Report on

THE ENIAC

(Electronic Numerical Integrator and Computer)

Developed under the supervision of the
Ordnance Department, United States Army

OPERATING MANUAL

UNIVERSITY OF PENNSYLVANIA
Moore School of Electrical Engineering
PHILADELPHIA, PENNSYLVANIA

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A REPORT ON THE ENIAC

(Electronic Numerical Integrator and Computer)


Between

Ordnance Department, United States Army
Washington, D. C.

and

The University of Pennsylvania
Moore School of Electrical Engineering
ENIAC OPERATING MANUAL

by

Dr. Arthur W. Burks

and

Dr. Harry D. Huskøy

Moore School of Electrical Engineering
University of Pennsylvania
INTRODUCTION TO REPORT ON THE

ELECTRONIC NUMERICAL INTEGRATOR AND COMPUTER (ENIAC)

0. INTRODUCTION

The Report on the ENIAC consists of five separately bound parts, as follows:

1) ENIAC Operating Manual
2) ENIAC Maintenance Manual
3) Part I, Technical Description of the ENIAC
   Volume I - Chapters I to VI
4) Part I, Technical Description of the ENIAC
   Volume II - Chapters VII to XI
5) Part II, Technical Description of the ENIAC

Included with the Operating Manual and Parts I and II of the Technical Description are all drawings (see Table 0.3 below) which are required for understanding these reports. The Maintenance Manual assumes access to the complete file of ENIAC drawings.

Part I of the Technical Description is intended for those who wish to have a general understanding of how the ENIAC works, without concerning themselves with the details of the circuits; it assumes no knowledge of electronics or circuit theory. Part II is intended for those who require a detailed understanding of the circuits. Its organization, to a great extent, duplicates that of Part I so as to make cross referencing between the two parts easy.

The ENIAC Operating Manual contains a complete set of instructions for operating the ENIAC. It includes very little explanatory material, and hence assumes familiarity with Part I of the Technical Description of the ENIAC. The ENIAC Maintenance Manual includes description of the various test units and procedures for testing, as well as a list of common and probable sources of trouble. It assumes a complete understanding of the circuits of the ENIAC, i.e., a knowledge of both Parts I and II of the Technical Description of the ENIAC.
The Report on the ENIAC and the complete file of ENIAC drawings constitute a complete description and set of instructions for operation and maintenance of the machine. The drawings carry a number of the form PX-n-m. The following tables give the classification according to this numbering system.

<table>
<thead>
<tr>
<th>TABLE 0.1</th>
</tr>
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<tbody>
<tr>
<td>Values of n</td>
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<tr>
<td>1</td>
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<td>2</td>
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<td>13</td>
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</table>

<table>
<thead>
<tr>
<th>TABLE 0.2</th>
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<tbody>
<tr>
<td>Values of n</td>
</tr>
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<td>101-200</td>
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<td>201-300</td>
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<td>301-400</td>
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<td>401-500</td>
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</tbody>
</table>
The reader of this report will be primarily interested in the types of drawings listed in the following paragraphs. A table on page 4 gives the corresponding drawing number for each unit of the ENIAC.

1) Front Panel Drawings. These drawings show in some detail the switches, sockets, etc., for each panel of each unit. They contain the essential instructions for setting up a problem on the ENIAC.

2) Front View Drawings. There is one of these drawings for each kind of panel used in the various units of the ENIAC. These show the relative position of the trays and the location of the various neon lights. Since these drawings show the neon lights, they can be used to check the proper operation of the various units.

3) Block Diagrams. These drawings illustrate the logical essentials of the internal circuits of each unit. That is, resistors, condensers, and some other electrical details are not shown; but complete channels (paths of pulses or gates representing numbers or program signals) are shown in all their multiplicity. These drawings will be of interest to those who are interested in Parts I and II of the Technical Report.

4) Cross-section Diagrams. These drawings are electronically complete except that only one channel is shown where there is more than one. Thus, these drawings show every resistor and condenser and any other electronic elements belonging to any circuit. These drawings will be of particular interest to the maintenance personnel and to those reading Part II of the technical report.

5) Detail Drawings. All other drawings of the ENIAC come under this heading. A complete file of drawings is available at the location of the ENIAC.
<table>
<thead>
<tr>
<th>Unit</th>
<th>Front Panel</th>
<th>Front View</th>
<th>Block Diagram</th>
<th>Cross - Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initiating Unit</td>
<td>PX-9-302</td>
<td>PX-9-305</td>
<td>PX-9-307</td>
<td></td>
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<tr>
<td>9-302R</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cycling Unit</td>
<td>PX-9-303</td>
<td>PX-9-304</td>
<td>PX-9-307</td>
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<tr>
<td>9-303R</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accumulator</td>
<td>PX-5-301</td>
<td>PX-5-305</td>
<td>PX-5-304</td>
<td>PX-5-115</td>
</tr>
<tr>
<td>Multiplier</td>
<td>PX-6-302</td>
<td>PX-6-309</td>
<td>PX-6-308</td>
<td>PX-6-112a</td>
</tr>
<tr>
<td>6-302R</td>
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<td>6-112b</td>
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<tr>
<td>6-303</td>
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<tr>
<td>6-303R</td>
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<td>6-304</td>
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<tr>
<td>6-304R</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Function Table</td>
<td>PX-7-302</td>
<td>PX-7-305</td>
<td>PX-7-304</td>
<td>PX-7-117</td>
</tr>
<tr>
<td>7-302R</td>
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<td></td>
<td></td>
<td>7-118</td>
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<tr>
<td>7-303</td>
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<tr>
<td>7-303R</td>
<td></td>
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</tr>
<tr>
<td>Divider and Square Rooter</td>
<td>PX-10-301</td>
<td>PX-10-302</td>
<td>PX-10-304</td>
<td></td>
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<tr>
<td>10-301R</td>
<td></td>
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<td>11-302R</td>
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<td>11-309</td>
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<td>11-303</td>
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<td>(C.T. and R.</td>
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<tr>
<td>11-303R</td>
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<tr>
<td>11-304</td>
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<tr>
<td>11-304R</td>
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<td></td>
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</tr>
<tr>
<td>Printer</td>
<td>PX-12-301</td>
<td>PX-12-306</td>
<td>PX-12-307</td>
<td>PX-12-115</td>
</tr>
<tr>
<td>12-301R</td>
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<tr>
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<td>12-303R</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Master Programmer</td>
<td>PX-8-301</td>
<td>PX-8-303</td>
<td>PX-8-304</td>
<td>PX-8-102</td>
</tr>
<tr>
<td>8-301R</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>8-302</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>8-302R</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Other drawings of particular interest:

- Floor Plan: PX-1-302, IBM Punch and PX-12-112
- A.C. Wiring: PX-1-303, Plugboard PX-12-305
- IBM Reader and plugboard: PX-11-119, Pulse amplifier and PX-4-302
- Interconnection of Multiplier and Accumulators: PX-6-311
- Interconnection of Divider and Accumulators: PX-10-307
The front view drawings and the large front panel drawings (whose numbers do not end with "R") are bound as a part of the Operator's Manual.

Included with the report is a folder containing all the drawings listed in the above table except the large front panel (see above) drawings.

1. **GENERAL INSTRUCTIONS FOR OPERATING PERSONNEL**

1. Inform maintenance personnel immediately of any trouble and note same in the log book.

2. Occasionally check the filament fuse indicator lights (refer to front view drawings bound in this volume); if any are out turn off the d-c power (switch is located on a-c distribution panel, see PX-1-304).

3. If ENLAC shuts down from overheating do not try to restart; call maintenance personnel. If any panel runs consistently much hotter than the others, do the same.

4. The d-c power should be turned on only with operation switch (either on cycling unit or on the hand control) turned to "continuous". After the d-c has been on a few seconds it may be turned to either of the other two positions. Failure to follow this rule causes certain d-c fuses to blow, -240 and -415 in particular.

5. As a general matter certain units not being used may have their heaters turned off. In such cases it is unnecessary to remove the d-c power or even to turn off the d-c power when turning on these units. On the other hand the three panels of the constant transmitter must be turned on or off simultaneously.

6. Do not remove any covers, front or back.

7. Do not open d-c fuse cabinet with the d-c power turned on. This not only exposes a person to voltage differences of around 1500 volts but the
person may be burned by flying pieces of molten fuse wire in case a fuse should blow.

8. Padlocks are provided for locking the d-c power off. Lock the power off and carry the key with you as long as you are working on the machine.

9. Do not remove accumulator interconnector plugs, or function table or IBM machine connector cables, while the d-c is on. All other front panel plugs may be safely moved while the power is on.

10. Do not pull directly on wire or cable; always use the plug case as a grip.

11. Do not put sharp bends in cables or hang anything on them.

12. Do not leave cables dangling on the floor.

13. Do not pound or force plugs; if they do not respond to steady pressure notify maintenance personnel.

14. Do not leave IBM cable connectors or portable function table connectors lying out in the open, keep in the receptacles provided. Also, make use of the ramps to protect the cables of any such units which are connected to the ENIAC.

15. Do not force any switches.

16. Keep the door to the room closed to keep out dust, avoid stirring up or producing dust.

17. Always move the portable function tables with care. Keep the brakes on when not moving them.

2. PROBLEM SET UP REMARKS

2.1. NEED FOR SYSTEMATIC CHECKS

Since the ENIAC makes use of a hierarchy of channels (first, in that a
number of units may be carrying on computations simultaneously; second, in that
it always handles ten to twenty digits of a number simultaneously; and third,
in that certain units use a coded system giving four channels for each digit)
running a standard check problem is not a sufficient check on the accuracy of
the results. Thus, in arranging a problem for the ENIAC provision should be
made for occasional systematic checks of all the units.

Procedures for systematic checking are described in some detail in
the maintenance manual. Brief procedures will be outlined here for the numerical
units. The following test procedures are not comprehensive tests and the ex-
perienced operator will perhaps use variations of them. In particular, the
tests given below are not designed to check the operation of the various program
controls. However, they are designed to check the numerical circuits in each
unit and to a considerable extent check the program control used to carry out
the test.

2.2. **TESTING AN ACCUMULATOR**

Cards should be prepared as follows:

1. P 11111 11111
2. P 00000 00001

The numbers should be so placed on a card that one group in the constant trans-
mitter, say A_{LR}, corresponds to these numbers. Next, a master programmer stepper
should be used to transmit the first number into the accumulators which are to
be tested eighteen times. At this time the accumulators should read

\[ M \ 99999 \ 99998 \]

and all stages of each decade have been checked as well as the delayed carry-over
circuits. Now the stepper (used above) should cause the reader to read the next
card and the number to be transmitted to the accumulators twice. This should
and checks the direct carry-over circuits. Note that this test assumes that
the significant figure switch is set to "10". If this is not so the operator
can modify the above procedure to take care of this.

