than two items.

A DOMAIN ERR is reported if:

- the right argument is not a simple integer value representing a valid blind I/O channel (0 through 9 inclusive) followed by a simple integer value in the range 0 through 3 inclusive.

- the left argument is not a simple integer vector of valid field numbers or -1.

An I/O ERR is reported if:

- the operation is not consistent with CP-6 requirements.
Appendix A

CP-6 APL Parameters

This appendix defines the limits that apply to the CP-6 APL implementation and references to (or definitions of) the implementation-defined algorithms. This information may be useful in comparing CP-6 APL to other implementations and in determining whether an existing APL application can be run on CP-6 APL.

Arithmetic Limits

Largest positive number: 8.3788799562141231863E152
Largest negative number: -8.3788799562141231872E152
Largest counting numbers: (2^60) (~2^60)
Maximum exponent field width: 5
Integer tolerance value: OCT
Digits in full print precision: 20

Array Limits

Maximum rank: 62
Maximum index: 34359738367
Maximum number of items: 34359738367

System Variables

The valid value range for the named system variables is:

<table>
<thead>
<tr>
<th>Name</th>
<th>Minimum Value</th>
<th>Maximum Value</th>
<th>Domain</th>
</tr>
</thead>
<tbody>
<tr>
<td>OCT</td>
<td>0</td>
<td>1E^-12</td>
<td>(0..1E^-12)</td>
</tr>
<tr>
<td>OCTO</td>
<td>0</td>
<td>1</td>
<td>Integer 0 or 1</td>
</tr>
<tr>
<td>DLX</td>
<td>1</td>
<td>34359738367</td>
<td>integers in range</td>
</tr>
<tr>
<td>DPL</td>
<td>1</td>
<td>20</td>
<td>Integers in range</td>
</tr>
</tbody>
</table>
## Implementation Defined System Variables

<table>
<thead>
<tr>
<th>Name</th>
<th>Minimum Value</th>
<th>Maximum Value</th>
<th>Domain</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPP</td>
<td>32</td>
<td>390</td>
<td>integers in range</td>
</tr>
<tr>
<td>OPS</td>
<td>-1</td>
<td>1</td>
<td>integer; for first two items</td>
</tr>
<tr>
<td></td>
<td>-2*35</td>
<td>-1+2*35</td>
<td>integer; for last two items</td>
</tr>
</tbody>
</table>

## Defined Functions

- Maximum number of lines: 65535
- Maximum function definition prompt: 9999.999

## APL Input and Output

- Direct input prompt: $(6p')$
- Quad input prompt: $[]$
- Function definition prompt: $[n]$
- Quote quad output limit: none

## Miscellaneous Limits

- Maximum number of shared variables: 16 + unlimited IDS/II shares
- Identifier length limit: 79
- Account identification: 8-item character vector
- Workspace name length limit: 31 characters
- Shared variable general offer: 20p'

## File System

- Maximum number of simultaneous file ties: 31
- File name length limit: 31 characters
- File account name limit: 8 characters

## Trigonometric and Hyperbolic Algorithms

<table>
<thead>
<tr>
<th></th>
<th>CP-6 LIBRARY</th>
<th>HART***</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cosine:</td>
<td>XPE_9DCOS</td>
<td>3346</td>
</tr>
<tr>
<td>Sine:</td>
<td>XPE_9DSIN</td>
<td>3346</td>
</tr>
<tr>
<td>Tangent:</td>
<td>XPE_9DTAN</td>
<td>4286</td>
</tr>
<tr>
<td>Inverse Cosine:</td>
<td>XPE_9DACOS</td>
<td>4904</td>
</tr>
<tr>
<td>Inverse Sine:</td>
<td>XPE_9DASIN</td>
<td>4904</td>
</tr>
<tr>
<td>Inverse Tangent:</td>
<td>XPE_9DATAN</td>
<td>4904</td>
</tr>
<tr>
<td>Hyperbolic Cosine:</td>
<td>XPE_9DCOSH</td>
<td>1067**</td>
</tr>
<tr>
<td>Hyperbolic Sine:</td>
<td>XPE_9DSINH</td>
<td>1986</td>
</tr>
<tr>
<td>Hyperbolic Tangent:</td>
<td>XPE_9DTANH</td>
<td>1067**</td>
</tr>
<tr>
<td>Inverse Hyperbolic Cosine:</td>
<td>XPE_9DACOSH</td>
<td>2705*</td>
</tr>
<tr>
<td>Inverse Hyperbolic Sine:</td>
<td>XPE_9DASINH</td>
<td>2705*</td>
</tr>
<tr>
<td>Inverse Hyperbolic Tangent:</td>
<td>XPE_9DATANH</td>
<td>2705*</td>
</tr>
</tbody>
</table>

* The standard logarithmic formula equivalents are used to evaluate these functions.
The standard exponential formula equivalents are used to evaluate these functions.


Numeric Algorithms

<table>
<thead>
<tr>
<th>Exponential:</th>
<th>CP-6 LIBRARY</th>
<th>HART</th>
</tr>
</thead>
<tbody>
<tr>
<td>XPE_9DEXP</td>
<td>1067</td>
<td></td>
</tr>
</tbody>
</table>

Gamma-function:

Chebyshev Approximations to the Gamma Function by Helmut Werner and Robert Collinge. Also Hart 5422 when overflow would otherwise occur.

Modulo:

XPE_9DMOD

Natural Logarithm:

XPE_9DLOG 2705
XPE_9PWRII
XPE_9PWRI
XPE_9PWDD 2705

Power:

Golub/Businger algorithm with Powell/Reid strategies for scaling and row interchanging except for square matrices where Gaussian reduction with partial pivoting is used.

Matrix Divide:

Semi Numeric Algorithms

Pseudo-random Number Generation

\[ R = ROLL N; X \]
\[ *(N^2*35)/BIG \]
\[ R = I0 + ln*ROLLM+2*31 \]
\[ +0 \]
\[ BIG*X+ROLLM+(2*31)*lnROLLM+2 \]
\[ R = I0 + ln*X+2*61 \]
\[ \]
Deal Function

\[ \forall R \cdot A \cdot \text{DEAL} \cdot B \cdot I \]

1. \( R \leftarrow 10 \)
2. \( R \leftarrow B \odot i \odot i \odot 10 \)
3. \( B \leftarrow \text{OP} \odot B \leftarrow 1 \cdot A \)
4. \( L \leftarrow (2 \odot A) / X \)
5. \( R \leftarrow B \odot i \odot 10 \cdot R \leftarrow i \odot 0, B \leftarrow i \)
6. \( \leftrightarrow L, i \leftarrow i + 1 \)
7. \( X \leftarrow R \leftarrow A + R \)
8. \( \leftrightarrow 0 \)

\[ \forall \]

CP-6 Dependent Algorithms

Input Conversion:
1. XPN_7NS8TOI,
2. XPN_7NS8TOD

Output Conversion:
1. XPN_7TONSS

Current time:
1. M$TIME \ *

Trace display:
1. fun[n] value
2. fun[n] \odot value
3. fun[n] \# n

Function display:
1. \( \forall \text{fun} \)
2. \( \forall \text{line} \)

Next Definition Line:
1. 99999.9991CURR \# INCRLAST

where CURR is the current line number and INCRLAST is 1 or the value associated with the last digit position entered that overrode a previously prompted line number.

Read Keyboard:
1. CP-6 M$READ monitor service \ *
2. DPS8 instructions: DFAD, ADQ **
3. DPS8 instructions: DFSB, SBQ **
4. DPS8 instructions: DFMP, MPY **
5. DPS8 instructions: DFDV, DFDI, DIV **

Time-Stamip
1. A seven item integer vector containing the current time as: year, month, day, hour, minute, second, and millisecond as returned by M$TIME. *

Pi-Times
1. The closest hardware approximation to \( \pi \) (to 19 digits) times the argument value.

* See CP-6 Host Monitor Services Reference (CE74, CE75)
** See DPS8 Assembly Instructions (DH03)
Array Representation

Arrays in CP-6 APL occupy a minimum of 16 bytes of workspace, where a byte contains 9 bits of information. The total size of the array depends upon the rank and the total number of items in the array.

Character arrays are stored one character in each byte of memory providing 512 possible characters. Numeric arrays are represented in one of four different methods depending, upon the value being represented and the method used to generate the value. Logical arrays are used to represent arrays containing only the values 0 and 1 using one bit, with up to 9 values packed in each byte. Integer arrays are used to represent the integer values -34359738368 to 34359738367 using four bytes for each value. Index sequences are used to represent the result of the index generator function. This representation always occupies 24 bytes of workspace. Finally, floating point arrays are used to represent all other numeric values using 8 bytes of workspace for each value.

Nested arrays are used to represent heterogeneous arrays, and arrays with items which are themselves APL arrays. Each item of a nested array occupies 4 bytes of workspace where each item contains either a simple scalar value or a pointer to another APL array.

Consistent Extensions to the ISO APL Standard

CP-6 APL provides many extensions over the ISO and ANSI APL standards. Some of the extensions are minor (in that almost all APL implementations provide the same extension) while some provide capabilities not generally available in other APL implementations. The use of these extensions in CP-6 APL will make a program non-conformant with the APL Standard. The following is a summary of the extensions that are found in CP-6 APL.

Nested Arrays

CP-6 APL provides a nested array capability where any item of an array may contain another APL array (as a scalar item). The introduction of nested arrays has extended the domain of all scalar functions to nested arrays, of all structural mixed functions to nested arrays, of all operators to nested arrays and the monadic format function creates a display form for a nested array.

In addition to providing nested arrays, CP-6 APL arrays may also contain items of differing types (mixed character and numeric).

Additional Primitive Functions

CP-6 APL provides eight primitive functions which are not present in the APL standard. They are: = (equivalence), monadic † (first), ⊢ (disclose and pick), ⟨ (enclose), monadic © (type), dyadic #: (grade-up), dyadic $ (grade-down), I (I-beam), and T (1-bar).

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Additional Primitive Functions

A-5
Extensions to Primitive Functions

CP-6 APL provides many extensions to the existing primitive functions in addition to those noted under the nested array datatype. Some of these extensions are common extensions to APL made in other implementations.

The dyadic \(^{\wedge}\) (and) function has been extended to permit any numeric value as arguments (as opposed to only 0 and 1). This extension returns the Least-Common-Multiple of the two values.

The dyadic \(\vee\) (or) function has been extended to permit any numeric value as arguments (as opposed to only 0 and 1). This extension returns the Greatest-Common-Divisor of the two values.

The monadic \(\&\) (grade-up) and monadic \(\&\) (grade-down) functions have been extended to sort character data and to sort arrays of any rank.

The left argument of the dyadic \(\div\) (compress) function may contain positive integers less than the maximum index limit. This new function is known as replicate because it replicates the right argument values the number of times specified by the left argument values.

The dyadic \(,\) (join) function does not report a DOMAIN ERR when the types of the left and right argument are different. The nested array extensions permit arrays to contain both character and numeric items. If both arguments are empty, the result type is the prototype of the right argument.

The functions which access the system variable \(\text{OCT}\) (comparision tolerance) will only attempt to access the value if the internal CP-6 APL datatype needs to have \(\text{OCT}\) applied.

The dyadic \(\rho\) (reshape) function does not report a DOMAIN ERR if the right argument is empty. Instead, it fills the resulting array with prototype values (if they are needed).

The monadic \(\&\) (execute) function always returns a value if the execution of the statement is successful. If the statement does not provide a result, execute returns an empty numeric vector. The line to execute may also contain system commands or function-definition-mode commands.

The monadic \(+\) (conjugate) function does not report a DOMAIN ERR if it is provided with an argument of type character. It returns the character value unchanged.

The \[\]~ (indexed assignment) function does not report a DOMAIN ERR when the type of the assigned value is not the same as the type of the name being assigned. The result is an array containing data of both types (numeric and character).

If the left argument of the \(\backslash\) (expand), \(\div\) (compress and replicate) or \(\rho\) (reshape) functions is a singleton, it is treated as a scalar.

If either argument of the dyadic \(?\) (deal) function is a singleton, it is treated as a scalar.

If the right argument of the monadic \(\%\) function is a singleton, it is treated as a scalar.
Additional Primitive Operators

CP-6 APL provides an operator which is not present in the ISO or ANSI APL standards. It is the " (each) operator.

Extensions to Primitive Operators

In addition to the extensions noted under the section on nested arrays, CP-6 APL contains an extension to the \ (scan) operator. A DOMAIN ERR is not reported if the type of the result of applying the function differs from the type of the argument.

All of the operators in CP-6 APL accept any function as an argument, not just a scalar function.

Additional System Functions

CP-6 APL provides many system functions in addition to those defined in the APL standard. These new system functions include:

- AT (set/query function attributes)
- CVT (convert datatypes)
- ERB (signal error)
- EXG (expunge globals)
- FI (fix input)
- FMT (format)
- GRP (group names)
- HDR (output heading)
- IBEX (IBEX expunge)
- IBLET (IBEX let)
- IBNL (IBEX names)
- IDLOC (identifier locations)
- LOK (function lock)
- NCC (nenclass globals)
- NR (room)
- RHC (room globals)
- SC (shared variable state change)
- SCP (string compare)
- SITEID (system siteid)
- TATTR (terminal attributes)
- TCO (terminal echo)
- TIN (terminal input prompt)
- TIX (text index)
- TLEX (text lexemes)
- TR (set/query function trace)
- UTIME (terminal timeout)
- VERSION (APL version)
- VI (verify input)
- XL (translate)

In addition to these system functions, this manual includes discussions of APL File I/O (section 12), APL I-D-S/II Interface (section 13), Packages (section 14), Graphics (section 15), and Blind I/O (section 16) which contains documentation for more CP-6 APL system functions.

Extensions to System Functions

The DL, DLW, STOP and TRACE system functions treat a singleton right argument as a scalar.

Name list arguments (identifier-row in the APL standard) to system functions may contain more than one name per row (separated by blanks or carriage returns). In this case, the result depends upon the number of identifiers found in the argument, not the number of rows in the namelist.

The dyadic STOP (set function stops) and dyadic TRACE (set function trace) system functions permit stopping and tracing line 0.

The FX system function permits its right argument to be a vector with carriage return characters separating lines. This function may also be used dyadically to create a function with specific execution properties.
Extensions to Defined Functions

Dyadic defined functions may be executed monadically.

The result name in the function header may be enclosed in brace brackets to turn off "output potential".

Additional System Variables

CP-6 APL provides the following system variables (which are not in the APL standard):

- OPM (platen width), ODS (positioning and spacing).

Extensions to System Variables

The value assigned to the system variables IO (index origin), OPP (print precision) and OCT (comparison tolerance) may be a singleton of any rank.

Additional System Commands

CP-6 APL contains many system commands in addition to those defined by the APL standard. (See section 8 for complete descriptions of these commands.)

The additional commands supplied in CP-6 APL are: )CATCH, )CONTINUE, )DIGITS, )EDITOR, )END, )ERROR, )GO, )GROUP )GRP, )GRPS, )IBEX, )LINK, )WMS, )OBSERVE, )OFF, )OPR, )OPRN, )ORIGIN, )PCOPY, )QCOPY, )QLOAD, )QPCOPY, )QUIT, )REPORT, )RESET, )SALVAGE, )SEAL, )SET, )SIL, )SIV, )STEP, )TERMINAL, and )WIDTH.

All of the system command names can be abbreviated to the first four characters.

Extensions to System Commands

A CP-6 APL workspace identifier may contain additional characters to those defined in the APL standard. The characters are: $, :, _, and -. The workspace identifier may be followed by a period, an 8 character account identifier and optionally followed by another period and an 8 character password.

The )COPY command copies groups (see section 8) and more than one name may be specified in the copy list.

The )DROP command with no workspace identifier drops the workspace created by the )CONTINUE command (see section 8).

The )ERASE command permits more than one name to be specified to be erased.

The )FNS and )VARS commands permit two names to be specified which are used to delimit the start and end of the list of names to display.

The )LIB command permits an account name to be specified.

