Then you need HMI’s development systems. We support the entire 68000 family. As Motorola enhances and increases integration of its microprocessors, you can count on HMI to be there with high-quality development products to support your projects. HMI believes in supporting the entire family of products for the Motorola family. Ease of use and familiarity are common in all the emulators.

Features of HMI’s development systems includes:

- Run at real-time with no wait states.
- Window driven source level debugging—SourceGate®.
- C, Pascal and ADA compiler source level support for all major compiler companies.
- Real-time hardware performance analyzer.
- Works with IBM PC family and UNIX based machines including Sun and Apollo.
- RS232 Interface up to 115.2K.
- Parallel Interface for high-speed code downloading.
- Complex events and sequences for break and trigger conditions.
- Two independent 4K deep trace buffers.
- 1 µsec resolution interval timer.
- 100 nsec resolution Time-stamp in trace buffer.
- Logic state analyzer capabilities built into the emulator.
- 16 External Trace bits.
- Overlay memory up to 4 Mbytes.

If you are looking for one emulator company that provides support for the entire Motorola family, then look to HMI for total support.

Motorola Devices Supported Include:

<table>
<thead>
<tr>
<th>Device Code</th>
<th>Description</th>
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<tbody>
<tr>
<td>68000</td>
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<td>68008</td>
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Huntsville Microsystems, Inc.
3322 South Memorial Parkway
Huntsville, AL 35801
Tel.: (205) 881-6005
FAX: (205) 882-6701

IBM is Reg. T.M. International Business Machines, Inc. Unix is Reg. T.M., Bell Laboratories, Inc.
MILITARY TRIMMERS from the Techno Division include broad MIL qualification to RT24, 26, 27, RTR24, RJ24, 26 and RJR24, 26. Techno RJ24 and RJR24 trimmers offer you 25 turns for precision adjusting, while the RJ26 and RJR26 offer 22 turns. They have zero backlash and offer a monolithic clutch. In addition, Techno offers ½” and ¾” multturn trimmers with a TCR of ± 50 PPM/°C for precision applications. All Established Reliability trimmers meet the requirements of MIL-STD-202, Method 208.

Contact: Techno Division, Dale Electronics, Inc., 7803 Lemona Avenue, Van Nuys, California 91405-1139 Phone (818) 781-1642.

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Having difficulty locating RF or pulse transformers with low droop, fast risetime or a particular impedance ratio over a specific frequency range?...Mini-Circuits offers a solution.

Choose impedance ratios from 1:1 to 36:1, connector or pin versions (plastic or metal case built to meet MIL-T-21038 and MIL-T-55831 requirements*). Ultra-wideband response achieves low droop and fast risetime for pulse applications. Ratings up to 1000M ohms insulation resistance and up to 1000V dielectric voltage. For wide dynamic range applications involving up to 100 mA DC primary current, use the T-H series.

Coaxial connector models are offered with 50 and 75 ohm impedance; BNC standard; request other types.

Available for immediate delivery with one-year guarantee.

*units are not QPL listed

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<table>
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<tr>
<th>NSN GUIDE</th>
<th>MCL NO.</th>
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<td>TMO1-1</td>
<td>5950-01-178-2612</td>
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</table>

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**Case styles**

- T, TH, case W 38, X 65 bent lead version, KK81 bent lead version
- TMO, case A 11, FT, case B 13
- FTB, case H 16

**NEW TC SURFACE MOUNT MODELS from 1MHz to 1500 MHz**
Spdt switches with built-in driver

**Absorptive or Reflective** to 5GHz

Truly incredible... superfast 3nsec GaAs SPDT reflective or absorptive switches with built-in driver, available in pc plug-in or SMA connector models, from only $19.95. So why bother designing and building a driver interface to further complicate your subsystem and take added space when you can specify Mini-Circuits' latest innovative integrated components?

Check the outstanding performance of these units... high isolation, excellent return loss (even in the "off" state for absorptive models) and 3-sigma guaranteed unit-to-unit repeatability for insertion loss. These rugged devices operate over a -55°C to +100°C span. Plug-in models are housed in a tiny plastic case and are available in tape-and-reel format (1500 units max, 24mm). All models are available for immediate delivery with a one-year guarantee.

**SPECIFICATIONS (typ)**

<table>
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<th>Absorptive SPDT</th>
<th>Reflective SPDT</th>
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<td>Isolation (dB)</td>
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<td>1dB Comp. (dBm)</td>
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<td>22 22 26</td>
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<td><strong>VSWR</strong> (on)</td>
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<td>YZWSA-2-50DR (pin) 69.95</td>
<td>YZWSA-2-50DR (SMA) 59.95</td>
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</table>

**Finding new ways...**

**Setting higher standards**

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**Mini-Circuits**
P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 Telexes: 6852844 or 620156
SPECIAL REPORT

32-bit floating-point DSP processors

Thirty-two-bit floating-point DSP processors are the muscle machines for the 1990s. These single-chip µPs are powerful math engines that have hardware bolted on for multiprocessing and large addressing. They're tackling applications ranging from voice recognition to near-supercomputer processing.—Ray Weiss, Regional Editor

DESIGN FEATURES

Wescon/91: Show and products

The Jim Williams Papers

In this issue, EDN presents the last three in a group of articles on high-speed analog design.

Filters and oscillators

Filters get rid of a signal's unwanted frequency components. Oscillators create signals at predictable frequencies. As you might imagine, the two types of circuits have more than a little in common.

High-speed data-conversion circuits

The variety of circuits that prove useful in high-speed data conversion is almost limitless. Here is a collection of circuits that can turn out to be lifesavers in several situations.

High-speed communications circuits

High-frequency communications signals need wideband analog circuits. High-speed monolithic amplifiers let you build simple, effective circuits to meet this need for both optical and RF transmission.

Continued on page 7
Our Westcor division’s family of configurable AC or DC input fan cooled StakPAC switchers reveals a new world of power density and output flexibility to the system designer...whatever your power needs. Each StakPAC is built with field proven robotically manufactured Vicor VI-200 Series power components providing you the flexibility of a customized supply combined with the off-the-shelf availability of standard catalog products..."first article" StakPACs are typically delivered in 2 weeks.

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Call VICOR EXPRESS for information and be sure to ask for a StakPAC or DC Mini Handbook: (800) 735-6200 or (508) 470-2900 at ext. 265. Or call Westcor (west coast) at (408) 395-7050.

VICOR
Component Solutions For Your Power System
As math software packages evolve and expand their palette of features, the question remains as to how much you need to spend to get the functions you want. See what your more than $400 will buy on pg 75.

EDN magazine now offers Express Request, a convenient way to retrieve product information by phone. See the Reader Service Card in the front for details on how to use this free service.

Use Spice and analog circuits to model control systems
If you already know Spice, you don’t have to learn another simulator to model control systems. You can just replace system block diagrams with equivalent circuits.—George Ellis, Industrial Drives

Vintage filter scheme yields low distortion in new audio designs
Digital audio systems having wide dynamic range can strain antialiasing and anti-imaging filter requirements. Increasingly, audio designers are employing an almost forgotten filter architecture, the GIC filter, to achieve simplicity while meeting adequate attenuation and low-distortion requirements.—Rick Downs, Burr-Brown Corp

TECHNOLOGY UPDATES
Factory-automation networks:
The best LAN may be found off the MAP
Before you select a local-area network (LAN) that will operate in an industrial environment, you must consider a variety of factors that range from the certainty of initial costs to the potential of future innovations.—J D Mosley, Regional Editor

Over-$400 math software packages:
Software smooths complex computations
Evolving math software packages reduce work associated with long and tedious calculations and let you concentrate more on the big picture.—John Gallant, Associate Editor

Silicon pressure sensors:
Inexpensive sensors provide precision
Today’s solid-state silicon pressure sensors take advantage of fabrication advancements in IC processing to provide a cost-effective solution for high-volume applications.—Tom Ormond, Senior Editor

Continued on page 9
As you would expect, the perfect Christmas calculator can do polar plots.

The HP 48SX will revolutionize the way you work.

No wonder the revolutionary HP 48SX is on so many wish lists this year. It's the only scientific calculator that has over 2100 built-in functions and custom capabilities.

You can type an equation just like it appears in a textbook. Graph an equation and determine its characteristics while viewing it. Or, with automatic unit management, enter data in any given unit and get the answer in the unit you want. And all with the option of accessing PCs via a built-in serial I/O.

And when you buy an HP 48SX this holiday season, you'll also be helping America's kids excel! Your purchase of an HP 48SX will help equip selected high schools with a $5,000 set of calculators and other key teaching materials.

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In-circuit emulator
Microcontroller for low-end voice processing
Digital encoder IC
Gyroscope for 3-D motion sensing
Fractal-based image-compression system

DESIGN IDEAS
Technique extends EEPROM life
Battery charger straddles input voltage
Charge pump powers high-side switch
5V powers filter-based oscillator
Radiation detector activates alarm
Feedback and Amplification

NEW PRODUCTS
Integrated Circuits
Components & Power Supplies
Test & Measurement Instruments
Computers & Peripherals
CAE & Software Development Tools

PROFESSIONAL ISSUES
The economic challenge of a united Europe
—Jay Fraser, Associate Editor

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OrCAD

Configure Schematic Design Tools

Category: Electrical Rules Matrix

Input Pin
Input/Output Pin
Output Pin
Open Collector Pin
Passive Pin
I I

Design Tools

Processors

Create Netlist

Create Hierarchical Netlist

Back Annotate

Select Field View

Cleanup Schematic

Transfers

To PLD

To Digital Simulation

To Layout

To Main

Universe

ms s s s s n

U I O B U C

John - This looks like ORCAD on the Sun Sparc Station. Call (503) 690-9881 and look into it.
The Microprocessors

Am386™ SXL-25 MICROPROCESSOR

1000 - PIECE PRICE

1992 1993 1994

$90

$80

$70

$60

$50

$40

$30

$20

$10

$0

1992 1993 1994
AMD Reintroduces Learning Curve Pricing With The Am386™ SXL-25 Microprocessor.

It's no ordinary 386SX.
It's the Am386SXL-25 microprocessor. A higher speed, lower power, plug-in replacement for the 386SX microprocessor.
And with it, AMD resurrects learning curve pricing.
That means aggressive, predictable price reductions between 20% and 30% each year.
Best of all, it's available today, available in quantity, and available to everyone.
That's why the Am386SXL-25 CPU is the microprocessor for the masses.
To get your hands on your own supply of Am386SXL-25 microprocessors, call AMD today at 1-800-222-9323.
You've heard the old saying, "we'll cross that bridge when we come to it." Well, we have.

Cost crossover today makes 4-meg DRAMs more economical per bit than 1-meg DRAMs. And given all the benefits in reliability and board real estate, that's good news.

People are lining up to take advantage of it.

One specific advantage is in memory modules. Samsung 4-meg-based modules are actually more cost-effective today than their 1-meg-based counterparts.

All the modules listed here have reliability specs based on 600 temperature cycles (0-125°C) and 500 hours (85°C, 85% RH). Available features include 70, 80, and 100 ns access.
ULES, COST-PER-BIT JUST BEEN COMPLETED.

times, fast page mode, low-power versions, gold lead finish, and customer-specific labeling.

**SAMSUNG MEMORY MODULES BASED ON 4-MEG DRAMs**

<table>
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<tr>
<th>Megabytes</th>
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</table>

Samsung is one of the world’s leading manufacturers of both DRAMs and memory modules. Our outstanding quality, reliability, and availability have helped us gain this leading position.

For data sheets on our 4-meg DRAMs and 4-meg-based modules, call 1-800-423-7364 or (408) 954-7229 today. Or write to Memory Module Marketing, Samsung Semiconductor, 3725 No. First St., San Jose, CA 95134.

*SAMSUNG Technology that works for life.*

CIRCLE NO. 9
HFA-0005.
Ultra high speed in a monolithic design. 420 V/µs slew rate. 300 MHz bandwidth.

HFA-0001.
This op really hops. Cause it's the world's fastest monolithic op amp. With 1000 V/µs slew rate, 350 MHz bandwidth.

CA-3080.
How about an operational transconductance amplifier? Harris has it. And it's a low-cost building block for high-speed systems.

HFA-0002.
Widely used for wideband applications, this monolithic features just 2.7 nV/√Hz input voltage noise.

HFA-0003.
Buffering video has never been easier. Thanks to a 1300 V/µs slew rate, excellent differential phase and gain.

HFA-0004.
This wideband precision op amp features 0.2 mV input offset voltage and 5 nA input bias current.

CA-3246.
This NPN transistor array covers a wide array of applications—all the way from DC to 1.5 GHz.

HA-5020.
Our low-cost version of the EL2020, but enhanced to give you a full 100 MHz bandwidth.

HA-2444.
A mux and 4 video op amps in a single chip. Ideal for digitally selectable 4-channel video.

HA-2548.
A mux and 4 video op amps in a single chip. Ideal for digitally selectable 4-channel video.

Ops till

From ops that really hop, to ops at low cost, nobody gives you more op amps to choose from than Harris. Where else could you get the fastest monolithic op amps in the world?

Over 35 op amps with bandwidth greater than 10 megahertz? Or 35 amps available in SOIC, as well as all the usual types and styles of packages?

EDN November 7, 1991
HA-5104 QUAD.
The synthesis of high performance and low noise in one op amp. This quad gives you 4.3 nV/√Hz input voltage noise.

HA-5221.
To be precise, there's no more precise 35 MHz op amp, just 3.4 nV/√Hz input noise voltage. Just 0.5 µV/C° offset voltage drift.

HA-5222.
What's better than an HA-5221? Two of them in one convenient package. Same low noise. Same low offset voltage drift.

HA-5004.
A 100 MHz current feedback amplifier with output current that's ultra-high: ±100 mA.

you drop.
Even processes from bipolar to CMOS to the best of both, BiCMOS? There's only one semiconductor company in the world that gives you all this. And that's Harris.

And there's only one number to call to find out more. 1-800-4-HARRIS, extension 1150.

CA-5470.
Low in cost, high in performance. This quad amp combo takes a single supply voltage from 3 to 16 V.
Once again, HP has its name in lights.

Leave it to HP to premiere the very first SMT LED offering the brightness, clarity, and color choices of through-hole LEDs.

As one of the world's most experienced LED suppliers, HP wrote the book on high-performance LEDs. Now you can see the same star performance on tape, because our new LED is compatible with tape-fed automatic pick & place equipment and SMT solder processes.

Its small footprint means you can pack more imprints per board. Yet it conforms to the EIA-535 BAAC standard specification for case size 3528 tantalum capacitors.

But we haven't let the bright lights go to our head. Our new SMT LED is competitively priced and multi-sourced.

A class production all the way, these new LEDs are designed to meet most quality and reliability standards, eliminating the need for incoming inspection.

Once again, HP sets the stage for quality, reliability, and innovation. To get the star treatment call 1-800-752-0900, ext. 2691, and ask for our FREE red & green SMT LED sample kit and the name of your nearest Hamilton/Avnet location—HP's largest electronic components distributor. You'll soon see what the biggest names in lights can do for you.

There is a better way.
MOTOROLA INTRODUCES LOW POWER, LOW COST 680x0s

Motorola is expanding its 680x0 CISC family of μPs with new design variations: a low-cost version of the 68040 without an FPU (floating-point unit), and a 3.3V, low-power member of the 68300 family. The LC040 ($126 (10,000) for a 20-MHz version) is a PC and embedded-system-application version of the 68040: the FPU is removed and low power memory buffers have been added. The embedded-system 68EC040 ($90 (10,000) for a 20-MHz version) is a stripped-down 68040 with the MMU (memory-management unit) removed and low-power buffers. The $24.15 (10,000) 68340 microcontroller is an upgraded 68300. The microcontroller is built around the 32-bit 68020 core and has a 16-bit external memory bus. The device operates to 8.39 MHz at 3.3V or to 16.78 MHz at 5V. It includes two DMA channels, two serial ports, two 16-bit timers, and 16 I/O lines. The device also incorporates a system integration module, taking on memory, clock, and system-control functions normally left to glue logic. Motorola, Austin, TX, (512) 891-2386.—Ray Weiss

VHDL PACKAGE SUPPORTS MODEL DEVELOPMENT

The Std_DevelopersKit is a collection of a modeling guidebook and five VHDL (VHSIC Hardware Description Language) subroutine packages. The guidebook is a style guide that presents information on how to write and validate functionally accurate models using defined interfaces, timing, and comprehensive testbenches. The five subroutine packages lay a foundation upon which you can build your VHDL models. These simulator-independent packages include Std_Timing for adding selectable minimum, maximum, and typical timing modes to your model; Std_IOpak for converting datatypes for file I/O and assertion statements; Std_Regpak for modeling addition, subtraction, multiplication, division, mod, remainder, shift, rotate, and relational operators at the register-transfer level; and Std_Mempak for efficient memory utilization of memory models and interface to VHDL for Intel hex and Jedec formats. Source-code licenses start at $35,900. VHDL Consulting Group, Allentown, PA, (215) 266-9791.—Michael C Markowitz

JOINT EFFORT YIELDS ETHERNET CONTROLLER ICs AND CARD

Racal-Datacom and NCR have joined in an agreement to produce Ethernet products. The result is Racal-Datacom's $369 NI6610-3M triple-media Ethernet card for 8- and 16-bit PC buses and NCR's Ethercore chip set. The card provides connectors for thin and thick-coaxial Ethernet and an RJ-45 connector for 10Base-T Ethernet LANs. A 2-media version of the card costs $279.

The chip set currently includes the NCR92C110 media-access controller with on-chip Manchester encoder and decoder and an attachment unit interface (AUI); the NCR92C105 network-management module, which tracks and records all 37 network events specified by the IEEE 802.3 Ethernet standard; the NCR92C143 ISA slave/host interface module, which links the media access controller to the PC bus and controls the LAN subsystem's RAM; and the NCR92C140 bus-interface module, which effects the physical interface between the host bus and the LAN subsystem. The chips cost $12.95, $10.95, $13.90, and $9.95 (5000), respectively. The company is planning more chips for other host CPU buses. NCR Corp, Dayton, OH, (303) 226-9603, FAX (303) 226-9626. Racal-Datacom, Boxborough, MA, (508) 263-9929, FAX (508) 263-8655.—Steven H Leibson
SPREAD-SPECTRUM MODEM COMMUNICATES OVER AC LINES

Intellon Corp’s modem-subsystem IC and evaluation system lets manufacturers implement carrier-sense/multiple-access (CSMA) networks over standard ac power lines. The products utilize the company’s spread-spectrum carrier technology, which is expected to be approved by the Electronic Industries Association as the power-line signaling standard for its Consumer Electronics Bus (CEBus). The CEBus, which supports data rates of 10,000 bps, enables communication and control among electrical devices, sensors, and control systems in commercial buildings and private homes. The spread-spectrum power-line modem (SSPM) is scalable over a range of frequencies and data rates. For example, to meet European regulatory requirements, the modem uses a frequency band of 20 to 80 kHz that supports a data rate of 2000 bps. In the US, the modem uses the FCC-accepted range of 100 to 400 kHz to achieve 10,000 bps.

The chip, which comes in a 28-pin plastic leaded chip carrier, handles the CEBus physical layer protocol, and assists the higher-layer protocols by performing preamble detection, carrier detection, collision detection, and a cyclical redundancy check. The chip costs $5 (25,000 OEM) plus a one-time $2500 license fee. No license fee is required for sample lots. A modem board incorporating the chip and power-line interface and protection circuitry costs $105 (10). An evaluation system, which includes software and three CEBus nodes, costs $3495. Intellon Corp, Ocala, FL, (904) 237-7416, FAX (904) 237-7616.—Dave Pryce

MIPS CHIP INTEGRATES GRAPHICS ENGINE

LSI Logic’s LR33020 is a MIPS processor that integrates a graphics coprocessor on chip. The chip has a graphics engine with bitbit processor (pixel mover and operator) and a graphics DMA channel. The MIPS core holds a 4-kbyte I and 1-kbyte D cache and integrates a dynamic RAM (DRAM) or volatile RAM (VRAM) memory controller. The device’s R3000 core lets the CPU set up graphics operations via the MIPS coprocessor interface. The CPU then monitors and increments the bitbit engine as it operates on as many as four memory words at one time. Suited for X-terminal and laser-printer applications, the processor lets designers build minimal chip-count implementations. The chip includes hardware-debugging support, including breakpoint registers and instruction trace features. Running to 40 MHz with zero-wait-state operation, the chip supports an interleaved, 64-bit DRAM and 8-bit VRAM interface. The chip will sample in December and prices start at $129 (1000) for a 25-MHz version. LSI Logic Corp, Milpitas, CA, (408) 433-4288.—Ray Weiss

THERMAL ANALYSIS PROGRAM PREDICTS HOT SPOTS

Flowmereric’s Flowtherm is a thermal analysis CAD program that lets you study 3-D air flow and heat transfer in electronic systems. The program accepts data on your hardware design and considers the effects of air viscosity, turbulence, and buoyancy force. The program outputs a picture of the hardware, showing fluid velocities and temperature profiles in all areas of your design. You can apply the program to one section of a pc board or to a complete rack of equipment. The program analyzes natural-, forced-, or mixed-convection designs and considers steady-state and transient effects. The program also solves conjugate heat-transfer problems by simultaneously calculating temperature distribution in fluid and solid sections of the design. A 386-PC version costs £12,000 and a SPARC-2 version costs £30,000. One-month trial and two days of tuition cost £1100. Flowmereric, Kingston-upon-Thames, UK, (81) 547-3373, FAX (81) 547-2682.—Brian Kerridge
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CIRCLE NO. 19
NEWS BREAKS

CLOCKED FIFO MEMORY ACHIEVES 70-MHZ SHIFT RATE

Cypress Semiconductor's family of clocked FIFO memories handles data using a gated clock instead of asynchronous handshaking. The read and write ports of these devices have independent clocks, letting you shift data in and out at different speeds. The devices also feature status flag signals that are synchronous with data movement. The flag signals indicate when the FIFO is full, half-full, and empty.