This test does not check the following circuits (for a complete check-
ning procedure see the maintenance manual):

<table>
<thead>
<tr>
<th>Transmission circuits</th>
<th>Input channels (except for the one used)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clearing circuits</td>
<td>Program controls (except for the one used)</td>
</tr>
<tr>
<td>Repeater ring</td>
<td></td>
</tr>
</tbody>
</table>

2.3. TESTING THE MULTIPLIER

The following set of cards should be prepared:

<table>
<thead>
<tr>
<th>Card</th>
<th>Multiplier $A_{LR}$ (say)</th>
<th>Multiplier $B_{LR}$ (say)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>P 00000 00000</td>
<td>P 11111 11111</td>
</tr>
<tr>
<td>2</td>
<td>P 11111 11111</td>
<td>P 11111 11111</td>
</tr>
<tr>
<td>3</td>
<td>P 11111 11111</td>
<td>P 22222 22222</td>
</tr>
</tbody>
</table>

| 10   | P 11111 11111            | P 99999 99999            |
| 11   | P 22222 22222            | P 11111 11111            |
| 12   | P 22222 22222            | P 22222 22222            |

| 82   | P 99999 99999            | P 99999 99999            |
| 83   | P 11111 11111            | M 11111 11111            |
| 84   | M 11111 11111            | P 11111 11111            |
| 85   | M 11111 11111            | M 11111 11111            |
On a second set of cards, or on these same cards in different fields the proper answers should be punched. Note that these answers will depend upon when ten or twenty digit products are used, that is, whether the product accumulators are used as ten or twenty digit accumulators.

There are two methods of using these cards to check the numerical circuits of the multiplier. One is to have the answer on the same card and arrange for its transmission to the product accumulators with its sign changed (or the sign of one of the factors may be changed). In this case the whole sequence of cards in run and the presence of "zero" in the product accumulators indicates (with high probability since there could be compensating errors) that the numerical circuits are all right.

A second method is to run the test and cause the answers to be punched on other cards. These results may then be compared with standard answers by use of the reproducing punch.

This procedure does not check the following:

Rounding off circuits
Program controls (other than the one used).

2.4. TO TEST A FUNCTION TABLE

An accumulator is used to build up the argument. A program control on the function table has its function switch set to "-2" and a second switch has its argument set to "+2".

The programming is so arranged that the "-2" program is activated and the output sent to an accumulator associated with the printer. The result is punched on a card, "one" is added to the argument, and the process repeated.
The master programmer can be used to repeat the "-2" program 96 times and then alternately activate the "-2" and the "+2" program four more times. (Or various other schemes may be devised to obtain all 104 entries to the function table.) The cards punched in this manner can then be compared with a standard deck.

Note that the above check is not a systematic check of the numerical circuits as a whole. In other words this check should be repeated if any switches on the portable table (or on panel No. 2) are changed.

Furthermore, the above procedure does not check the various program controls of the function table.

2.5. TO TEST THE DIVIDER AND SQUARE ROOTER

The divider and square rooter can best be checked by performing test division problems and square root problems. Drawing PX-10-111 gives the neons which should be lit at various places in the process. The operator can check against this by going through the problem at one addition time.

2.6. CONSTANT TRANSMITTER TEST PROCEDURE

The 1, 2, 2', 4 channels in the constant transmitter can all be checked simultaneously by reading cards with nine punches on them. Since it is undesirable that the same number be punched in all columns of a card (this weakens a card increasing the probability of "jamming" in the feeding mechanism of the IBM machines) it is suggested that cards be prepared as follows.

1) 9's in groups $A_{LR}$ and $B_{LR}$
2) 9's in groups $C_{LR}$ and $D_{LR}$
3) 9's in groups $E_{LR}$ and $F_{LR}$
4) 9's in groups $G_{LR}$ and $H_{LR}$

5) Four more cards similar to above but with minus punches.

The programming should be arranged so that the numbers are transmitted into accumulators when they can be inspected visually or perhaps punched on other cards and compared with a standard deck using the reproducing punch.

Note that $J_{LR}$ and $K_{LR}$ should be checked in a similar manner. (These only need be checked for the numbers used in the set-up provided they are re-checked any time that some of the switch settings are changed.)

This procedure does not check all the program controls.

2.7. PRINTER TEST PROCEDURE

The printer can be tested by causing all possible digits in each channel to be punched and by checking the PM delays. The following cards should be prepared.

1) P 01234 56789
2) P 11111 11101
3) P 11111 11011
6) P 11111 11106
10) P 01111 11111
11) P 11111 11111

The programming should be arranged to cause the numbers on the test cards to be read by the IBM reader, transmitted to the printing accumulators, and the result punched. The resulting cards may be compared with a standard deck by use of the reproducing punch.

Card number one has the numbers 0 to 9 punched in it to prevent the same digit from being punched all across a card.
If any decades of the master programmer are used in printing they may be checked at this time by transmitting the program pulse (used to activate the above sequence) into each decade direct input.

This constitutes a complete test of the printer.

2.8. TESTING FOR TRANSIENT FAILURES

If transient failures are suspected a master programmer stepper should be used to repeat the appropriate test (such as one of those above) a large number of times.

In case of an accumulator this can be done using only one card (say, p 99999 99999) and using a second program control set to αC (receive on α and correct) to obtain the one pulse in the units decade.

For the multiplier it becomes necessary to punch the answers on the cards with the factors (see 2.3) and cause these to be transmitted to the product accumulators for each multiplication. If more than ten digit answers are used the adjusted answer to card 83 must be carefully prepared in order to get minus the answer from the constant transmitter to the product accumulators (since the constant transmitter only complements at most ten digits at a time).