The )SI and )SINL commands indicate when an execute or quad entry is found in the state indicator. These commands also permit the keyword options ON, OFF and CLEAR to be specified.
Miscellaneous Extensions

The quote quad output prompt may be formed by assignment to \( ~ \) multiple times. The value assigned to \( ~ \) is permitted to be any APL array. If an APL statement begins with the left pointing arrow (assignment arrow), default output that would have been generated by the statement is not displayed.

During \( \langle \rangle \) input, defined functions may be modified or created, and system commands may be issued.

When an identifier exceeds the identifier length limit, an error is not reported. Instead, the name is truncated to the limit.

Vector notation may be used to create nested arrays.

Vector assignment may be used to assign the values of a vector to a list of identifier names.

Selective assignment may be used to modify items of an array.
Appendix B

CP-6 APL Character Set

The appendix describes the atomic vector for CP-6 APL. The CP-6 APL atomic vector (oAV) is a character vector of length 512. The last 256 character positions of this vector are not assigned any meaning and are not permitted to appear in APL expressions.

In the following table each of the first 256 elements of oAV are described in terms of their position, the ascii characters to enter on non-APL terminals, the APL character, the APL characters that form the overstrike and the name of the character. Some of these characters are unassigned and do not have a meaning.

APL characters which have no corresponding character in ASCII may be entered as mnemonics. Mnemonics are introduced by the $ character and are followed by 1, 2 or 3 characters which are mapped into the internal APL character during input processing. When the introducer is not followed by a defined mnemonic, the characters entered are passed through the APL input routine. This permits the $ character to be entered in normal input. A true dollar sign can be entered where it could be interpreted as a mnemonic by doubling it. That is, $$ is always a single dollar sign.
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Appendix C

Error Messages

Table C-1 is an alphabetic listing of possible APL error messages. The first column contains the message and the second column contains explanatory details and recovery procedures where appropriate. The effects of error detection on APL processing are described in more detail in Section 10.

<table>
<thead>
<tr>
<th>Message</th>
<th>Description</th>
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<tr>
<td>name NOT COPIED</td>
<td>The item has the same name as a pendent function in the active workspace.</td>
</tr>
<tr>
<td>name NOT ERASED</td>
<td>The item name in an )ERASE command was not erased because it was a pendent function.</td>
</tr>
<tr>
<td>name NOT FOUND</td>
<td>The item named in a )COPY command was not found (the item may have been a local variable).</td>
</tr>
<tr>
<td>ABORTED BY BRK OR CTRL-Y</td>
<td>An enqueue request has been aborted by the user (pertains to shared files).</td>
</tr>
<tr>
<td>BAD CHAR</td>
<td>A bad input character was detected. This is usually the result of a transmission error or the input of an illegal overstrike. In the case of nonstandard I/O devices, the message can also indicate the input of a character which is &quot;illegal&quot; for that device.</td>
</tr>
<tr>
<td>BAD COMMAND</td>
<td>An improper command construct was detected.</td>
</tr>
<tr>
<td>BAD FILE REF</td>
<td>A bad reference to an existing file name was made during a )SAVE command. This could occur, for example, if the workspace name specified in the )SAVE command referenced some existing workspace that was protected by a password. The )SAVE command should be respecified using a different workspace name. This message will also result on a )CONTINUE command if a passworded CONTINUE workspace already exists.</td>
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<tr>
<td>Message</td>
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<tr>
<td>BROKEN WORKSPACE</td>
<td>Damaged workspace reported during loading. It may be possible to copy specific items from the broken workspace with the ( )\SALVAGE ( )\ command.</td>
</tr>
<tr>
<td>DEADLOCK</td>
<td>An enqueue request has been made (pertaining to shared files) which, if honored, would create a deadlock stopping further activity of two or more users.</td>
</tr>
<tr>
<td>DEFN ERR</td>
<td>This message is output for any sort of error in function definition, such as misplaced del symbol (( )), improper syntax of header editing, or an attempt to edit a pendent function.</td>
</tr>
<tr>
<td>DOMAIN ERR</td>
<td>The indicated argument is of the wrong type or out of the proper range for the specific function or for the other argument. Examples are character data input for a numeric operation, or numbers input for a logical operation which do not reduce to 0 or 1. See the domain tables in Section 5 for examples of acceptable types of argument data for each APL function.</td>
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<tr>
<td>ENQ FULL</td>
<td>The CP-6 Enqueue tables are full.</td>
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<tr>
<td>FILE ACCESS ERR</td>
<td>This file I/O error often means a password is missing or is incorrect.</td>
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<tr>
<td>FILE DAMAGE</td>
<td>This file I/O error indicates some damage to the file contents was discovered, but not necessarily to every record or component in the file. Recovery is often possible by copying undamaged material to a new file, replacing damaged items.</td>
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<tr>
<td>FILE IN USE</td>
<td>The file named in a ( )\SAVE ( )\ command is currently in use, i.e., another user may be simultaneously executing a load of that file. Since this situation is a momentary timing conflict, the user should retry the command after a short wait. This type of timing conflict may also occur when using file I/O.</td>
</tr>
<tr>
<td>Message</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>FILE INDEX ERR</td>
<td>This file I/O error may mean that an index (record identifier, sometimes called a key) is incorrect, or an attempt has been made to read beyond the limits of a file.</td>
</tr>
<tr>
<td>FILE I/O ERR nnn-xxxxx-s</td>
<td>This is a general file I/O error message. It indicates errors detected by the monitor and corresponds to I/O error codes shown in the CP-6 Programmer Reference Manual (CE46).</td>
</tr>
<tr>
<td>FILE NAME ERR</td>
<td>This file I/O error may mean that a file identifier is improperly formatted, an attempt has been made to use a file that does not exist, or an attempt has been made to create a file that already exists.</td>
</tr>
<tr>
<td>FILE SPACE TOO LOW</td>
<td>Either the user's or the packset's file space limit has been reached. This can occur when workspaces are being saved or during file I/O operations. Recovery is usually possible; the user drops unneeded files from his account and retries the aborted statement.</td>
</tr>
<tr>
<td>FILE TBL FULL</td>
<td>This file I/O error means that the maximum permissible number of files have been &quot;tied&quot; (designated).</td>
</tr>
<tr>
<td>FILE TIE ERR</td>
<td>This file I/O error may mean either that the file has not yet been opened (designated as an input or output stream), or that the file being opened has already been opened, or that an attempt has been made to write into a file owned by another user.</td>
</tr>
<tr>
<td>FORMAT SYNTAX ERR</td>
<td>A syntax error was detected in the left argument of a OFHT expression. See Section 9 for an explanation of correct syntax.</td>
</tr>
<tr>
<td>I/O ERR</td>
<td>This message indicates that an irrecoverable system I/O error occurred and an error exit has been made from APL. A system I/O error should be reported to the user's field representative along with the conditions under which it occurred (see also SYS ERR).</td>
</tr>
<tr>
<td>Message</td>
<td>Description</td>
</tr>
<tr>
<td>------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>I/O ERR nnn-xxxxx-s</td>
<td>If blind I/O was being used, this message indicates that the requested blind read or write could not be executed for some reason. The user may retry the I/O or otherwise continue operation. The error codes are described in the CP-6 Programmer Reference Manual (CE40).</td>
</tr>
<tr>
<td>INDEX ERR</td>
<td>The index subscript specified in an expression is out of the range of the particular array to which it is applied. For example, if A is a four-item vector, the expression A[6] would generate an INDEX ERR since the requested sixth item does not exist.</td>
</tr>
<tr>
<td>LENGTH ERR</td>
<td>The length(s) of the indicated argument(s) are not conformable or are incorrect for the function used. For example, the expression 9 7 8 + 5 3 results in a LENGTH ERR because the two vectors do not have the same number of items.</td>
</tr>
<tr>
<td>LINSCAN ERR</td>
<td>An obvious error in form (leading right bracket, misplaced colon line ending with a function, etc.) was detected in the scan of a line input for execution or function definition. No part of the line is executed. In function definition mode, the line is entered as part of the function and may then be replaced or edited.</td>
</tr>
<tr>
<td>NO RESULT</td>
<td>A defined function that generated no result was used in a context that requires a result.</td>
</tr>
<tr>
<td>NO SHARES</td>
<td>Another user logged onto the same account is using shared variables. Create a unique account identifier with the OSVN system function. If the shared variable administrator is not available or has become unavailable, this message is reported and the APL user may no longer access the variables he may have previously shared.</td>
</tr>
<tr>
<td>NOT APL FILE</td>
<td>This file I/O error means that a component read failed because it did not have the structure required by APL.</td>
</tr>
<tr>
<td>Message</td>
<td>Description</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>NOT GROUPED</td>
<td>The group name specified in a )GROUP or )GRP command references an existing item which is not a group. A different group name must be used.</td>
</tr>
<tr>
<td>NOT HELD</td>
<td>The OFDEQ system function specified a file and resource that is not currently enqueued.</td>
</tr>
<tr>
<td>NOT SAVED, THIS WS IS name</td>
<td>If &quot;name&quot; = CLEAR WS, either there is nothing to save or the )SAVE command did not specify a name for the saved workspace. Otherwise, the )SAVE command named an existing saved workspace and the active workspace name is different. Change the active workspace name or drop the saved workspace.</td>
</tr>
<tr>
<td>OPEN QUOTE</td>
<td>The Execute function has been used on an argument that has an odd number of quotes before the end of the line (or first embedded carriage return).</td>
</tr>
<tr>
<td>RANK ERR</td>
<td>The rank of the indicated argument is incompatible with the function or with that of the other argument.</td>
</tr>
<tr>
<td>SEALED WS</td>
<td>An attempt was made to save a sealed workspace.</td>
</tr>
<tr>
<td>SI DAMAGE</td>
<td>A suspended function has been erased or replaced, and the state indicator has been modified to delete all references to it from its active list. This may occur in function definition, or upon execution of an )ERASE or )COPY command.</td>
</tr>
<tr>
<td>SI DAMAGE WILL RESULT: PROCEED?</td>
<td>This warning message is output in function definition when the header of an existing active function is changed. It indicates that references to this function in the state indicator list will be damaged if the header change is implemented. In order to avoid SI damage, the user may restore the header to the old form or change the function name in the header before closing the function. The user types YES in reply to the warning message.</td>
</tr>
<tr>
<td>Message</td>
<td>Description</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>SING. MATRIX</td>
<td>The right argument of a matrix divide operation ((A)) is a singular matrix, i.e., it had no inverse.</td>
</tr>
<tr>
<td>SV QUOTA EXHAUSTED</td>
<td>The APL user may share up to 16 variables at any one time. This message is reported if the user attempts to share another variable.</td>
</tr>
<tr>
<td>SYNTAX ERR</td>
<td>Improper syntax was detected in the executed line. Examples of improper syntax are unbalanced parenthesis or an attempt to assign a value to a label.</td>
</tr>
<tr>
<td>SYSTEM ERR</td>
<td>An irrecoverable system error of indeterminate origin has occurred and an error exit has been made from APL. If APL is reaccessed, it should operate correctly unless the conditions which led to the SYSTEM ERR recur. Please report these problems to Honeywell.</td>
</tr>
<tr>
<td>TOO BIG</td>
<td>A )COPY command refers to more material than would fit in the current workspace; no items were copied.</td>
</tr>
<tr>
<td>TOO BIG TO LOAD</td>
<td>The workspace specified in a )LOAD command was saved by a user with larger memory allocation than the present user, and there is insufficient space for the workspace to be loaded (in some cases it cannot even be copied). See also the description of the )COPY command, Section 8.</td>
</tr>
<tr>
<td>TRUNCATED INPUT</td>
<td>The input line was too long.</td>
</tr>
<tr>
<td>UNDEFINED</td>
<td>The indicated symbol has not been assigned a value.</td>
</tr>
<tr>
<td>WS FULL</td>
<td>The active workspace is full. This may occur during execution, in function definition, or because of a )GROUP command. Depending on the particular situation, the user may choose to use an )ERASE command to erase unneeded objects from the workspace, clear the state indicator, or )CLEAR the entire workspace in order to free up space.</td>
</tr>
<tr>
<td>Message</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>WS NOT FOUND</td>
<td>The workspace file specified in a <code>LOAD</code> or a <code>COPY</code> command was not found.</td>
</tr>
</tbody>
</table>
Appendix D

CP-V Compatible Workspace Functions

CP-6 APL provides a set of intrinsic functions, \( \Delta CR \), \( \Delta WH \), and \( \Delta TE \) to aid in conversion from CP-V to CP-6. This appendix is provided for CP-V conversion purposes only. CP-6 APL provides more powerful system functions to perform these tasks.

Canonical Representation

The \( \Delta CR \) intrinsic function converts user functions to character form, creates user-defined functions, and locks existing functions.

Function to Text

\( R+1 \ \Delta CR \ A \)

If \( A \) is not a character vector representing a valid name in APL, \( \text{DOMAIN ERR} \) is reported.

If \( A \) contains a name which does not represent a user-defined function in the dynamic environment, \( \text{DEFN ERR} \) is reported.

If no error is indicated, \( R \) is a character vector consisting of lines of the defined function with embedded carriage returns as separators.

Text to Function

\( R+2 \ \Delta CR \ LL \)

If \( LL \) is not a linelist, \( \text{DOMAIN ERR} \) results.

\( \text{DEFN ERR} \) is reported if the 'header' line is not in the proper format for a function or if the function name has an active referent which is not a user function.

If no errors occur, a defined function, with the name specified by \( LL \), is created.

\( R \) is a character vector indicating the name of the function created.

Locking Function

\( R+3 \ \Delta CR \ NL \)

\( NL \) must be a namelist. For each name in \( NL \), if the current referent is a function, it is locked. If not, the name is included in \( R \).

\( R \) is a character vector consisting of any names in \( NL \) which were not current function names.
Intrinsic To Text

\( R+4 \ \Delta CR \ A \)

\( R \) is a character vector containing the name of the intrinsic mentioned in \( A \), an assignment arrow, and the particular intrinsic definition statement that defined the named intrinsic.

Workspace Management

The workspace management function, \( \Delta WH \), is a dyadic intrinsic function providing a variety of operations described below.

Expunge, Local (Active)

\( R+1 \ \Delta WH \ NL \)

\( NL \) must be a namelist. The active referents of names found in \( NL \) are erased. \( R \) is a namelist of any names for which referents were found but not erased.

Expunge, Global

\( R+2 \ \Delta WH \ NL \)

Same as \( 1 \ \Delta WH \ NL \) except that only global referents of names are erased.

List Workspace Named Items

\( R+3 \ \Delta WH \ I \)

The value of \( I \) must be an integer from 1 to 6. \( R \) is a character vector with carriage returns separating the names. The entities named depend on \( I \).

1 Category Listed
   1 Labels.
   2 Active variables.
   3 Active functions.
   4 Groups.
   5 Global variables.
   6 Global functions.

List Elements of a Group

\( R+4 \ \Delta WH \ A \)

\( A \) must be a character vector containing one name. \( R \) is a character vector with names of the members of group \( A \).

List Workspace Parameters

\( R+5 \ \Delta WH \ I \)

The value of \( I \) must be an integer from 1 to 8. \( R \) depends on the value of \( I \).

1 WSID as character vector.
2 State indicator as character vector with embedded line feeds.
3 Origin as integer.
4 Width as integer.
5 Digits as integer.
6 Symbol table size.
7 Number of symbols still available.

Compatible Workspace Functions
Identify Local Use of Names

R+6 ΔWH NL

The namelist NL is scanned for current use of the names. R is a numeric vector. Values are as indicated.

0 No current referent.
1 Logical variable.
2 Character variable.
3 Integer variable.
4 Real variable.
5 Index sequence.
7 Label.
8 User-defined function, niladic, no result.
9 User-defined function, niladic, with result.
10 User-defined function, monadic, no result.
11 User-defined function, monadic, with result.
12 User-defined function, dyadic, no result.
13 User-defined function, dyadic, with result.
14 Intrinsic function, dyadic.
15 Intrinsic function, monadic.
16 Intrinsic function, niladic.
17 Group.