The family has four members: the CY7C441 and -451 (512 x 9 bits) and the CY7C442 and -453 (2k x 9 bits). The -45x family members offer more features than the -44x parts, including programmable near-full and near-empty flags, built-in parity generation and checking, and direct depth cascadability. Parts are available in 300-mil DIP and 32-pin plastic leaded chip carriers for the same cost. The -441 costs $25.85 (100); the -443, $41.30; the -451, $33.75; and the -453, $56.80. Cypress Semiconductor, San Jose, CA, (408) 943-2600.—Richard A Quinnell

DSP CARD SUITS SBUS HOST

The SDSP/C30D from Loughborough Sound Images is a DSP system on a card suitable for Sbus-compatible workstations. The system hardware consists of a Texas Instruments 33-MHz TMS320C30 processor, 2k x 32-bit-word dual-port static RAM (SRAM), and 128k x 32-bit-word zero-wait-state SRAM (expandable to 512k). The base card accepts plug-in analog-signal I/O daughter boards, and the combination fits an Sbus single-slot space. Options exist for either a proprietary 16-bit parallel I/O port, or a SCSI port. Software support includes an interface library of control functions, and a device driver. Other software tools include a debug monitor, C compiler, and Spectron Microsystems Spox applications programming interface. System with device driver, debug monitor, and interface library costs £2695; analog daughter board is an additional £600. Loughborough Sound Images, Loughborough, UK, (509) 231843, FAX (509) 262433.—Brian Kerridge

DIGITAL SCOPE HAS FOUR 350-MHZ CHANNELS FOR $7495

The TDS 460, a new member of TDS series of digital oscilloscopes from Tektronix, offers midrange performance with a graphical user interface, automatic measurements, and fast screen updates. The $7495 scope digitizes at 100 Msamples/sec with 8-bit resolution. Waveform record length is 5k points, optionally expandable to 30k points. A 150-MHz version, the TDS 420, is also available for $5995. Tektronix, Beaverton, OR, (800) 426-2200.—Doug Conner

MONOLITHIC 12-BIT ADC SAMPLES AT 3 MSPS

The HI-5800 ADC from Harris Semiconductor is a complete data-conversion system containing a buffered S/H amplifier, precision-temperature and curvature-corrected bandgap 2.5V reference, 2-step subranging ADC with 7-bit flash and 7-bit DAC with digital error correction, control logic and timing generator. Competitive performance alternatives to this $110 (100) device are higher-pin-count and more-expensive hybrids and slower monolithic ADCs that may require off-chip S/H amplifiers and references. For 500-kHz inputs sampled at 3 MSPS, the chip features a S/N ratio plus distortion of 71 dBc. The device is available in industrial and commercial temperature ranges, and comes in 40-pin DIPs and plastic leaded chip carriers. Samples will be available in January, 1992, with production quantities available in March. Harris Semiconductor, Melbourne, FL, (800) 442-7747, FAX (407) 724-3937.—Anne Watson Swager
You've chosen the '040 because you need maximum performance in your VME system. But look carefully, because other Single Board Computers may only give you only half of what you expected from the '040.

Compare Synergy's SV430 performance to any other SBC. Compare bus speed, MIPs, support, flexibility, documentation, reliability, I/O intelligence or any spec you can think of. We think you'll find the same thing we did—the SV430 outperforms every other SBC on the market by as much as 150%.

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VME64 doubles bus performance to 66 MB/s—and the SV430 is the only '040 board that has it. But we don't need VME64 to win this comparison.

Even normal 32-bit transfers race at 33 MB/s. That's 200% faster than Force or Motorola.

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DRAM Random Accesses
Non-burst '040 performance is measured in wait states. Fewer wait states mean higher performance. The SV430 is not only 66% faster than Force or Motorola, it supports twice the on-board memory—32 MB.

I/O Modules
Synergy's EZ-Bus modules are compatible with our entire line of SBCs. This means Synergy's current line of 12 intelligent I/O modules are immediately available for the SV430—today. No other vendor comes close for selection, functionality or availability.

'020-'030 Compatibility
Software compatibility between Synergy SBCs means users have simple upgrades to the SV430 from our '020 and '030 SBCs. Force offers compatibility only from the '030 level, and Motorola offers "upward migration"—a polite phrase that means rewriting your code.

Product Warranty
Synergy backs the reliability of its SBCs with a two year standard warranty. Force and Motorola only offer you one.

Data from Motorola MVME65 data sheet dated 2/90, and Force CPU-40 data sheet AJ Rev. 1. DRAM measurements shown are with parity. VMEbus transfers are to a 60ns slave.

VME64 is a trademark of Performance Technologies, Inc.

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- surface-mount • over 100 off-the-shelf models • immediate delivery

### low pass dc to 1200MHz

<table>
<thead>
<tr>
<th>MODEL NO.</th>
<th>PASSBAND, MHz (loss &lt;1dB)</th>
<th>fco, MHz (loss &lt;3dB)</th>
<th>STOP BAND, MHz (loss &gt;20dB)</th>
<th>STOP BAND, MHz (loss &gt;40dB)</th>
<th>VSWR pass-band</th>
<th>VSWR stop-band</th>
<th>PRICE</th>
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### high pass dc to 2500MHz

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<tr>
<th>MODEL NO.</th>
<th>PASSBAND, MHz (loss &lt;1dB)</th>
<th>fco, MHz (loss &lt;3dB)</th>
<th>STOP BAND, MHz (loss &gt;20dB)</th>
<th>STOP BAND, MHz (loss &gt;40dB)</th>
<th>VSWR pass-band</th>
<th>VSWR stop-band</th>
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### bandpass 20 to 70MHz

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<th>MODEL NO.</th>
<th>CENTER FREQ. MHz</th>
<th>PASS BAND, MHz (loss &lt;1dB)</th>
<th>STOP BAND, MHz (loss &gt;10dB)</th>
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<td>PIF-21.4</td>
<td>21.4 18 25 4.9 85 13 150</td>
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<td>PIF-30</td>
<td>30 25 35 7 120 1.9 210</td>
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<td></td>
<td>1.3 17</td>
<td>14.95</td>
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<td>PIF-40</td>
<td>40 35 49 10 168 2.5 310</td>
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<td>1.3 17</td>
<td>14.95</td>
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<td>PIF-50</td>
<td>50 41 58 11.5 200 3.1 350</td>
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<td>1.3 17</td>
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<td>PIF-60</td>
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<td>PIF-70</td>
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### narrowband IF

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<tr>
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<td>10.7 9.5-11.5</td>
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<td>PBP-30</td>
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<td>22 40 3.2 99-1000</td>
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<td>PBP-40</td>
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<td>44 79 4.6 190-1000</td>
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<td>PBP-50</td>
<td>50.0 46.0-61.0</td>
<td>51 94 6.6 180-1000</td>
<td>1.7 18.95</td>
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</tbody>
</table>

CIRCLE NO. 27
Presenting the biggest little innovation in software history.
Ask any computer maker; our little memory cards are big news. And the software media of choice for the next generation of portable systems.

The little, palm-sized systems driving tomorrow's market won't have room for heavy floppy drives and hard disks. They'll take their software "to go." In the form of 68-pin memory cards from Fujitsu Microelectronics.

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And higher densities on the way.

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*PCMCIA (Personal Computer Memory Card International Association) and JEIDA (Japan Electronic Industry Development Association).
Power tool
KEPCO DIGITAL POWER CONTROLLERS

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Kepco's power tools are carefully calibrated to provide you with just the right combination for the work you need to do.

dc, unipolar power
- Listen only, GPIB
- 12 bit control, 0-6V to 0-325V, unipolar dc
- Power: 50W, 100W, 250W, 500W, 1000W
- Control one, four or eight units, analog drive

Kepco Group SN/ATE Power Supplies

dc, bipolar power
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- 12 bit control, ± 20V to ± 200V, bipolar dc
- Power: 100W, 200W, 400W
- Single unit, self-contained

Kepco Group BIT/BOP Power Supplies

dc, unipolar power
- Listen, talk-verify, GPIB
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EDN November 7, 1991
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EDN November 7, 1991
When automatic phone answering doesn’t work

With reference to the letter, “Reader objects to automatic phone answering” (EDN, Sept 2, 1991, pg 36), my experience with computerized switchboards is one of actual inconvenience as opposed to minor irritation.

Having had cause to telephone a company in the States, I was greeted by a pleasant voice explaining the office hours and giving a list of options I could select by pressing a key. Unfortunately, I could not get any further into the system. Although touch-tone dialing is being introduced in this country, it is by no means widespread as yet.

Assuming companies with automated switchboards are not deliberately discriminating against callers with pulse-dialing telephones, would it not be possible to either provide an announcement of an alternative number for personal attention, or arrange that no response within a given time passes the call to a receptionist?

Ken Wood
Senior Design Engineer
Digital Imaging Systems Ltd
Newport, Wales, UK

Discussion of NPR specification may “mislead”

Part 2 of the series “Designers’ guide to subranging A/D converters” (EDN, April 25, 1991, pg 155) by Ray Ushani contains a discussion of the noise power ratio (NPR) specification for ADCs that may be misleading to your readers.

You can find the seminal work in this area in “Quantization and Saturation Noise Due to Analog-to-Digital Conversion” published by Gray and Zeoli, IEEE Transactions on Aerospace and Electronic Systems, January 1971. This paper describes the calculations that are used to optimize noise conditions in the type of applications discussed in Ushani’s article. Although the equation for NPR is correct, the method of application to communications systems is not.

Optimization of NPR is based on an assumption of a Gaussian distribution for the input-signal amplitude (see Fig 5 in the article) in communications systems. The designer needs to choose the full-scale range of the ADC based on the rms amplitude of the input signals, or σ, the standard deviation from the Gaussian distribution. The designer must optimize this full-scale range by trading off the quantization noise, which depends on the A/D resolution versus the potential for saturation noise when signals exceed full scale. Gray and Zeoli’s paper provides an excellent description of these two sources of noise. By determining the load factor “k” on the basis of guaranteeing that saturation never occurs, as Ushani suggests, the noise ratio will become dominated by the quantization noise source for all nonsaturating signals.

In the article, it’s recommended that the loading factor should be set to 8 in a 12-bit ADC. Because the full-scale range of the ADC is equal to kσ, this results in 68% of the input signals being digitized with only one-eighth of the ADC’s range. This is equivalent to a loss of 3 bits of dynamic range, or a loss of 18 dB by using only 8 bits of a 12-bit ADC. From the same calculations, 95% of the signals would use only one-fourth the range, resulting in a loss of 2 bits and 12 dB. To optimize the overall noise performance, the analysis by Gray and Zeoli recommends a loading factor of approximately 5 for a 12-bit ADC, allowing 99.7% of the signals to be digitized over 60% of the ADC’s range, rather than 37.5% as Ushani suggested.

Mike Demler
Micro Networks Co
Worcester, MA

(Author’s reply: Mr Demler believes that the method of application to communications systems is incorrect. Specifically, he explains that to optimize the overall noise performance, a loading factor of 5, rather than 8 for a 12-bit ADC, should be selected.

He believes the equation for NPR is correct. According to this equation (NPR = 6.02N + 20 log(√3/2)), a loading factor of 8 will result in an NPR of 58.83 dB. This NPR is 3.85 dB less than the ideal NPR of 62.7 dB that’s the result of a loading factor of 5.

It’s not clear to me what Demler is referring to when he deducts a loss of 18 dB. I hope he’s not referring to a loss of 18 dB in NPR.

Although a loading factor of 5 (5.01) is theoretically the ideal loading factor, in practice, FDM (frequency-division multiplexing) systems usually operate at a noise-loading level of a few decibels below the point of maximum NPR.)

More information on stacked bar codes

Concerning the article on stacked bar codes (EDN, December 20, 1990, pg 108), I’d like to clarify a few points. Codablock MLC-2D is not the only suitable stacked-bar code symbology currently available. In fact, Code 49 and Code 16K are equally suitable.

- The article implies that only Code 49 requires multiple check characters. In fact, all stacked symbologies require multiple check characters to ensure data integrity.
- The article states that Codablock is easier to print. This is not the case. All stacked symbologies can be printed, using current printing technologies, with equal ease.
- Code 49 and Code 16K have been accepted as viable symbologies by the bar-code industry, and symbology specifications for them are available.
Currently, only the original company specification is available for Codablock.

- Code 16K and Code 49 are compatible with existing, linear barcode symbologies, and bar-code readers can automatically distinguish among them.
- Because Codablock uses Code 39 and other symbologies and doesn't require special start and stop characters or other decoding checks, Codablock symbols cannot be automatically distinguished from conventional Code 39 or other symbols. Codablock readers cannot automatically distinguish between conventional and stacked versions of a symbology. Codablock readers, therefore, require a switch (hardware or software) that enables them to change from reading Codablock to conventional symbols. These comments don't mean that Codablock would not be a suitable solution for a particular application. However, Code 49 and Code 16K should also be considered on their actual merits.

Bert Moore
Director of Technical Communications
Technical Symbology Committee
Aim USA
Pittsburgh, PA

Reader notes observations about dissociation of skills

In the editorial, “Intelligences theory reshapes thought” (EDN Software Engineering Special Supplement, June 20, 1991, pg 9), Charles Small’s observations about the dissociation of skills of programmers and engineers are interesting, and not something I would have anticipated. Of course, I assume that both groups are at least adequate in logical-mathematical thinking, or they could not survive in their chosen fields. Small’s remarks also remind us that sometimes what is thought to be intrinsic to a field (use of language in programming) may be a cultural or historical accident.

Howard Gardner
Harvard Project Zero
Graduate School of Education
Harvard University
Cambridge, MA

Next week in EDN

In the November 14 EDN News Edition, look for a Product Watch on SBus cards and a Career Opportunities article on ISDN.

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**15-Bit ADC Uses Only 125μA Supply Current!**

The MAX135 low-noise, 5V-powered, multi-slope integrating ADC provides ±0.005% accuracy at 16 conversions per second, while requiring only 125μA of supply current over temperature (10μA in sleep mode). Resolution is extended to 18 bits with 3 sub-LSB bits and data averaging. 8-bit data bus and 3 logic control lines simplify interface.

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The MAX501/502 combine a BiCMOS amplifier with ±10V drive capability and a laser-trimmed, thin-film-resistor DAC on a single chip. These DACs accept a DC or AC reference and have buffered input latches that are easily interfaced to both 8-bit (MAX501) and 16-bit-wide (MAX502) data busses.

**Dual 12-Bit Multiplying DAC in 20-Pin DIP/SO Saves Space**

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**Broadcast Quality Video Op Amp**

The MAX404 video op amp has 0.01% differential phase and 0.005% differential gain while operating from ±5V supplies. Featuring 80MHz gain-bandwidth and 500V/μs slew rate, this amplifier is ideal for video and other high-speed applications. 50mA continuous output current is guaranteed.

**Lowest Noise Dual Op Amp For 5V Systems**

The MAX412 provides the best noise performance—even at very low supply voltages. <2.4nVRMS at 1kHz is guaranteed. With a guaranteed output voltage swing of 7.3Vpp and greater than 97% SINAD (Signal/THD+N) while operating from 5V supplies, the MAX412 is ideal for 5V systems. 8-pin DIP/SO.
Complete +5V Serial Port IC With 1µF External Caps!

The MAX241 is a complete serial port on a single chip. It features 4 drivers and 5 receivers in a 28-pin SO package. A separate shutdown mode reduces supply current to a mere 1µA.

(CIRCLE 283)

Complete +5V Serial Programmer

The MAX730 is the smallest complete PWM step-down switch available. Its 6-pin SOIC package and all surface-mount external components fit into 0.55 square inches. It delivers up to 300mA from 5.2V to 11.0V inputs with 94% efficiency.

(CIRCLE 284)

Complete Flash Memory Programmer in 1/2 Square Inch!

The MAX7219 has an easy-to-use serial 3-wire interface and digital/analog brightness control. Only one external resistor is required to set the segment current for all LEDs. The MAX7219 has 1kHz per digit scan rate and is available in a compact 24-pin SO package.

(CIRCLE 285)

Simplify Battery Load Management, Drive 4 Low-Cost N-MOSFETs from +5V

The MAX261/620 drive 4 low-cost 35A/0.028µF N-MOSFETs from 4.5V to 16.0V inputs. It combines a power supply, four latched MOSFET drivers, protection circuitry — all in a single 18-pin IC. The MAX261 has internal charge-pump capacitors; MAX620 costs less and requires 3 inexpensive external components.

(CIRCLE 286)

Small +5V PWM Regulator Has 94% Efficiency!

The MAX660 charge-pump voltage inverter converts a +1.5V to +5.5V input to a -1.5V to -5.5V output. It is a pin-compatible high-current upgrade of the ICL7660. 100mA is supplied with only a 0.65V voltage drop, compared to only 15µA with the ICL7660. Efficiency exceeds 90% for most applications.

(CIRCLE 287)

Guaranteed 750mA Output From Small +5V PWM Regulator

The MAX328 PWM step-down switch regulator is ideal for high-efficiency step-down applications. It has a 6V to 16V input voltage, up to 750mA output current, and 88% efficiency.

(CIRCLE 288)

8-Digit 10MHz LED Display Driver Works With Any µP!

The MAX249 has 6 drivers and 10 receivers — two complete Data Terminal Equipment (DTE) serial ports on one chip, making it ideal for space-critical applications. Plus, the MAX249 uses space saving SOIC package.

(CIRCLE 289)

Four 0.2Ω Switches in 0.3in² — No External Components!

The MAX265 allows logic signals to switch four 1A loads (4A peak), simplifying load switching in low-voltage systems and extending battery life. It has a 4.5V to 16.5V input supply range and 70µA typical quiescent current. Ideal for battery-powered and distributed power applications requiring high efficiency and small size. Available in 24-pin narrow plastic DIPs.

(CIRCLE 290)

100mA-Output, Monolithic Voltage Converter Upgrades ICL7660

The MAX660 charge-pump voltage inverter converts a +1.5V to +5.5V input to a -1.5V to -5.5V output. It is a pin-compatible high-current upgrade of the ICL7660. 100mA is supplied with only a 0.65V voltage drop, compared to only 15µA with the ICL7660. Efficiency exceeds 90% for most applications.

(CIRCLE 291)

DATA SHEETS

MAX190 (Circle 274) MAX404 (Circle 281)
MAX135 (Circle 275) MAX412 (Circle 282)
MAX501/502 (Circle 276) MAX414 (Circle 283)
MAX507/508 (Circle 277) MAX730 (Circle 284)
MAX526 (Circle 278) MAX738 (Circle 285)
MAX516 (Circle 279) MAX732 (Circle 286)
MAX516 (Circle 280) MAX7219 (Circle 287)
MAX249 (Circle 288)
MAX601 (Circle 289)
MAX621 (Circle 290)
MAX638 (Circle 291)

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Tape duplicator system sought and found

I am searching for a magnetic-tape duplicating system. The tape is a ½-in. DC300 cartridge formatted per ANSI X3.56-1977. Ideally, the system would copy one or more masters to five blank tapes.

Robert Roy
Test Engineer
Lockheed Sanders
Nashua, NH

One company that sells tape duplicator systems is Trace Mountain
1040 E Brokaw Rd
San Jose, CA 95131
(408) 441-8040.

JEDEC and Intel HEX files are not the same

Does anyone have any information regarding JEDEC data files? I am familiar with Intel hex-format data files—are they the same?
Stephen Gibbons
Frequency and Time Systems
Medford, MA

No, the JEDEC file is not the same as Intel HEX files. The JEDEC file format was developed, and is periodically updated, by a joint civilian-military committee. Members of this committee include engineers from Data I/O (800) 426-1045. The file format is used to program PLDs of all kinds and includes a standard header identifying the design, author, and part number; programming data for the PLD; and, optionally, test vectors for a programmed device.

If you hunt around on the EDN Bulletin Board Service, you will find numerous examples of JEDEC files attached to messages about PLD designs. Check the /freeware and /di_sig Special Interest Groups.

Help arrives for slide-rule collectors

Reader Steven A Zilber asked for information on slide rules in the July 18, 1991, issue. I’ve been collecting them for 30 years—my oldest is a Bulldog Handy Calculator for wiring electric motors, copyrighted in 1935. I know of no collector society. I have found flea markets to be a good source.

I suggest he contact manufacturers of promotional slide rules including

American Slide Chart
445 Gunderson Dr
Wheaton, IL 60187
(312) 665-3333

Datalizer Slide Chart Inc
1736 Armitage Ct
Addison, IL 60101
(312) 620-5050

Promotional Slideglide Corp
33 Rockwell Pl
Brooklyn, NY 11217
(212) 858-2917

Robert W Tillotson, Sr
Magnavox Electronic Systems Co
Fort Wayne, IN.

Orphaned meter needs new LCD

I hope that someone may be able to identify and inform me of a source of replacement for the liquid-crystal display in my “orphane d” Doric C-Meter, Model 130A. B eck man Industrial (Cedar Grove, NJ) was the last parent, but it no longer supports the unit and has not retained a parts list. Instead, the company has a new meter with a rotary, 9-position switch replacing a totally autoranging unit. I can’t see that as a technology improvement.

The markings on the LCD are 118 E 7 R15-485 LX D 22-79. It is a ¾-digit display with a LOW BAT indication on the left side, edge mounted in a 40-pin holder. I would be most grateful for any information that anyone has in helping me make a repair on an excellent test unit.