Repetition of a function table test is straightforward. It may be worth while to receive into a twenty digit accumulator and repeat the transmission 10^4 times, say, and see if the proper number is obtained.

The square root of zero is perhaps the easiest test to repeat on the divider-square rooter.

The constant transmitter can be caused to transmit any group repeatedly to some accumulator. Dust particles may cause transient relay failures, so avoid stirring up dust in the ENIAC room. Also, if any relay case is removed, always
replace in exactly the same position in order not to disturb dust inside the case.

Transient failures in the printer are probably relay failures. See maintenance manual for list of probable failures.
### Neons On During Division

<table>
<thead>
<tr>
<th>ADD TIME</th>
<th>PROG RING</th>
<th>PLACE RING</th>
<th>RECEIVER</th>
<th>D'y Ns</th>
<th>D N' N'</th>
<th>N* N'</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-1</td>
<td>A</td>
<td>9</td>
<td></td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td>2</td>
<td>B</td>
<td>9</td>
<td></td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
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<tr>
<td>3</td>
<td>A</td>
<td>9</td>
<td></td>
<td>ON</td>
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<td>ON</td>
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<td>II-1</td>
<td>A</td>
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<td>ON</td>
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<td></td>
<td>I-10n/10c</td>
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<td></td>
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<td></td>
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<td>ON</td>
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<td>ON</td>
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<td></td>
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<td>A</td>
<td></td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
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<td>III</td>
<td>A</td>
<td>9</td>
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<td>ON</td>
<td>ON</td>
<td>ON</td>
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<td></td>
<td>2</td>
<td>B</td>
<td></td>
<td>ON</td>
<td>ON</td>
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<td></td>
<td>3</td>
<td>1</td>
<td></td>
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<td></td>
<td>4</td>
<td>2</td>
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<td>7</td>
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<td>ON</td>
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<td>ON</td>
</tr>
</tbody>
</table>

#### Notes
1. On if previous program was a division.
2. On if denominator is positive when received in denominator accumulator.
3. If before denominator is added to or subtracted from numerator, the numerator is positive, neon #4 is on; otherwise neon #3 is on.
4. Goes on when interlock pulse is received.
5. Goes on when one addition time after III-9.

### Neons On During Square Rooting

<table>
<thead>
<tr>
<th>ADD TIME</th>
<th>PROG RING</th>
<th>PLACE RING</th>
<th>RECEIVER</th>
<th>D'y Ns</th>
<th>D N' N'</th>
<th>N* N'</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-1</td>
<td>A</td>
<td>9</td>
<td></td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td>2</td>
<td>B</td>
<td>9</td>
<td></td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td>3</td>
<td>A</td>
<td>9</td>
<td></td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td>II-1</td>
<td>A</td>
<td>9</td>
<td></td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>D'y+1</td>
<td></td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>D'y+2</td>
<td></td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
<td>A</td>
<td></td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td></td>
<td>(2)</td>
<td>A</td>
<td></td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td>III</td>
<td>A</td>
<td>9</td>
<td></td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>B</td>
<td></td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1</td>
<td></td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>2</td>
<td></td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>3</td>
<td></td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>4</td>
<td></td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>5</td>
<td></td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>6</td>
<td></td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>7</td>
<td></td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
</tr>
</tbody>
</table>

#### Notes
1. On if previous program was a division.
2. On if denominator is positive when received in denominator accumulator.
3. If before denominator is added to or subtracted from numerator, the numerator is positive, neon #4 is on; otherwise neon #3 is on.
4. Goes on when interlock pulse is received.
5. Goes on when one addition time after III-9.

**Foot Notes**
- On if previous program was a division.
- On if denominator is positive when received in denominator accumulator.
- If before denominator is added to or subtracted from numerator, the numerator is positive, neon #4 is on; otherwise neon #3 is on.
- Goes on when interlock pulse is received.
- Goes on when one addition time after III-9.

**Notes**
- In I case, in which ever occurs later: two addition times after III-9 or one addition time after neon 7.
- Only if no overdraft results.
THE ENIAC
ELECTRONIC NUMERICAL INTEGRATOR AND COMPUTER

Developed, Designed and Constructed by

Moore School of Electrical Engineering
University of Pennsylvania

DC voltage for motor

DC voltage selector switch

DC voltage selector switch

While tensions on the voltage selector switches are at least one tension is derived from a voltage selector.

DC voltage selector switch

The four voltage selector switches are controlled by the four major voltage sources of the circuit.

Start and stop switches

Pushing the start switch turns on the four major voltage sources.

Stop switch

Turning the stop switch turns off the major voltage sources.

DC power supply switch

This switch is used to control the four major voltage sources.

Initial clear switches

These switches are used to clear the circuit prior to operation.

Initialization switches

These switches are used to clear the circuit prior to operation.