Identify Global Use of Names

R+7 ΔWH NL

Similar to 6 ΔWH except that global use of names is indicated.

List Storage Requirements for Named Active Items

R+8 ΔWH NL

NL is a namelist. R is a numeric vector. Each item of R is the number of bytes of workspace occupied by the active referent.

List Storage Requirements for Named Global Items

R+9 ΔWH NL

NL is a namelist. R is a numeric vector. Each item of R is the number of bytes of workspace occupied by the global referent of the corresponding name.

Text Editing

The character editing function, ΔTE, provides five capabilities, described below, to facilitate the examination and modification of character variables in APL.

Text Index Function

R+1 ΔTE L

L is a 'list' with two items.

L+1 ΔTE (TV;DV)

TV may be any character vector.

DV is a character scalar or vector of 'delimiters'.

R is an N-by-2 numeric matrix. Each row contains the index and length of a string of non-delimiter characters in TV. The values of column 1 of R are I/O dependent.
Substring Search

R+2 ΔTE L

L must be a list with 2, 3, or 4 items.

R+2 ΔTE (TV;SS)

TV may be any character vector.

SS may be any character scalar or vector not longer than TV.

L+2 ΔTE (TV;SS;FCOL)

FCOL may be any integer scalar value such that FCOL is less than or equal to the highest index value of TV. FCOL indicates the first column in TV at which search is to start or

L+2 ΔTE (TV;SS;FCOL;LCOL)

LCOL may be any integer scalar value less than or equal to the highest index value of TV and greater than or equal to FCOL. LCOL is the last column of TV involved in the search.

R is a numeric vector with the beginning indexes of non-overlapping occurrences of SS in TV, starting at position FCOL and ending at LCOL.

Substring Search and Replacement

R+3 ΔTE L

L must be a list of 3, 4, or 5 items.

L+3 ΔTE (TV;SS;RS)

TV may be a character scalar or vector.

SS may be a character scalar or vector not longer than TV.

RS may be any character scalar or vector.

R is a character vector formed by replaced occurrences of SS, in TV, by RS. Replacement is on a non-overlap basis. Or

L+3 ΔTE (TV;SS;RS;FCOL)

FCOL may be any integer scalar value such that FCOL is less than or equal to the highest index value of TV. FCOL may also be null.

L+3 ΔTE (TV;SS;RS;FCOL;LCOL)

LCOL may be any integer scalar value less than or equal to the highest value of TV and greater than or equal to FCOL.

Substring Replacement (Without Search)

R+4 ΔTE L

L is a list with 4 items.

L+4 ΔTE (TV;RS;FCOL;LCOL)

TV must be a non-empty character vector.

RS must be a character vector or scalar. It may be empty.

FCOL must be an integer scalar representing a valid index of TV.

LCOL must be an integer scalar representing a valid index of TV. LCOL must be greater than or equal to FCOL.
String Comparison

\[ R = 5 \Delta E L \]

L must be a list with two items:

\[ L = 5 \Delta E (A;B) \]

A and B must be character vectors or character scalars.

R is a two-item numeric vector describing the comparison of A and B. Comparison is based on the ASCII collating sequence as modified to support the CP-6 APL character set.

The first item of R indicates which item of L should be first in left to right sorted order.

- 0 means the character vectors are identical.
- 1 means A should sort first.
- 2 means B should sort first.

The second item of R indicates the lowest position I at which A[I] and B[I] differ.

If A and B are identical, the second item of R is -1. Thus R is 0 -1.

If B is longer than A but A[I] = B[I] that is B differs from A only by being longer, then A is considered first in sorting order and R is 1 -1.

If A is longer than B, but each B[I] = A[I] then R is 2 -1.

T-bar Functions

The T-bar function, \( \top \) (the encode character, T, overstruck by the negative sign, \( - \)) is provided for certain system interfaces.

One use of T-bar is the character generator function. It converts integer data into corresponding character data, and thus allows the user to generate special characters, possibly unrecognized by APL. The integer n corresponds to the nth character in the table of APL Codes. This is equivalent to indexing \( \text{AV} \).

To generate the nth character, the following form is used.

\[ 2^{\top} n \]

The left argument must be the scalar integer 2; this designates that the T-bar function is to be used for character generation. The right argument may have any shape, but its domain must be integer, with values between 0 and 511. The result has a shape identical to the right argument, but is character data.

File Input/Output

CP-6 APL provides more functionality than is available with these functions through the system functions discussed in section 12. The file intrinsic is:

\[ \text{A fname B} \]

where

A is the I/O operation number (ranging from 1 to 29).
B is the argument applicable to the I/O operation.
Opening and Creating Files

Following are the forms for the set of functions required to establish parameters prior to opening a stream to a file.

- Establishing "file number":
  1 \texttt{fname} \texttt{B}

  where \texttt{B} is a positive integer specifying the file number to be used for subsequent file operations.

- Establishing file name:
  2 \texttt{fname} \texttt{B}

  where \texttt{B} is a character vector specifying the file name for the currently set file number.

- Establishing or resetting account:
  2 \texttt{fname} \texttt{B}

  where \texttt{B} is either zero or a character vector specifying the account for the currently set file number.

- Establishing or resetting password:
  4 \texttt{fname} \texttt{B}

  where \texttt{B} is either zero or a character vector specifying the password for the currently set file number.

- Establishing file identification as a single primitive:
  21 \texttt{fname} \texttt{fid}

  where \texttt{fid} is a character vector specifying a CP-6 file identifier in the same format permitted for system commands such as \texttt{LOAD}.

- Assigning serial numbers for pack set utilization:
  20 \texttt{fname} \texttt{B}

  where \texttt{B} is a character vector of up to 6 characters, or the numeric value 0.

- Opening stream in indicated mode:
  5 \texttt{fname} \texttt{B}

  If \texttt{B} is an integer specifying the mode of DCB for the currently set file number, as follows:

  1 indicates \texttt{FUN=IN,DISP=NAMED,EXIST=OLDFILE}.
  2 indicates \texttt{FUN=CREATE,DISP=NAMED,EXIST=NEWFILE}.
  4 indicates \texttt{FUN=UPDATE,DISP=NAMED,EXIST=OLDFILE}.
  8 indicates \texttt{FUN=CREATE,DISP=SCRATCH,EXIST=NEWFILE}.
  17 indicates \texttt{FUN=CREATE,DISP=NAMED,EXIST=ERROR,TEST=YES}.
  20 indicates \texttt{FUN=UPDATE,DISP=NAMED,EXIST=OLDFILE,SHARE=ALL}.
Closing Files

- Closing and saving the file for indicated file numbers:
  6 fname B
  where B is an integer specifying the file number.

- Closing and releasing the file for indicated file number:
  7 fname B
  where the argument B is the same as above. (This form is used to delete files.)

Maintaining Key Range and Current Key Value

When files are created by APL or accessed in other than sequential mode, primitives are provided to find the key range of an existing file. When a file is opened in CREATE mode, values for the ‘first component’ and ‘last component’ are initialized to empty vectors and updated when the first record is written.

- Return the value of a designated key for the currently set file number:
  8 fname B
  where B is 1, 2, or 3, specifying which key the value is to be returned for (the key returned will be that for the currently open file, if any, of the most recently referenced file number):

  1 indicates that the value of the first key in the file.
  2 indicates that the value of the current key is to be returned.
  3 indicates that the value of the highest key is to be returned.

- Setting the value of the current key for the currently set file number:
  9 fname B
  where B is an integer or character vector specifying the value for the current key.

Writing APL Records

- Writing a record containing the value of an expression:
  10 fname expression
  The currently set key value and file number are used.

- Writing a component:
  11 fname expression
  The record contains the time, date, and the user's account and name, and the expression value. The currently set key value and file number are used.

Writing Non-APL Records

Data records may be written that do not retain the APL internal attributes of 'shape' and other internal reference data.

22 fname B
where B is any APL expression. The data represented by B is written as a single record in ravel order. If B is a logical vector the length is rounded up to a multiple of 9 bits.
Reading APL Records

- Reading a data record:
  12 fname B
  where B is an integer specifying the size of the data record in bytes. The data record is read using current key and file number.

- Reading a component datablock:
  13 fname B
  where B is an integer specifying the key value.

- Reading a component user/time stamp:
  14 fname B
  where B is an integer specifying the key value. The identification record is returned as a character vector with the following format:

<table>
<thead>
<tr>
<th>DATE</th>
<th>bb</th>
<th>TIME</th>
<th>ACCT</th>
<th>UNAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>16</td>
<td>17</td>
<td>24</td>
<td>25</td>
<td>36</td>
</tr>
</tbody>
</table>

Reading Non-APL Records

- 23 fname B
  Reads a non-APL record using currently set key and file number. B is an integer specifying the record size in bytes. The result is a character vector.

Deleting Records Or Components

- Deleting a specified record:
  15 fname B
  16 fname B
  where B is an integer specifying the key value. The current file number is used in deleting the record.

Sequential Access to Existing APL Files

- 17 fname B
  where B is an integer specifying the size of the record in bytes. Records are read sequentially, using the current file number. If an integer of zero is specified, the record is accessed but data is not read, regardless of actual record size.

- 13 fname 0
  This is similar to "13 fname B" except that it reads the next record. If it is not a component record, records are skipped until a component record is reached. At end of read, the current key is set to that of the last record read. If no component record is found, an error is reported.

- 14 fname 0
  This is similar to "14 fname B" except that it skips forward to next component record. The current key is updated. If no component record is found, an error is reported.
Sequential Access to Non-APL Files

24 fname B

where B is an integer specifying the size of the record in bytes. Records are read sequentially, using the current file number. Operation is analogous to 23 fname B except that the read is sequential rather than keyed.

Converting Data Types

Primitives 23 and 24, for reading non-APL records, create character vector results.

- Convert character vector to logical vector.

25 fname B

where B is a character vector. The result is a logic vector consisting of the actual data in B.

- Convert character vector to integer vector.

26 fname B

where B is a character vector. The length must be a multiple of 4. The result is an integer vector consisting of the actual data in B.

- Convert character vector to real vector.

27 fname B

where B is a character vector. The length must be a multiple of 8. The result is a numeric vector consisting of the actual data in B.

Controlling Access to Shared Files

The following features are provided to permit the user to lock out records of a file for purposes of reading without other intervening updates or completing an update without interference.

- Locking out a record.

28 fname B

B is a key value. Causes the designated record to be enqueued for exclusive use.

- Releasing a locked record.

29 fname B

B is a key value.

Listing File Names and Numbers

These operations may be used in functions designed to list file components by number, with or without contents of the records.

- File names in a specified account

18 fname B

where B is a character vector specifying a user account. Result is a character matrix. Each row has account in columns 1 through 8 and file name in columns 10 through 40.

- Names or numbers of currently open files

19 fname B
where \( B \) is an integer specifying the structure of the result as follows:

1. indicates a character matrix with names of currently open files, one file per row.
2. indicates a numeric vector with the currently open file numbers.
Appendix E
Honeywell CP-6 APL Summary

Scalar Primitive Functions

All scalar functions are applied item-by-item on all operands at all levels of nesting. A scalar or single item array may be used as an argument of a scalar dyadic function and its value is applied to all items of the other argument.

Table E-1. Scalar Monadic Functions

<table>
<thead>
<tr>
<th>Form</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>+Y</td>
<td>Conjugate of Y (Y)</td>
</tr>
<tr>
<td>-Y</td>
<td>Negate Y (0-Y)</td>
</tr>
<tr>
<td>*Y</td>
<td>Sign of Y (-1, 0, 1)</td>
</tr>
<tr>
<td>Y</td>
<td>Reciprocal of Y (1/Y)</td>
</tr>
<tr>
<td>&quot;Y</td>
<td>e to the Y'th power</td>
</tr>
<tr>
<td>IY</td>
<td>Ceiling of Y (round up)</td>
</tr>
<tr>
<td>LY</td>
<td>Floor of Y (round down)</td>
</tr>
<tr>
<td>Y</td>
<td>Absolute value of Y</td>
</tr>
<tr>
<td>@Y</td>
<td>Natural logarithm of Y</td>
</tr>
<tr>
<td>Y</td>
<td>Factorial of Y (Gamma of Y+1)</td>
</tr>
<tr>
<td>OY</td>
<td>Pi times Y</td>
</tr>
</tbody>
</table>

Table E-2. Scalar Dyadic Functions

<table>
<thead>
<tr>
<th>Form</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>X+Y</td>
<td>Add Y to X</td>
</tr>
<tr>
<td>X-Y</td>
<td>Subtract Y from X</td>
</tr>
<tr>
<td>X*Y</td>
<td>Multiply Y by X</td>
</tr>
<tr>
<td>X\Y</td>
<td>Divide Y into X</td>
</tr>
<tr>
<td>X^Y</td>
<td>X raised to the power Y</td>
</tr>
<tr>
<td>X&gt;/Y</td>
<td>Maximum of X and Y</td>
</tr>
<tr>
<td>X&lt;Y</td>
<td>Minimum of X and Y</td>
</tr>
<tr>
<td>X</td>
<td>R\Y</td>
</tr>
<tr>
<td>X&gt;</td>
<td>Y</td>
</tr>
<tr>
<td>X&lt;Y</td>
<td>Greatest common divisor of X and Y (or)</td>
</tr>
<tr>
<td>X!Y</td>
<td>Binomial coefficient. Number of combinations of Y things taken X at a time</td>
</tr>
<tr>
<td>X</td>
<td>Y</td>
</tr>
<tr>
<td>X]Y</td>
<td>Circular functions:</td>
</tr>
<tr>
<td>00Y</td>
<td>(1-Y*2)*0.5</td>
</tr>
<tr>
<td>10Y</td>
<td>sine Y</td>
</tr>
<tr>
<td>20Y</td>
<td>cosine Y</td>
</tr>
<tr>
<td>30Y</td>
<td>tangent Y</td>
</tr>
<tr>
<td>40Y</td>
<td>(1+Y*2)*0.5</td>
</tr>
<tr>
<td>50Y</td>
<td>sinh Y</td>
</tr>
<tr>
<td>60Y</td>
<td>cosh Y</td>
</tr>
<tr>
<td>70Y</td>
<td>tanh Y</td>
</tr>
<tr>
<td>-0Y</td>
<td>arcsin Y</td>
</tr>
<tr>
<td>-20Y</td>
<td>arccos Y</td>
</tr>
<tr>
<td>-30Y</td>
<td>arctan Y</td>
</tr>
<tr>
<td>-40Y</td>
<td>arcsinh Y</td>
</tr>
<tr>
<td>-60Y</td>
<td>arccosh Y</td>
</tr>
<tr>
<td>-70Y</td>
<td>arctanh Y</td>
</tr>
</tbody>
</table>
The relational and logical functions obey the rules of scalar conformability and return 0 if the condition is false, and 1 if true.

<table>
<thead>
<tr>
<th>Form</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>X&lt;Y</td>
<td>X less than Y</td>
</tr>
<tr>
<td>X≤Y</td>
<td>X less than or equal to Y</td>
</tr>
<tr>
<td>X&gt;Y</td>
<td>X greater than Y</td>
</tr>
<tr>
<td>X≥Y</td>
<td>X greater than or equal to Y</td>
</tr>
<tr>
<td>X=Y</td>
<td>X equal to Y</td>
</tr>
<tr>
<td>X≠Y</td>
<td>X not equal to Y</td>
</tr>
</tbody>
</table>

The following functions operate on arguments which are 0 or 1.