Ray E Edester
Merritt Island, FL

The markings you describe must be company specific because we couldn’t use them to find out any specific information about the LCD in question. However, the following vendors all offer small LCDs that could fit your needs.

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An Inside Look At FDDI (seminar), University of New Hampshire, Durham, NH. Trellis Communications Corp, 749 E Industrial Park Dr, Manchester, NH 03109. (603) 668-1213. FAX (603) 668-9211. November 12 to 13.


End-Use Power Line Harmonics (short course), Foster City, CA. BMI, 335 Lakeside Dr, Foster City, CA 94404. (415) 570-5355. FAX (415) 574-2176. TWX 910-374-3059. November 21 to 22.
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SEMI Technology Symposium, Makuhari, Japan. SEMI, 805 E Middlefield Rd, Mountain View, CA 94043. (415) 940-6903; (415) 964-5111. December 6 to 7.


Winter Simulation Conference, Phoenix, AZ. EPIC Management Inc. (800) 447-6949. December 8 to 11.


Designing Industrial Experiments (short course), University of Wisconsin, Madison. Dept of Engineering Professional Development, University of Wisconsin, Madison, 432 N Lake St, Madison, WI 53706. (608) 262-2061. FAX (608) 263-3160. December 9 to 13.

Dexpo Fall, Anaheim, CA. Miller Freeman Expositions, 1050 Commonwealth Ave, Boston, MA 02215. (800) 873-3976; (617) 232-3976. December 10 to 12.
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Buy this and you’re a thief

The recording industry is lobbying Congress to slap outrageous royalty fees on digital-audio-tape (DAT) recorders and blank digital audio tape. This unprecedented “theft tax” presumes that your main intent in buying products capable of recording near-perfect audio is to make illegal use of copyrighted audio material. You have been prejudged a thief. The only reason this problem has come to a head is because the recording lobby has convinced our legislators that the vastly improved recording quality possible with digital audio has somehow changed the status quo.

You see, retailers have been able to sell other types of recording products, such as reel-to-reel, 8-track, and cassette tapes, without royalty fees. The same goes for the recorders that imprint sound on these tapes. Home use of these recording products is a well-established legal concept. Recently, the home-use concept was tested yet again in the courts. The Supreme Court ruled that people use VCRs mostly for time-shifting and other appropriate uses and not for illegal copying. It denied similar royalty fees on blank VCR tape.

In fact, the digital audio recorders sold in the US will have a copy-protection mechanism that prevents people from making copies of copied tapes. Thus digital-audio-tape recorders already safeguard copyrights. Many laws protect copyrighted material from commercial exploitation, and these laws are not about to wink out of existence when DAT recorders become widely available.

With an electronic preventative in place and thorough protection provided by existing copyright laws, the recording industry’s further attempt to bleed the public with unwarranted fees is nothing more than blind greed. If Congress decides to put fees on DAT products, the precedent could be earth-shaking. One could easily imagine the subsequent need for royalty fees on other recording products such as cassette recorders and VCRs. Similarly, one could imagine fees on photocopiers and photocopier paper, or worse, on computers and floppy disks. If you agree that the royalties proposed by the recording industry are absurd and would set a very bad precedent, please contact your local legislator and say so.

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high form factor make them ideal for a full range of desktop computers.

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It's all a part of our innovative sell-design-build business philosophy. To identify our customer's needs sooner. Then fill them faster with the most advanced products. In fact, we're the technological leader with nine patents issued and 27 pending. Which is why more and more PC users are asking for systems with Conner drives.

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Introducing

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FLUKE 90 SERIES SCOPEMETER SELECTION GUIDE

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ScopeMeter is a breakthrough in portable power. It slips easily into a briefcase, tool kit, or its own optional soft or hard case; and runs on rechargeable NiCad batteries, standard C-cells or the included line voltage adapter/battery charger. On the job, its adjustable tilt-stand is a strong, secure hanger, too. And ScopeMeter is compatible with a wide range of Fluke and Philips accessories.

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Before you select a local-area network (LAN) that will operate in an industrial environment, you must consider a variety of factors that range from the certainty of initial costs to the potential of future innovations.

*J D Mosley, Regional Editor*

**FACTORY-AUTOMATION NETWORKS**

The best LAN may be found off the MAP

Although factories are notorious for communication-degrading elements such as dirt, electromagnetic interference (EMI), and heat, computer-integrated manufacturing (CIM) is the only way many companies can remain competitive in today's global market. Linking computers, programmable controllers, and a variety of LAN gateways requires specialized hardware, and deciding among the many available networks can raise serious design dilemmas if you don't understand the significance of different features.

If you prefer the flexibility and security of a multivendor-supported standard, the Manufacturing-Automation Protocol (MAP) is a prudent choice. Frustrated by the growing numbers of “automation islands” that had proliferated throughout General Motors’s (GM) facilities by the mid-1980s, that company's system integrators adopted a communication standard called MAP that conformed to the International Standards Organization/Open Systems Interconnection (ISO/OSI) model. Other significant end-users, such as Boeing, Ford, DuPont, Kodak, and McDonnell Douglas, joined GM to support MAP as a de facto standard for factory-floor communications.

The problem of automation islands began when factories first attempted computerized control of individual processes such as conveyors, product-test stands, and other manufacturing equipment. By 1985, GM had installed 20,000 programmable controllers and 2000 robots, yet only about 15% of those processor-controlled machines could exchange information. So, GM’s system integrators turned to a token-bus protocol dubbed IEEE 802.4 for real-time LAN nodal control within the ISO/OSI model. This protocol uses a deterministic-access method that ensures each node on the

If you need to tap into a MAP LAN, many proprietary networks offer gateways like this Pyramid Integrator for Allen-Bradley's Data Highway Plus LAN. Using such gateways lets you eliminate “islands of automation” that arise when the controllers from competing vendors can’t exchange data.
Factory-automation networks

LAN will have an opportunity to transmit data within a specific length of time.

IEEE 802.4 addresses the functions of the physical and data-link layers of the 7-layer ISO/OSI communications model. The physical layer specifies the network's connecting, cabling, and electrical signaling considerations for transmitting and receiving the serial stream of data bits. The data-link layer includes the Media Access Control (MAC) sublayer, which converts frames of data called messages into serial bit streams and transmits them across the physical layer according to the IEEE 802.4 token-bus specification. By providing standardization at these first two layers, the specification establishes a stable hardware base that permits software-based customization at the upper layers of the model. Fig 1 illustrates the ISO/OSI layers and their relationship to IEEE 802.4.

Layers and layers of data

The MAC sublayer is one point at which the IEEE 802.4 and MAP specs differ in scope. While MAP encompasses only 10 Mbps broadband and 5- to 10-Mbps phase-coherent frequency-shift keying (FSK) carrierband data rates, the IEEE spec includes 1, 5, and 10 Mbps broadband, a 1-Mbps phase-continuous FSK, and 5-, 10-, and 20-Mbps fiber-optic variations. Accordingly, a proprietary industrial LAN can meet the IEEE 802.4 spec without being MAP compliant.

MAP's broadband token bus forms the backbone of the network. Connected to this backbone are single-channel carrierband subnets, which in turn connect to the various machines in the factory via nodes. You can obtain a copy of the specification for the latest version of this network, MAP 3.0, by contacting the Corporation for Open Systems (McLean, VA) at (703) 883-2765. You can also write to the Chairman of MAP's Technical Review Committee, AES MAP Program, Mail Stop A/MD-39, 3300 Mound Rd, Warren, MI 48090.

But the easiest way to get up to speed on what it will take to integrate your site with a MAP network is to contact any of the various MAP-component or -board vendors such as Allen-Bradley, Digital Equipment Corp (DEC), Texas Instruments, or Motorola. Most of these vendors offer a proprietary network in addition to MAP and can offer alternate products for your comparison. Motorola, however, has elected to concentrate its design efforts on MAP components and boards.

Minimize to economize

In 1985, Motorola manufactured the first single-chip VLSI implementation of the IEEE 802.4 MAC sublayer and dubbed it the MC68824 Token-Bus Controller Chip. This chip operates at both the 10-Mbps broadband and the 5- to 10-Mbps carrierband data rates specified for the physical layer in the MAP protocol. By reducing ISO/OSI layers 1 and 2 to hardware, the MC68824 offers cost and space savings while providing a silicon embodiment of MAP's written standards. A surface-mount version of the chip sells for $32.10 (10,000).

Motorola's latest MAP component is the MHW11005 carrierband modem module, which interfaces via a serial interface to the MC68824. This modem, measuring less than 5 in.,² simplifies nodal integration by managing the node's physical-layer requirements, and

<table>
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<tr>
<th>Network</th>
<th>Proprietary</th>
<th>Vendor</th>
<th>IEEE 802.4 compatible?</th>
<th>Media access</th>
<th>Modulation</th>
<th>Data rate (bps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arcnet</td>
<td>Open (specs available)</td>
<td>Standard Microsystems</td>
<td>No</td>
<td>Token passing</td>
<td>Baseband dipulse</td>
<td>2.5M</td>
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<td>Bitbus</td>
<td>Open (Intel specification)</td>
<td>Digital Equipment Corp, Microsys</td>
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<td>Multidrop</td>
<td>Not applicable</td>
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<tr>
<td>Data Highway Plus</td>
<td>Yes</td>
<td>Allen-Bradley</td>
<td>No</td>
<td>Token passing</td>
<td>Baseband</td>
<td>578k</td>
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<td>Open (specs available)</td>
<td>Digital Equipment Corp</td>
<td>Yes</td>
<td>Token ring and CSMA/CD</td>
<td>Binary phase-shift key; Manchester Encoding</td>
<td>10M to 100M</td>
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<td>802.3/Ethernet</td>
<td>No</td>
<td>Digital Equipment Corp</td>
<td>Yes</td>
<td>CSMA/CD</td>
<td>Binary phase-shift key</td>
<td>10M</td>
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<td>No</td>
<td>Motorola, Digital Equipment Corp, Hewlett-Packard, Texas Instruments, Allen-Bradley, etc</td>
<td>No</td>
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<td>Phase-coherent FSK</td>
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<td>TLway</td>
<td>Open (specs available)</td>
<td>Texas Instruments</td>
<td>No</td>
<td>Poling</td>
<td>Nonreturn to zero, inverted</td>
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by encoding, modulating, receiving, and decoding data. Management functions include local loopback, command reset, and transmitter enable. The module includes a LAN cable interface with a 75Ω F connector. Return loss is ≥14 dB over the operating frequency of 2 to 15 MHz. Operating at 5 Mbps, this baseband modem requires a 5V dc power supply and sells for $250 (500).

However, MAP is not always the recommended network for a given site. Due to installation costs that run two, three, and even four times the price of other industrial networks, MAP has a reputation for being a luxury-class network. The LANs developed by individual vendors are generally less expensive and less complex. And although these networks are often generically referred to as proprietary networks, several vendors have made their documentation public to encourage proliferation as an open specification.

Furthermore, these proprietary LANs typically provide an easy migration path to MAP. One such example is TIway from Texas Instruments (TI). This host-based network lets a central computer control as many as 254 separate nodes to provide a central collection point for information. Thus, with the appropriate software, a TIway operator can program, monitor, and control any controller on the network from a single location. Implemented in the early 1980s and based on the high-level data-link-control (HDLC) protocol, TIway specifies extremely high data accuracy with an undetected bit-error rate of $6 \times 10^{-13}$. In comparison, MAP specs a rate of $10^{-9}$.

Mel Hagar, senior member of TI's TIway technical staff, suggests that if your greatest concern is overall life-cycle cost, a standard network such as MAP would be your best choice. Although the initial cost per node can be as much as three or four times greater than the cost of a proprietary network, the certainty of being able to expand the network to suit your firm's future needs without having to retrain your staff in usage and maintenance procedures makes MAP a cost-effective solution over the life of the network.

Yet, proprietary networks are often the only reasonable way to connect the industrial controllers that are already installed in your factory. For example, TI's TIway network is the only communication link that supports every controller TI has produced since 1972. To prevent TIway from creating an automation island within your plant, TI sells gateways to MAP and to other vendor's networks and will even custom-design a gateway for you. However, Mr. Hagar cautions that the biggest problem encountered when customizing a gateway involves obtaining the protocol and documentation for the non-TIway LAN. Some LAN vendors
Factory-automation networks

are highly protective of the specs for their networks, but Hagar notes that his company offers TIway as an open specification with full documentation available upon request.

Meanwhile, DEC is challenging the venerable belief that data communication in a factory is impossible unless the network was specifically designed to combat EMI. In tests conducted at 14 manufacturing sites, including a 90-building aerospace complex and a 2200-acre chemical-plant location, DEC's system integrators discovered that its IEEE 802.3/Ethernet LAN was immune to the EMI levels encountered at each site.

Of course, it remains true that high levels of EMI will degrade any network's performance by corrupting the packets of data being sent and increasing the network's traffic load due to the required retransmission of data. However, the DEC study sought to quantify the amount of EMI actually present on plant floors and the effect of that EMI on Ethernet LANs.

Using anechoic chamber tests to measure EMI levels simultaneously, the testers generated network load levels that ranged from 10% to 30%. The maximum loads generated for this test were substantially greater than the network load levels encountered at any of the plants running full production shifts. The test also employed a spectrum analyzer to determine whether the electric field generated around the cable passed through its covering, shielding, and insulation to induce a voltage on the conductor.

The test results showed that the highest EMI level was 0.1412 V/m at 11 kHz in a control room that was located above high-voltage transformers in a metal-smelting plant. However, even this reading was less than 10% of the IEEE 802.3/Ethernet noise-immunity specs. And the number of data-transmission errors were practically nonexistent. Further testing showed that Ethernet cables are unaffected by EMI levels reaching 20V/m at all frequencies, a figure well surpassing the specification's EMI limits of 2V/m over frequencies ranging from 10 kHz to 30 MHz and 5V/m from 30 MHz to 1 GHz.

<table>
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Factory-automation networks

Yet some system integrators disdain Ethernet's tendency to suffer from reduced data throughput under heavy loads due to its carrier-sense multiple-access/collision-detection (CSMA/CD) network-accessing scheme. Although this method can provide fast access to the network under average loading conditions, Ethernet's lack of flow-control functions makes its performance unpredictable when data transmissions exceed 30% of the maximum data rate of 10 Mbps. At that point, network traffic reaches the point where collisions become common and network contention problems arise.

In contrast, Arcnet specs a 2.5-Mbps data rate but employs a deterministic token-passing protocol that provides predictable performance at 96.8% of maximum loading. Furthermore, for messages of seven or fewer data bytes, Arcnet data packets occupy less time on the network than equivalent Ethernet packets. Such small data packets commonly occur in control applications. As a result, even though Arcnet's specs aren't as impressive as Ethernet's at first glance, under heavily loaded factory conditions, Arcnet can actually meet or exceed Ethernet's data throughput.

In addition, the RG-62U coaxial cable that Arcnet LANs often use costs about $0.30/ft, or one-third the cost of standard Ethernet cabling. However, Arcnet allows you to opt for twisted-pair wiring or fiber-optic cables if you wish. You may lay out the network in any mix of star, tree, and bus topologies. These configurations simplify troubleshooting because you can simply unplug each network node until you isolate the problem area. And in the event of a node failure or cable damage, Arcnet automatically reconfigures around the problem and continues to operate.

Acronyms used in this article

ATA—Arnet Trade Association
CCITT—International Telegraph and Telephone Consultative Committee
CIM—Computer-integrated manufacturing
CSMA/CD—Carrier-sense multiple-access/collision detection
EMI—Electromagnetic interference
FSK—Frequency-shift keying
HDLC—High-level data link control
ISO/OSI—International Standards

Organization/open systems interconnection
LAN—Local-area network
MAC—Media access control
MAP—Manufacturing automation protocol
MMS—Manufacturing message specification
SNA—Systems network architecture
TCP/IP—Transmission-control protocol/internet protocol

To further reduce costs and simplify installation, Standard Microsystems Corp developed the COM20020 Arcnet controller chip that includes a LAN controller, a 2k x 8-bit dual-port static RAM buffer, and a glue-free interface to several popular microcontrollers, including the Intel 80xx and the Motorola 68xx families.

Its 40-nsec dual-port memory allows the COM20020 and a microcontroller to arbitrate for and access the on-chip memory in a single clock cycle without incurring wait states, independent of the network data rate. This LAN controller also provides hardware diagnostics and automatically detects and adapts to

For more information . . .

For more information on the factory-automation network products discussed in this article, circle the appropriate numbers on the Information Retrieval Service card or use EDN’s Express Request service. When you contact any of the following manufacturers directly, please let them know you read about their products in EDN.

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the type of microcontroller interface its node employs. The chip has a list price of $16.23 (1000), although high-volume pricing falls below $10.

Arcnet was originally introduced by Datapoint Corp in 1977 and presently has over 3,000,000 nodes installed worldwide. You can receive a copy of the Arcnet spec by writing to the Arcnet Trade Association (ATA), ATA Standards Committee, 3365 N Arlington Heights Rd, Suite J, Arlington Heights, IL 60004. You can call the ATA at (708) 255-3003 or access the FAX by calling (708) 577-7276.

The ultimate factors that will influence your factory-automation decisions are cost, performance, reliability, service, and ease of expansion. You must first decide what you want the network to accomplish. Then, identify the minimum set of functions and performance levels necessary to meet your application requirements.

Set priorities for the enhancements you’d like the network to offer so that you can determine which functions and operations are indispensable and which you can sacrifice for improved cost, reliability, or performance. Finally, make certain you have considered both the initial installation costs and the ongoing maintenance costs. Think of the time you spend researching LAN alternatives for your industrial site as an investment in your company’s future productivity.

Acknowledgments
Special thanks to Robert Burckle of Winsystems Inc (Arlington, TX) and Paul Eastman, IEEE 802.4 committee chairman, for their assistance.

References

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Evolving math software packages reduce work associated with long and tedious calculations and let you concentrate more on the big picture.

John Gallant, Associate Editor

OVER-$400 MATH SOFTWARE PACKAGES

Software smooths complex computations

In the early- to mid-1970s, the newly invented µP-based calculator threatened to replace an old friend, the slide-rule, which had become such a reliable and familiar standby for many years. With the advent of affordable high-performance personal computers in the 1980s, perhaps another metamorphosis is taking place—from the calculator to the math software package.

Current math software packages are the product of university and government projects. These projects developed sophisticated algorithms using mainframe computers to solve complex problems well beyond the capabilities of early calculators. Now commercial software packages have incorporated these algorithms. EDN reviewed many math software packages a year and a half ago (Ref 1). In addition, a recent EDN article (Ref 2) concentrated on the capabilities of math packages and state-of-the-art calculators costing $400 or less. After reviewing these articles, two obvious questions arise—"What revisions and additions have been introduced in the last year and a half?" and "What do I get if I shell out more than $400 for a math package?"

The 1-word answer to the first question is—considerable. All of the math packages are evolving entities, and each revision reflects their customer-feedback wish list. The answer to the second question is not as clear cut. The under-$400 math packages are powerful tools and can solve a variety of complex everyday engineering problems. In general, the over-$400 math packages offer more functions, GUIs, sophisticated graphic displays, and a breadth of esoteric mathematical capabilities that cover many fields. All of this extra power requires lots of computer memory space, however.

As a baseline, consider the capabilities of an under-$400 package—Soft Warehouse's $250 Derive. Derive oper-
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Over-$400 math software

ates on an MS-DOS version-2.1-compatible computer having at least an 8086 µP and a minimum of 512 kbytes of RAM. The software employs a command-line user interface and an on-line help menu. The interface lets you enter expressions using algebraic notation.

This general math package lets you perform vector and matrix operations, solve recurrence equations, solve basic first-order differential equations, and generate 2-D and 3-D mesh plots. You can also store results in a Basic, Pascal, or Fortran file for use by an external program.

You can symbolically solve simultaneous equations, perform partial fraction expansion, factor expressions, and expand functions in a Taylor series. A symbolic solution means that you can enter an expression using variables, such as x, y, and z, and obtain a solution as a function of these variables. In addition, you can enter numerical values and differentiate and integrate expressions.

Version 2.07 of Derive answers some of Derive's early critics. For example, the addition of IF-THEN-ELSE conditional statements, logical AND and OR functions, and iteration statements provides some programmability that was lacking in earlier versions. Version 2.07 can now calculate eigenvectors and plot complex expressions in 2-D.

Although this synopsis describes only some of the capabilities of under-$400 math packages, they do lack many functions that you find in over-$400 packages. For example, the over-$400 variety lets you calculate the forward and inverse Fourier transform of an expression using a single-line statement—something not available in a package like Derive. In addition, because Derive and others don't require a coprocessor, their floating-point computations can take a long time.

The over-$400 math packages generally complement each other and the under-$400s by offering different specific features not available on the other packages. Therefore, many universities and industrial facilities often own multiple math-package licenses for specific application-related problems.

Mathsoft's $495 MathCAD version 3.0 runs on the Microsoft Windows 3.0 operating system. The package emphasizes ease of use. To this end, it offers 10 application programs designed specifically for different disciplines, such as electrical, chemical, civil, and mechanical engineering, for $99 each. For example, the electrical engineering package contains custom analysis programs for networks, transmission lines, digital filters, Chebyshev polynomials, and antenna patterns.

The GUI is slick, and using this software is as easy as scratching on a blackboard or on the back of a napkin. Using the mouse, you pull down familiar mathematical symbols from an operator palette and build equations on a workspace area. You then can solve the equation and dynamically change parameters with a mouse click. A few more mouse clicks opens a window to display 2-D or 3-D graphics re-
Over-$400 math software

sults while maintaining a view of the scratchpad area.
You can create and print entire documents containing text with embedded math calculations. Besides its large palette of math functions, which includes the solution to linear or nonlinear equations having as many as 50 unknowns, MathCAD automatically handles units conversion. It allows some conditional and logical-operator statements for limited programming.