F1 = pulse input terminal for printer

F2 = program pulse output terminal for printer

F3 = pulse input terminal for printer

F4 = program pulse output terminal for printer

F5 = pulse input terminal for printer

F6 = program pulse output terminal for printer

F7 = pulse input terminal for printer

F8 = program pulse output terminal for printer

F9 = pulse input terminal for printer

F10 = program pulse output terminal for printer

F11 = pulse input terminal for printer

F12 = program pulse output terminal for printer

F13 = pulse input terminal for printer

F14 = program pulse output terminal for printer

F15 = pulse input terminal for printer

F16 = program pulse output terminal for printer

F17 = pulse input terminal for printer

F18 = program pulse output terminal for printer

F19 = pulse input terminal for printer

F20 = program pulse output terminal for printer

F21 = pulse input terminal for printer

F22 = program pulse output terminal for printer

F23 = pulse input terminal for printer

F24 = program pulse output terminal for printer

F25 = pulse input terminal for printer

F26 = program pulse output terminal for printer

F27 = pulse input terminal for printer

F28 = program pulse output terminal for printer

F29 = pulse input terminal for printer

F30 = program pulse output terminal for printer

F31 = pulse input terminal for printer

F32 = program pulse output terminal for printer

F33 = pulse input terminal for printer

F34 = program pulse output terminal for printer

F35 = pulse input terminal for printer

F36 = program pulse output terminal for printer

F37 = pulse input terminal for printer

F38 = program pulse output terminal for printer

F39 = pulse input terminal for printer

F40 = program pulse output terminal for printer

F41 = pulse input terminal for printer

F42 = program pulse output terminal for printer

F43 = pulse input terminal for printer

F44 = program pulse output terminal for printer

F45 = pulse input terminal for printer

F46 = program pulse output terminal for printer

F47 = pulse input terminal for printer

F48 = program pulse output terminal for printer

F49 = pulse input terminal for printer

F50 = program pulse output terminal for printer

F51 = pulse input terminal for printer

F52 = program pulse output terminal for printer

F53 = pulse input terminal for printer

F54 = program pulse output terminal for printer

F55 = pulse input terminal for printer

F56 = program pulse output terminal for printer

F57 = pulse input terminal for printer

F58 = program pulse output terminal for printer

F59 = pulse input terminal for printer

F60 = program pulse output terminal for printer

F61 = pulse input terminal for printer

F62 = program pulse output terminal for printer

F63 = pulse input terminal for printer

F64 = program pulse output terminal for printer

F65 = pulse input terminal for printer

F66 = program pulse output terminal for printer

F67 = pulse input terminal for printer

F68 = program pulse output terminal for printer

F69 = pulse input terminal for printer

F70 = program pulse output terminal for printer

F71 = pulse input terminal for printer

F72 = program pulse output terminal for printer

F73 = pulse input terminal for printer

F74 = program pulse output terminal for printer

F75 = pulse input terminal for printer

F76 = program pulse output terminal for printer

F77 = pulse input terminal for printer

F78 = program pulse output terminal for printer

F79 = pulse input terminal for printer

F80 = program pulse output terminal for printer

F81 = pulse input terminal for printer

F82 = program pulse output terminal for printer

F83 = pulse input terminal for printer

F84 = program pulse output terminal for printer

F85 = pulse input terminal for printer

F86 = program pulse output terminal for printer

F87 = pulse input terminal for printer

F88 = program pulse output terminal for printer

F89 = pulse input terminal for printer

F90 = program pulse output terminal for printer

F91 = pulse input terminal for printer

F92 = program pulse output terminal for printer

F93 = pulse input terminal for printer

F94 = program pulse output terminal for printer

F95 = pulse input terminal for printer

F96 = program pulse output terminal for printer

F97 = pulse input terminal for printer

F98 = program pulse output terminal for printer

F99 = pulse input terminal for printer

F100 = program pulse output terminal for printer

Note: The initiating switches are used to clear the circuit prior to operation.

Initial clear switches

When the switches are turned on, the switches are used to clear the circuit prior to operation.

Initialization switches

These switches are used to clear the circuit prior to operation.