<table>
<thead>
<tr>
<th>Form</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>X·Y</td>
<td>X and Y (1 if both X and Y are 1)</td>
</tr>
<tr>
<td>X∨Y</td>
<td>X or Y (1 if either X or Y is 1)</td>
</tr>
<tr>
<td>X nand Y</td>
<td>not both X and Y</td>
</tr>
<tr>
<td>X nor Y</td>
<td>X nor Y (neither X nor Y)</td>
</tr>
<tr>
<td>¬Y</td>
<td>not Y</td>
</tr>
</tbody>
</table>
### Mixed Functions

#### Table E-4. Mixed Functions

<table>
<thead>
<tr>
<th>Form</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>XPY</td>
<td>Reshape Y to dimensions X.</td>
</tr>
<tr>
<td>PY</td>
<td>Shape of Y.</td>
</tr>
<tr>
<td>X:Y</td>
<td>Index of first occurrence of Y within X.</td>
</tr>
<tr>
<td>t:Y</td>
<td>First Y consecutive integers from index origin.</td>
</tr>
<tr>
<td>XY</td>
<td>1 if X occurs in Y, otherwise 0.</td>
</tr>
<tr>
<td>1Y</td>
<td>Type of Y.</td>
</tr>
<tr>
<td>X:Y</td>
<td>1 if X and Y are identical, otherwise 0.</td>
</tr>
<tr>
<td>z:Y</td>
<td>Maximum nesting depth of Y.</td>
</tr>
<tr>
<td>X(N)Y</td>
<td>Representation of Y in number system X.</td>
</tr>
<tr>
<td>X(1)Y</td>
<td>Value of Y in number system X.</td>
</tr>
<tr>
<td>X:YY</td>
<td>X integers selected randomly without repetition from Y (deal).</td>
</tr>
<tr>
<td>Y</td>
<td>A random integer from Y.</td>
</tr>
<tr>
<td>XQY</td>
<td>Y rotated along last dimension by X.</td>
</tr>
<tr>
<td>XR</td>
<td>Y rotated along first dimension by X.</td>
</tr>
<tr>
<td>X(W)Y</td>
<td>Y rotated along the N'th dimension by X.</td>
</tr>
<tr>
<td>(Y</td>
<td>Y reversed along last dimension.</td>
</tr>
<tr>
<td>(Y</td>
<td>Y reversed along first dimension.</td>
</tr>
<tr>
<td>(W)Y</td>
<td>Y reversed along the N'th dimension.</td>
</tr>
<tr>
<td>XSY</td>
<td>Transpose of Y by coordinates in X.</td>
</tr>
<tr>
<td>(Y</td>
<td>Transpose of Y (by reversing all coordinates).</td>
</tr>
<tr>
<td>X.Y</td>
<td>X joined to Y along the last coordinate.</td>
</tr>
<tr>
<td>X.(N)Y</td>
<td>If N is an integer, X is joined to Y along the N'th coordinate of X; otherwise, X and Y are joined (laminated) along the new (N) coordinate.</td>
</tr>
<tr>
<td>(Y</td>
<td>Ravel of Y (make Y a vector).</td>
</tr>
<tr>
<td>X+Y</td>
<td>Take the first (X) items from Y ((X&gt;0)) or take the last ((IX)) items from Y ((X&lt;0)).</td>
</tr>
<tr>
<td>+Y</td>
<td>Disclose the first item from Y.</td>
</tr>
<tr>
<td>X*Y</td>
<td>Drop the first (X) items from Y ((X&gt;0)) or drop the last ((IX)) items from Y ((X&lt;0)).</td>
</tr>
<tr>
<td>X(Y)</td>
<td>The indices of Y select items (or rows) of Y in increasing order of magnitude using the collating sequence X.</td>
</tr>
<tr>
<td>(Y</td>
<td>The indices of Y select items of Y in increasing order of magnitude.</td>
</tr>
<tr>
<td>X(Y)</td>
<td>The indices of Y select items (or rows) of Y in decreasing order of magnitude using the collating sequence X.</td>
</tr>
<tr>
<td>(Y</td>
<td>The indices of Y which select items of Y in decreasing order of magnitude.</td>
</tr>
<tr>
<td>cY</td>
<td>Enclose of array Y (make a nested scalar).</td>
</tr>
<tr>
<td>c(W)Y</td>
<td>Enclose along selected axes of Y.</td>
</tr>
<tr>
<td>&gt;Y</td>
<td>Disclose Y, by decreasing depth and increasing rank.</td>
</tr>
<tr>
<td>&gt;(N)Y</td>
<td>Disclose Y, inserting new axes at (N).</td>
</tr>
<tr>
<td>X(Y)</td>
<td>Select item from array Y at depth ((pX)).</td>
</tr>
<tr>
<td>eY</td>
<td>Inverse of matrix Y.</td>
</tr>
<tr>
<td>(X)Y</td>
<td>Matrix division (least squares fit).</td>
</tr>
<tr>
<td>(X)Y</td>
<td>Format Y according to specifications in X.</td>
</tr>
<tr>
<td>(Y</td>
<td>Format of Y.</td>
</tr>
<tr>
<td>(Y</td>
<td>Evaluate APL expression contained in Y.</td>
</tr>
</tbody>
</table>
### Primitive Operators

In the following examples, f and g stand for any dyadic function and h stands for a monadic function.

<table>
<thead>
<tr>
<th>Form</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>f/Y</td>
<td>reduction along the last dimension of Y</td>
</tr>
<tr>
<td>f/[N]Y</td>
<td>reduction along the N’th dimension of Y</td>
</tr>
<tr>
<td>f\Y</td>
<td>scan along the last dimension of Y</td>
</tr>
<tr>
<td>f[N]Y</td>
<td>scan along the N’th dimension of Y</td>
</tr>
<tr>
<td>X/Y</td>
<td>replication along the last dimension of Y</td>
</tr>
<tr>
<td>X/[N]Y</td>
<td>replication along the N’th dimension of Y</td>
</tr>
<tr>
<td>X\Y</td>
<td>expansion along the last dimension of Y</td>
</tr>
<tr>
<td>X[N]Y</td>
<td>expansion along the N’th dimension of Y</td>
</tr>
<tr>
<td>X f.g Y</td>
<td>inner product of X and Y</td>
</tr>
<tr>
<td>X o.g Y</td>
<td>outer product of X and Y</td>
</tr>
<tr>
<td>X f&quot; Y</td>
<td>apply function f to each item of X and Y</td>
</tr>
<tr>
<td>h&quot; Y</td>
<td>apply function h to each item of Y</td>
</tr>
</tbody>
</table>

### System Variables

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>@AV</td>
<td>Atomic vector. The full CP-6 APL character set.</td>
</tr>
<tr>
<td>@CT</td>
<td>Comparison tolerance. Used in numeric comparisons.</td>
</tr>
<tr>
<td>@IO</td>
<td>Index origin. Used in indexing, t, &amp;.</td>
</tr>
<tr>
<td>@LC</td>
<td>Line counter. Vector of lines in execution.</td>
</tr>
<tr>
<td>@LX</td>
<td>Latent expression. Executed after }LOAD.</td>
</tr>
<tr>
<td>@PP</td>
<td>Print precision. Maximum digits in numeric output.</td>
</tr>
<tr>
<td>@PS</td>
<td>Positioning spacing. Control nested array display.</td>
</tr>
<tr>
<td>@PW</td>
<td>Print width. Maximum width of output lines.</td>
</tr>
<tr>
<td>@RL</td>
<td>Random link. Seed for random number generator.</td>
</tr>
<tr>
<td>@SA</td>
<td>Stop action. Control entry into direct input mode.</td>
</tr>
<tr>
<td>@SP</td>
<td>Session parameter. Variable saved across }LOAD’s.</td>
</tr>
<tr>
<td>@TS</td>
<td>Time stamp. Year, month, day, hour, min, sec, millisec.</td>
</tr>
<tr>
<td>@TT</td>
<td>Terminal type.</td>
</tr>
<tr>
<td>@UL</td>
<td>User load. Number of users logged onto system.</td>
</tr>
<tr>
<td>@WA</td>
<td>Workspace available. Measured in bytes.</td>
</tr>
</tbody>
</table>
### Special Symbols

<table>
<thead>
<tr>
<th>Form</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( )</td>
<td>Parentheses. Expressions may be of any complexity and are evaluated from right to left except as indicated by parentheses.</td>
</tr>
<tr>
<td>A[X]+Y</td>
<td>Indexed assignment. The elements of A selected by the indices X are replaced by Y.</td>
</tr>
<tr>
<td>(A f B)+Y</td>
<td>Selective assignment. The elements of B selected by the expression (A f B) are replaced by Y. The function f may be one of the following dyadic functions: &amp;, +, ⊕, ⊙, &quot;/&quot;, or . The function f may also be one of the following monadic functions: ≡, ⊕, ⊙ or () (ravel).</td>
</tr>
<tr>
<td>(A B)+Y</td>
<td>Vector assignment. A is assigned the first value in the vector Y and B is assigned the second.</td>
</tr>
<tr>
<td>+X</td>
<td>Branch. If X is an empty vector, execution continues. If the first item of X is 0 or beyond the range of statement numbers, execution of the function terminates.</td>
</tr>
<tr>
<td>+</td>
<td>Terminates execution of function and related pendent functions.</td>
</tr>
<tr>
<td>⊕X</td>
<td>Quad output. Prints the value of X.</td>
</tr>
<tr>
<td>⊕X</td>
<td>Bare output. Prints X without terminating carriage return.</td>
</tr>
<tr>
<td>X+0</td>
<td>Quad input. The input expression is evaluated and assigned to X.</td>
</tr>
<tr>
<td>'XYZ'</td>
<td>Character vector of 3 elements: XYZ.</td>
</tr>
<tr>
<td>a</td>
<td>Lamp. Characters to the right of this symbol are treated as commentary.</td>
</tr>
<tr>
<td>v</td>
<td>Del. Enter or exit function definition mode</td>
</tr>
<tr>
<td>v</td>
<td>Lock function.</td>
</tr>
<tr>
<td>X</td>
<td>Label. X is a line label within a function.</td>
</tr>
<tr>
<td>;</td>
<td>Semicolon. Index separator.</td>
</tr>
<tr>
<td>⊥</td>
<td>Diamond. Statement separator.</td>
</tr>
</tbody>
</table>
Function Definition

A \& preceding the name of a defined function is used to enter definition mode. In definition mode, entries are held and saved in a function body for later execution. Each entry in definition mode is preceded by a prompt containing a line number in brackets.

<table>
<thead>
<tr>
<th>Table E-8. Function Header Syntax</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valence</td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>Niladic</td>
</tr>
<tr>
<td>Monadic</td>
</tr>
<tr>
<td>Dyadic</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table E-9. Directive Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entry</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>[D]</td>
</tr>
<tr>
<td>[n]</td>
</tr>
<tr>
<td>[n-m]</td>
</tr>
<tr>
<td>[n]</td>
</tr>
<tr>
<td>[n-m;/st/1]</td>
</tr>
<tr>
<td>[n-m;/st/S/rt/1]</td>
</tr>
<tr>
<td>[&amp;n]</td>
</tr>
<tr>
<td>[&amp;n-m]</td>
</tr>
<tr>
<td>[&amp;n-m;/st/1]</td>
</tr>
<tr>
<td>[/&amp;S/1]</td>
</tr>
<tr>
<td>[\S/1]</td>
</tr>
</tbody>
</table>

Defined Function Controls

<table>
<thead>
<tr>
<th>Table E-10. Defined Function Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
</tr>
<tr>
<td>------------</td>
</tr>
<tr>
<td>R=1 CAT F</td>
</tr>
<tr>
<td>H+ OCR F</td>
</tr>
<tr>
<td>H+ OPX M</td>
</tr>
<tr>
<td>H+ A OPX M</td>
</tr>
<tr>
<td>E+ OSH F</td>
</tr>
<tr>
<td>E+ E OSM F</td>
</tr>
<tr>
<td>V+V STOP F</td>
</tr>
<tr>
<td>V+V STOP F</td>
</tr>
<tr>
<td>V+V TRACE F</td>
</tr>
<tr>
<td>V+V TRACE F</td>
</tr>
</tbody>
</table>
Sidetracking on Errors and Interrupts

The OSM system function is used to set and obtain the current sidetrack settings for a defined function. The optional left argument is a sidetrack matrix of shape \((N,2)\) where each row contains a line number in the first column to indicate where execution will resume when the error number in the second column occurs. The right argument is a namelist containing the name of the defined function whose sidetrack matrix is to be set. If the optional left argument is not present, the result is the sidetrack matrix of the function named.

<table>
<thead>
<tr>
<th>Num</th>
<th>Message</th>
<th>Num</th>
<th>Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>all errors</td>
<td>46</td>
<td>TOO BIG</td>
</tr>
<tr>
<td>1</td>
<td>WS FULL</td>
<td>48</td>
<td>name NOT Copied</td>
</tr>
<tr>
<td>2</td>
<td>SYNTAX ERR</td>
<td>49</td>
<td>name NOT FOUND</td>
</tr>
<tr>
<td>3</td>
<td>UNDEINEF</td>
<td>50</td>
<td>name NOT ERASED</td>
</tr>
<tr>
<td>4</td>
<td>DOMAIN ERR</td>
<td>51</td>
<td>NOT GROUPED</td>
</tr>
<tr>
<td>5</td>
<td>RANK ERR</td>
<td>52</td>
<td>SEALED WS</td>
</tr>
<tr>
<td>6</td>
<td>LENGTH ERR</td>
<td>53</td>
<td>OLD WS, MUST EXPORT</td>
</tr>
<tr>
<td>7</td>
<td>INDEX ERR</td>
<td>54</td>
<td>NOT HELD</td>
</tr>
<tr>
<td>8</td>
<td>NO RESULT</td>
<td>55</td>
<td>ALREADY HELD</td>
</tr>
<tr>
<td>10</td>
<td>IMPLICIT ERR</td>
<td>56</td>
<td>no shares</td>
</tr>
<tr>
<td>11</td>
<td>LIMIT ERR</td>
<td>57</td>
<td>HOLD ABORTED</td>
</tr>
<tr>
<td>15</td>
<td>SINGULAR MATRIX</td>
<td>58</td>
<td>HOLD DEADLOCK</td>
</tr>
<tr>
<td>16</td>
<td>FORMAT SYNTAX ERR</td>
<td>59</td>
<td>NOT HELD</td>
</tr>
<tr>
<td>20</td>
<td>BAD CHAR</td>
<td>60</td>
<td>ALREADY HELD</td>
</tr>
<tr>
<td>21</td>
<td>LINESCAN ERR</td>
<td>61</td>
<td>FILE SPACE TOO LOW</td>
</tr>
<tr>
<td>22</td>
<td>TRUNCATED INPUT</td>
<td>62</td>
<td>FILE I/O ERROR fcg-Mxxxx-s</td>
</tr>
<tr>
<td>23</td>
<td>OPEN Quote</td>
<td>63</td>
<td>FILE DAMAGE</td>
</tr>
<tr>
<td>30</td>
<td>I/O ERR fcg-Mxxxx-s</td>
<td>64</td>
<td>FILE NAME ERR</td>
</tr>
<tr>
<td>35</td>
<td>DEFN ERR</td>
<td>65</td>
<td>NOT APL FILE</td>
</tr>
<tr>
<td>36</td>
<td>SI DAMAGE</td>
<td>66</td>
<td>FILE TBL FULL</td>
</tr>
<tr>
<td>40</td>
<td>BAD COMMAND</td>
<td>67</td>
<td>FILE ACCESS ERR</td>
</tr>
<tr>
<td>41</td>
<td>NOT SAVED, THIS WS IS</td>
<td>68</td>
<td>FILE TIE ERR</td>
</tr>
<tr>
<td>42</td>
<td>FILE IN USE</td>
<td>69</td>
<td>PACKSET NOT MOUNTED</td>
</tr>
<tr>
<td>43</td>
<td>BAD FILE REF</td>
<td>70</td>
<td>FILE INDEX ERR</td>
</tr>
<tr>
<td>44</td>
<td>WS NOT FOUND</td>
<td>71</td>
<td>PACKAGE TOO BIG</td>
</tr>
<tr>
<td>45</td>
<td>TOO BIG TO LOAD</td>
<td>72</td>
<td>INTERRUPT</td>
</tr>
</tbody>
</table>