Version 3.0, which was released in June 1991, also answers some previous criticisms. Previous MathCAD versions could only perform numerical computations. Through a royalty agreement with Waterloo Maple Software, MathCAD now incorporates some of Maple’s symbolic capabilities. You can now open a window that performs symbolic calculations based on the Maple algorithm.

Version 3.0 also lets you thumb through a software version of the CRC Standard Mathematical Tables handbook. This allows you to use the mouse to find cookbook solutions to standard electrical engineering problems. Unfortunately, the current version can only send

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<th>Table 1—Representative $400-and-up math software packages</th>
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<td>Mathworks Inc</td>
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<tr>
<td>Symbolics Inc</td>
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<tr>
<td>Waterloo Maple Software</td>
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<td>Wolfram Research Inc</td>
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</table>

Note: NA = Not applicable.
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Over-$400 math software

calculation results to an ASCII print file, which requires external conversion if destined for a Fortran or C program.

Because version 3.0 also runs on Sun's Unix-based workstations, Mathsoft no longer offers its Mathstation package.

**Numerics are rapid**

Matlab, from Mathworks Inc, is a math software package that specializes in matrix computations. You can trace the roots of this mature package to the University of New Mexico in the 1970s. Mathworks rewrote the original Fortran code in C language to speed up calculations. This speed merchant performs numeric computations only, however.

Matlab is available for a range of computers including PCs, Macintosh, DEC, HP, Apollo, Sun, IBM, Convex, and Cray computers. A PC version costs $695, a Macintosh version costs $795, and a multiuser workstation license can cost as much as $6500. Mathworks also offers a special 386-Matlab version for 80386 and 80486 MS-DOS computers.

Because of its maturity, Matlab contains a broad range of math functions developed by many users. In fact you can obtain free software routines via a Matlab user group. Specialized toolbox packages are optionally available for $295 each. The toolboxes are optimized for custom functions associated with DSP, control-system theory, and state equations. A spline toolbox lets you generate piecewise polynomials and arbitrary waveforms that have smooth transitions between breakpoints.

Matlab's syntax lets you create complex functions with very few statements. For example, you can build a digital filter by typing Butter or Cheby and the number of poles. You can also extract data from an external C and Fortran subroutine using MEX-files. The MEX-files let you call functions from math subroutine libraries and access data from a data-acquisition board.

Mathwork's Simulab is a modeling and simulation program that acts as a shell for and uses Matlab's computation system. A $3995 Macintosh version and a $4000 Sun workstation version employ the Macintosh or X-Windows GUI, respectively, to model block diagrams of multiple-input and multiple-output systems. You can model nonlinear functions such as deadband zones and limiting characteristics. Its 2-D and 3-D color graphics can perform polygon fills and animation. The package also lets you listen to the sound of a waveform such as a chirp signal.

If your application requires symbolic solutions to specialized problems, you should consider one of the 3 Big Ms—Macsyma, Mathematica, and Maple. All of these programs have comparable features and differ primarily in syntax, user interface, and graphics capability. Macsyma, from Symbolics Inc, is the oldest of the three and dates back to work performed at MIT in the late 1960s. Fig 1 shows a sample of Macsyma's particular brand of syntax. The software is written in Lisp and, because much of the code is inefficient, it requires lots of memory. The PC386 package requires 4 Mbytes of RAM, but Symbolics recommends 8 Mbytes.

Macsyma boasts of having more than 1500 commands. You can symbolically solve any first-order and some second-order differential equations. You can compute the forward and inverse Laplace transform of a large collection of functions, including Bessel and error functions. Release 417.1 has added symbolic functions to compute the exponential of a matrix; expand algebraic and transcendental equations in a Taylor series; perform tensor analysis; and perform statistical analysis, using 10 commonly used probability density functions.

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interface. Using a mouse, you can scroll through calculations to review previous results. It can plot 2-D and 3-D color graphics and fill in the space between curves. The graphics have a rotation feature that lets you change the perspective of a 3-D drawing by simply clicking the mouse. You can display contours of 3-D drawings just as easily.

Knockout graphics

Mathematica, from Wolfram Research, probably has the slickest graphics of the 3 Big Ms. And clear graphics help you to visualize computations. Mathematica's color graphics are as polished as any graphics drawing program. You can create 2-D and 3-D color surfaces with fills, remove hidden surfaces, simulate the effects of a light source, and generate contour plots. The graphics output format is in Postscript's page-description language for plotting graphics on a Postscript-compatible printer.

The documentation for Mathematica is overwhelming at first glance. In fact, Addison Wesley has published the second edition of a 1000-pg book entitled “Mathematica” by Stephan Wolfram, one of Mathematica's originators, to guide the uninitiated. Even the book's introduction admits that you may never learn all the details of Mathematica's features. Version 2.0 boasts of adding 283 functions to its predecessor for a total of 843 functions. Announced in January 1991, Version 2.0's cost varies from $595 for the Macintosh to $30,000 for a Convex computer.

Mathematica can manipulate strings, differentiate and integrate differential equations symbolically and numerically, interpolate functions, and expand trigonometric expressions. The package has an extensive programming language that includes DO, FOR, and NEXT statements as well as trace functions for debugging and error detection. Version 2.0 also has commands that create and play musical sounds. In addition, a Mathlink communications program lets an external C-language or Fortran program call Mathematica, and vice versa.

Maple’s strength appeals to pure mathematicians. The package from Waterloo Maple Software operates on 80386 or 80486 PCs, Macintosh computers, and popular workstations. The software performs integer arithmetic and represents fractions by the ratio of 2 rational numbers. Therefore, it can generate numbers having arbitrary precision.

Maple uses a command-line inter-

\begin{verbatim}
INTEGRATION

\textbf{SYMBOLIC INTEGRATION}
\begin{itemize}
  \item \texttt{INTEGRATE} (indefinite)
    \begin{verbatim}
    (c1) INTEGRATE( 1/y^(3/4)/(y-1), y );
    (dl) - log(y^(1/4) + 1) - 2 atan(y^(1/4)) + log(y^(1/4) - 1)
    \end{verbatim}
  \item \texttt{INTEGRATE} (definite, contour integral method)
    \begin{verbatim}
    (c1) \texttt{2*INTEGRATE( sin(x)/x, x, 0, inf );
    (dl) \%pi}
    \end{verbatim}
\end{itemize}

\textbf{NUMERICAL INTEGRATION}
\begin{itemize}
  \item \texttt{ROMBERG}
    \begin{verbatim}
    (c1) ROMBERG( exp(-x^2), x, 0.0, 1.4 );
    (dl) 0.84394073
    \end{verbatim}
  \item \texttt{NEWTON-COTES}
    \begin{verbatim}
    (c1) (load(qq) , QUANC8( sin(1/x), x, 0.1, 1.0 ));
    (dl) 0.515292
    \end{verbatim}
\end{itemize}

\textbf{LAPLACE AND FOURIER TRANSFORMS}
\begin{itemize}
  \item \texttt{LAPLACE}
    \begin{verbatim}
    (c1) LAPLACE( sin(t), t, s );
    (dl) \%pi
    \end{verbatim}
  \item \texttt{ILT}
    \begin{verbatim}
    (c2) ILT( dl, s, t );
    (dl) sin(t)
    \end{verbatim}
  \item \texttt{TOTALFOURIER}
    \begin{verbatim}
    (c1) load('fourier')$
    (c2) TOTALFOURIER( abs(x), x, %pi );
    inf
    \%pi
    \end{verbatim}
\end{itemize}
\end{verbatim}

Fig 1—The over-$400 packages differ widely in syntax. This sample from a product brochure gives a feel for Macsyma's syntax. You type in statements such as those beginning with "c," and the program returns the "d" statements.
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face, but a Windows version is under development. Its set of commands is almost as large as Macsyma's, and it can symbolically integrate some algebraic and logarithmic integrands that Macsyma can't (by Symbolics Inc's own admission). Its programming language contains DO, WHILE, IF-THEN-ELSE, FOR, and NEXT statements as well as trace-debugging features.

Maple performs tensor mathematics; solves recurrence equations; solves first- and second-order differential equations; and performs arithmetic over finite fields such as Galois fields. A functional library contains a linear algebra package and a statistics package. The package can make 2-D and 3-D color plots having color-patch shading, but the plots don't look as slick as Mathematica's. The software also generates Postscript files for compatible printers. Some reviews have found Maple's numeric ability to be extremely fast. You can also write C and Fortran programs from within Maple.

Finally, if you have access to a Sun SPARCstation running X Windows, you may want to take a look at Xmath from Integrated Systems Inc. The package is a C+ + revamped version of Matlab's matrix-based kernel. Xmath is an object-oriented package that manipulates numerical data using pull-down menus. The package has 200 mathematical functions and 18 application-specific engineering objects. A DSP module lets you call and design an object such as an IIR (infinite impulse response) filter for programming use.

Acronyms used in this article
EGA—Extended graphics adapter
GUI—Graphical user interface
IIR—Infinite impulse response
VGA—Video graphics adapter

Xmath's editor displays matrix entries in a spreadsheet-style display. A point and click of the mouse highlight entries to change and can perform calculations on specific entries. You can also generate 2-D and 3-D plots and rotate objects using the mouse.

A brief article such as this can only mention a few highlights of the various math packages. All of the math packages have considerably more capability than space allows. Not all of these packages are good at everything, however. A specific
TECHNOLOGY UPDATE

application will determine which package to use. These packages complement each other, so you really should consider purchasing more than one if you have a wide range of computations to do.

References

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486SX FUNCTIONS

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<thead>
<tr>
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<th>DTI CAT 1011 Integrated</th>
<th>DTI CAT 1001 CPU Only</th>
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<tr>
<td>20MHz - Shipping Now</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Up to 32M RAM Onboard</td>
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<td>✔</td>
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<tr>
<td>Noise Reduction Circuitry For FCC Class B</td>
<td>✔</td>
<td>✔</td>
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<td>PS/2 Mouse Support</td>
<td>✔</td>
<td>✔</td>
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<tr>
<td>PS/2 / AT Keyboard Support</td>
<td>✔</td>
<td>✔</td>
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<tr>
<td>Secondary CACHE</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>On-Board Battery Real-Time Clock</td>
<td>✔</td>
<td>✔</td>
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<tr>
<td>Printer Port</td>
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<td>✔</td>
</tr>
<tr>
<td>2 Serial Ports-Up to 115K baud</td>
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<td>✔</td>
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<td>Future Domain SCSI</td>
<td>✔</td>
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<td>Floppy Interface</td>
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<tr>
<td>Up to 512Kb User PROM Disk</td>
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<td>Double-Sided Surface Mount Technology</td>
<td>✔</td>
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<tr>
<td>Manufactured In-House (USA)</td>
<td>✔</td>
<td>✔</td>
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<td>✔</td>
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Today’s solid-state silicon pressure sensors take advantage of fabrication advancements in IC processing to provide a cost-effective solution for high-volume applications.

Tom Ormond, Senior Editor

SILICON PRESSURE SENSORS

Inexpensive sensors provide precision

Solid-state silicon sensors are rapidly gaining acceptance for applications in the automotive, avionics, medical, and process-control industries. In fact, the majority of all pressure transducers used today incorporate a micromachined silicon conversion element (see box, “The inside story”).

Silicon sensors are highly accurate and smaller, more reliable, and more cost effective than devices that employ more traditional technologies such as variable capacitance, potentiometric, force balance, piezoelectric, or vibrating wire. Small size provides significant advantages in such applications as avionics, where instruments must fit in confined spaces and weigh as little as possible. And of course, low cost is of prime importance when you get into consumer areas like automotive electronics. Table 1 lists silicon sensors and some of the parameters integral to meeting the needs of high-volume applications at a low cost.

These sensors’ pressure-measurement capability ranges from less than 1 psi to 10,000 psi, comparing favorably with other sensor types. Their output levels are high enough for use—without amplification—by most logic families. In addition, they can operate in hostile environments. Best of all, you get this performance for a very moderate cost.

When you go shopping for a silicon sensor, you'll find many products to choose from. As the table illustrates, you'll also find many levels of product performance. If the variety seems daunting, you can simplify sensor selection by deciding what capabilities you'll need. For example, you can specify a unit that provides only the basic sensing function, which is all you need if your system already includes compensation and signal-conditioning circuitry.

Series 24PC sensors from Micro Switch typify what's available in the sensor-only category. In these sensors, the sensing element (an integral part of an IC chip) is a silicon diaphragm that contains four implanted piezoresistors. The four piezoresistive elements are symmetrically positioned over the diaphragm to implement a balanced bridge.

A key feature of the 24PC sensors is a novel seal design (Fig 1) that cuts assembly time and reduces production time significantly. Signal conditioned to interface directly with a µP, Motorola's MPX5100A is a single-chip, 15-psi absolute pressure sensor. It has a 0.5 to 4.5V output and is temperature compensated for operation over a 0 to 85°C range.

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Silicon pressure sensors

costs. The design eliminates wire bonding and tab tape connections, resulting in improved reliability. The conductive seal also allows Micro Switch to employ a large diaphragm area, which improves sensor stability. The sensors' assembly provides wet-wet sensing capability and increases application versatility. You can mount the devices on a pc board, and they are wave-solder compatible.

Sense-only devices certainly have their place in some applications; however, more often than not you'll require a transducer that can do more than provide the basic sense capability. Fortunately, a number of devices offer an increase in performance sophistication—temperature-compensated operation.

Handling harsh environments

Sensym's SCXL004 sensors work in applications that require high accuracy over very low operating pressure ranges. These internally calibrated and temperature-compensated sensors are designed to provide an accurate and stable output over a 0 to 50°C range. The devices are ratiometric to the supply voltage, so changes in the supply voltage will cause proportional changes in the offset voltage and full-scale span. The SCXL sensors are calibrated for offset and output span and require little user adjustment.

SCXL sensors are intended for use with noncorrosive, nonionic working fluids such as air and gases. The fluids must not react with plastic, aluminum, RTV, silicon, or glass. The sensor's housing is designed for convenient pressure connection and pc-board mounting. To mount a sensor in a horizontal position on a board, you simply bend the leads and attach the package using mounting screws. Tygon or silicon tubing is recommended for terminations at the pressure ports.

If you're moving into new application areas, you'll be looking for as much sensing capability as you can get. You're in luck, because, of course, some vendors offer units with all the bells and whistles. Motorola's MPX5100 Series pie-

The inside story

The foundation for semiconductor pressure-sensing technology is chemically pure silicon. The silicon force collector is inherently linear and highly shock resistant.

Automated semiconductor-fabrication techniques are used to diffuse a 4-arm Wheatstone bridge into the lattice structure of the silicon crystal. A cavity is then micromachined from the opposite surface of the chip to create a thin-diaphragm force collector precisely indexed relative to the four arms of the Wheatstone bridge. When pressure is applied to the diaphragm, the four bridge arms, which are positioned to act as strain sensors, detect the resultant plate stress and develop a classic unbalanced bridge.

In this fashion, the device is able to derive an electrical signal that is proportional to the pressure from a monocrystalline force collector. This force collector features integrated strain gauges and thereby eliminates problems associated with the construction of pressure sensors from multiple, discrete components.

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Model</th>
<th>Property*</th>
<th>Full-scale pressure (psi)</th>
<th>Accuracy (%)</th>
<th>Full-scale output (mV)</th>
<th>Operating range (°C)</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endevco</td>
<td>8540</td>
<td>A</td>
<td>15 to 500</td>
<td>0.25</td>
<td>300 mV</td>
<td>-54 to +260°</td>
<td>$950</td>
</tr>
<tr>
<td>Foxboro/ICT</td>
<td>1230/1231</td>
<td>A, G</td>
<td>5 to 5000</td>
<td>0.125, 0.25</td>
<td>100 mV</td>
<td>-28 to +82°</td>
<td>$75-$90</td>
</tr>
<tr>
<td>Fujikura</td>
<td>FPM</td>
<td>G, A</td>
<td>5 to 120</td>
<td>0.2</td>
<td>80 to 130</td>
<td>0 to 50°</td>
<td>From $14.95</td>
</tr>
<tr>
<td>IC Sensors</td>
<td>1431</td>
<td>A</td>
<td>15 to 300</td>
<td>0.25</td>
<td>60 mV</td>
<td>-40 to +125°</td>
<td>$2 (OEM qty)</td>
</tr>
<tr>
<td>Keller PSI</td>
<td>Series 2</td>
<td>A, D, G</td>
<td>1.5 to 300</td>
<td>0.25</td>
<td>18 to 250 mV</td>
<td>-10 to +80°</td>
<td>$46.50</td>
</tr>
<tr>
<td>Lucas Novasensor</td>
<td>NPI</td>
<td>A, G</td>
<td>15 to 10,000</td>
<td>1.0</td>
<td>100 mV</td>
<td>0 to 70°</td>
<td>$38 (1000)</td>
</tr>
<tr>
<td>Micro Switch</td>
<td>24PC</td>
<td>G</td>
<td>1.0 to 30</td>
<td>1.0</td>
<td>44 to 315 mV</td>
<td>-40 to +85°</td>
<td>$15</td>
</tr>
<tr>
<td>Motorola</td>
<td>MPX5100A</td>
<td>A</td>
<td>15</td>
<td>0.2</td>
<td>4.5V</td>
<td>0 to 85°</td>
<td>$45 (100)</td>
</tr>
<tr>
<td>Sensym</td>
<td>SCXL004</td>
<td>D, G</td>
<td>0.15</td>
<td>1.0</td>
<td>40 mV</td>
<td>0 to 50°</td>
<td>$39.75 (100)</td>
</tr>
</tbody>
</table>

Notes:
1. A=absolute; D=differential; G=gauge.
2. Temperature compensated.
3. Distributed in US by Servoflow Corp—see manufacturers' box.
Silicon pressure sensors

Zoresistive transducers are state-of-the-art monolithic silicon pressure sensors designed for a range of applications. However, the units are particularly well suited for those applications employing a microcontroller or microprocessor that has A/D converter inputs. The patented transducer combines advanced micromachining techniques, thin-film metallization, and bipolar semiconductor processing to integrate the sensing element, offset calibration, temperature compensation circuitry, signal amplification, and an absolute pressure reference onto a single monolithic chip. The unit employs a Motorola-patented shear stress strain gauge that has a 0.2% linearity specification.

The MPX5100A essentially responds in a straight line. Design techniques employed for the chip-carrier element containing the pressure die improve the sensor's reliability. A silicon gel isolates the die surface and wire bonds from harsh environments without interfering with the transmission of the pressure signal to the silicon diaphragm.

For more information...

For more information on the silicon pressure-sensor products discussed in this article, circle the appropriate numbers on the Information Retrieval Service card or use EDN's Express Request service. When you contact any of the following manufacturers directly, please let them know you saw their products in EDN.

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  - Circle No. 713

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  - San Jose, CA 95134
  - (408) 432-1010
  - FAX (408) 432-1859
  - Bruce Hanson
  - Circle No. 714

- **Fujikura Ltd**
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  - Tokyo 135, Japan
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  - TLX 252-2292
  - Circle No. 715
  - In the US:
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- **Micro Switch**
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  - Freeport, IL 61032
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  - Circle No. 720

- **Motorola Inc**
  - 5005 E McDowell Rd
  - Phoenix, AZ 85008
  - (602) 244-4556
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Silicon pressure sensors

Motorola employs a single piezoresistive implant to sense shear stress rather than the more traditional Wheatstone bridge configuration. MPX devices are compatible with most noncorrosive gases. However, the measured media must not react with silicon gel, RTV, or valox plastic.

The MPX5100 Series transducers are available in absolute, differential, and gauge versions. You can purchase the devices in basic element form as well as in top- or side-ported packages. Customized packaging is also available to help minimize the use of additional adapters.

Sensor vendors are still striving to develop sensors for low-pressure applications—areas where full-scale readings are less than 1 psi. On another front, vendors are looking to add significant levels of sophistication to their sensor products to develop smart devices (see box “Adding some smarts”). Given the way the silicon-sensor market has developed over the past few years, it seems quite likely that vendors will be offering both low pressure sensors and smart sensors in the very near future.

Adding some smarts

Increasing the intelligence of a sensor is nothing more than an example of added value. Most of today’s solid-state sensors interface with computers or µPs. Smart sensors would be able to take over some of the functions that would normally have to reside in the computer. There are several levels of sensor sophistication—conversion, environmental compensation, communication, and diagnostics. A sensor need not incorporate all levels to be considered a smart device—one level may be all the smarts a device needs to satisfy the application at hand.

Conversion involves the transformation of a condition or an image to a measurable electric or electronic signal. All sensors have this capability, and in some cases, this capability may be all that’s needed for the job. Conversion-level sensors may employ sophisticated technologies (like silicon micromachining) in order to detect changes in specific variables such as pressure.

Environmental compensation can involve a couple of factors. For example, the sensor may be able to compensate for changes in its operating environment and provide an output signal that reflects the conditions. Compensation for temperature changes is a common enhancement in a number of today’s silicon pressure sensors. Other environmentally compensated sensors might incorporate circuitry that protects them from the operating environment. For example, the circuitry might cause the sensor to shut off if conditions reach damaging levels.

A sensor with communication capabilities can interface with a monitoring system without going through an intermediate communications device. The most basic example of communication capability involves the conversion of an analog signal into a digital signal. Other capabilities could include sensor addressability or the ability to interface with system protocols. An addressable sensor can identify itself, interpret selective signals from the host computer, and provide its output only on demand. A/D conversion represents one-way communication—from the sensor to the system—but addressable sensors would be capable of receiving and transmitting data.