F1 = pulse input terminal for printer

F2 = program pulse output terminal for printer

F3 = pulse input terminal for printer

F4 = program pulse output terminal for printer

F5 = pulse input terminal for printer

F6 = program pulse output terminal for printer

F7 = pulse input terminal for printer

F8 = program pulse output terminal for printer

F9 = pulse input terminal for printer

F10 = program pulse output terminal for printer

F11 = pulse input terminal for printer

F12 = program pulse output terminal for printer

F13 = pulse input terminal for printer

F14 = program pulse output terminal for printer

F15 = pulse input terminal for printer

F16 = program pulse output terminal for printer

F17 = pulse input terminal for printer

F18 = program pulse output terminal for printer

F19 = pulse input terminal for printer

F20 = program pulse output terminal for printer

F21 = pulse input terminal for printer

F22 = program pulse output terminal for printer

F23 = pulse input terminal for printer

F24 = program pulse output terminal for printer

F25 = pulse input terminal for printer

F26 = program pulse output terminal for printer

F27 = pulse input terminal for printer

F28 = program pulse output terminal for printer

F29 = pulse input terminal for printer

F30 = program pulse output terminal for printer

F31 = pulse input terminal for printer

F32 = program pulse output terminal for printer

F33 = pulse input terminal for printer

F34 = program pulse output terminal for printer

F35 = pulse input terminal for printer

F36 = program pulse output terminal for printer

F37 = pulse input terminal for printer

F38 = program pulse output terminal for printer

F39 = pulse input terminal for printer

F40 = program pulse output terminal for printer

F41 = pulse input terminal for printer

F42 = program pulse output terminal for printer

F43 = pulse input terminal for printer

F44 = program pulse output terminal for printer

F45 = pulse input terminal for printer

F46 = program pulse output terminal for printer

F47 = pulse input terminal for printer

F48 = program pulse output terminal for printer

F49 = pulse input terminal for printer

F50 = program pulse output terminal for printer

F51 = pulse input terminal for printer

F52 = program pulse output terminal for printer

F53 = pulse input terminal for printer

F54 = program pulse output terminal for printer

F55 = pulse input terminal for printer

F56 = program pulse output terminal for printer

F57 = pulse input terminal for printer

F58 = program pulse output terminal for printer

F59 = pulse input terminal for printer

F60 = program pulse output terminal for printer

F61 = pulse input terminal for printer

F62 = program pulse output terminal for printer

F63 = pulse input terminal for printer

F64 = program pulse output terminal for printer

F65 = pulse input terminal for printer

F66 = program pulse output terminal for printer

F67 = pulse input terminal for printer

F68 = program pulse output terminal for printer

F69 = pulse input terminal for printer

F70 = program pulse output terminal for printer

F71 = pulse input terminal for printer

F72 = program pulse output terminal for printer

F73 = pulse input terminal for printer

F74 = program pulse output terminal for printer

F75 = pulse input terminal for printer

F76 = program pulse output terminal for printer

F77 = pulse input terminal for printer

F78 = program pulse output terminal for printer

F79 = pulse input terminal for printer

F80 = program pulse output terminal for printer

F81 = pulse input terminal for printer

F82 = program pulse output terminal for printer

F83 = pulse input terminal for printer

F84 = program pulse output terminal for printer

F85 = pulse input terminal for printer

F86 = program pulse output terminal for printer

F87 = pulse input terminal for printer

F88 = program pulse output terminal for printer

F89 = pulse input terminal for printer

F90 = program pulse output terminal for printer

F91 = pulse input terminal for printer

F92 = program pulse output terminal for printer

F93 = pulse input terminal for printer

F94 = program pulse output terminal for printer

F95 = pulse input terminal for printer

F96 = program pulse output terminal for printer

F97 = pulse input terminal for printer

F98 = program pulse output terminal for printer

F99 = pulse input terminal for printer

F100 = program pulse output terminal for printer

Note: The initiating switches are used to clear the circuit prior to operation.

Initial clear switches

When the switches are turned on, the switches are used to clear the circuit prior to operation.

Initialization switches

These switches are used to clear the circuit prior to operation.
Time schedule for multiplication

A multiplication requires from 6 to 10 addition times (depending upon the setting of the plunger switch) including the time required for loading the multiplier and multiplicand, but not including the time required for display of the product.

Addition times

<table>
<thead>
<tr>
<th>Operation</th>
<th>Multiplier and multiplicand received</th>
<th>Five round-off pulses transmitted to left-hand product reg. (A1, A2)</th>
<th>Multiplied (10) times</th>
<th>Network multiplied by first place</th>
<th>and left and right hand components transmitted to left and right hand product reg.</th>
<th>P.S.</th>
<th>P.S.</th>
<th>(Program input pulse and enemy diagonal pulse enabled at end of 5th addition time)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P.S.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P.S.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Significant figures switch

This switch may be used to give a variable round-off, i.e., a product which is rounded off to a different place for each program control. This switch governs the addition of 2 pulses into the proper place of the left-hand product reg. (A1, A2) during the second addition time of the multiplication.

It does not control the addition of the non-significant digits of the product but the placing of the significant digits in the proper amount of the product in a correct ternary number. Since these digit terms are of the right-hand digit terms, they must be taken care of all the accumulation time as well as the product. If more than one place is to be rounded off in the same number of places, it is best to use the round-off facilities of the right-hand product reg. (A3, A4).

Place switch

This provides the number of places of the multiplier that are to be used in the multiplication. The multiplier digits are read from left to right, so that the most significant digits are used first. The places referred to are the places of the multiplier reg. created from the left.

The place switch is completely independent of the significant figures switch. The reason for this is that all rights of the multiplicand are used in the multiplication process. The only purpose of the place switch is to ease use.
NOTE—Horizontal lines above the units represent digit trays. The dotted lines represent trays which need be used only when 20 digit products are found.
Function output template

Each digit plate represents the value of a function assigned to those terminals. The figures shown for this plate are only examples of the possible arrangements of the function output terminals. It is to be noted that the direction of the right constant digit switch and the left constant digit switch for any number can be reversed by any means.

Field showing connection of function output template

**Line**
- 16 (ground)
- 12 (120 ohm line)
- 10 (120 ohm line)
- 8 (120 ohm line)
- 4 (120 ohm line)
- 2 (120 ohm line)
- 1 (120 ohm line)

**Terminal A**
- Constant digit switch A
- Constant digit switch B
- Constant digit switch C
- Constant digit switch D
- Constant digit switch E
- Constant digit switch F
- Constant digit switch G

**Terminal B**
- Constant digit switch A
- Constant digit switch B
- Constant digit switch C
- Constant digit switch D
- Constant digit switch E
- Constant digit switch F
- Constant digit switch G

Constant digit switch

For the digit delete switch, in order to delete the digit from the function output terminal, the digit must be left unconnected. For all values of a function, the sum of all the digits may be set up in the constant digit

Constant digit switch

Delete digit switch

The digit delete switch is set in order to delete the digit from the function output terminal. When the digit is left unconnected, the digit may be set up in the constant digit switch for all values of a function. If all switches are in the terminal, the output of the terminal is represented by the number that is shown. If the switch corresponding to the terminal is set up to 12, then the switch corresponding to the terminal is set up to 12; the sum is the total number of digits in the terminal.

Pulse output template

The digit delete switch is set in order to delete the digit from the function output terminal. The digit is left unconnected. The constant digit switch for all values of a function may be set up in the constant digit switch for all values of a function. If all switches are in the terminal, the output of the terminal is represented by the number that is shown. If the switch corresponding to the terminal is set up to 12, then the switch corresponding to the terminal is set up to 12; the sum is the total number of digits in the terminal.

Sample view of switches on portable function table showing connection to function output terminals.