Error Control Functions

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>T+</td>
<td><code>ORF</code> Name of function involved in recent error.</td>
</tr>
<tr>
<td>T+</td>
<td><code>ORH</code> Description of most recent I/O error.</td>
</tr>
<tr>
<td>T+</td>
<td><code>ORL</code> Line executing most recent error.</td>
</tr>
<tr>
<td>T+</td>
<td><code>ORM</code> Error message for most recent error.</td>
</tr>
<tr>
<td>T+</td>
<td><code>ORR</code> Error number and line number of error.</td>
</tr>
<tr>
<td>T+</td>
<td><code>ORS</code> Signal error number I with error message T.</td>
</tr>
<tr>
<td>T+</td>
<td><code>ORX</code> Monitor code associated with I/O error.</td>
</tr>
</tbody>
</table>
# CP-6 APL System Functions

## Table E-13. CP-6 APL System Functions

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1+ CPU</td>
<td>CPU time used measured in milliseconds.</td>
</tr>
<tr>
<td>I+ DDL I</td>
<td>Delay execution for at least I seconds.</td>
</tr>
<tr>
<td>V+ DXK N</td>
<td>Erase objects named in N.</td>
</tr>
<tr>
<td>V+ DJT T</td>
<td>Convert character representation to number.</td>
</tr>
<tr>
<td>N+ DCRP N</td>
<td>Return namelist of group members.</td>
</tr>
<tr>
<td>N+ IBEX T</td>
<td>Erase IBEX variable named in T.</td>
</tr>
<tr>
<td>T+ IDLET N</td>
<td>Return value of IBEX variable named in N.</td>
</tr>
<tr>
<td>T+ IDLET N</td>
<td>Assign value T to IBEX variable named in N.</td>
</tr>
<tr>
<td>R+ IDBH N</td>
<td>Return names of current IBEX variables.</td>
</tr>
<tr>
<td>R+ IDLOC N</td>
<td>Return name correspondence of each name in N at each level of the state indicator.</td>
</tr>
<tr>
<td>I+ DLCT</td>
<td>APL invocation time in milliseconds.</td>
</tr>
<tr>
<td>I+ DLOK N</td>
<td>Lock functions named in N.</td>
</tr>
<tr>
<td>R+ DGC N</td>
<td>Return name class of names in N.</td>
</tr>
<tr>
<td>R+ DGC N</td>
<td>Return global name class of names in N.</td>
</tr>
<tr>
<td>N+ DKL K</td>
<td>Return names of objects of class K.</td>
</tr>
<tr>
<td>N+ DKL K</td>
<td>Like monadic DKL but includes only names beginning with a letter in T.</td>
</tr>
<tr>
<td>I+ DQLN</td>
<td>Session mode: 0=batch,1=online.</td>
</tr>
<tr>
<td>I+ DOVH</td>
<td>Processor overhead time in milliseconds.</td>
</tr>
<tr>
<td>V+ DGM N</td>
<td>Size in bytes of objects in N.</td>
</tr>
<tr>
<td>V+ DGM N</td>
<td>Size in bytes of global objects in N.</td>
</tr>
<tr>
<td>I+ DSCT</td>
<td>Milliseconds elapsed since APL was invoked.</td>
</tr>
<tr>
<td>T+ DSI</td>
<td>Text vector containing result of DSI.</td>
</tr>
<tr>
<td>T+ DSITEID</td>
<td>Text vector containing CP-6 site identifier.</td>
</tr>
<tr>
<td>T+ DSITEID</td>
<td>Text vector containing CP-6 site name.</td>
</tr>
<tr>
<td>T+ DSTEPCC I</td>
<td>Sets value to use as step condition codes.</td>
</tr>
<tr>
<td>T+ DSYED</td>
<td>Text vector containing current CP-6 sysid.</td>
</tr>
<tr>
<td>T+ DVA</td>
<td>8 item character vector of current account.</td>
</tr>
<tr>
<td>I+ DUL</td>
<td>Number of CP-6 system users.</td>
</tr>
<tr>
<td>T+ DVERSION</td>
<td>Version of the CP-6 APL processor.</td>
</tr>
<tr>
<td>V+ DVT T</td>
<td>Indicate legal representations of numbers.</td>
</tr>
<tr>
<td>T+ DWSID</td>
<td>Text vector of the current workspace name.</td>
</tr>
</tbody>
</table>

## Shared Variable Functions

## Table E-14. Shared Variable System Functions

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I+ SSC</td>
<td>Wait for a shared variable event.</td>
</tr>
<tr>
<td>C+ SSVN N</td>
<td>Obtain controls on shared variables in N.</td>
</tr>
<tr>
<td>C+ SSVN N</td>
<td>Set controls on shared variables in N.</td>
</tr>
<tr>
<td>T+ SSVN T</td>
<td>Set current process identification to T.</td>
</tr>
<tr>
<td>I+ SSVO N</td>
<td>Obtain degree of coupling for names in N.</td>
</tr>
<tr>
<td>V+ P SSV N</td>
<td>Offer names in N to share with process P.</td>
</tr>
<tr>
<td>N+ SSVQ P</td>
<td>Obtain names of shares not accepted.</td>
</tr>
<tr>
<td>V+ SSVR N</td>
<td>Retract names in N from sharing.</td>
</tr>
<tr>
<td>R+ SSVS N</td>
<td>Shared variable states of names in N.</td>
</tr>
</tbody>
</table>
File I/O

File I/O functions may be used to access all CP-6 files provided access permission have been granted.

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>CP-6 account or a fid with a ? within the filename.</td>
</tr>
<tr>
<td>F</td>
<td>CP-6 fid (name.account.pass).</td>
</tr>
<tr>
<td>I</td>
<td>Scalar integer dependent upon function.</td>
</tr>
<tr>
<td>K</td>
<td>Integer or character vector record identifier (key).</td>
</tr>
<tr>
<td>L</td>
<td>For INDEXed files: Numeric key matrix of shape (N,3). Column 1 is the character index of the key start, column 2 is the key length and column 3 is 0 if duplicate keys are permitted.</td>
</tr>
<tr>
<td>R</td>
<td>Array dependent upon function.</td>
</tr>
<tr>
<td>S</td>
<td>Integer scalar file I/O stream number.</td>
</tr>
<tr>
<td>T</td>
<td>Integer record type 1=component,2=datablock,3=raw.</td>
</tr>
<tr>
<td>X</td>
<td>Encryption seed (integer or 4-item character vector).</td>
</tr>
<tr>
<td>Z</td>
<td>Shape (N,17) character file access matrix. Columns 1-8 contain accounts, 9 must be blank and 10-17 contain Y or N for access control: READ, DELR, WNEW, UPDATE, DELF, NOST, REATTR and EXEC.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>R OFAPPEND S X T</td>
<td>Add record or component to end of file.</td>
</tr>
<tr>
<td>K+R OFAPPENDR S X T</td>
<td>Same as OFAPPEND but returns key.</td>
</tr>
<tr>
<td>OFCLEAR</td>
<td>Close all open files.</td>
</tr>
<tr>
<td>OFCLOSE</td>
<td>Close streams in S.</td>
</tr>
<tr>
<td>OFCRIPT S X</td>
<td>Set default encryption seed.</td>
</tr>
<tr>
<td>OFDROP S K</td>
<td>Delete record from file.</td>
</tr>
<tr>
<td>OFENQ S K</td>
<td>Hold a record.</td>
</tr>
<tr>
<td>OFERASE S</td>
<td>Close streams and delete files in S.</td>
</tr>
<tr>
<td>H+ OFLDS Y</td>
<td>Return record field matrix.</td>
</tr>
<tr>
<td>F+ OFID S</td>
<td>Return CP-6 file identifier for stream S.</td>
</tr>
<tr>
<td>L+ OFKEYINT S I</td>
<td>Set increment for OFAPPEND to keyed file.</td>
</tr>
<tr>
<td>M+ OFKEYS S</td>
<td>Return matrix describing keys.</td>
</tr>
<tr>
<td>H+ OFLIB A</td>
<td>Return names of files in account A.</td>
</tr>
<tr>
<td>H+H OFLIB A</td>
<td>Return fids of type H in account A.</td>
</tr>
<tr>
<td>T+ OFMA</td>
<td>Current file management account.</td>
</tr>
<tr>
<td>H+ OFNAMES</td>
<td>Names of open files.</td>
</tr>
<tr>
<td>R+ OFNUNS</td>
<td>Numbers of open files.</td>
</tr>
<tr>
<td>F OFOPEN S</td>
<td>Open file I/O stream.</td>
</tr>
<tr>
<td>Z+ OFRDAC S</td>
<td>Return access control matrix for file S.</td>
</tr>
<tr>
<td>R+ OFRDCI S K X</td>
<td>Return component information.</td>
</tr>
<tr>
<td>R+ OFREAD S K X T</td>
<td>Read a record.</td>
</tr>
<tr>
<td>K+ OFREAD S K X T</td>
<td>Return key (1=first,2=current,3=last).</td>
</tr>
<tr>
<td>T+ OFSIZE S</td>
<td>Return size of file S in bytes.</td>
</tr>
<tr>
<td>Z OFSTAC S</td>
<td>Set file access matrix.</td>
</tr>
<tr>
<td>R OFWRITE S K X T</td>
<td>Write a record or component.</td>
</tr>
</tbody>
</table>
Table E-17. File I/O Open Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IN</td>
<td>Create a new file.</td>
</tr>
<tr>
<td>CREATE</td>
<td>Update on existing file.</td>
</tr>
<tr>
<td>UPDATE</td>
<td>For create, always create a new file.</td>
</tr>
<tr>
<td>NEWFILE</td>
<td>For create, if file already exists use it.</td>
</tr>
<tr>
<td>OLDFILE</td>
<td>For create, if file exists report error.</td>
</tr>
<tr>
<td>ERROR</td>
<td>If UPDATE, open file for exclusive use, if IN, open shared with other IN,NONE users.</td>
</tr>
<tr>
<td>NONE</td>
<td>Open file shared with multiple updaters.</td>
</tr>
<tr>
<td>ALL</td>
<td>Open file shared with multiple readers.</td>
</tr>
<tr>
<td>SHAREIN</td>
<td>Create a permanent file.</td>
</tr>
<tr>
<td>NAMED</td>
<td>Create a scratch file.</td>
</tr>
<tr>
<td>SCRATCH</td>
<td>For create, specify file organization.</td>
</tr>
<tr>
<td>KEYED</td>
<td>For create, specify file organization.</td>
</tr>
<tr>
<td>CONSEC</td>
<td>For create, specify file organization.</td>
</tr>
<tr>
<td>RANDOM</td>
<td>For create, specify file organization.</td>
</tr>
<tr>
<td>UR</td>
<td>For create, specify file organization.</td>
</tr>
<tr>
<td>RELATIVE</td>
<td>For create, specify file organization.</td>
</tr>
<tr>
<td>INDEXED</td>
<td>For create, specify file organization.</td>
</tr>
<tr>
<td>CG</td>
<td>For create, specify file organization.</td>
</tr>
<tr>
<td>CRE INDEXED</td>
<td>For create, specify file organization.</td>
</tr>
<tr>
<td>RER</td>
<td>For create, specify file organization.</td>
</tr>
<tr>
<td>DIRECT</td>
<td>Add file name to directory during open.</td>
</tr>
<tr>
<td>SEQUEN</td>
<td>Build record indices on CLOSE.</td>
</tr>
<tr>
<td>CTG</td>
<td>Request record compression.</td>
</tr>
<tr>
<td>LOAD</td>
<td>Use IBEX !SET for additional options.</td>
</tr>
</tbody>
</table>

* indicates default.

Text Editing Functions

The right argument to these functions is a vector of text vectors.

Table E-18. Text Editing Functions

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>T+OSCP T T2</td>
<td>Compare strings T and T2.</td>
</tr>
<tr>
<td>T+OSCP T TR C1 C2</td>
<td>Replaces positions C1 through C2 of string T with string TR.</td>
</tr>
<tr>
<td>T+SSR T TS TR</td>
<td>Replaces occurrences of string TS with string TR in string T.</td>
</tr>
<tr>
<td>V+SSS T TS</td>
<td>Returns indices of string TS in string T.</td>
</tr>
<tr>
<td>M+TIX T SDV TDV DDV</td>
<td>Return matrix locating text lexemes.</td>
</tr>
<tr>
<td>V+TILEX T SDV TDV DDV</td>
<td>Return text lexemes.</td>
</tr>
</tbody>
</table>
### I-D-S/II Functions

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>R+ODBACCEPT D</td>
<td>Return db-key or area name.</td>
</tr>
<tr>
<td>I+ODBBUFFERS I</td>
<td>Set number of buffers to use.</td>
</tr>
<tr>
<td>I+ODBCHECK I</td>
<td>Indicate a checkpoint.</td>
</tr>
<tr>
<td>R+ODBCONNECT D</td>
<td>Connect a record to a set.</td>
</tr>
<tr>
<td>ODSCRPT I</td>
<td>Indicate an area encryption seed.</td>
</tr>
<tr>
<td>R+ODBBASE D</td>
<td>Remove record from a set.</td>
</tr>
<tr>
<td>R+ODBFIND D</td>
<td>Delete a record.</td>
</tr>
<tr>
<td>R+ODBFINISH D</td>
<td>Locate a record.</td>
</tr>
<tr>
<td>R+ODBFROM D</td>
<td>Close area(s).</td>
</tr>
<tr>
<td>R+ODBFROM D</td>
<td>Obtain data from workarea.</td>
</tr>
<tr>
<td>R+ODBGET D</td>
<td>Read a record from database.</td>
</tr>
<tr>
<td>R+ODBDIF D</td>
<td>Test for set membership.</td>
</tr>
<tr>
<td>V+ODBMEMBER D</td>
<td>Return member indices of set or record.</td>
</tr>
<tr>
<td>R+ODBMODIFY D</td>
<td>Re-write a record.</td>
</tr>
<tr>
<td>T+ODBNAMES</td>
<td>Return latest I-D-S/II error message.</td>
</tr>
<tr>
<td>R+ODBNAMES</td>
<td>Names of all objects in current subschema.</td>
</tr>
<tr>
<td>V+ODBOWNER D</td>
<td>Return owner indices of set or record.</td>
</tr>
<tr>
<td>R+ODBPRIVACY D</td>
<td>Specify privacy locks.</td>
</tr>
<tr>
<td>R+ODBREADY D</td>
<td>Open an area.</td>
</tr>
<tr>
<td>R+ODBDRETAI N D</td>
<td>Indicate currencies to be retained.</td>
</tr>
<tr>
<td>ODDBRLL</td>
<td>Roll back updates to last checkpoint.</td>
</tr>
<tr>
<td>R+ODDBSTATS</td>
<td>Report statistics.</td>
</tr>
<tr>
<td>R+ODDBSTATSOFF</td>
<td>Turn statistics gathering off.</td>
</tr>
<tr>
<td>R+ODDBSTATSON</td>
<td>Turn statistics gathering on.</td>
</tr>
<tr>
<td>R+ODDBSTORE D</td>
<td>Write a new record.</td>
</tr>
<tr>
<td>T+ODBSUB T</td>
<td>Indicate subschema name to use.</td>
</tr>
<tr>
<td>R+ODBTO D</td>
<td>Move data into work area.</td>
</tr>
<tr>
<td>R+ODBTTRACEON I</td>
<td>Initiate I-D-S/II trace.</td>
</tr>
<tr>
<td>R+ODBTTRACEOFF I</td>
<td>Terminate I-D-S/II trace.</td>
</tr>
<tr>
<td>R+ODBTYPE</td>
<td>Indicate types of objects in subschema.</td>
</tr>
<tr>
<td>V+ODBBUSE V</td>
<td>Namelist of use procedures for errors in V.</td>
</tr>
<tr>
<td>V+V+ODBBUSE V</td>
<td>Set use procedures associated with errors.</td>
</tr>
</tbody>
</table>

### Terminal Control System Functions

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>V+OTATTR</td>
<td>Return terminal attributes.</td>
</tr>
<tr>
<td>OTREON T</td>
<td>Control terminal echo: 0=off, 1=on.</td>
</tr>
<tr>
<td>OTIN T</td>
<td>Set input re-read line.</td>
</tr>
<tr>
<td>R+OTSQZ T</td>
<td>Translate to or from mnemonics.</td>
</tr>
<tr>
<td>OTTIME I</td>
<td>Set timeout on terminal reads.</td>
</tr>
<tr>
<td>R+OTWINDOW</td>
<td>Return terminal window locations and sizes.</td>
</tr>
</tbody>
</table>
Report Formatting Functions

Table E-21. DFMT Format Controls

<table>
<thead>
<tr>
<th>Form</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>rAw</td>
<td>Blank insertion</td>
</tr>
<tr>
<td>rEw.s</td>
<td>Exponential notation (scientific format)</td>
</tr>
<tr>
<td>r qFw.d</td>
<td>Fixed decimal notation</td>
</tr>
<tr>
<td>r q&lt;text&gt;</td>
<td>Picture format</td>
</tr>
<tr>
<td>r q/</td>
<td>Integer</td>
</tr>
<tr>
<td>Tw</td>
<td>Column tabbing</td>
</tr>
<tr>
<td>rAw</td>
<td>Blank insertion</td>
</tr>
<tr>
<td>r&lt;text&gt;</td>
<td>Text insertion</td>
</tr>
<tr>
<td>r&lt;text&gt;</td>
<td>Text insertion</td>
</tr>
<tr>
<td>r&lt;text&gt;</td>
<td>Text insertion</td>
</tr>
</tbody>
</table>

Where:

- \( r \) optional replication count
- \( w \) total field width
- \( s \) digits in E format
- \( d \) digits to include after the decimal point
- \( c \) column at which the next field will start
- \( q \) optional qualifier

Optional qualifiers:

- \( B \) field is blank if it is exactly zero
- \( C \) insert comma between triads of digits
- \( L \) formatted field is left justified
- \( H<text> \) prefixes negative fields with text
- \( P<text> \) prefixes positive fields with text
- \( Q<text> \) postfixes positive fields with text
- \( R<text> \) sets background for formatted value
- \( S<text> \) substitutions for '92*O_.'