Sensors with self-diagnostics would be able to perform one or both of two functions. First, they could inform the system when they have, or soon will have, problems operating. Secondly, they could provide some kind of output to alert the system when they fail. The latter function would be very important in systems employing many sensors; repair personnel could then easily find which sensor (or sensors) needed to be replaced.
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It's very clear that ASSPs are the best option for a rapidly growing number of designs. At Zilog we've been producing ASSPs and developing Superintegration design methodology longer and better than anyone, which is why we have the largest library of familiar cores and cells in the industry. You can be sure Zilog will continue to develop new members of the Z80 MPU family. And, because we have our own fabrication facilities, you know that every new part will have the same high standards for quality, cost/performance and reliability for which Zilog has always been known.

The smart thing to do is to find out more about the Z80 family of Intelligent Peripheral Controllers, or any of Zilog's rapidly growing Superintegration product families. Contact your local Zilog sales office or your authorized distributor today. Zilog, Inc., 210 East Hacienda Ave., Campbell, CA 95008-6600, (408) 370-3000.

CIRCLE NO. 111
Zilog's Z8® family offers an impressive range of microcontrollers; each one of them aimed at optimum system cost/performance in specific applications.

The Z8 family is one of the broadest MCU lines in the industry. Choose from 1k to 16k ROM, and from 18 to 80 pins configured in the latest packages. You can even get multiprocessor and DSP capabilities. It's a cost-effective, high performance 8- to 16-bit microcontroller family. And more importantly, it's precisely targeted, with hardware and software designed for particular applications in specific markets.

Zilog’s Superintegration™ technology assures more performance with fewer components. The Z8's familiar, elegant architecture guarantees it's easy to program and simple to use. Whether you need a highly sophisticated microcontroller, like the Z86C94 with DSP—an industry first—or something much simpler, you’ll find the MCU you’re looking for in the innovative, high-integration Z8 family.

We offer an enormous range of Superintegration ASSPs. And every member of the Z8 family was developed for specific applications in specific markets, such as mass storage, auto, computer peripherals, speech processing and embedded control. We know that you're looking for the best cost/performance you can get in your system, in your market.
ASSPs are clearly the best choice for a fast growing number of today's designs. At Zilog, we've been producing ASSPs and refining the technology longer and better than anyone. So we offer the largest library of familiar cores and cells in the industry and an easy, code-compatible migration path. Since we have our own fabrication facilities, we can maintain the high standards of quality and reliability for which Zilog has always been known. As we continue to develop new members of the Z8 family, you know they'll be right on target.

To find out more about the Z8 Microcontroller family, or any of Zilog's rapidly growing Superintegration product families, contact your local Zilog sales office or your authorized distributor today. Zilog, Inc., 210 East Hacienda Ave., Campbell, CA 95008-6600, (408) 370-8000.

EDN November 7, 1991

There’s only one connector system designed to meet the ever-changing needs of electronic system designs. Du Pont Metral.

It’s the first – and best – modular connector system for designers and engineers who need a system that will meet their needs today and tomorrow, even as design trends move toward higher density, metric measures, global standardization, and surface mount compatibility. In fact, that’s why Metral was selected as the IEEE connector standard for Futurebus + and SCI.

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DuPont Electronics

CIRCLE NO. 113
Module-generation tool eases top-down FPGA design

Engineers no longer need to face a Hobson's choice between low-level gate delay or high-level language for FPGA design. With Xilinx's Blox tool, which uses high-level module generation, engineers can define their designs graphically with parameterized functional blocks similar to those in silicon-module or data-path compilers.

Blox comprises 30 logic modules, including adders, subtracters, registers, static RAMs, comparators, multiplexers, accumulators, shift registers, PROMs, bus interfaces, counters, 3-state buffers, and bus functions.

With this tool, you don't need to learn a new front-end tool. Instead, you can continue to use current schematic editors, such as Viewlogic's Viewdraw, Mentor's Netedit, Futurenet's Dash, the Cadence editor, and the OrCAD-SDT. Blox accepts netlist entry from these popular editors, and has the ability to specify a design in higher-level, parameterized models.

By simply changing a parameter, a module such as an adder can have its size automatically changed. Thus, modules can be changed from 9 to 10 bits without having to redraw anything. In addition, the tool is "smart"; it can take one parameter size and backtrack to other modules that feed the labeled entity—and change their sizes as well. A single parameter change can scale a design up or down.

The software then converts a generic design to a standard, hierarchical Xilinx netlist file (XNF) and feeds the file to the tool for processing. This design is then synthesized into an FPGA implementation. But unlike most gate-level designs, Blox has the advantage of top-down design information. This grouping of function and location helps to ensure efficient routing.

The Blox tool does the following operations on the netlist:
- Scales data-path widths
- Assigns clock and high fanout signals to buffers
- Assigns master reset signal
- Remaps arithmetic functions to use XC4000 fast-carry logic
- Moves registers/flip-flops to I/O blocks on the chip periphery (these I/O blocks have built-in flip-flops)
- Expands and merges the logic modules.

Blox is built with a rule-based system, which makes it easy to map designs into the underlying RAM-based logic architecture. The software has an advantage over the older gate-based mapping: Blox has high-level design knowledge, which aids in mapping the logic into the FPGA architecture.

Engineers no longer have to use pure module-based design; they can mix design representations. The circuit structure and major blocks can be defined graphically. But, control logic, such as state machines, can be defined in a number of ways, such as schematics or equations.

Blox links into the standard Xilinx XACT 4000 development system and costs $2995 for a PC and $4995 for a workstation version.

—Ray Weiss
Xilinx Inc, 2100 Logic Dr, San Jose, CA 95124. Phone (408) 559-7778. FAX (408) 559-7114. TWX 510-600-8750.

Circle No. 734
In-circuit emulator supports multiprocessing debugging

Debugging software is a major barrier to building multiprocessor systems. Traditional test approaches, such as ICEs, become unaffordable for large numbers of CPUs. However, a Texas Instruments's hardware/software team, the TMS32C40, with on-chip debugging, and the XDS 510 parallel debugger, lets you debug DSP multiprocessing systems.

With the XDS 510 debugger you can control multiple C40s. They can stop and start all or just one processor; halt one or more CPUs with breakpoints; and single-step one or all processors. The processors can be stopped within a few clock steps. Also, you can group and control processors by a defined name. And, executing software can be debugged at the source-code level with a host window for each processor.

Each TMS320C40 has a JTAG (IEEE JTAG 1149.1 test bus) serial port for onboard test and real-time execution control. The JTAG serial port links to an on-chip analysis module and can be used to control the processor. The CPU can be halted, registers and status read or set, breakpoints set, and events monitored. Multiple C40 processors are linked via a JTAG serial link.

The XDS 510 parallel In-System Emulator development system utilizes the C40's JTAG interface to control one or more C40 processors. The emulator runs on a PC. It has a PC half-card, which drops into the PC host bus. A target cable runs from the half-card to an Active Buffer Pod and a short cable that links to an onboard, 14-pin JTAG connector. A full C/assembler source-code debugger also comes as part of the package. The debugger provides a set of interactive windows for each C40 CPU; they allow users to view the processors' source and disassembled code, memory, function call, and a watch window.

The XDS 510 comes with a TMS320C40 C compiler, which has a parallel runtime support library. Library functions support interprocessor communications via the C40's six communication-link ports (each C40 has six ports for point-to-point links with other C40s). Each 8-bit port has a peak throughput of 20 Mbytes/sec. A parallel-processor assembly/linker partitions code between processors. The assembler/linker has directives for mapping program and data code to specific processors.

Each C40 has an on-chip DSP analysis module, which takes on key ICE-like functions. Each module has breakpoint address comparators for program, data, and DMA addresses. Discontinuities—program trace address changes—are saved in a program discontinuity stack, which holds the from, to, and PC addresses. Also included is an event counter for benchmarking and profiling execution.

Currently, the XDS 510 runs on a PC under OS/2. The development software runs on PCs (DOS, OS/2) and the Apple Macintosh, as well as Sun and DEC workstations.

The company is also fielding a parallel development system (PDS), which integrates four C40s onto a single board. These DSP processors each have no-wait-state 64k x 32-bit words or static RAM (SRAM) and 8 kbytes of EPROM. The system also has a shared global memory on a common bus with 128k x 32 words of one-wait-state SRAM. A board JTAG connector links in the XDS 510 emulator. The debugger system costs $8000; the compiler costs $1500.—Ray Weiss
Texas Instruments, Semiconductor Group, Box 809066, Dallas, TX 75380. Phone (800) 336-5236.
Circle No. 733
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**Microcontroller combines CISC and DSP for low-end voice processing**

The NS32AM160 microcontroller (µC) is part of a 3-chip set for low-end voice processing. When combined with two chips, an ARAM (audio-quality DRAM that’s flawed) and a codec, the µC performs voice processing. It handles voice synthesis, recording, and playback, as well as modem and phone-line processing.

In addition, the company provides application software and algorithms for voice processing. Also available is a set of turnkey answering-machine software. You can modify this generic code to build tailored applications or run it as is for a fast out-of-the-box implementation.

The µC has a dual-processor arrangement. It combines the company’s 32-bit embedded CISC (complex-instruction-set-computer) core processor with a 16-bit DSP processor. In this arrangement, the host 32-bit CISC CPU handles overall system control and I/O, as well as setting up and kicking off DSP. Both processors run at 20 or 25 MHz.

The chip contains a 25-kbyte ROM to hold program and constants and a 2.1-kbyte RAM for dynamic data and code. Off-chip memory can hold processing parameters and data. The DSP processor runs from its own 4-kbyte RAM. However, one on-chip memory space serves both the CISC and DSP processors, allowing data exchanges between the processors. The DSP processor runs as a slave to the host CPU and executes out of on-chip memory.

The DSP module is a pipelined, vector-processing engine. In many ways, it resembles the old-fashioned display-list processors for vector graphics. The host CPU sets up the initial program and initializes processing by setting a program pointer to nonzero. The DSP module runs the program to completion and then stops, waiting for its next assignment. It can pass data to the host via shared memory, as well as trigger a host interrupt for immediate response. A 16-bit processor, the DSP module provides a simplified instruction set, having 52 instructions. It’s a DSP processor that handles complex math calculations.

At 25 MHz, the µC executes an FIR-filter algorithm at 40 nsec/tap and a complex FIR-filter algorithm at 160 nsec/tap. The chip has a dynamic-RAM controller, a 1-MHz PWM unit, a timer, a watchdog timer, a 4-level interrupt control unit, and 16 bit-programmable I/O lines. For off-chip memory, the µC relies on an 8-bit bus and 11 address lines.

The chip sells for $17 (10,000) and comes in a 68-pin plastic-lead-chip-carrier package.—Ray Weiss
National Semiconductor Corp, Box 58090, Santa Clara, CA 95052. Phone (408) 721-5000.

Circle No. 735

EDN November 7, 1991
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(404) 436-1300
**PRODUCT UPDATE**

**IC encodes RGB or YCrCb inputs to produce NTSC or PAL outputs**

The Bt858 digital encoder IC converts computer-graphics images to formats used with television display standards. It can drive NTSC video devices used in the USA and PAL (phase-alternation-line) units that are common in Europe. It also provides Y and C outputs for S-Video display applications and can accept input data in RGB (red-green-blue) or YCrCb color-space formats.

The IC provides one of the key capabilities needed in multimedia systems. Boards that use the encoder can output computer-generated presentations directly to televisions or to consumer video-tape recorders. Other applications include video editing and using the IC with video peripherals such as scanners and cameras and photo databases.

The IC's generated 4-field, 525-line NTSC signals are considered nearly studio quality. For PAL applications, the chip produces an 8-field, 625-line image. In NTSC, PAL, or S-video modes, the IC provides pixel clock rates ranging from 12 to 18 MHz. You can also program the number of pixels generated for each scan line, allowing you to use the IC in applications other than standard 12.27-MHz NTSC, 13.5-MHz CCIR601, and 14.75-MHz PAL.

Fig 1 depicts the internal architecture of the Bt858. The IC has three 256×8-bit lookup-table RAM arrays. A separate stack of 15 24-bit registers stores overlay information. The IC also has an on-chip color-bar generator and can handle mixing of computer-generated graphics and captured video images.

The IC accepts composite sync or separate horizontal and vertical sync signals for timing control. It can also accept the CCIR601 H, V, and F control signals, or it can generate horizontal and vertical sync signals. The color-conversion blocks perform RGB to YIQ/YUV for NTSC applications and YCrCb to YIQ/YUV for PAL applications.

The video encoder represents the first in a family of ICs from the company that targets multimedia applications. The CMOS device requires a 5V power supply and typically dissipates 900 mW. It comes in a 132-pin quad flatpack and costs $67 (100).—Maury Wright

Brooktree Corp, 9950 Barnes Canyon Rd, San Diego, CA 92121. Phone (800) 843-3642; (619) 452-7580. FAX (619) 452-1249.

Circle No. 731

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**Fig 1—A choice of S-Video, NTSC, or PAL outputs makes the Bt858 video-encoder IC useful in applications that require compatibility with different international television standards.**
NKK introduces the surface mount
G3T with patented STC contacts,
gull-wing terminals. VPS or infrared
reflow solderable.

JW rockers & JP pushbuttons. High
inrush current resistance protects
against contact welding. TV-8
(16 Amp) + TV-5 (10 Amp) Rated.

Logic-level for PCB or power rating
for snap-in panel mounting, from
very low-profile UB pushbuttons with
full-face LED illumination.

Million operations from unique LED
illuminated JB keypad switch. Red,
green or yellow LED options.

New ND switch is half the size
of ordinary binary coded
DIP rotaries. Washable and
universal footprint pattern.

Logic-level for PCB or power rating
for snap-in panel mounting, from
very low-profile UB pushbuttons with
full-face LED illumination.

Washable Binary Coded DIP rotary
DR-A switch can be PC or panel
mounted. Crisp operation. Right
angle or straight terminals.

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Worth a Million

100,000 CHOICES

YB pushbutton yields literally
100,000+ part numbers with
variations in mounting, illumination,
circuitry and color.

EASY DOES IT

Washable M2B subminiature
pushbuttons feature
very-light-touch, snap-acting
contacts. Straight, right
angle, vertical PC terminals.

TURNING POINT

WORLD'S SMALLEST

ULTRA-MINI
Gyroscope allows 3-D motion sensing for robotics and desktop computers

The Gyropoint pointing device lets you add to your computer the ability to sense either linear or angular motion with three degrees of freedom. A miniature gyroscope is the key to the pointer's unique ability and is available to system developers for other motion-sensing applications.

The pointing device resembles a 3-button mouse, but it's a mouse with wings. Instead of being confined to a flat surface, the pointer works in unrestricted free space and allows you three degrees of freedom. If you're using it in its mouse-compatible mode, the pointer gives you X- and Y-axis position data. You can either slide the pointer along a flat surface (it has a Teflon bottom for easy sliding) or wave it around in mid-air.

If your application software signals the pointer that it can accept 3-D data, the pointer operates as an angular sensor, giving you direct measurements of roll, pitch, and yaw. The pointer's mode switch lets you signal the application software whether to interpret the pointer's data as linear or angular motion. It also has an activate switch, allowing you to turn the pointer when you're not pointing with it.

An embedded microcontroller handles all the pointer's interface functions and translation between angular and linear data in mouse-compatible mode. At rates from 1200 to 4800 baud, the device will handle RS-232C, RS-423, and Apple Desktop Bus protocols.

The key element of this pointer is a miniature spin gyroscope, the Gyroengine. The Gyropoint uses two of these devices to provide three degrees of freedom. Like a conventional gyroscope, the Gyroengine uses a spinning motor inside a double-gimbaled housing to establish an inertial reference axis. The gim­bals allow the axis to remain stable if the housing moves. Optical sensors detect the housing's movement relative to the axis and an onboard microcontroller translates that movement into a serial data stream.

The gyroscope is small, measuring 1.75 in. high by 1.25 in. in diameter. It weighs 1.2 oz and draws a nominal 0.1W at 3V when running. Its microcontroller handles all of the gyroscope's control functions, including spinning up the motor, sampling the position data, and recovery from out-of-range motion. The gyroscope's range is 360° for yaw and ±80° for roll and pitch, with an angular resolution of 10 bits/degree. It has a drift of <2°/min.

You can't see the wings on this mouse, but it has them. The Gyropoint 3-D pointer can operate like a mouse, but it doesn't need to stay on a table.

The gyroscope is also fairly rugged. It will operate in 0 to 70°C temperature at unlimited altitude. It will also tolerate shocks as great as 1000G for 3 msec.

Although the Gyropoint is available to OEMs as a product for bundling with 3-D application software, it is intended to be a demonstration vehicle for the Gyroengine. The engine suits a range of motion-sensing applications. Electronic navigation, robotic arm movement, and platform stabilization are among the possibilities. A developer's kit that includes a pointer, interface schematics, and documentation costs $1000. Production pointers will be available in early 1992.

—Richard A Quinnell
Gyration Inc, 12930 Saratoga Ave, Bldg C, Saratoga, CA 95070.
(408) 255-3016. FAX (408) 255-9075.

Circle No. 730
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PONTIAC We Build Excitement

CIRCLE NO. 116
Fractal geometry compresses video images that have independent resolution

In the late 1970s Benoit Mandelbrot, a professor at the Massachusetts Institute of Technology, demonstrated that you can create abstract pictures by the repeated use of some fundamental mathematical formulas called fractals. This work stimulated the interest of scientists as to whether still or moving video images could be represented by a fractal model. The P.OEM series uses fractals for image compression in hardware and image decompression in software.

In the mid-1980s, Dr. Michael Barnsley discovered that you can describe an image using a mathematical breakthrough called the “fractal transform.” In May of 1987, Dr. Barnsley helped found Iterated Systems Inc to put the fractal transform into practical use in image-compression applications. The company currently offers a family of fractal-based, image-compression products for the OEM, software development, and system-integration market. The product family name, P.OEM, stands for Pictures for OEMs.

The company has developed an ASIC that performs the fractal transform and offers an ISA bus board having eight fractal-transform ASICs, 256 kbytes of RAM, and an Intel 80960 µP. The board accepts data from a frame grabber or a scanner and the eight fractal-transform chips operate in parallel to compress an image into fractal-image-format (FIF) files. The board can compress a 768-kbyte image to 10 kbytes in 240 sec or less. The company recently announced a price reduction for this board, called the FTC-8B, from $8850 to $2995.

In addition, a lower-cost version of the board, called the FTC-1B, has one fractal-transform ASIC. The $1995 board calculates the fractal transform at a much slower rate, however. An $8850 board, called the FTC-II, uses eight fractal-transform chips, 1 Mbyte of RAM, and an 80960 µP. This board operates with the latest version of the company's software development kit, called P.OEM Color Stillframe Developer's Kit version 2.1, which performs decompression in software.

By taking advantage of a feature of fractal-transform technology called fractal Zoom, version 2.1 of the developer's kit can demonstrate compression ratios as high as 2456:1. This feature can scale sections of a compressed image file to create a “zoom effect” without degrading the resolution.

Because of the resolution-independent nature of fractal image compression, the resolution is limited only by the display circuitry. The $2995 software package consists of MS-DOS linkable modules, which can be ac-
cessed by a C language program for OEM use.

To illustrate the power and viability of fractal image-compression, the company is offering a $79 software package that has a "clip-art library" of 250 color images having $640 \times 400 \times 24$-bit resolution. This software, called the Fractal Formatter, occupies less than 4 Mbytes of hard-disk space and represents 192 Mbytes of uncompressed color-image data. The images are in FIF format and are compressed using the P.OEM compression algorithm.

In addition, Fractal Formatter accepts image files from a variety of formats including Targa, Tiff, and Raster files for editing or conversion to FIF files. You can cut and paste images, rotate images, and shrink the dimensions. Because the software runs under Microsoft Windows, you can extract images from the "clip-art library" into a graphic design with the click of a mouse.—John Gallant

Circle No. 732

IT'S COMING

In the November 21, 1991, issue of EDN Magazine, we'll present the 18th annual microprocessor directory. We'll investigate the advanced scheduling techniques that allow emerging µPs to break current performance barriers, followed by more than 40 pages of specs and analyses on current 8-, 16-, and 32-bit µPs and µCs. It's a reference guide worth saving.

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PRODUCT UPDATE-NEW NICOLET MULTIPRO

**Multi-Channel Instruments Get Oscilloscope Operation**

Uses unique Microsoft Windows 3.0® “Front Panel”

Nicolet Instrument Corporation announced the new MultiPro multi-channel transient analyzer. The MultiPro, companion product to the recently-announced Nicolet Pro Digital Oscilloscopes, extends the Nicolet Pro architecture to high channel counts, and offers a unique Microsoft Windows 3.0® “front panel” to retain an oscilloscope’s ease of operation. The MultiPro was designed for engineers and scientists with advanced requirements for data integrity and trigger reliability in a multi-channel instrument. Nicolet has enhanced the flexibility of the system by making it easy to mix memory depths, sampling rates and resolution levels without programming.

**Multi-Channel Data Acquisition Without Programming**

Synchronous acquisition of multi-channel analog data used to force a choice between racks and racks of scopes (for ease of setup and operation), or weeks of programming under the aging CAMAC standard (for economy at high channel counts). Nicolet's use of the familiar Windows® user interface breaks the ease vs. economy dilemma, and delivers other benefits besides. Under Windows®, the output data is immediately portable to other programs, including spreadsheets, word processors, graphics programs and Nicolet FAMOS®. What's more, Nicolet macros can be used to sequence error-free repetitive tests.

**Total Event Capture**

But important as they are, ease and economy can't be the top priorities in multi-channel recording. Often, the event of interest is a high-speed impact, explosion, or other rare and expensive transient, and its magnitude, duration and timing are hard to predict. The Nicolet MultiPro's solution is a combination of wide dynamic range, extreme memory length, unique triggering and simultaneous acquisition.