Terminal A
- Constant digit switch A
- Constant digit switch B
- Constant digit switch C
- Constant digit switch D
- Constant digit switch E
- Constant digit switch F
- Constant digit switch G

Terminal B
- Constant digit switch A
- Constant digit switch B
- Constant digit switch C
- Constant digit switch D
- Constant digit switch E
- Constant digit switch F
- Constant digit switch G

For a positive number, set 0 to 12 and set the number on the switches. For a negative number, set 0 to 12 and set the complement of the number with respect to 12 on the switches.

MOORE SCHOOL OF ELECTRICAL ENGINEERING
UNIVERSITY OF PENNSYLVANIA

FUNCTION TABLE FRONT PANEL NO. 2

MATERIAL: FINISH: SCALE:

Drawn by: Checked by: Approved by:

JANUARY 1944

PX7-303
No Load Box is used on this tray which carries pulses for the answer. No other units are to be connected into it.

**Digit Tray With Load Box**

<table>
<thead>
<tr>
<th>ITEM</th>
<th>DESCRIPTION</th>
<th>REFER TO</th>
</tr>
</thead>
<tbody>
<tr>
<td>ST1, SU1</td>
<td>Accumulator Interconnector Terminals</td>
<td>PX-5-105</td>
</tr>
<tr>
<td>SU2, SU3</td>
<td>Divider &amp; Square Rooter Programming Terminals</td>
<td>PX-10-108</td>
</tr>
<tr>
<td>a</td>
<td>Special Cable from Digit Tray to ST1, SU1, on Quotient Acc.</td>
<td>PX-5-134</td>
</tr>
<tr>
<td>b, c</td>
<td>Adaptors from SU2 to Digit Tray or from SU3 to Digit Tray</td>
<td>PX-4-114A, A &amp; AC Adaptor, PX-4-114B, A &amp; SC Adaptor, PX-4-114C, AC &amp; SC Adaptor</td>
</tr>
<tr>
<td>d</td>
<td>Special Cable from Digit Tray to ST1, SU1, on the Denom. &amp; Sq. Root Acc.</td>
<td>PX-5-136</td>
</tr>
<tr>
<td>e</td>
<td>Special Cable from Digit Tray to ST1, SU1, on the Shift Acc.</td>
<td>PX-5-135</td>
</tr>
<tr>
<td>f</td>
<td>Special Cable from SV to ST1, SU1, on the Numerator Acc.</td>
<td>PX-5-137</td>
</tr>
</tbody>
</table>

Interconnection of Divider & Square Rooter with Associated Accumulators ~ PX-10-307

Moore School of Electrical Engineering
University of Pennsylvania
The constant transmitter has a capacity of 100 digits and 30 signs. These are divided into 10 sets (A, B, C, etc.), each consisting of 10 digits and 3 signs. Eight of these sets (A, B, C, etc.) are supplied from IBM readers through the IBM reader when proper connections are made in the IBM reader plug board (see Fig 15-20-21). Two of these sets (A1 and A2) are supplied from the constant set switches and no modifications are necessary.

This set may be further divided into two groups, a left-hand group and a right-hand group, each consisting of 5 digits and a sign. This division must remain fixed throughout a given setup. For example, if set 5 is divided into five digits, then 5 and all of the constant selector switches 1 to 15 may be used in the left-hand group, but not in the right-hand group. Conversely, if the set is not divided, then any one of all of the constant selector switches 1 to 15 may be used in the left-hand and right-hand group.

The IBM reader is programmed from the initiating unit (see Fig 15-20). The IBM reader controls and plugboard are described in Fig 15-20-21.

Constant Transmitter Program Controls

There are 35 constant transmitter program controls, each capable of transmitting certain of the constants to the right output terminal. Only one program control can be used at a time, hence only one constant can be transmitted at a time.

Each program control consists of:
1. Program pulses input terminals (when activated by the IBM reader during program "transmission" of a given set to the constant selector switch)
2. Program selector switches
3. Program selector switch selection
4. Program selector switch selection
5. Program selector switch selection
6. Program selector switch selection
7. Program selector switch selection
8. Program selector switch selection
9. Program selector switch selection
10. Program selector switch selection
11. Program selector switch selection
12. Program selector switch selection
13. Program selector switch selection
14. Program selector switch selection
15. Program selector switch selection
16. Program selector switch selection
17. Program selector switch selection
18. Program selector switch selection
19. Program selector switch selection
20. Program selector switch selection
21. Program selector switch selection
22. Program selector switch selection
23. Program selector switch selection
24. Program selector switch selection
25. Program selector switch selection
26. Program selector switch selection
27. Program selector switch selection
28. Program selector switch selection
29. Program selector switch selection
30. Program selector switch selection
31. Program selector switch selection
32. Program selector switch selection
33. Program selector switch selection
34. Program selector switch selection
35. Program selector switch selection

Program controls 1-19, which transmit constants read from the IBM reader, cannot be used during the operation of the right hand group (see Fig 15-20). These controls may be used during the 50 subsequent addition times, but not thereafter until a pulse is supplied from the initiating unit.
For a positive number, set the A/B to 2 and set the number on the switches.

For a negative number, set the A/B to 1 and set the complement of each digit with respect to 0 in all 10 switches where the complement with respect to 0 is set.

For a two-digit number, both 10 switches should be set to the signs of the number.
Note: Do not change polarity switch while motor-generator is on.
General Description of Printer

The printer operates from the static output of accumulator and master programmer decoder. The cables connecting the decade static terminal to the printer lie in a trough at the top of the frame of the machine, a table, showing the original set of connections, appears on 12/12/16. Every accumulator decade and 3-bit unit and every master programmer decade has a static input terminal.