Table E-22. Report Formatting Functions

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N+Q</td>
<td>Format ( L ) according to specification ( Q ).</td>
</tr>
<tr>
<td>HDR T</td>
<td>Set heading for output pages to ( T ).</td>
</tr>
<tr>
<td>I+</td>
<td>NLS Return lines remaining on output page.</td>
</tr>
<tr>
<td>FGE</td>
<td>Begin future output on a new page.</td>
</tr>
<tr>
<td>VFC B</td>
<td>Set VFC character for next output line.</td>
</tr>
<tr>
<td>T+X</td>
<td>Translate characters in ( T ) using vector ( X ).</td>
</tr>
</tbody>
</table>
Blind I/O Functions

Blind I/O is provided to access CP-6 devices using the special variables \( I \) through \( S \). The APL system command \( \)SET is used to direct blind I/O to a particular device.

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( I )</td>
<td>Integer scalar.</td>
</tr>
<tr>
<td>( J )</td>
<td>Optional integer scalar whose presence indicates a set mode operation and whose absence causes the current setting to be returned.</td>
</tr>
<tr>
<td>( K )</td>
<td>Scalar integer or character vector key.</td>
</tr>
<tr>
<td>( L )</td>
<td>Matrix of shape ((W,H)) where (4\leq W \geq H) and the following column meanings are assigned: 1-field number, 2-line, 3-column, 4-length, 5-attributes, 6-input attributes, 7-initial value.</td>
</tr>
<tr>
<td>( S )</td>
<td>Blind I/O stream number (0 through 9).</td>
</tr>
<tr>
<td>( T )</td>
<td>Character vector.</td>
</tr>
<tr>
<td>( V )</td>
<td>Vector of form field numbers.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( I^+ )</td>
<td>Set or query binary I/O mode.</td>
</tr>
<tr>
<td>( OBIN )</td>
<td>Close blind I/O stream ( S ).</td>
</tr>
<tr>
<td>( OBPFLD )</td>
<td>Define forms mode fields.</td>
</tr>
<tr>
<td>( OBPFILE )</td>
<td>Position to beginning or end of file.</td>
</tr>
<tr>
<td>( OBKEY )</td>
<td>Key of current file position.</td>
</tr>
<tr>
<td>( OBKR )</td>
<td>Key returned by last operation.</td>
</tr>
<tr>
<td>( OBLINES )</td>
<td>Return lines per page and lines remaining.</td>
</tr>
<tr>
<td>( OBFRMFLD )</td>
<td>Modify forms mode fields.</td>
</tr>
<tr>
<td>( OBRS )</td>
<td>Size of record last read (F$DCB.ARS$).</td>
</tr>
<tr>
<td>( OBRSF )</td>
<td>Select forms mode fields.</td>
</tr>
<tr>
<td>( OBRSIZE )</td>
<td>Set read size.</td>
</tr>
<tr>
<td>( OBTRANS )</td>
<td>Set or query transparency.</td>
</tr>
<tr>
<td>( OBVFC )</td>
<td>Set or query VFC.</td>
</tr>
<tr>
<td>( OBXFLD )</td>
<td>Expunge forms mode fields.</td>
</tr>
<tr>
<td>( ONSET )</td>
<td>Return character vector containing CP-6 fid and ( )SET ) options.</td>
</tr>
<tr>
<td>Index</td>
<td>APL</td>
</tr>
<tr>
<td>-------</td>
<td>-------</td>
</tr>
<tr>
<td>0</td>
<td>NUL</td>
</tr>
<tr>
<td>1</td>
<td>SOH</td>
</tr>
<tr>
<td>2</td>
<td>STX</td>
</tr>
<tr>
<td>3</td>
<td>ETX</td>
</tr>
<tr>
<td>4</td>
<td>EOT</td>
</tr>
<tr>
<td>5</td>
<td>ENQ</td>
</tr>
<tr>
<td>6</td>
<td>ACK</td>
</tr>
<tr>
<td>7</td>
<td>BEL</td>
</tr>
<tr>
<td>8</td>
<td>BS</td>
</tr>
<tr>
<td>9</td>
<td>HT</td>
</tr>
<tr>
<td>10</td>
<td>LF</td>
</tr>
<tr>
<td>11</td>
<td>VT</td>
</tr>
<tr>
<td>12</td>
<td>FF</td>
</tr>
<tr>
<td>13</td>
<td>CR</td>
</tr>
<tr>
<td>14</td>
<td>SO</td>
</tr>
<tr>
<td>15</td>
<td>SI</td>
</tr>
<tr>
<td>16</td>
<td>DLE</td>
</tr>
<tr>
<td>17</td>
<td>DC1</td>
</tr>
<tr>
<td>18</td>
<td>DC2</td>
</tr>
<tr>
<td>19</td>
<td>DC3</td>
</tr>
<tr>
<td>20</td>
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</table>
Index

Note: Index references indicate the page on which the paragraph containing the index term actually ends. Should the paragraph straddle two pages, the actual indexed term might be on the first page, while the index reference is to the second page.

A

A Programming Language - 1-1
abort - 6-2 7-20 7-21 10-2
Absolute value function - 3-17 5-10
access control vector - 11-26
access controls - 12-13
Accessing Data - 13-6
Accessing Files with Blind I/O - 16-3
account - 3-4 11-22 11-25 11-28 12-18
Active Workspace - 8-2 11-25
clearing - 8-13
expunge names - 8-19 11-8
name - 8-43
name classification - 11-12 11-14
names - 11-15
output width - 8-42
saving - 8-3 8-13 8-34 8-35
addition - 3-42 5-1
Addition function - 3-14 5-4 5-45
Additional Primitive Functions - A-5
Additional Primitive Operators - A-7
Additional System Commands - A-8
Additional System Functions - A-7
Additional System Variables - A-8
Affixture codes - 9-6
Aids for Sidetrack Users - 10-10
Alternate Indexed Files - 12-23
And function - 3-20 5-16 5-45 A-6
APL Character Set, CP-6 - B-1
APL Exponential Notation - 3-2
APL Functions and Operators - 3-14
APL Input and Output - A-2
APL invocation options - 8-3
APL Standards Compatibility - 1-1
APL typewheel - 2-1
append record to a file - 12-8
arccos - 5-11 A-2
arccosh - 3-18 5-11 A-2
arcsin - 3-18 5-11 A-2
arcsinh - 3-18 5-11 A-2
arctan - 3-18 5-11 A-2
arctanh - 3-18 5-11 A-2
Argument characteristics - 5-1
Arithmetic Functions - 5-3
Arithmetic Limits - A-1
Array Limits - A-1
Array Representation - A-5
array -
depth - 3-13 3-28 5-22
nested - 3-13 3-43 5-2
prototype - 3-26 3-44 5-39 5-39
rank - 3-8 3-13 3-35 5-2
shape - 3-8 3-13 3-23 3-35 5-2 5-26
simple - 3-13 3-43
type - 3-13 3-26 5-35 5-40
arrays - 2-7 3-8 3-13
Arrays and Indexing - 3-8
Arrays of two or more dimensions - 3-42
ascending order - 3-23 5-31
ASCII - B-1
assigning a value to an array - 3-11
Assignment - 3-5 3-36
Assignment and Non-assignment Statements - 6-5
Assignment control - 1-1
assignment statements - 6-5
asterisk - 7-21
 OAT System Function (Function Attributes) - 7-28 E-6
atomic vector - 11-6 8-1
attention - 3-44
 MAV Function (Atomic Vector) - 11-6 E-4
Axis Operator - 3-14 11-2

Bare output - 3-44
base value - 3-25 5-34
Batch - 1-1 3-38 11-16
OBBIN Function (Set and Query Binary Mode) - 16-4 E-13
OBCLOSE Function (Close Blind I/O Channel) - 16-10 E-13
OBDELREC Function (Delete Record) - 16-11
best fit - 3-29 5-43
OBFIELD Function (Field Definition) - 16-14 E-13
binary I/O - 16-4
BINARY MODE - 16-4
Binomial function - 3-18 5-12 5-45 A-3
OBKEY Function (Return Key) - 16-6 E-13
OBKR Function (Key Returned) - 16-10 E-13
Blind I/O - 1-1 3-38 A-7
Blind I/O Functions - E-13
Blind I/O on a Device - 16-2
Blind I/O System Functions - 16-4
Blind I/O - 1-2
binary mode - 16-4
close I/O channel - 16-10
current key - 16-6
delete record - 16-11
field definition - 16-14
field erase - 16-18
field modification - 16-16
field selection - 16-17
last key returned - 16-10
lines of output - 16-6
position file - 16-7
position record - 16-7
previous record size - 16-9
read size - 16-5
record encryption - 16-8
release field - 16-18
return DCB setting - 16-12
rewind - 16-8
rewrite record - 16-8
skip to new page - 16-11
terminal re-read - 16-9
transparent mode - 16-6
uses - 16-1
VFC - 16-5
Blind Input/Output - 1-2
blind output - 3-44
OBBLINES Function (Lines Remaining) - 16-6 E-13
OBFIELD Function (Modify Field) - 16-16 E-13
body of a function - 7-2 7-5
OBPAGE Function (Skip to New Page) - 16-11
OBPROFILE Function (Position File) - 16-7 E-13
C
canonical representation - 7-26 7-27 11-4 A-7
)CATCH Intercepting Assignments - 1-3 8-4 8-10 8-10 8-13
Catching assignments - 1-3
Catenation function - 3-14 3-23 5-23 14-1 A-6
Ceiling function - 3-17 5-8 11-2
Changing a Function Header - 7-17
changing a line - 7-15
Changing Assignments of Input/Output Streams - 8-35
Changing Input/Output assignments - 8-35
Changing Suspended Functions - 7-5
character - 2-7 3-2 3-5 3-13 3-42 5-31 5-33 5-48 5-41 A-6
Character Constants - 3-2
character vectors - 3-42
Circular function - 3-18 5-11 5-45
classification of functions - 3-35
)CLEAR Clearing Workspace - 3-40 5-42 7-19 8-4 8-11 8-13 8-13 11-3 12-1 13-10
Clearing the state indicator - 8-37
Clearing Workspace - 8-13
close blind I/O channel - 16-10
closing files - 12-6
colon - 6-4
Combination function - 3-18 5-12 A-3
Command Processor - 8-4 8-35
Comment Statements - 6-1
Comments - 2-6 6-1
Communicating with computer center operator - 8-30
Communicating with operator - 8-30
Communication Commands - 8-6
comparison tolerance - 3-42 5-13 5-22 11-2 A-1 A-6 A-8
component information - 12-1 12-11
component records - 12-1
Compound statements - 1-2 6-6
Compression A/ Operator (Replicate) - 5-47
Compression along the first coordinate - 3-32
Compression operator - 3-31 5-47 5-48 A-6
Conjugate function - 3-14 5-4 A-6
connecting to the CP-6 system - 2-1
Considerations after Gaining a Sidetrack - 10-9
Consistent Extensions to the ISO APL Standard - A-5
Constants - 3-1
)CONTINUE Saving Active Workspace and Leaving APL - 3-40 7-19 8-6 8-13
)CONTINUE HOLD - 3-40
Continue Workspace - 8-3
Control Keys - 2-6
Controlling the state indicator - 8-36
Conversion - 11-7
correct data - 11-7
Coordinating Shared Files - 12-14

CE38-03 Index
D
Database access - 1-3
datablock records - 12-1

DBACCEPT Function (Return db-key or Area Name) - E-11
DBANLZ Function (Analyze Subschema Names) - 13-5
DBBUFFERS Function (Set Number of Buffers) - E-11
DBCHECK Function (Indicate a Checkpoint) - E-11
DBCONNECT Function (Connect Record to Set) - E-11
DBCRPT Function (Indicate an Area Encryption Seed) - E-11
DBDELETE Function (Remove Record from Set) - E-11
DBERASE Function (Delete a Record) - E-11
DBFIND Function (Locate a Record) - E-11
DBFINISH Function (Close Area(s)) - E-11
DBFROM Function (Retrieving Data) - 13-7 E-11
DBGET Function (Read a Record from Database) - E-11
DBIF Function (Test for Set Membership) - E-11
DBINFORM Function (Database Register) - 13-6
DBMEMBER Function (Set Member) - 13-5 E-11
DBMODYIFY Function (Re-write a Record) - E-11
DBREF Function (Return Latest I-D-S/II Error Message) - E-11
DBNAME Function (List Subschema Names) - 13-2 E-11
DBOWNER Function (Set Owner) - 13-5 E-11
DBPRIVACY Function (Specify Privacy Locks) - E-11
DBREADY Function (Open an Area) - E-11
DBRETAIN Function (Indicate Currencies to be Retained) - E-11
DBROLL Function (Roll Back Updates) - E-11
DBSTATS Function (Report Statistics) - E-11
DBSTATSOFF Function (Turn Statistics Gathering Off) - E-11
DBSTATSON Function (Turn Statistics Gathering On) - E-11
DBSTATUS - 13-9
DBSTORE Function (Write a New Record) - E-11
DBSUB Function (Identify Subschema) - E-11
DBTO Function (Storing Data) - 13-7 E-11
DBTRACEOFF Function (Stop I-D-S/II Trace) - E-11
DBTRACEON Function (Start I-D-S/II Trace) - E-11
DBTYPES Function (Subschema Name Types) - 13-2 E-11
DBUSE Function (Use Procedures) - 13-9 E-11
DCB name - 16-12
Deal function - 3-24 5-19 8-31 11-2 11-3 A-4 A-6
Debugging Aid for Intercepting Assignments - 8-10
Decode function - 5-34
Default Output - 4-2
define from package - 14-5
Defined Function Controls - E-6
Defined Function References - 3-35
Defined Functions - 2-7 7-1 A-2
examples - 7-2
syntax - 7-2
definition mode - 2-4
degree of coupling - 11-25 11-27 11-29
del - 7-1
Delay - 11-8
delay execution - 11-8
Delay function - A-7
Deleting a line - 7-12
deleting -
  file - 12-7
  function line - 7-12
  IBEX variable - 11-11
  line - 2-3 7-11
  record from file - 12-10
  saved workspace - 8-17
  variables, functions - 11-8
  variables, functions and groups - 8-19
depth - 3-13
Depth function - 3-28 5-22
derived function - 3-13 4-2
descending order - 3-24 5-33
Diablo 1620 - 2-1
diamond - 1-2 5-42 6-6
)DIGITS Specifying Numeric Print Precision - 2-3 2-4 3-42 8-5 8-16
Dimension function - 5-26
Direct Input - 3-39
Direct-Line Prompt - 2-5
Directives - 7-6 E-6
Diclose function - 3-27 5-21 A-5
Display -
  function - 7-8
  index origin - 8-31
Displaying a Range of Lines - 7-9
Displaying All Lines - 7-8
Displaying Lines Containing a String - 7-10
Displaying One Line - 7-9
Displaying the Next Occurrence of a String - 7-10
Displaying User-defined Functions - 7-8
division - 3-42
Division function - 3-15 5-6 5-45
)DL Function (Delay) - 11-8 E-8
domain - 3-35 5-1
domain tables - 5-1
)DROP Dropping a Saved Workspace - 8-5 8-17 A-8
Drop function - 3-28 5-40
Dropping a saved workspace - 8-17
Dummies - 3-5 7-4
Dyadic - 3-13 3-35 7-2
Dyadic format - 3-25
dyadic function - 3-13 5-1 5-46
Dyadic functions with explicit result - 7-2
Dyadic functions with no explicit result - 7-2
dyadic scalar functions - 3-30 5-2
Dyadic Shared Variable Control - 11-26
Dyadic Shared Variable Offer - 11-27
Dyadic transpose function - 3-29 11-2
Dynamics of Sidetracking - 10-8