When an event's magnitude can't be known in advance, Nicolet's 12-bit digitizers allow conservation gain settings without unacceptable loss of resolution. And when timing or duration is uncertain, the optional ultra-long memories (up to 3 megawords per channel) give plenty of margin for safety.

Triggering received special attention from the MultiPro's designers, because a missed or false trigger in multi-channel event capture is a disaster. The MultiPro, like Nicolet's new scopes, has a unique variable-sensitivity "hysteresis" control to prevent false triggers. The MultiPro arms or triggers when the input passes sequentially through two operator-selected voltages, eliminating triggers due to noise or baseline instability. Advanced "logic analyzer" trigger modes such as minimum-interval, dropout and n-event are implemented.

**Instruments for Measurement Experts**

The new Nicolet MultiPro systems come in a compact seven-slot "tower," or a rack for systems with up to several hundred channels. With the introduction of the MultiPro, Nicolet's "measurement expert" customers have a multi-channel instrument that helps them focus on their measurement.

Call Nicolet Measurement Instruments (800) 356-8088

Nicolet MultiPro system with compact seven-slot tower.
Announcing A Simple Way To Get From PLDs To FPGAs.

If you're a PLD designer with an interest in fast, flexible FPGAs, but you think you don't have time to learn new design techniques, we'd like to change your mind.

First of all, you don't have to give up your existing PLD design tools or Boolean equations. Actel's ALES™ 1 program translates the output of PLD tools like CUPL™ and LOG/iC™ into logic optimized for our ACT™ devices. ABEL* 4.0 includes optimization for Actel devices. Entire FPGA designs can be developed with PGADesigner™.

Actel devices offer everything you want in an FPGA. Like high I/O and flip-flop counts. And 100% automatic place and route gets you to market fast.

Once your FPGA is designed, our Action Logic™ System (ALS) converts the captured design into a completed device in minutes. To give you true, high-density, field-programmable, channeled gate arrays.

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It's never been easier to make your innovative designs a reality. We offer you a complete family of powerful FPGAs, like the A1010 and A1020, available in 44, 68 and 84 pin PLCC versions and implementing up to 273 flip-flops or up to 546 latches. And the first member of our ACT 2 family, the power-
FPGAs The Same Way The Similarity Ends There.

More Flexibility And Capacity.
Designing with Actel FPGAs gives you more freedom than you ever imagined. More gates. More flip-flops. More I/O. In fact, our new A1280 is the largest FPGA in the world.

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EDN November 7, 1991

CIRCLE NO. 118
Thirty-two-bit floating-point DSP processors are the muscle machines for the 1990s. These single-chip μPs are powerful math engines that have hardware bolted on for multiprocessing and large addressing. They’re tackling applications ranging from voice recognition to near-supercomputer processing.

Ray Weiss, Regional Editor

Processing power is here for engineers who need it. Today’s 32-bit, floating-point DSP processors offer 25 to 50 million floating-point operations per second—power readily available for heavyweight, math-intensive applications.

To use digital signal processing (DSP), engineers familiar with only conventional microprocessors will have to deal with a new set of processing architectures and programming limitations. DSP microprocessors are not conventional RISC (reduced-instruction-set-computer) or CISC (complex-instruction-set-computer) architectures. In fact, they more resemble the original computers that were designed for solving math problems, such as ballistic firing tables. And programming DSP chips involves learning new ways to build tight processing loops and taking advantage of the chips’ multioperation architectures.

Thirty-two-bit, floating-point DSP processors introduced within the past year combine the addressing range of 32-bit RISC chips with the number-crunching ability of near-supercomputer vector processors. Larger memory sizes make high-level languages like C a reality for current-generation DSP chips. And C, in turn, opens the DSP door to more and more engineers and application programmers.

New DSP-chip architectures lend themselves to multistage processing as well as to parallel operations. One chip, Texas Instruments’ TMS320C40 has communications ports that can link a single processor to as many as six other C40 CPUs for data exchange and coordination. DSP chips that don’t do parallel processing con-
Processors like the TMS32C40 and DSP96002 are designed for large-scale multiprocessing. They don’t even have a serial port.” — Tony Agnello, Ariel

continue to grow in raw processing power. New chips such as Analog Devices’ ADSP-21020 deliver millions of floating-point operations per second running directly out of local memory.

DSP, once the stuff of high-end signal processing, is becoming a key tool for multimedia applications, such as combining voice and video information. DSP CPUs are moving to the system motherboard as coprocessors for multimedia processing. And the software is falling into place to ease the transition from microprocessor- to DSP-style processing. “Programming DSP chips,” says Jimmie Edrington, an IBM design engineer, “is no more difficult to learn than programming a microprocessor.”

However, dedicated DSP processors are not alone. Standard RISC processors are taking on DSP characteristics for higher processing throughput. New CPUs are emerging, such as the National Semiconductor Swordfish and Intel’s i860, that deliver both RISC integer performance and millions of 32-bit floating-point operations per second. Table 1 compares the capabilities of the i860 and two dedicated DSP chips. The i860 has a faster instruction cycle but lacks the hardware to do the real-time digital signal processing of the

<table>
<thead>
<tr>
<th>Table 1—RISC vs DSP floating-point CPUs</th>
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<tr>
<td><strong>Intel i860 RISC CPU</strong></td>
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<tr>
<td>Designed to run Unix</td>
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<tr>
<td>64-bit arithmetic</td>
</tr>
<tr>
<td>25-nsec instruction cycle (pipelined)</td>
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<tr>
<td>No DMA for concurrent I/O</td>
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<tr>
<td>Slow context switch</td>
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<tr>
<td>Standard interrupt mechanism</td>
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<tr>
<td>One external bus</td>
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<tr>
<td>Off-chip memory penalty</td>
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<tr>
<td>No cache lock</td>
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<td>Pipelined FPU</td>
</tr>
<tr>
<td>No integer-to-floating-point conversion instruction</td>
</tr>
<tr>
<td>No integer multiples</td>
</tr>
<tr>
<td>Graphics engine</td>
</tr>
<tr>
<td>Need high-level language</td>
</tr>
<tr>
<td>C compilers</td>
</tr>
<tr>
<td>Long-instruction-word operation; as many as 2 instructions/word, 1 integer, 1 floating point</td>
</tr>
</tbody>
</table>

Texas Instruments TMS320C40 and Motorola DSP96002.

The first thing to realize about DSP chips is that they are not standard processors. Instead, they represent a new and different track in CPU evolution—they were designed for the digital-signal-processing techniques first developed in the 1960s. Also, DSP chips do not support any particular programming language or operating system. In contrast, 32-bit RISC chips are tightly bound to C and Unix.

Thirty-two-bit DSP chips have many embedded-system microprocessor attributes, such as relatively simple memory hierarchies and moderately clean glue-logic requirements. Typically, high-end DSP chips have Harvard architectures (dual program and data access), which allow for dual memory access and high application throughput.

A major feature distinguishing DSP chips from microprocessors is a high-speed MAC (multiply-and-accumulate) capability for high-speed, iterative algorithmic processing (Fig 1). MAC hardware enables many DSP chips to perform single-cycle, floating-point multiplies, which the MAC generally accumulates without additional overhead. MAC cycles are a key advantage for math-intensive processing such as matrix manipulation and building a sum-of-product series.

DSP chips offer fast iterative processing with built-in iteration controls. Unlike standard processors, for which programmers must explicitly set up, iterate, and control processing loops, many of these DSP chips have built-in hardware-control mechanisms. These mechanisms include loop controls, which define loop
boundaries and loop counts; circular buffer controls (module access to a table) and separate memory structures and addressing units for walking through X, Y (coefficient and data) tables and defining the data stride or item length. These mechanisms are extremely efficient for building a series or for matrix/vector manipulation.

DSP chips are surprising. You can do a lot of processing with little written code because these devices can do multiple operations per instruction. The operations include built-in looping and addressing. The chips have iterative controls for walking through two data memories and a result matrix at the same time. Doing multiple operations eliminates much of the algorithm bookkeeping and control necessary to implement an FFT in Motorola’s 680x0, for example. DSP-chip architectures are highly complex, but there’s a real payoff for that complexity in reduced code.

“I’m very pleased with DSP processors. Chips like the TI C30 are easy to code for and provide fast looping,” says Mark Graham, a design engineer at Evans and Sutherland Computer Group (Salt Lake City, UT).

Sophisticated DSP chips, such as the Motorola 96002 and the Analog Devices 21020, can do multiple operations per instruction cycle. Relying on multiple-bus

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Texas Instruments TMS320C40

- Clock speed: 40, 50 MHz (clock divided by 2 internally)
- Instruction cycle: 40 nsec at 50 MHz
- MAC cycle: 40 nsec at 50 MHz
- Accumulator size: 40 bits
- Floating-point formats: 40 and 32 bit
- Registers: twenty-two 32 bit, twelve 40 bit
- On-chip memory: two 4-kbyte RAMs
- On-chip program memory: 512 bytes
- External buses: 2 each has 32-bit address and 32-bit data
- Internal buses: program, two data, DMA, peripheral
- Off-chip fetch: no wait states using 21-nsec SRAM
- CPU pipeline: 4 stages
- Pipelined MAC: 1-cycle multiply and 1-cycle addition
- Special addressing: modulo, bit reverse
- Loop controls: repeat (block or instruction)
- Maximum parallel operations: 11
- Number of instructions: 135
- Special instructions: programmable delayed branch
- Floating-point divide: 360 nsec
- Interrupt response: 4 instructions
- 1024-point FFT: 1.025 msec
- Interrupts: 4 external
- Pins: 325
- DMA channels: 6
- Timers: two 32 bit
- Serial port: none
- Byte addressing: word
- Special features: 6 communications ports (20 Mbytes/sec using DMA); internal ICE and parallel debug features: breakpoint, trace, count
- Price/availability: $560/sampling

*Includes addressing, register operations, loops, DMA, and DMA addressing.
**IEEE-754 floating point.
"It’s work setting up loops and handling arrays. With DSP/C, we added special data types to minimize C expressions.”
—Marc M Hoffman, Analog Devices

architectures lets these chips schedule more than one operation in an instruction cycle. For example, running with on-chip instruction cache and data memories, the 96002 can do a floating-point multiply, add, and subtract while loading two registers and doing a DMA transfer, all in one instruction cycle.

Additionally, floating-point DSP chips eliminate scaling—one of the major problems in fixed-point DSP and numeric application code. Without floating-point capabilities, programmers must continually scale intermediate results for processing. Many floating-point chips automatically scale results to hold maximum significance. Engineers, however, still have to be careful not to lose a result’s significance when combining two values with different exponents.

Most 32-bit DSP chips can do real-time processing and deliver low-latency interrupt responses. Also, DSP interrupt handling is highly deterministic. And although DSP processors are pipelined, their pipelines tend to be fairly simple, which minimizes overhead for pipeline flushing and restoration.

Many floating-point DSP chips lend themselves to multiprocessing. Some of the newer second-generation chips are specifically designed for both the sequential-staging and parallel-processing variations of multiprocessing. Texas Instruments’ TMS320C40, for example, has six communications channels. Each channel is 8 bits wide and has its own DMA port; each port can move data as fast as 20 Mbytes/sec.

Digital signal processing and many other math-intensive applications lend themselves to multiple-processor designs. These applications tend to be algo-

<table>
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<tr>
<th>Texas Instruments TMS320C30</th>
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<tr>
<td>Clock speed</td>
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*Load/store architecture
rithm oriented, and many of these algorithms—such as digital filters, FFTs, and matrix manipulation—consist of building a series with a sum-of-products form or ordered processing applied to regular structures, such as matrices. In many cases, you can break down problems into segments that can be processed separately, either in sequential or parallel stages.

The 32-bit floating-point DSP product world is divided on the issue of multiprocessing. Some chip vendors see multiprocessing as the key to the nineties. Others favor limited multiprocessing and high DSP throughput as the critical design criteria for 1990s DSP applications.

One way to get increased throughput for an application is to partition the problem and add CPUs for each application subset stage. Doing so with DSP chips is fairly easy because, unlike their RISC cousins, DSP chips tend to have regular memory structures with minimal memory hierarchies and run directly with local memory or out of on-chip memory. Another plus is that DSP chips tend to have clean interfaces that require a minimum of glue logic or support chips. For example, Motorola's 96002 needs no support logic to drive SRAM (static RAM) directly.

However, designing a parallel or staged processing system has its own family of problems. For one thing, designers must balance data throughput against processing time to ensure that the system is limited by neither the data flow nor the processing speed. For another, designers have to coordinate system data flow between processors to ensure lock-step processing.

A major design constraint of multiprocessing systems is the need for global, or common, memory—memory accessible by more than one processor. A physical means must exist for the processors to get to the data, and you need a system to ensure that data is locked when a CPU accesses or changes it. Many DSP processors use shared local memory to pass data.

Two new DSP processors stand out for their multiprocessing architectures: the Motorola DSP96002 and the Texas Instruments TMS320C40. Each company has taken a different tack toward multiprocessing. Motorola has opted for a bus-oriented, tightly coupled architecture to take advantage of the company's excellent bus technology. Texas Instruments has taken the opposite approach, that of loosely coupled processors connected via point-to-point links.

![Diagram](image)

**Fig 2**—Featuring six communications ports and six DMA channels, Texas Instruments' TMS320C40 brings a new dimension to DSP multiprocessing. Designers can link multiple C40s point to point and move data as fast as 20 Mbytes/sec/port.
Both DSP chips have large die and complex, multi-operation architectures. Neither chip has traditional DSP serial ports. As one DSP-board designer put it, these two chips don’t fit the classic DSP-chip mold of A/D serial data in, do fast DSP processing, and serial D/A data out. The chips are heavyweight processors for staged multiprocessing.

Motorola’s 96002 has two complete memory ports. Each port can access local or shared memory and is a system bus complete with system arbitration. A 96002 can act as a bus master and access a slave processor’s internal memory. Thus, staged processors can directly pass data to the next CPU. Data transfers via an output bus to the slave processor’s host interface. Both the output bus and the slave’s host interface use one of the processors’ DMA channels. Designers can choose among three transfer techniques ranging from a full-handshake DMA transfer to a no-handshake transfer. Bus-arbitration logic must be added for master/slave-type bus operations.

TI’s TMS320C40, which is available in sample quantities, is an upgrade of the popular TMS32C30 rigged for parallel processing (Fig 2). The company has added dual buses, similar to the 96002’s, for dual bus access as well as bus-oriented multiprocessing. The earlier C30 has two buses (24 and 13 bits) with limited addressing.

But the real surprise in the C40 is its six communications ports. In many ways, TI’s port approach resembles the Inmos/SGS Thomson Transputer’s parallel-processing scheme. The Transputer, a 32-bit stack-oriented CPU, was designed for parallel processing. It has four 20-Mbps serial communications channels on chip for point-to-point CPU links. Although not well accepted by American designers, the Transputer is the base for a hotbed of parallel-system architectures in Europe, particularly in the United Kingdom.

TI architects went the Transputer one better: They gave the C40 six 8-bit communications ports, each capable of passing data at rates up to 20 Mbytes/sec. These ports can link, point-to-point, to other C40s. Each port has DMA capabilities: Port data transfer is independent of the chip CPU. The six DMA channels share a DMA bus for the main external ports. They also share

### AT&T DSP32C

- **Clock speed**: 40 MHz
- **Instruction cycle**: 80 nsec
- **MAC cycle**: 80 nsec
- **Accumulator size**: 40 bits
- **Floating-point format**: 32 bit (sign, 23-bit mantissa, 8-bit exponent)
- **Registers**: twenty-two 32-bit integer, 4 floating point
- **On-chip memory**: three 2-kbyte RAMs for instructions or data
- **On-chip program memory**: see above
- **External buses**: 24-bit address, 32-bit data
- **Internal buses**: 1 (operates at 4x system bus rate)
- **Off-chip fetch**: 40 nsec (as many as 2 accesses per instruction cycle)
- **CPU pipeline**: 3 stages
- **Pipelined MAC**: 2-stage multiply/accumulate in 4-stage pipeline
- **Special addressing**: bit reverse
- **Loop controls**: yes
- **Maximum parallel operations**: 7
- **Number of instructions**: 9
- **Special instructions**: integer-to-floating-point conversion, forced branch/return for interrupt handling
- **Floating-point divide**: 880 nsec
- **Interrupt response**: 3 instructions
- **1024-point FFT**: 2.9 msec
- **Interrupts**: 6 (4 external)
- **Pins**: 133 (PGA)
- **DMA channels**: 3 (serial, I/O, parallel)
- **Timer**: none
- **Serial port**: 1 (plus 16-bit parallel port)
- **Byte addressing**: 8, 16, and 32 bit
- **Special features**: C-like assembly language, 16-bit parallel port
- **Price**: $71 (10,000)

### A helping hand for DSP

For those who have no current signal-processing training, reading these two books can easily bring you up to speed on DSP:

the peripheral bus, which also serves the timers. A C40 can move as much as 120 Mbytes of data without loading down the DSP CPU. DMA data movement, however, may slow main processing because of memory-access conflicts.

Designers can use the C40 to build multiprocessor DSP systems that can take on architectural forms such as hypercubes and meshes. Companies have already started deploying the C40 as a parallel processor. Ariel Corp is fielding a VMEbus board that integrates four C40s, each of which has as much as 2 Mbytes of SRAM and 64 Mbytes of DRAM (dynamic RAM). The V-C40 card links the onboard processors via their communications ports and brings out 12 of the ports for large-scale parallel-processing interconnections.

But the C40's communications ports are not the latest word in parallel processing. The Inmos/SGS Thomson designers are upgrading the Transputer. A new chip, the T9000, will be available in sample quantities next year. The T9000's serial link speed will be 100 Mbps (12.5 Mbytes/sec), and the chip will have virtual packet-switching links instead of the older point-to-point links. Packets of data can travel over a network of links. Transputer systems will dynamically route these packets to addressed processors. An additional chip, the C104, will handle dynamic routing for networks of T9000s.

Both the TI and Motorola DSP chips have on-chip emulation features for debugging. These features let developers breakpoint, examine machine states, and control execution via a serial interface. TI uses a JTAG interface for both test and emulation; Motorola uses its own serial interface.

TI, however, has gone a step further by directly building into its chip the facility to control and debug multiple processors. Users can control multiple processors all linked by a single, serial JTAG test interface. Any or all processors can be halted within a few clocks by the user or by breakpoints. Users can single-step the processors as well.

"We believe that the future of DSP is in parallel

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**Acronyms used in this article**

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
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<tbody>
<tr>
<td>ALU</td>
<td>Arithmetic and logic unit</td>
</tr>
<tr>
<td>API</td>
<td>Application program interface</td>
</tr>
<tr>
<td>ASIC</td>
<td>Application-specific integrated circuit</td>
</tr>
<tr>
<td>bps</td>
<td>Bits per second</td>
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<tr>
<td>CPU</td>
<td>Central processing unit</td>
</tr>
<tr>
<td>DMA</td>
<td>Direct memory access</td>
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<tr>
<td>DRAM</td>
<td>Dynamic random-access memory</td>
</tr>
<tr>
<td>DSP</td>
<td>Digital signal processing</td>
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<tr>
<td>EPROM</td>
<td>Erasable programmable read-only memory</td>
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<tr>
<td>FFT</td>
<td>Fast Fourier transform</td>
</tr>
<tr>
<td>FPU</td>
<td>Floating-point unit</td>
</tr>
<tr>
<td>ICE</td>
<td>In-circuit emulator</td>
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<tr>
<td>ISR</td>
<td>Interrupt service routine</td>
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<tr>
<td>JTAG</td>
<td>Joint Test Action Group</td>
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<tr>
<td>LIW</td>
<td>Long instruction word</td>
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<tr>
<td>MAC</td>
<td>Multiply and accumulate</td>
</tr>
<tr>
<td>MESI</td>
<td>Modified, exclusive, shared, and invalid</td>
</tr>
<tr>
<td>Mflops</td>
<td>Millions of floating-point operations per second</td>
</tr>
<tr>
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<td>Millions of instructions per second</td>
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<td>MMU</td>
<td>Memory-management unit</td>
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<td>PC</td>
<td>Personal computer</td>
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<tr>
<td>PGA</td>
<td>Pin-grid array</td>
</tr>
<tr>
<td>PQFP</td>
<td>Plastic quad flatpack</td>
</tr>
<tr>
<td>RAM</td>
<td>Random-access memory</td>
</tr>
<tr>
<td>RISC</td>
<td>Reduced-instruction-set computer</td>
</tr>
<tr>
<td>ROM</td>
<td>Read-only memory</td>
</tr>
<tr>
<td>SRAM</td>
<td>Static random-access memory</td>
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processing," says Ray Simar, architect of the C40. "For example, the majority of C30 designs involve more than one processor. So we recognized the need for low-cost debugging for parallel processing. The C40 lets you control a number of C40s with a single JTAG serial interface. This interface also lets you test your board components."

Both the DSP96002 and the TMS32C40 inherit traditional DSP architectures. Both CPUs have complex architectures for DSP-class operations. Such operations include iterative processing with dual access of ordered operands such as constants and array variables. The chips' floating-point units have parallel functional units. Both processors have dual internal data RAMs and an instruction cache for tight, on-chip processing loops.

Some vendors have taken the middle road by designing their DSP chips for minimal multiple-processor designs. These chips can handle sequential or staged processing as well as limited shared-memory multiprocessing.

In many cases, limited multiprocessing is all that's needed for dedicated applications such as graphics and image processing. For example, the new graphics subsystem for the IBM RS/6000 workstations is based on multiple TMS320C30s. The subsystem can do high-resolution 2- and 3-D graphics on an X terminal. "We've looked at the C40, and it looks good, but we just don't need the communications capability for our application," says IBM's Jimmie Edrington. "In fact, I wish TI would move some of the instruction upgrades in the C40 back into the C30 where we could use them."