The decoder to be printed are divided into eleven groups of 5 digits and 2 3-bit units: 1-11. The printing switches common to all groups are connected to the IBM switch panel, excepting 1-11, which has its own switch panel. Each group of 5 digits also is connected by switches to the IBM switch panel, except 1-11. Any group of 5 digits may be connected to an adjacent group by means of the coupling sections in the panel, 11B, 12B, 13B, 14B, and 15B which may be selected.

The master to be printed is located in a compartment (see the compartment at the lower right side of the machine). The 1-11 switch panel is operated along with an 11 switch to indicate that 11 is required.

Storage information in the master programmer is printed selector 10/10/15 13 must be set at the printer panel to panel 0 so as to provide the proper input leads going into the printer.

The printer is programmed from the printing unit (see 10/10/10). Controls on the IBM key panel are explained on 12/12/16.

Positive Switch

This switch connects to the positive position or disconnects the master from the panel position. The master may be connected to the buffer via the panel, so that these records are for use only. It is necessary that this switch be set at the proper position when the printer is connected. For the use of this switch it is necessary that only this position be set when the printer is connected. It is necessary that this switch be set at the proper position. When the printer is connected, the positive switch must be turned off if the printer is disconnected and not turned on.

MOORE SCHOOL OF ELECTRICAL ENGINEERING
UNIVERSITY OF PENNSYLVANIA

PRINTER FRONT PANEL NO. 2

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>FINISH</th>
<th>SHEET</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

Drawn by: J. R. SMITH
Date: 1/1/1964

Changed by: Approved by:
Date: 1/1/1964

PX12-302
Computer punch unit

These nine contacts directly to the digit relays of the printer. To punch positive numbers they can be plugged to the punch magnet hole in any desired arangement. Thus, it is possible to plug the digits coming from the group 1 relays in any three of the eight columns on the IBM card.

Side indications

The eighteen holes under side indications go directly to the 84 relays of the sixteen groups. The side indications of any group could be plugged side indications can be plugged to the corresponding side indications of the punch magnets.

Usually, however, the side indication will appear above some digit of the number on the card. To place the side indication (as all punch magnets) above the first digit of the number the side indication of the corresponding group is plugged to one of the terminals labeled 'a' on side indication strips. The hole in the 'a' strips directly under the punch end are to be plugged, respectively, to the digit relays of the punch magnets that indicate the numbers desired. The side indication is connected to the corresponding hole of the punch magnets.

The column splice is simply a sixteen pole double throw relay switch. This switch is controlled by a cam in the IBM punch which causes the 'a' holes to be connected to the respective 'a' holes during the 11 position of the card and to the 'b' holes during the 12 position of the card.

Punch outputs

If one of these holes is plugged to a punch magnet but the corresponding number will be plugged in that column of the card. The first row of five columns has the right of the center column enables one to punch the same number in more than three columns. The connection labeled 'a' in the diagram causes holes to be punched in all columns 17, 18, 19, 20 on the card. Connections such as these cause the corresponding number to be punched in every column. This can be used for identifying numbers to the reader in 9 to 10 places on the card. Alphanumeric punching cannot be done on this machine.
A stepper is a six stage ring counter. It has the following associated with it:

1. Stepper program pulse input terminals.
2. Six stepper program pulse output terminals, one associated with each stage of the stepper.
3. A group of decade switches (0 to 9) mounted upon the stacker and the settings of the decade switches are connected to a direct current input circuit (through a relay), to the output terminals of each group and across the decade switches as described in the schematic diagram. The position of the decade switches is indicated by a decimal counter or digital indicator. Each decade switch has a corresponding digit (0 to 9) which is used to select a particular state of the stepper.
4. Stepper clear switch.
5. Stepper direct input terminal.
6. Stepper clear direct input terminal.
7. Each decade has a direct input terminal.

The operation of a stepper and its associated equipment is as follows:

At the end of the initial cycle each steppers is set on the least stage or first decade is cleared to 0.

Suppose a program pulse is applied on a stepper program pulse input terminal. One additional time later a program pulse is emitted from the program pulse output terminal corresponding to the stage the stepper is on at the time it is activated and a program pulse is sent to the units decade of the group of associated decades.

During a group of decades equals to the number of the decade switches corresponding to the position of the stepper, one additional time later the decade switches are cleared and the steppers are either stopped at the next position 0 or (if it is the last position on the ring) they are turned off. After all decades have been cleared, the steppers will either be cleared or stopped at the next position. If the next position is not within the range of the associated decades, the steppers will remain in their current position. If the next position is within the range of the associated decades, the steppers will be cleared or stopped at the next position.

The decade switches with the pulses supplied to the associated steppers program pulse input terminals (with one additional time delay) and those supplied to the decade direct input terminals. This setup is permissible since the output pulses are transferred to a decade and the decade switches are cleared (if they are not already cleared) and the steppers are either stopped at the next position or (if it is the last position on the ring) they are turned off. After all decades have been cleared, the steppers will either be cleared or stopped at the next position. If the next position is not within the range of the associated decades, the steppers will remain in their current position. If the next position is within the range of the associated decades, the steppers will be cleared or stopped at the next position.

The additional time delay is necessary to ensure that the output pulses are transferred to a decade switches and the steppers are either stopped at the next position or (if it is the last position on the ring) they are turned off. After all decades have been cleared, the steppers will either be cleared or stopped at the next position. If the next position is not within the range of the associated decades, the steppers will remain in their current position. If the next position is within the range of the associated decades, the steppers will be cleared or stopped at the next position.