e - 3-15 5-7 5-8 A-3
Each operator - 3-35 5-53 A-7
Easy function copying - 1-2
Echoing of input - 8-36
Editing a line number - 7-17
editing defined functions - 5-42
Editing User-defined Functions - 7-11
)EDITOR Selecting the APL Function Editor - 8-7 8-18
empty array - 3-8 3-43
Enclose function - 3-27 5-20 14-1 A-5
Encode function - 3-25 5-35
encryption - 16-8
encryption seed - 12-1 16-4
)END Exiting APL - 8-7 8-19 11-3
Equals function - 3-19 5-14 5-46 11-2
Equivalence function - 3-28 5-22 11-2 A-5
)ERASE Deleting Objects from Active Workspace - 7-19 7-21 8-5 8-19 8-22 14-1 A-8
)ERASE Deleting Objects from Active Workspace - 7-19 7-21 8-5 8-19 8-22 14-1 A-8
)ERROR Selecting Error Message Information Level - 8-7 8-20
Error and Break control - 1-3
ERROR CONTROL - 10-4 10-7
Error Control Functions - E-7
Error Stop - 10-3
Errors and Breaks - 4-3
Errors on Input or Output - 8-36
EX Function (Expunge) - 11-8 11-9 E-8
Examples of Defined Functions - 7-2
Execute - 3-27
Execute function - 1-3 3-26 5-41 6-6 7-1 10-5 A-6
executing defined functions - 7-20
Execution and Definition Modes - 2-4
Execution Break - 10-1
execution mode - 2-4
execution time - 11-7 11-17
EXG Function (Expunge Globals) - 11-9 E-8
exiting APL - 8-13 8-19
Expansion along the first coordinate - 3-34
Expansion A Operator - 5-49
Expansion operator - 3-34 5-49 A-6
Exponential function - 3-15 5-7 A-3
exponential notation - 3-2
Exponentiation function - 3-15 3-16 5-7 5-45 A-3
expression evaluation - 4-1
expunge - 8-19 11-8 11-9
Expunge Global - 11-9
expunge IBEX variable - 11-11
Expunge names - 14-7
Extensions to Defined Functions - A-8
Extensions to Primitive Functions - A-6
Extensions to Primitive Operators - A-7
Extensions to System Commands - A-8
Extensions to System Functions - A-7
Extensions to System Variables - A-8

Factorial function - 3-17 5-12
FAPPEND Function (Append Record to File) - 12-8 E-9
FAPPENDR - 12-8 E-9
FCLEAR Function (Close All Open Files) - 12-7 E-9
FCLOSE Function (Closing and Renaming Files) - 12-6 E-9
FCRPT Function (Set File Encryption Seed) - 12-17 E-9
FRDR Function (Release Record or File) - 12-14 E-9
FDROP Function (Delete Record from File) - 12-10 E-9
FENW Function (Hold a record) - 12-14 E-9
FERASE Function (Close and Delete File) - 12-7 E-9
FFLDS Function (Return Record Fields) - 12-22 E-9
FPI Function (Fix Input) - 11-9 E-8
fid - 3-3 3-4 12-4 12-4
FPID Function (File Identifier) - 12-4 E-9
Field Definition Matrix - 16-13
Field Definition Matrix Columns - 16-13
file - A-7
displaying - 7-8
editing lines - 7-11
header - 3-35 7-1 11-4 A-8
header modification - 7-17
line deletion - 7-12
line insertion - 7-13
line modification - 7-15
line replacement - 7-14
locking - 7-22 7-27 11-4 14-7
sidetracking - 10-4 10-7
stop controls - 7-25 10-2 11-5 A-7
stop display - 8-33
suspended - 3-36
trace - 7-23 8-27 11-5 A-4 A-7
functions - 2-7 3-13 A-8
Functions and Arguments - 3-13
Functions -
  Defined - A-2
dyadic - 3-13
Logical - E-2
Mixed - E-3
monadic - 3-13
Relational - E-2
Scalar Dyadic - E-1
Scalar Monadic - E-1
OFWRITE Function (Write or Replace a Record) - 12-10 E-9
OFX System Function (Fix Definition) - 7-27 E-6

G

GCD function - 5-16
General APL Input - 2-2
General Input/Output - 3-39
Generalized combination function - 3-17
Generalized factorial function - 3-17
Generalized inner product function - 3-32
Generalized outer product function - 3-33
global function names - 8-21
Global Name Classification - 11-15
Global Room - 11-18
Global Variable Names, Listing - 8-41
global variables - 3-6
GO Resume Execution - 8-7 8-21
Grade-down function - 1-4 3-24 8-31 11-2 A-5 A-6
Grade-up function - 1-4 3-23 8-31 11-2 A-5 A-6
graphics - A-7
Graphics Attribute Variables - 15-20
Graphics Control Functions and Variables - 15-41
Graphics Output Functions - 15-2
graphics Segment Functions - 15-10
Graphics Viewing Variables - 15-30
GBACKGROUND Variable (Background Index) - 15-53
GBATCH Function (Control Batching of Updates) - 15-48
GRBCLIP Variable (Back Plane Clipping) - 15-38
GRCAPABILITIES Function (Inquire Capabilities) - 15-44
GRJUST Variable (Character Justification) - 15-28
GRPATH Variable (Character Path) - 15-27
GRCHPLANE Variable (Character Plane) - 15-26
GRCHPREC Variable (Character Precision) - 15-28
GRCHSIZE Variable (Character Size) - 15-25
GRCHSPACE Variable (Character Space) - 15-27
GRCHIP Variable (Character Up) - 15-26
GRCLIP Variable (Window Clipping) - 15-37
GRCOLINDEX Function (Set/Inquire Color Indices) - 15-51
GRCOLMODEL Function (Color Model) - 15-50
GRCOORD Variable (Coordinate System Type) - 15-39
GRCP Function (Current Position) - 15-18
GRSTATUS Function (Inquire Control Status) - 15-49
GRCURRENT Function (Make Picture Current) - 15-48
GRDONE Function (Terminate APL Graphics) - 15-42
GRDRAW Function (Draw Picture) - 15-5
Greater Than function - 3-19 5-15 5-46 11-2
Greater Than or Equal function - 3-19 5-14 5-46 11-2
Greatest Common Divisor Function - 1-4 3-21 A-6
GRFLCLIP Variable (Front Plane Clipping) - 15-38
GRFILL Variable (Fill Index) - 15-29
GRFONT Variable (Font) - 15-24
GRFRAME Function (New Frame) - 15-50
GRFHIGHLIGHT Variable (Set/Inquire Highlighting) - 15-19
GRIMMVISIBILITY Function (Immediate Visibility) - 15-47
GRINIT Function (Initialize APL Graphics) - 15-41
GRMITSURF Function (Initialize View Surface) - 15-42
GRINDEX Function (Set/Inquire Intensity Indices) - 15-52
GRIL Variable (Line Index) - 15-23
GRLINE Function (Draw Line) - 15-3
GRLS Variable (Line Style) - 15-23
GRPW Variable (Line Width) - 15-22
GRMARK Function (Draw Marker Symbols) - 15-3
GRMARKER Variable (Marker Symbol) - 15-21
GRNDC Function (Map to NDC) - 15-8
GROUP Creating a Group - 8-5 8-22
GROUP Listing Members of a - 8-23 11-10
groups - 3-4 11-10
GRP Listing Members of a Group - 8-7 8-23
GRP Function (Return Group Members) - 11-10 E-8
GRPEN Variable (Pen) - 15-24
GRPES Variable (Polygon Edge Style) - 15-22
GRPIN Variable (Polygon Interior Style) - 15-21
GRPIXEL Variable (Pixel Array) - 15-53
GRPIXELORG Variable (Pixel Pattern Origin) - 15-54
GRPOLYGON Function (Draw Polygon) - 15-4
GRPROJECT Variable (Projection Type) - 15-36
GRPROPS Listing Names of Groups - 8-8 8-24 18-1
GRSEGCLOSE Function (Close Retained Segment) - 15-11
GRSEGCURR Function (Inquire Open Segment) - 15-15
GRSEGDEL Function (Delete Retained Segment) - 15-12
GRSEGHIGHLIGHT Function (Segment Highlight) - 15-18
GRSEGOPEN Function (Create a Retained Segment) - 15-10
GRSEGREN Function (Rename Retained Segment) - 15-13
GRSEGS Function (Inquire Retained Segment Names) - 15-14
GRSEGSRFS Function (Inquire Segment Surfaces) - 15-13
GRSEGVISIBILITY Function (Segment Visibility) - 15-17
GRSPACE Variable (NDC Space) - 15-31
GRSURFACE Function (Select View Surface) - 15-45
GRSURFACES Function (Inquire Selected Surfaces) - 15-47
GRTERMNSURF Function (Terminate View Surface) - 15-43
GRTEXT Function (Draw Text) - 15-6
GRTEXT1 Variable (Text Index) - 15-25
GRTEXTX Function (Inquire Text Extent) - 15-9
GRTSEGC Function (Inquire Open Temporary Segment) - 15-16
GRTSEG Function (Close Temporary Segment) - 15-15
GRTSEGR Function (Create Temporary Segment) - 15-15
GRUNSURFACE Function (Deselect View Surface) - 15-46
GRVARIABLE (View Up) - 15-31
GRVDEPTH Variable (View Depth) - 15-35
GRVERTEX Variable (Vertex Indices) - 15-29
GRVIEWPORT Variable (Viewport) - 15-32
GRVVISIBILITY Variable (Set/Inquire Visibility) - 15-19
GRVPLNDIS Variable (View Plane Distance) - 15-34
GRVPLNORH Variable (View Plane Normal) - 15-34
GRVREFFPT Variable (View Reference Point) - 15-33
GRWF Variable (Window) - 15-30
GRWORLD Variable (World Transformation) - 15-40
GRWORLD Function (Map to World Coordinates) - 15-7
header - 3-35 7-17 11-4 A-8
header of a function - 7-2
higher-order array - 3-8
hold a file - 12-14
hyperbolic cosine - 3-18 5-11 A-2
hyperbolic sine - 3-18 5-11 A-2
hyperbolic tangent - 3-18 5-11 A-2

I-beam function - A-5
I-D-S/II Error Reporting and Handling - 13-9
I-D-S/II Function Arguments - 13-4
I-D-S/II Functions - E-11
I-D-S/II
  list name - 13-2
  list name types - 13-2
lookup names - 13-5
retrieving data - 13-7
system functions - A-7
use procedures - 13-9
IBEX Issuing CP-5 Commands - 8-8 8-24
IBEX Function (IBEX Expunge) - 11-11 E-8
IBEX -
  variable - 11-11 11-12
IBLET Function (Set/Query IBEX Variable) - 11-11 E-8
IBNL Function (IBEX Namelist) - 11-12 E-8
identifier location - 11-12
identifying active workspace - 8-43
IBLOC Function (Identifier Location) - 11-12 E-8
immediate execution - 2-4 A-2
Implementation Defined System Variables - A-2
Index generator function - 3-22 5-19 8-31 11-2 A-6
Index of function - 3-22 5-19 8-31 11-2 14-1
index origin - 3-22 3-37 5-19 8-31 11-2 A-1 A-8
Index Origin, Setting - 8-31
Indexed Assignment - 3-37
indexing - 8-31 14-1 A-6
Indexing an Indexed Argument - 3-12
Indexing of Arrays - 3-9
information level - 8-20
Initiating an APL Session - 8-3
Inner product - 3-32 5-50
Inner Product f.g Operator - 5-50
Input Types -
  blind - 3-39
direct - 3-39
evaluated - 3-39
quote quad - 3-39
input, APL - 2-2
Input/Output - 3-38
Input/Output Assignment Control - 1-1 8-3 8-35
Input/Output Devices - 3-38
Input/Output streams, changing assignments - 8-35
Inquiry Commands - 8-6
Insert Package - 143
Inserting a Line - 7-13
integer - 3-1
intercepting assignments - 8-10
intermediate results, observation of - 1-3
interrupt - 3-44
inverse cosine - 3-18 5-11 A-2
Inverse function - 3-27
inverse hyperbolic cosine - 3-18 5-11 A-2
inverse hyperbolic sine - 3-18 5-11 A-2
inverse hyperbolic tangent - 3-18 5-11 A-2
inverse sine - 3-18 5-11 A-2
inverse tangent - 3–18 5–11 A–2
Invocation of the CP-6 Command Processor - 8–24
Invoking APL - 8–3
\[IO\] Variable (Index Origin) - 11–2 8–13 E–4
Issuing Multiple Directives - 7–15
Issuing System Commands - 7–19
item - 3–8
Items Subject to Sidetracking - 10–6

J
Join function - 3–23 5–23 14–1 A–6

K
key - 12–15 12–16 16–6 16–10

L
Labels - 3–4 3–5 6–4 7–4 7–5
Lamination function - 5–23
latent expression - 8–26 11–2 A–1
\(~L~C\) Function (Line Chain) - 11–13 7–21 E–4
LCM - 5–16
Least Common Multiple Function - 1–4 3–20 A–6
least squares fit - 3–29 5–43
leaving APL - 8–13 8–32
left argument - 3–35
length - 5–1
Less than function - 3–18 5–13 5–46 11–2
Less than or equal function - 3–19 5–13 5–46 11–2
\(~LCT\) Function (Logon Time) - 11–14 E–8
\}LIB \ Listing Names of Saved Workspaces - 8–8 8–25 10–1 A–8
Library - 12–18
Library or Account Information - 12–18
library workspace - 7–1 8–2
Line Corrections during Input - 2–3
line counter - 7–21
line numbers - 7–14
line numbers in execution - 11–13
Line width setting - 8–42
Listing function names - 8–21
Listing global variable names - 8–41
Listing Group Names - 8–24
Listing Members of a Group - 11–10
Listing names of saved workspaces - 8–25
Listing the Members of a Group - 8–23
Listing the State Indicator - 8–38
listing -
  active workspace name - 8–43 11–25
  current DCB setting - 16–12
  file access matrix - 12–12
  file keys - 12–15 12–16
  file names and members - 12–3
  files in account - 12–18
  global function names - 8–21
  global names - 8–27
  global variable names - 8–41
  group members - 8–23 11–10
  group names - 8–24
  IBEX variable - 11–12
  names - 11–15
  package names - 14–3
  platen width - 8–42
  print precision - 8–16
  saved workspaces - 8–25
  state indicator - 7–20 8–36
  state indicator lines - 8–38
storage requirements - 11-17
workspace available - 11-24
literals - 3-5
LOAD Retrieving a Saved Workspace - 3-40 5-42 7-1 7-19 8-5 8-26 11-2 11-3 12-1
13-10
Local and Global Variables - 3-5
Local Variables - 3-6 6-4
locals - 7-4 7-5
Locking Functions - 7-22
Logarithm function - 3-16 5-8 5-45 A-3
Logging off - 8-29
Logging On - 2-1
Logical Functions - 5-16 E-2
Logon time - 11-14
LOCK Function (Lock Function) - 11-4 E-8
LX Variable (Latent Expression) - 11-2 8-13 8-34 E-4