Analog Devices' ADSP-21020 chip suits high-throughput, limited-multiprocessing DSP applications. Although the chip has a dual-bus architecture, the buses are for local and shared memory, not tightly coupled processing.

The ADSP-21020 does dedicated digital signal processing and follows the cache and bus-sharing strategy Analog Devices used in its earlier fixed-point DSP processors (Fig 3). The ADSP-21020 has a Harvard architecture with a data and program bus. However, for complex DSP instructions, the CPU uses the instruction bus as a second data bus while instructions execute out of cache. Basically, complex, 3-address instructions are cached with their addresses in a small 32-word cache. This cache frees up the program bus for use as an additional data path for DSP calculations that require coefficients and data simultaneously.

Unlike most caches, this small cache holds single instructions and their associated addresses. Only complex instructions—ones that need to use the instruction

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**Fig 3—An on-chip cache lets Analog Devices' AD21020 do fast inner-loop processing. The processor caches complex instructions then uses the program bus as a second data bus.**
bus for data—are cached; regular instructions execute directly from memory. The complex instructions are typically the core inner-loop instructions. Thus, a small cache can be sufficient for a multiloop algorithm. The 21020 executes directly out of memory with no wait states for instructions or data. The only drawback to this scheme is in initializing the cache, which means paying the penalty for the first access of a complex instruction.

The 25-MHz 21020 runs with 35-nsec SRAM, which minimizes memory costs. You can hook the chip directly to memory. On the down side, the chip uses 48-bit instruction words and 40-bit data words, which leads to some incompatibility in sharing the program bus. Because of its architecture, the chip requires a minimum of eleven 8-bit-wide memory chips. Processors can share data memory for coordination.

AT&T’s DSP32C also fits into this mainstream processing camp, although it also serves as a base for multi-processor implementations. This processor is a first-generation 32-bit DSP chip that combines a pipelined floating-point DSP engine with a pipelined floating-point MAC.

Coding the DSP32C in assembly language is relatively easy—the assembly syntax is C-like, which makes coding the processor an easy transition for C programmers. However, the processor’s floating-point unit has a 4-stage pipeline. So although floating-point results appear every cycle, a calculation actually takes four cycles to work through the pipeline. This pipeline can create difficulties for exception processing and for interrupts that can break into the cycle. Also, because the chip is pipelined as well as the FPU, there can be programming difficulties in accessing intermediate results. Many programmers first do straightforward code for the inner loops while minimizing parallel operations. They then tighten up the code incrementally and add parallelism.

The DSP32C architecture is flexible. It has three on-chip RAMs, which can be used for code and data. Its internal bus has four stages, each of which can be used for bus operations.

**Bare-bones DSP**

Many dedicated applications, such as speech processing, telecommunications, and graphics, require 32-bit floating-point processing with a minimum of costly overhead. What many of these specialized low-end applications need is a bare-bones DSP processor with a small die and an uncomplicated architecture.

NEC’s two 32-bit floating-point DSP processors suit such single-chip DSP applications. The company built these two chips around a tight ALU with 8 accumulators and incorporated a floating-point multiply unit. They have two 512-word RAMs for application constants and data, and each RAM has a dedicated pointer. A single level of loop control provides low-overhead table or matrix processing.

The company’s minimal-architecture approach is evident in the chips’ straightforward instruction set. Each chip has only 26 instructions; many of their rivals have more than 100. Moreover, the CPUs are easy to program because of their 1-bus architecture.

Even floating-point multiplies are simple: The CPUs don’t have a traditional multiply instruction. Instead, they have an automatic multiplier, which turns two 32-bit operands into a 55-bit result (47-bit mantissa, 8-bit exponent) each cycle. To multiply, all you have to do is load the registers, and the next cycle will
produce a floating-point result on the internal bus. MAC cycles are pipelined in that a multiply can be followed by its accumulate, which runs in parallel with the next multiply. However, the chips have no floating-point-divide instruction.

The two chips are the NEC 13.3-MHz µPD77230, which has a 150-nsec instruction cycle time, and the 11.1-MHz µPD77240, which has a 90-nsec cycle time. Each instruction cycle takes two clock cycles. The chips share a common inner architecture but have different external interfaces. The older device, the µPD77230, is structured for traditional “serial-in, serial-out” DSP processing and has an external bus for accessing off-chip data. In slave mode, the chip can directly interface to a microprocessor host as a coprocessor.

The newer µPD77240 speeds processing with two external buses, one for data and one for instructions. The chip can address as many as 62k program words and 16M words of data memory. The µPD77230 can address 4k program words and 8k words of data memory.

DSP chips of all stripes are finding their way onto system mother boards as coprocessors. Next Inc (Redwood City, CA) started this trend by putting the 24-bit Motorola 56001 on its workstation mother board. Today, mother-board-based DSP is attracting attention as a low-cost way to build in multimedia capability for applications ranging from modems and voice processing to video graphics.

AT&T engineers have configured a DSP32C variation for system mother boards. The DSP3210 lowers the cost of integrating DSP capability on mother boards by executing out of the host CPU’s DRAM rather than requiring its own dedicated local memory. Engineers redesigned the DSP32C’s interface by eliminating the 16-bit interface and substituting a 32-bit, byte-addressable memory interface. The chip can interface to page RAMs and accommodates both Intel and Motorola CPU memory interfaces (big-endian and little-endian memory configurations). The DSP3210 has programmable wait states with ¼-cycle granularity. It also has two 1-kbyte, on-chip RAMs for data or instructions and a 256-word boot ROM.

AT&T developed a new real-time operating sys-

DSP chips are building blocks for large-scale processing systems. Spectrum’s Vasp (a) is a scalable, multiprocessor system built around Motorola’s 96002 (b). The system was designed for aperture radar applications.
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32-bit floating-point DSP processors

system—VCOS, the Visible Caching Operating System—that makes the DSP3210 a reality as a coprocessor. VCOS is a portable, real-time, multitasking and multiprocessing operating system. VCAS, the VCOS Application Server, resides on the host and loads and links DSP tasks and provides memory management and I/O buffering between the host and DSP CPUs. A debugger is also available from AT&T.

VCOS is a minimal operating system—it takes up less than 400 32-bit words in on-chip memory. The OS uses the host’s large, slow system memory for program and data storage. It treats host memory as a resource to cache data and code for faster on-chip processing. VCOS-based code tries to retrieve chunks of data using block moves for high-throughput on-chip processing. VCOS is “slaved” to the host OS, which allocates and controls VCOS data structures, thus eliminating host-DSP memory contention. VCOS executes in both the foreground and the interrupt levels. In the foreground, DSP tasks are an execution list of linked modules, which VCOS calls. On the interrupt level, an interrupt execution list runs in response to an interrupt.

VCOS comes with a complete library of DSP functions for multimedia applications. These applications include V.32 modem, V.29 FAX modem, music and video recording, speech processing, graphics, audio, and video-compression functions.

AT&T’s DSP3210 won’t be alone on the mother board. DSP board vendor Spectrum Signal Processing Inc offers an ASIC controller to put high-performance DSP processing on the PC mother board. An SSP42C100 Medialink Controller (MLC) chip is needed for each PC, workstation, or DSP board subsystem. The chip sets up a high-speed, 66-Mbyte/sec (sustained), 16-bit data bus between the subsystems. MLC chips at each subsystem provide a memory-to-memory transfer mechanism for moving data in packets among the subsystems.

The MLC chip provides a base for multiprocessing as well as linking subsystems to a host. It can act as a data gateway by providing high-speed processor-to-processor transfers. Currently, the chip can link Texas Instruments TMS320C3X processors and Intel 80386 hosts.

DSP operating software

Until the current generation of 32-bit, floating-point DSP processors, DSP processing was the domain of bare-bones, assembly-language programming. Tight, efficient code was the order of the day, especially for 16-bit DSP processors with limited address space and first-generation C compilers.

Today’s 32-bit, floating-point DSP chips are forcing a reevaluation of DSP software. For one thing, these DSP CPUs have much larger address spaces than previous-generation DSP chips. Many can address 16 Mbytes to 4 Gbytes. And the performance of C compilers for these chips has reached professional standards.

Larger address spaces mean that programs no longer have to live in small, restricted data and code spaces. Moreover, as one DSP-board developer puts it, memory size and cost is no longer a limiting factor for DSP applications. Many DSP projects routinely use tens of megabytes of memory or more.

Today, many DSP programmers are turning to C to limit program complexity. Programmers use C for writing the overall program and for structuring data, but they still rely on assembly language for fast, critical code, such as for algorithm inner loops. “I do about 90% of my code in C,” says IBM’s Edrington, “and 10%
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32-bit floating-point DSP processors

in assembly language for speed.” Chris Hodges, director of software at DSP-board vendor Atlantic Signal Processing Inc (Atlanta, GA), agrees with this scheme. “No one even pretends to put all their critical code in C. You use C for your control code and data structures, and assembly language for time-critical code.”

C is also opening up high-end DSP processing to higher-level operating software. C lets vendors develop tools and operating systems generically and then port them to other DSP processors, even those from different vendors. Using specialized application function libraries finely tuned in assembly language for each DSP architecture generally enhances the performance of each chip.

Currently, there are two breakthrough development tools for high-level, floating-point DSP chips. One, Spectron Microsystems’ Spox operating system, is a generic DSP operating system and application environment. The second, Comdisco’s Multiprox development tool, lets engineers graphically specify and partition DSP applications for multiple DSP processors.

Spox was developed by engineers who got tired of reinventing the DSP wheel for each application. Spox is a full-fledged, message-passing operating system structured for signal-processing and math-intensive applications. This high-level application environment has easy to use features including device-independent I/O, processor set up, and host interfacing. But Spox does more than just offer those functions: It provides an object-based model for DSP and math processing. Spox actually defines new data types, such as vector and matrix, for DSP-class processing.

Last year Spectron introduced OSPA (Open Signal Processing Architecture), an extension to Spox for host-driven DSP applications. Running on software such as Microsoft Windows 3.0, OSPA provides a host-level interface. Using this interface, host applications can schedule and control multiple tasks running on a DSP coprocessor. Essentially, OSPA is a software layer, or API (application program interface), that eases integrating DSP processing power into host-based interactive applications.

Spectron initially developed Spox for Texas Instruments’ C30, but now the operating system also runs on the Motorola 96002, and the company is porting it to the TI C40 and the Analog Devices 21020.

Spectron is also working on a parallel-processing version of Spox, which is in beta testing. “Spox was designed with parallel processing in mind,” says Spectron President David Wong, “The underlying message-passing model supports multiprocessing. Now we are adding a software layer to link multiple processors, each running Spox.” The multiprocessing extensions are built around message-based primitives and can implement high-speed data streaming through named pipes. The Spox resource-lock monitor allocates shared memory.

The second breakthrough DSP tool is Comdisco’s Multiprox development package, which is a new option to its Signal Processing Workstation (SPW) tool set. Using the tool set, engineers can specify DSP applications graphically by using icons that represent DSP-specific processing to draw a data-flow diagram. Multiprox enables engineers to partition these data-flow designs into processor-specific portions.

Additionally, the SPW tool set and Multiprox automatically convert the diagrams to processor-specific C code and build in the software links, or IPC (interprocessor communication) routines, to move data from one processor to another. The data-flow diagrams convert to a C program, which calls processor-specific routines, many of which are hand-optimized assembly code for efficiency. Thus, an engineer can use the tools to map top-level software designs to different processors or mixes of processors.

The SPW and Multiprox tool set is flexible enough to map a DSP application onto Sun workstations, each

---

**NEC µPD77230**

- **Clock speed**: 13.3 MHz (2 clocks per instruction)
- **Instruction cycle**: 150 nsec
- **MAC cycle**: 150 nsec
- **Accumulator size**: 55 bits
- **Floating-point format**: NEC format
- **Registers**: 8 55-bit accumulators, 2 multiply registers
- **On-chip memory**: 2 2-kbyte RAMs, 1 4-kbyte ROM
- **External buses**: Master (13-bit address, 32-bit data) slave (16-bit bus, plus 4 I/O pins)
- **Internal buses**: 32-bit main, 55-bit ALU
- **CPU pipeline**: 3 stages
- **Off-chip fetch**: 2 instruction cycles (fast), 4 instruction cycles (slow)
- **Pipelined MAC**: 1 cycle (multiply then add)
- **Special addressing**: Modulo
- **Loop controls**: 10-bit loop counter
- **Maximum parallel operations**: 9
- **Number of instructions**: 26
- **Special instructions**: Automatic multiply each cycle
- **Floating-point divide**: N/A
- **Interrupt response**: 3 instructions
- **1024-point complex FFT**: 11.78 msec
- **Interrupts**: 2
- **Pins**: 68 (PGA)
- **DMA channels**: None
- **Timer**: None
- **Serial port**: 1 in, 1 out
- **Byte addressing**: None
- **Special features**: Automatic multiply, slave mode to 16-bit microprocessor
- **Price**: $75 (1000)
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of which subs for a DSP processor. Thus developers can use networks of workstations linked via Ethernet and TCP/IP to emulate and debug multiprocessor DSP designs.

More software changes are underway. TI's TMS320C40 is attracting a lot of attention in Europe because of its Transputer-like communications ports. Many Transputer users will be porting their parallel-processing technology to the 32-bit floating-point DSP-chip world. For starters, Perihelion Software Ltd (Somerset, UK) is porting its Helios, a Unix-like operating system, to the C40. Other software, including parallel-application C compilers, should follow suit.

DSP C compilers, including Texas Instruments's, are taking a turn for the better according to users. And Intermetrics (Cambridge, MA), the cross-development-tool vendor, is shipping a C compiler for the Motorola 96002 and NEC 77240. These compilers are part

<table>
<thead>
<tr>
<th>NEC µPD77240</th>
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<td>Clock speed</td>
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<td>External buses</td>
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<td>Pipelined MAC</td>
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<tr>
<td>Special addressing</td>
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<tr>
<td>Loop controls</td>
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<tr>
<td>Maximum parallel operations</td>
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<tr>
<td>Number of instructions</td>
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<tr>
<td>Special instructions</td>
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<tr>
<td>Floating-point divide</td>
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<tr>
<td>Interrupt response</td>
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<tr>
<td>1024-point complex FFT</td>
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<tr>
<td>Interrupts</td>
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<td>Pins</td>
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<td>DMA channels</td>
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<tr>
<td>Timer</td>
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<td>Serial port</td>
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<tr>
<th>Intel i860XP</th>
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<tr>
<td>Clock speed</td>
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<tr>
<td>Instruction cycle</td>
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<tr>
<td>MAC cycle</td>
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<tr>
<td>Accumulator size</td>
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<td>Floating-point formats</td>
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<td>Registers</td>
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<td>On-chip memory</td>
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<td>On-chip program memory</td>
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<tr>
<td>External buses</td>
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<td>Internal buses</td>
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<td>Off-chip fetch</td>
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<td>CPU pipeline</td>
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<td>Pipelined MAC</td>
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<td>Special addressing</td>
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<td>Loop controls</td>
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<td>Maximum parallel operations</td>
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<td>Special instructions</td>
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<td>Floating-point divide</td>
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<td>Interrupt response</td>
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<td>1024-point FFT</td>
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<td>Interrupts</td>
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<td>Byte addressing</td>
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<tr>
<td>Special features</td>
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<td>Price/availability</td>
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*Superscalar—1 or 2 instructions per cycle.  **Load/store architecture.
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32-bit floating-point DSP processors

Dedicated DSP processors aren't the only game in town for single-chip, DSP applications. DSP-like features are finding a home in conventional microprocessor architectures. For example, vendors of 8- and 16-bit microcontrollers are adding DSP capabilities to applications such as motor, servo, and car controls. On the 32-bit front, two RISC processors deliver DSP-class floating-point performance: Intel's i860 and National Semiconductor's NS32SF641 Swordfish. Both CPUs combine RISC main processors with an integrated DSP unit. Single-cycle execution times for these processors are extremely fast: The clocks of the i860 and Swordfish run at 40 and 50 MHz, respectively. The typical DSP effective cycle rate is 20 to 25 MHz.

Developers of applications that need DSP-class performance, but require a standard processor, should look carefully at these two high-throughput processors. Both combine RISC architectures with DSP MAC units but have taken different implementation paths. The i860 resembles a standard CPU: It has an MMU and can run Unix. The Swordfish is tailored for real-time, embedded processing.

Both processors increase throughput by issuing multiple instructions per instruction cycle. This approach differs from the traditional DSP method of defining multiple operations in one instruction. However, the Intel and National Semiconductor architects took different tacks. Intel's i860 is a long-instruction-word (LIW) machine: It accepts two 32-bit instructions on a 64-bit bus. One instruction is for the integer unit; the other is for the floating-point/graphics unit.

The Swordfish, however, has a modified superscalar architecture: The chip executes as many as two instructions per instruction cycle. Its CPU is fed from a 64-bit external data bus and includes two parallel, linked pipelines (A and B), each of which has its own integer ALU. The CPU can receive and dispatch two instructions to or from the linked pipelines. The B pipeline, however, schedules only one floating-point unit. When executing noninterlocked instructions out of cache, the Swordfish's execution peaks at 100 MIPS. However, if executing out of external memory for code or data, the chip's peak rate can fall to 50 MIPS or less.

The Swordfish's two pipelines, each of which has an ALU, provide easy indexing to walk through coefficients and data tables for DSP processing. The CPU has a 64-bit bus that takes in two instructions or data words at a time from the cache, which helps keep both pipelines fed. Both RISC CPUs have pipelined DSP functional units. The i860 floating-point unit is four stages deep; the Swordfish's is five stages. Such pipelining complicates processing, especially in a real-time system in which interrupts must be serviced. Servicing interrupts means breaking the pipeline's execution, which causes the CPU logic to flush and later restore or restart the pipeline.

The i860 further complicates interrupt handling because it has an exposed pipeline with internal states that must be stored and reset to continue. Also, many developers consider programming the i860's pipeline difficult because of its complexity. Using assembly language to program inner DSP loops is especially difficult. And the chip's software was designed for C and Fortran programming. Assembly-language coding for optimal inner-loop processing is difficult to write due to the RISC architecture and the exposed pipeline.

In contrast, coding the Swordfish is a bit easier given its small, compact instruction set (58 instructions vs 98 for the i860). Additionally, the Swordfish's software and hardware are configured for easy assembly or C programming.

### National Semiconductor Swordfish

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clock speed</td>
<td>33-, 40-, 50-MHz bus (internal)</td>
</tr>
<tr>
<td>Instruction cycle</td>
<td>20 nsec at 50 MHz, as many as 2 instructions/cycle</td>
</tr>
<tr>
<td>MAC cycle</td>
<td>20 nsec at 50 MHz (pipelined)</td>
</tr>
<tr>
<td>Accumulator size</td>
<td>64 bits</td>
</tr>
<tr>
<td>Floating-point formats</td>
<td>32-bit single precision, 64-bit double precision**</td>
</tr>
<tr>
<td>Registers</td>
<td>thirty-two 32-bit integer (32-/16-bit single-/double-precision floating point)</td>
</tr>
<tr>
<td>On-chip memory</td>
<td>1-kbyte data cache (locking)</td>
</tr>
<tr>
<td>On-chip program memory</td>
<td>4 kbytes (locking)</td>
</tr>
<tr>
<td>External buses</td>
<td>32-bit address, 64-bit data</td>
</tr>
<tr>
<td>Internal buses</td>
<td>64 bit</td>
</tr>
<tr>
<td>Off-chip fetch</td>
<td>64 bit (40 nsec)</td>
</tr>
<tr>
<td>Pipelined MAC</td>
<td>5 stages; 2 cycles per multiply for multiply/multiply sequences, 1 cycle for multiply/add sequences</td>
</tr>
<tr>
<td>Floating-point divide</td>
<td>16/31 instruction cycles for single/double precision</td>
</tr>
<tr>
<td>Interrupt response</td>
<td>16 instruction cycles</td>
</tr>
<tr>
<td>1024-point FFT</td>
<td>1.025 msec</td>
</tr>
<tr>
<td>Interrupts</td>
<td>as many as 15 external (4-bit coded)</td>
</tr>
<tr>
<td>Pins</td>
<td>223 (PGA)</td>
</tr>
<tr>
<td>DMA channels</td>
<td>2</td>
</tr>
<tr>
<td>Timer</td>
<td>16 bit</td>
</tr>
<tr>
<td>Serial port</td>
<td>1 for on-chip ICE</td>
</tr>
<tr>
<td>Byte addressing</td>
<td>yes</td>
</tr>
<tr>
<td>Special features</td>
<td>2 pipelines, ALU, branch prediction, fault-tolerant shadow mode</td>
</tr>
<tr>
<td>Hardware debug support</td>
<td>6 debug registers; instruction trace, trap, count</td>
</tr>
<tr>
<td>Price/availability</td>
<td>$880/sampling</td>
</tr>
<tr>
<td>**IEEE-754 floating point</td>
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<tr>
<td>*** Load/store architecture</td>
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However, the i860 has some solid built-in advantages. These advantages are confined mainly to moderate real-time processing due to the chip's high interrupt overhead. The chip also has a built-in pipelined graphics engine, which makes the chip a good choice as a math-intensive graphics coprocessor.

Intel has recently upgraded to a second-generation chip, the i860XP, which has a 50-MHz clock. The upgrade has two large 16-kbyte caches for instructions and data and is designed for multiprocessor configurations. The device also has a built-in MESH (modified, exclusive, shared, and invalid) cache-coherency protocol.