M
Magnitude function - 3-17 5-10
Match function - 3-28 5-22 11-2
mathematical notation - 3-2
matrix - 3-8
Matrix Divide function - 3-27 5-43
Matrix Inverse function - 5-43
Maximum function - 3-17 5-8 5-45
Membership function - 5-40 11-2
Minimum function - 3-16 5-9 5-45
Minus function - 3-14 5-4 5-45
Miscellaneous Extensions - A-9
Miscellaneous Limits - A-2
Mixed Function Summary - 3-22
Mixed Functions - 5-19 E-3
mnemonics - 11-39 B-1
MODE -
  BINARY - 16-4
  TRANSPARENCY - 16-4
VFC - 16-4
Modifying a Line - 7-15
Modulus function - 3-17 5-10 5-45 A-3
Monadic - 3-13 3-35 7-2
Monadic function - 3-13 5-1
Monadic functions with explicit result - 7-2
Monadic functions with no explicit result - 7-2
Monadic Operator - 5-45
Monadic Scalar functions - 5-2
Monadic transpose function - 3-29
Multiple Assignments - 3-37
multiplication - 3-42
Multiplication function - 3-15 5-5 5-45

N
Name and Set Information - 13-5
name classification - 11-12 11-14
Name Format - 3-3
Name List - 11-15
Name Usage - 3-4
Nameclass in package - 14-4
namelist - 11-4 11-15 11-17 11-25 A-7
Namelist and Canonical Representations - 11-4
Names - 2-3 3-3
Names in package - 14-3
names of open files - 12-3
Nand function - 3-21 5-17
Natural Logarithm function - 3-16 5-8
ONE Function (Name Classification) - 11-14 E-8
ONCE Function (Name Correspondence of Global) - 11-15 E-8
Negate function - 3-14 5-4

CE38-03 Index i-13
negative symbol - 3-1
nested arrays - 1-3 3-13 3-43 5-2 5-37 A-5
Niladic - 3-35 7-2
Niladic functions with explicit result - 7-2
Niladic functions with no explicit result - 7-2
OVL Function (Namelist) - 11-15 14-1 E-8
OWLS Function (Number of Lines Remaining) - 9-8 E-12
NMS - Displaying Global Names - 8-8 8-27
non-assignment statements - 6-5
non-dyadic - 3-14
Nor function - 3-21 5-18 5-45
Normal Stop - 10-1
Not equal function - 3-20 5-15 5-46 11-2
Not function - 3-21 5-18
Notation -
  exponential - 3-2
  mathematical - 3-2
Number of lines remaining - 9-8
number of users - 11-23
numbers of open files - 12-3
numeric - 2-7 3-1 3-5 3-42 5-3 5-37 5-40
Numeric Algorithms - A-3
Numeric Constants - 3-1
numeric vectors - 3-42

O

Observation of intermediate results - 1-3
OBSERVE Observing Intermediate Results - 1-3 7-24 8-5 8-27
Observing intermediate results - 8-27
OFF Logging Off - 3-40 5-42 7-19 8-8 8-29
OFF HOLD - 3-40
OVL Function (Online) - 11-16 E-8
open file - 12-4
Opening, Closing, and Deleting Files - 12-4
Operation of OPHT - 9-3
Operation -
  Batch - 1-1 11-16
  On-line - 1-1
Operator Summary - 3-31
Operators - 5-45 E-3
OPR Communicating with Computer Center Operator - 8-8 8-30 10-1
OPRN Communicating with Computer Center Operator - 8-8 8-30
optional items - 3-4
Or function - 3-20 5-16 5-45 A-6
Order of Evaluation - 4-1
ORIGIN Setting Index Origin - 8-5 8-31
Other CP-6 facilities, availability of - 1-2
Outer product - 3-33 5-63
Outer Product o.d Operator - 5-53
Output - 3-41
Output Formatting Aids, Other - 9-8
Output Values, Forms of - 9-5
Overstriking a Character - 7-17
OVRH Function (Overhead Time) - 11-17 E-8

P

OPACK Function (Package Create) - 14-2
Package Names - 14-2
Package System Functions - 14-1
Package Value - 14-2
package -
  creation - 14-2
  define contents - 14-5 14-5
  insertion - 14-2
  list name classification - 14-3
  list names - 14-3
  lock function - 14-7
name removal - 14-7
return value - 14-4
selection - 14-6
Packages - 1-3 7-1 14-1
Page heading - 9-8
Parentheses - 3-3 4-1
password - 3-4
)PCOPY Copying from Saved Workspace - 1-2 7-19 8-5 8-31
)PDEF Function (Package Definition) - 14-5
pendent - 7-20
pendent functions - 3-36 7-21
)PEX Function (Package Expunge) - 14-7
)PGE Function (Skip to New Output Page) - 9-8 E-12
pi - A-4
Pi times function - 3-18 5-11
Pick function - 3-28 5-21
Picture Format - 9-5
)PINS Function (Package Insert) - 14-2
Platen Width - 3-41 8-6 8-42 11-2 A-2 A-8
)LOCK Function (Package Lock) - 14-7
Plus function - 3-14 5-4 5-45
)PNAMES Function (Package Names) - 14-3
)PNC Function (Package Name Correspondence) - 14-3
positioning and spacing - 3-43 11-2 A-2 A-8
)PP Variable (Print Precision) - 11-3 3-42 8-13 8-16 E-4
)PPDEF Function (Protected Package Definition) - 14-5
Precedence of Functions - 4-1
Precedence of Operators - 4-2
primitive functions - 3-13 5-1
Primitive Operators - E-4
Print precision - 3-42 8-5 8-16 11-3 A-1 A-8
Prompts - 2-4
Protective definition - 14-6
prototype - 3-26 3-44 5-39 5-39
)PS Variable (Positioning and Spacing) - 11-2 E-4
)PSEL Function (Package Select) - 14-6
Pseudo-random Number Generation - A-3
)PWAL Function (Package Value) - 14-4
)PW Variable (Platen Width) - 11-2 3-41 8-13 E-4

Q

)QCOPY - 7-19 8-5
)QLOAD, )QCOPY, and )QPCOPY Quiet Commands - 1-2 7-19 8-6 8-32
)QPCOPY - 7-19 8-6
quad output - 3-44
Quad Prompt - 2-5
query IBEX variable - 11-11
query IBEX variable names - 11-12
Quiet commands - 8-32
)QUIT Leaving APL - 8-8 8-32
quote symbols - 3-2
Quote-Quad Input - 3-41
Quote-Quad Prompt - 2-6

R

radians - 3-18 5-11 A-2
random link - 11-3 A-1
rank - 3-8 3-13 3-35 5-1
Ravel function - 3-23
re-read - 11-38 16-9
read -
  file - 12-9
Reading and Writing Records - 12-8
real number - 3-1
Reciprocal function - 3-15 5-6
Record Field Descriptions - 12-20
record format - 12-1
selecting error messages - 8-20
Selecting function Stop Display - 8-33
selective assignment - 1-4 3-38
Semi Numeric Algorithms - A-3
session parameter - 11-3
session time - 11-18
SET Changing Assignments of Input/Output Streams - 1-1 8-9 8-35 16-12
Set line spacing - 9-9
Setting -
  file access controls - 12-13
  IBEX variable - 11-11
  index origin - 8-31
  line width - 8-42
  re-read line - 11-38
  shared variable processor name - 11-30
shading - 3-6
shape - 3-8 3-13 3-35 5-1
Shape function - 3-23 5-26
Shared Variable Functions - E-8
Shared Variable Process Name - 11-30
Shared Variable Query - 11-28
shared variable state change - 11-31
Shared Variable System Functions - 1-3 11-25
shared variable -
  access control vector - 11-26
  limit - A-2
  offer - 11-27 11-28
  process name - 11-25 11-30
  query - 11-28
  retract - 11-29
  state - 11-30
Sharing Files - 12-14
)SI Controlling the State Indicator - 1-2 7-20 8-9 8-13 8-36 10-1 11-19 A-8
)SI Function (State Indicator) - 11-19 E-8
)SIC Clearing the State Indicator - 1-2 3-40 7-20 8-9 8-38
Sidetrack Users, Aids for - 10-10
Sidetrack, Considerations after Gaining a - 10-9
sidetracking - 1-3 7-20 10-1 10-4 10-7
Sidetracking On Errors And Breaks - 10-4
Sidetracking on Errors and Interrupts - E-7
Sidetracking, Dynamics of - 10-8
Sidetracking, Items Subject to - 10-6
Sidetracks, Settings - 10-7
Signaling errors - 10-4 10-12
significant digits - 3-42
Signing off - 8-13 8-29
Signing off and saving active workspace - 8-13
Signum function - 3-15 5-5
)SIL Listing the State Indicator Lines - 1-2 8-9 8-38
simple array - 3-13 3-43
Simple Assignment - 3-36
Simulate a branch and stop - 8-39
size - 3-18 5-11 A-2
Single step execution - 1-3 8-39
)SINL Listing the State Indicator - 7-21 7-22 8-9 8-38 10-1 A-8
site name - 11-20
site-id - 11-20
)SITEID Function (Site ID) - 11-20 E-8
)SITENAME Function (Site Name) - 11-20 E-8
size of file - 12-16
Skip to new output page - 9-8
skip to new page - 16-11
)SH Function (Set/Query Sidetrack Matrix) - 10-7 E-6
Sorting - 1-4
SP Variable (Session Parameter) - 11-3 E-4
Special Action Table - 10-9
Special Symbols - E-5
Specialized File Options - 12-23
Specifying Input/Output Device - 8-40
Specifying number of significant digits - 8-16
specifying numeric print precision - 8-16
\textbf{SRP} Function (Substring Replace) - 11-36 E-10
\textbf{SSR} Function (String Search and Replace) - 11-35 E-10
\textbf{SSS} Function (Substring Search) - 11-34 E-10
\textbf{ST} Function (Set/Query Stop) - 11-5
Standard 1-D-5/11 Functions - 13-7
Starting APL - 8-3
State Change - 11-31
state indicator - 8-36 11-12 11-13 11-19
state of shared variable - 11-30
Statement Labels - 6-4
Statements and System Commands - 2-6
\textbf{STEP} Single Step Execution - 1-3 8-9 8-39
step condition codes - 11-20
\textbf{STP} Function (Step Condition Codes) - 11-20 E-8
stop action - 7-20 10-2 11-3
Stop Control Vector - 10-2
Stop For User Input - 10-2
\textbf{STOP} System Function (Stopping Execution) - 7-20 7-25 8-33 E-6
\textbf{STOP} System Function (Suspending Execution) - 10-2
stopping a display - 3-44
stopping execution - 7-25 11-5 A-7
string compare - 11-37
string replace - 11-36
string search - 11-34
string search and replace - 11-35
string -

tokenizing - 11-32
Subschema Information Functions - 13-2
subtraction - 3-42
Subtraction function - 3-14 5-4 5-45
Suspending Execution - 7-20
\textbf{SV} Function (Shared Variable Controls) - 11-26 E-8
\textbf{SVW} Function (Shared Variable Process Name) - 11-30 E-8
\textbf{SVO} Function (Shared Variable Offer) - 11-27 13-6 E-8
\textbf{SVQ} Function (Shared Variable Query) - 11-28 E-8
\textbf{SVR} Function (Shared Variable Retract) - 11-29 E-8
\textbf{SVS} Function (Shared Variable State) - 11-30 E-8
Syntax of Defined Functions - 7-2
sysid - 11-21
\textbf{SYSID} Function (Sysid) - 11-21 E-8
System Command Summary - 8-4
System command -

eenhancements - 1-2
system commands - 5-42 7-19 A-8
System Functions - 11-3 A-7 A-7 E-8
System Functions Controlling Defined Functions - 7-22
System Functions for Function Definition - 11-4
System functions used with packages - 14-1
System Variables - 3-36 A-1 E-4

\textbf{T}

t-bar function - A-5 D-5
take function - 3-26 5-39
tangent - 3-18 5-11 A-2
\textbf{TATTR} Function (Terminal Attributes) - 11-38 E-11
\textbf{TCECHO} Function (Terminal Echo) - 11-39 E-11
\textbf{TERMINAL} Specifying Input/Output Device - 1-2 8-10 8-40 11-22
Terminal Control System Functions - E-11
Terminal I/O System Functions - 11-37
Terminal status information - 11-38
terminal type - 11-22
terminal windows - 11-40
Terminals without APL Characters, Operation from - 1-1
Text editing functions - 1-3 E-10
Text Editing System Functions - 11-31
Text index - 11-32
time - 11-14 11-18 11-21
time stamp - A-4
Timeout period - 11-39

TIME Function (Terminal Input) - 11-38 E-11
TIME Function (Text Index) - 11-32
TEXT Function (Text Lexemes) - 11-34
tokenizing - 11-32
TR Function (Set/Query Trace) - 11-5
TRACE System Function (Tracing Execution) - 7-23 E-6
tracing execution - 7-23 8-27 11-5 A-4 A-7
Translate text - 9-10
TRANSPARENCY - 16-4
Transpose function - 5-27
dyadic - 3-29
monadic - 3-29
Trigonometric and Hyperbolic Algorithms - A-2
Trigonometric functions - 3-18 A-2
TS Function (Time Stamp) - 11-21 E-4
TSZ Function (Terminal Mnemonic Translation) - 11-39 E-11
TT Function (Terminal Type) - 11-22 E-4
TT Variable (Terminal Type) - 8-40
TIME Function (Terminal Timeout) - 11-39 E-11
WINDOW Function (Terminal Windows) - 11-40 E-11
type - 3-13 3-35 5-40
Type function - 3-26 5-40 A-5
types of Input - 3-39

U

UA Function (User Account) - 11-22 E-8
UL Function (User Load) - 11-23 E-4 E-8
UNSET Function (Unset DCB) - 16-12 E-13
user account - 11-22
User Accounts - 8-4
User function extensions - 1-3
User Input versus Computer Output - 2-3
user load - 11-23
User prompts - 8-36
User-Defined Functions - 7-1
User-defined functions, Editing - 7-11
User-defined, Displaying - 7-8
Using Blind I/O - 16-1

V

Value in Package - 14-4
Value of a Variable versus its Name - 4-2
Variable Names used in System Function Summaries - 11-3
Variable versus its Name, Value of - 4-2
Variables - 3-5 11-1
Variables and Functions - 2-7
Variables Local to a Defined Function - 7-4
Variables, system - E-4
)VARS Listing Global Variable Names - 8-10 8-41 10-1 14-1 A-8
vector - 5-41
vector assignment - 1-4 3-37
Vector notation - 1-3 3-2
verify input - 11-23
VERSION Function (Version) - 11-24 E-8
Vertical Format Control - 9-9 16-5
VFC - 16-4
VFC Function (Set Line Spacing) - 9-9 E-12
VI Function (Verify Input) - 11-23 E-8
OWA Function (Workspace Available) - 11-24 E-4
wait - 11-8
wait for shared variable event - 11-31
width - 11-2
)WIDTH Setting Line Width - 3-41 8-6 8-42
width of line - 3-41
window - 16-12
Window Clipping Variables - 15-37
workspace - 3-4
Workspace Available - 11-24
Workspace Concept - 8-2
Workspace Management Functions - 11-3
Workspace Management System Functions - 11-6
workspace name - 2-3
workspace -
copy - 8-15
writing record in a file - 12-8
writing records - 12-10
)WSID Identifying the Active Workspace - 2-3 8-6 8-43 11-25
)WSID Function (Workspace Identifier) - 11-25 E-8

X

XL Function (Translate Text) - 9-10 E-12
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