Intel engineers included a quick fix to minimize i860XP pipeline overhead for interrupts. If interrupt service routines (ISRs) don't use the pipeline, they don't have to save and restore the pipeline. The ISR can set a status bit; the bit will trigger an exception if any instruction tries to use the pipeline.

Although introduced in 1983, DSP processors, especially the 32-bit floating-point chips, are still a relatively new engineering tool. The newer 32-bit floating-point DSP CPUs and their tools—high-level language compilers, top-down design systems, and operating systems—are now opening digital signal processing to wider use. You can expect to see DSP processors in more applications as more and more engineers use them as drop-in solutions to bounded processing problems that require math-intensive performance.

Today, DSP chips aren't thought of as general processors, even with their 32-bit addressing. However, that assessment will change as DSP power goes up and operating systems like Spox and Helios come into use. Expect DSP chips to take on more generalized applications as well as become application hosts.

Compared with RISC processors, high-end DSP chips still have an advantage for complex, math-intensive processing. However, higher-performance RISC chips are reaching DSP processing plateaus as RISC clock rates increase and multioperation techniques take effect. Also, RISC architectures are starting to take on DSP-chip characteristics, such as on-chip MAC units and multiple operations.

The race is on. To keep their lead, DSP chips will have to track the RISC/CISC performance curve. That curve predicts CPU performance levels of 2000 to 3000 VAX MIPS and 250-MHz on-chip clock rates by the year 2000. The question is whether the evolution of complex DSP architectures can compete with the fast turnaround time of the simpler RISC CPUs, whose performance doubles every 18 to 24 months.

DSP processors have a real-time advantage because next-generation RISC CPUs rely on complex memory hierarchies and superscalar instruction scheduling. These techniques have performance penalties for cache misses and interrupts that limit determinism. Unlike RISC designers, DSP-chip developers live within the constraints of restricted memory hierarchies, fast MAC cycles, and multiple operations. But there's room for improvement: DSP-chip instruction cycles currently run at 20 to 25 MHz, far below RISC rates.

Manufacturers of 32-bit floating-point DSP µPs

For more information on 32-bit floating-point DSP µPs such as those described in this article, circle the appropriate numbers on the Information Retrieval Service card or use EDN's Express Request service. When you contact any of the following manufacturers directly, please let them know you saw their products in EDN.

**Analog Devices**
Digital Signal Processing Div
1 Technology Way
Norwood, MA 02062
(617) 329-4700
Circle No. 665

**Ariel Corp**
453 River Rd
Highland Park, NJ 08904
(201) 249-2900
FAX (201) 349-2123
Circle No. 666

**AT&T Microelectronics**
555 Union Blvd
Allentown, PA 18103
(800) 372-2447
Circle No. 667

**Inmos**
SGS Thomson Microelectronics Group
13-10 Electronics Dr
Carrollton, TX 75006
(214) 466-8844
Circle No. 668

**Intel Corp**
3065 Bowers Ave
Santa Clara, CA 95054
(800) 548-4725
Circle No. 669

**Motorola Inc**
Microprocessor Products Group
6501 William Cannon Dr
West Austin, TX 78735
(512) 891-2030
Circle No. 670

**National Semiconductor Corp**
2900 Semiconductor Dr
Santa Clara, CA 95052
(408) 562-5900
Circle No. 671

**NEC Electronics Inc**
401 Ellis St
Mountain View, CA 94039
(415) 960-6900
Circle No. 672

**Spectrum Microsystems**
600 Ward Dr
Santa Barbara, CA 93111
(805) 967-0503
FAX (805) 967-0503
Circle No. 673

**Texas Instruments**
Semiconductor Group
Dallas, TX 75260
(800) 336-5296
Circle No. 675

**Spectrum Signal Processing Inc**
Suite 301, Discovery Park
3700 Gilmore Way
Burnaby, BC
V5G 4M1 Canada
(604) 438-7266
Circle No. 674

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EDN November 7, 1991

Philips Components
Pure, unwavering determination frequently works miracles. It did for Gerard Philips a century ago, when he bought a small factory, hired 10 workers, and proceeded to build what would become a global business enterprise.

With carbon filament lamps as the firm's first product, and Gerard's brother Anton Philips as its first sales manager, the startup company grew quickly to prominence in the lighting market of Europe.

Through the years, the company's continuous, wide-ranging research yielded knowledge and capabilities to broaden the product range. The original carbon-filament lamps gave way to incandescent lamps, and later, to gas-discharge lamps. X-ray tubes were followed by X-ray equipment; and the early radio valves, followed by complete radio receivers.

By the midpoint of the company's first century, Philips' technical expertise had grown to encompass phonographs, telecommunications equipment, and electric shavers.

Today, worldwide, Philips Components serves major end markets which include computers and electronic data processing, the multifaceted automotive and industrial markets, the military/government sector, and highly specialized professional systems.

In automotive electronics, Philips Components products fulfill traditional applications such as car radios and sound systems, engine and transmission controllers, instrument displays, driver information centers, and other electronic systems. Other applications include anti-lock braking systems, airbags, and cellular telephones.

Philips Components Discrete Products Division has become a strong component supplier to the electronic data processing industry. Primary application areas for our components are telecommunication and networking products, monitors and terminals, peripheral board-level components, power supplies, and tape storage products.

The hundred-year story of Philips is one of marketing growth, based on ever-increasing technical expertise—a direct result of the intense dedication to research which has characterized the company since year one. As the world's technological capability continues to expand, so too will the commercial opportunities for Philips, in existing markets and in new ones yet unknown.

Our century-long spirit of innovation continues. Use the attached reply card to learn more about our products.
TOPFET® provides over-temperature protection for Tj above 150 °C...short-circuit load protection... rugged overvoltage clamping for inductive load repetitive switching...input ESD protection...and reverse battery protection.

This integrated device embodies N-channel enhancement mode DMOS technology, and requires minimal external components for high-reliability protection.

Characteristics include good immunity to high dv/dt, and a low operating input current at an input level of 5 V. Maximum on-state resistance ranges from 28 mΩ to 100 mΩ and maximum continuous drain source voltage is 50 V.

The first TOPFET at 50 mΩ resistance is available now. The rest of the series will become available by 2nd quarter 1992.

NEW: 719J4 Series Capacitors For Interference Suppression Designed To Meet Worldwide Requirements.

Philips' extensive product line provides over 160 high-quality coaxial and waveguide circulators and isolators. Applications include radio and TV transmitters, navigation aids and radio links, air traffic control systems, radar, mobile telephone systems, magnetic resonance tomography, industrial microwave heating systems, and wideband measurement.

Both product types range in frequencies from 68 MHz to 18 GHz, providing up to 50 dB isolation, with insertion loss as low as 0.2 dB, and CW power ratings from 1 W to 0.5 KW.

The full-color brochure lists the complete selection of available circulators and isolators. Devices with alternate connectors and operating frequencies may also be available on request.

Maximum Capacitance In Minimum Size: Series 49XC Tantalum SMD® Chips.

Here's top performance in surface mount tantalum chip capacitors: the highest capacitance rating at a given rated voltage. And the advanced 49XC XTRA CHIP Series devices require as little as one-seventh the volume needed for typical molded tantalum chip capacitors.

49XC Series capacitance range is 1.0 µF to 220 µF, in the voltage range from 4 to 50 VDC. These capacitors operate from −55 °C through +85 °C with full rating; through +125 °C with voltage derating.

In five standard case sizes (D, E, F, G, and H), 49XC Series chips possess a unique, patented construction which yields devices exhibiting AC characteristics ideally suited for high-frequency applications.

Packaging is 12 mm embossed tape, reeled, for efficiency in handling and storage. This packaging conforms to EIA Standard RS-481 and is compatible with all tape-fed high speed placement equipment.

Availability of 49XC Series tantalum chips: stock to eight weeks ARO.


Philips 2222-139 Series Long Life SMD® Capacitors now offer longer working life as well as enhanced specifications.

Useful life of the devices is 200,000 hours @ 40°C. Load life rating is 2,000 hours, at 105 °C.

The series provides capacitances from 22 µF to 220 µF in the operating temperature range of −55 °C to +105 °C. Voltage ratings between 6.3 V and 63 V are standard; 100 V and 160 V are available on special order.

Cases sizes for the series are 10.8 x 4.1 x 4.4 mm, 13.8 x 4.1 x 4.4 mm, 14.3 x 6.2 x 6.9 mm, and 14.3 x 7.6 x 8.2 mm. The 4.4 mm mounting height is ideal for use on low-profile printed circuit boards.

Fully flame-retardant, molded construction helps to insulate and protect against harsh environments, and make these capacitors suitable for flexible terminals, reflow and wave soldering.

Due to their self-healing, dielectric, electrolytic technology, the devices are insensitive to voltage spikes. Thus they do not require current-limiting resistors.

Application areas include automotive, telecommunications, electronic data processing, and control equipment. Smoothing, coupling, decoupling, buffering, and timing are among the frequently specified functions. Availability: stock to 12 weeks ARO.

NEW: Fast-Acting, Highly Durable NTC Thermistors For Harsh Environments.

Excellent temperature-sensing performance comes in a choice of glass-encapsulated packages!

Series 2322 633 8...thermistors are axial-leaded, in the SOD-27 package developed in Europe. Series 2322 633 5...devices are electrically equivalent, in the SOD-80 surface mount MELF package.

Both series offer resistance ratings of 10, 20, or 30 KΩ, tolerances of ± 5% or ± 10%, ± (25/85) of 3977, and β tolerance of 1.3%.

Series 232 633 8...performance is guaranteed from −40°C to +155°C. These devices are ideal for automotive and telecommunication applications. Both series are available from stock.

Thin Film Technology, SMD® Combined In MELF Resistor.

Philips'9B1406 MELF precision resistor benefits from technology used in manufacturing leaded metal film resistors—even though it comes in a surface mount package. This thin film SMD® resistor is formed by depositing metal film on a high alumina core which is then capped and spiralled to value. The 9B1406's end caps are coated with nickel-copper-nickel and pure tin. The result: excellent soldering characteristics are maintained after long storage.

The MELF resistor offers TCRs down to ±15 ppm/°C and tolerances to 1%. Availability is .22 ohm to 10 megom in the 5% 50 PPM version. In bulk or tape and reel.
Ultra Precision Metal Film Resistors Available Now.

Philips is taking aim at test and instrumentation and measurement equipment with its UPR 5000Z series of ultra precision metal film resistors.

Initially developed to replace high precision wirewounds, the series is ideal for replacing bulky metal foil designs. Use them for A to D conversions and other circuitry requiring precise, stable resistors.

Available in three body sizes ranging from 1/20W to 1/3W, the resistors feature tolerances as low as ±0.1% and temperature coefficients starting as low as ±2ppm/°C. Other series characteristics: excellent temperature and time stability, low voltage, low noise, and high initial accuracy and tracking.

Ask UPR 5000Z resistors in bulk or on tape and reel. Delivery from stock or within 8 weeks ARO.

NEW: Ferrite Beads For Surface Mount Production.

New beads are in .335" (8.9mm) and .160" (4.6mm) size categories, and are manufactured of 452 ferrite material.

Impedances match those of the most frequently used tape and reeled beads-on-wire.

Construction: a piece of flat tinned copper wire passed through and cramped on the rectangular ferrite bead.

Sales Offices and Manufacturer Representatives

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<td>Mexico</td>
<td>Mexico City, Philips Components</td>
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1-800-447-3762
Dr. Gilbert F. Amelio, President and Chief Executive Officer of National Semiconductor Corporation.

Dr. Gilbert Amelio, President and CEO of National Semiconductor Corporation, will be the keynote speaker at EDN's Second Annual "Innovation and Innovator of the Year Awards" Banquet on November 19 during Wescon in San Francisco. EDN's Innovation program recognizes the year's most innovative products and innovative engineer or engineering team in the electronics industry. Dr. Amelio will speak on the "Role of Innovation in Global Competition." Dr. Amelio holds 16 patents and is credited with being the co-inventor of the industry's first charge-coupled image sensor. These devices are used in most consumer video cameras today.

Come hear what the leader of one of the world's largest semiconductor corporations has to say about innovation. Support these innovative people and products awarded EDN's 1991 "Innovation and Innovator of the Year Awards."

To receive a reservation form for the industry event of the year, fax Pam Winch at (617) 558-4470.
THE HISTORY OF LINEAR TECHNOLOGY FOR THOSE OF YOU WHO LIKE DETAILS (AND PICTURES).

It's crazy, isn't it? One day a bunch of enterprising young turks start a company.

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Regrettably, we couldn’t list them all. But over the last ten years, all of them have given us problems. Problems that required a cost effective, high performance linear solution. Which is good because when we started this business we figured the best way to become successful was to become the best at solving high performance linear application problems.

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And every product we make is backed by a worldwide network of service and support.

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AND FOR THE REST OF YOU.

SO FAR,
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Linear Technology Corporation, 1630 McCarthy Blvd., Milpitas, CA 95035
IT ALMOST READS YOUR MIND.

CADSTAR's revolutionary new user interface almost reads your mind, anticipating your next move and intelligently defaulting to the most likely action. For example, if you pick a part, CADSTAR lets you move it without selecting an action from a menu. If you pick a connection, you can manually route it instantly.

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CADSTAR works with Racal-Redac's 386 Advanced Router, the most powerful PC based router available. It features 32 bit, gridless, shove aside, rip up and retry technology for 100% routing completion.

Is There A CADSTAR In Your Future?
Call or write for your free CADSTAR demo disk and brochure. See for yourself how powerful, and easy to use, new CADSTAR really is. Call (508) 692-4900.
To satisfy the information needs of today's designers, Wescon/91 features programs that stress state-of-the-art information and identify future trends.

Tom Ormond, Senior Editor

More than 40,000 electronics engineers are expected to attend the 41st annual Wescon at the Moscone Center and the San Francisco Marriott in San Francisco, CA. The show runs from Tuesday, November 19 through Thursday, November 21 and features live product demonstrations from more than 1000 vendors.

Wescon/91 features a full slate of special events, starting with an all-day executive program on Tuesday, November 19. The executive program begins with an economic-forecast session running from 9:30 until 11 AM. The program continues with a business conference from 2:30 until 4:00 PM.

The business conference offers attendees a chance to learn about technological opportunities in the Eastern Bloc countries. Business and technical representatives from the Soviet Union, Poland, and...
The TO-5 family of relays were always good in RF switching applications. We didn’t plan it that way. It just happened. Low intercontact capacitance. Low insertion loss. Up through 500 MHz. No problem.

But then you wanted to go even higher. You wanted gigahertz performance. And not just 1 GHz, but 3 or 4. That took some serious doing. But our combination of experience and innovation was equal to the task. We married our two decades of TO-5 technology with some new techniques we developed to enhance the RF characteristics. The result? We were able to extend the relay’s performance from the MHz range to the GHz range. And handle RF switching functions all the way up to 4 GHz. With intercontact isolation even higher and insertion loss even lower than in the MHz range.

The high performance gigahertz Centigrind relay. It will handle your toughest RF switching assignments, especially when power drain is critical. Call or write today for complete details.
Czechoslovakia will answer questions and provide information regarding the capabilities and procedures available to nurture business ventures in these countries. The attending Eastern Bloc representatives are all top executives from the electronics industry in their respective countries. The session is a great opportunity to investigate the 2-way potential for developing commercial relationships with countries in transition from state-owned enterprises to private establishments.

Also on Tuesday afternoon, you can attend a special session about PCs vs workstations: There is an ongoing controversy within the industry over which platform to use for electronic design. Numerous surveys have been conducted to determine achievable performance levels of PCs vs workstations. The surveys compare DOS and Unix: Which platform has been the platform of choice among EDA companies and end users? EDAC (Electronic Design Automation Companies), the voice of the EDA industry, asserts that the applications software drives EDA productivity more than the hardware on which the software runs. The panelists in this session represent platform manufacturers and EDA companies and all have experience using various platforms. They will explore the role of standards in achieving maximum application performance independent of the system used.

On Wednesday, November 20, a panel of editors and analysts will explore the future of the semiconductor industry—an area that seems to change almost daily. As chips become more complex, some manufacturers have positioned themselves as system houses. Others have begun advertising in mainstream media, rather than in trade publications. Still other manufacturers have spun off software-support divisions into separate companies. Attend the panel session and hear a lively discussion exploring current semiconductor issues. Take a look into the crystal ball and hear predictions as to where this volatile industry is heading.

Also on Wednesday, the Purchas-
ing Management Association of Sil­
icon Valley will present a program
titled "Out Sourcing: A New
Wave of the Future." To implement
or sustain a successful out-sourcing
program, the working relationships
amongst engineering, manufactur­
ing, and purchasing must be clearly
defined. The Wescon/91 Purchasing
Conference explores critical issues,
such as how to develop a team ap­
proach for negotiations, how to help
engineering clearly define and docu­
ment specifications, how to intimately
involve manufacturing, and how to
build effective ties with suppliers.

Short courses offer variety

In addition to the special semi­
nars, you can attend a variety of
short courses. This year's short
courses were chosen specifically to
meet the needs of management and
engineering professionals. These
courses are in session all three days
of the show and provide valuable
information that will help advance
your career now and in the future.
The program includes three man­
agement seminars—"Doing Busi­
ness with the Japanese" on Novem­
ber 19; "The Healing Manager: Short­
teuts to Total Quality and
Process Improvement" on Novem­
ber 20; and "Protecting and Mark­
ing Software in a Competitive Mar­
ket" on November 21.

The technical segment of the
short-course program includes nine
sessions. On Tuesday, November
19, the program includes courses
on concurrent engineering, surface-
mount technology, and optical-
based sensors. Wednesday's pro­
gram features four sessions—
"Design for Testability", "Surface
Mount/Fine Pitch Technology", 
"Short-Run Statistical Process
Control for Electronics Manufacturing",
and "3000-Series Field Programma­
ble Gate Array Design." The pro­
gram concludes on November 21 ,
with two sessions—"Data Storage:
Magnetic, Optical, and Systems," 
and "From DIPs to Multichips: An
Introduction to High Performance
Packaging." All short courses will
be held at the San Francisco
Marriott.

The Wescon/91 technical con­
ference is intended to highlight the
most relevant and promising techni­
cal topics for today's electronics in­
dustry and to set the stage for to­
morrow's products and markets.
Emerging technologies, new devel­
opments and applications for exist­
ing technologies, and new solutions
for persistent problems are all part
of this year's program. In general,
the sessions emphasize practical
technical applications and realistic
solutions to authentic problems.
This emphasis is certainly evident
in the area of high-speed logic de­
sign—a topic discussed in five sepa­
rage sessions.

As processors increase in speed,
the problems encountered when
distributing clock signals to vari­
ous loads also increase. Skew and duty­
cycle distortion, for example can re­
duce the cycle budget by several
nsec; however, you can solve this
problem by using minimum-skew
clock drivers. In Session 5, suppli­
ers will highlight the benefits, fea­
tures, and application details of
these products.

As noted, the rapid increase in
µP clock frequencies has considerably reduced the cycle-time budgets
of designers. As a result, designers
are continually looking for the fast­
est standard devices they can get.
While speed may be the main con­
sideration, it is not the only one—
noise reduction, power consump­
tion, and packaging are also key pa­
rameters in high-speed logic design.
The discussions presented in Ses­sion 17 will let designers compare
the most recent high-speed logic of­
ferings and thereby let them make an
informed choice regarding the best
technology for their application.

The presentations in Session 18
will deal with interconnect issues in
high-speed logic design. With clock
rates for VLSI circuits approaching
100 MHz, electromagnetic interfer­
ence is emerging as a major barrier
for high-speed operation. Speakers
will examine different hardware ap­
proaches to circumvent the EMI
problem at various stages of the de­
sign. These approaches include
the use of novel devices and intercon­
nects, new ICs and multichip mod­
ule designs, and innovative archi­
tectures.

Advanced TTL families are be­
coming the technology of choice for
high-speed system designers. How­
ever, the features that make these
logic families so popular may also

Transportation and show details

Parking in downtown San Francisco is severely
limited. Avoid parking problems at Moscone Con­
vention Center by taking the Cow Palace Shuttle.
Park at the Cow Palace (parking costs $5 per
day) and take the free shuttle to the show. If you
take the BART/MUNI metro, Powell Station at
4th and Market is closest to the Moscone Con­
vention Center. If you're riding the MUNI, take
the 45 Union or 30 Stockton for Moscone Center.

Registration at the door costs $10. This fee
admits you to both the exhibits and the Profes­sional Program. For more information, contact
Electronic Convention Management, 8110 Air­
port Blvd, Los Angeles, CA 90045. Phone (213)
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Is incomplete support preventing your MCU design from moving forward? Join the nX crew at Oki, where our nX MCUs provide the performance upgrades and toolset support needed to propel your design swiftly to the finish line.

Choose from a range of nX-generation 8-bit or 16-bit MCUs, including OTPs, and a variety of on-chip features: A/Ds, I/Os, PWMs, and more.

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Starting a new design? Want to convert your resident 80C51 codes? Look to the team that won't leave your design dead in the water. With nX and Oki's total tool support, your design glides smoothly and quickly from concept to code.

Call 1-800-0KI-6388 for our nX Brochure (ask for Package 052).

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<th>Oki Toolset Support for nX</th>
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<td><strong>Description</strong></td>
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<td><strong>Software</strong></td>
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<td>Linker</td>
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<td>OMFICE + EVM67620</td>
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<td>* Under development</td>
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</table>
Two DSP Tools

ONE POWERFUL DSP SOLUTION

Start with the blazing speed of our DSP32C-based ZPB34 DSP processor board, then add the versatility of our upgraded DSPlay XL™ code development software. The unique combination forms one of the most powerful integrated DSP platforms available on an IBM® PC or compatible. Simple, painless, and powerful.

The ZPB34 features AT&T’s 50MHz DSP32C floating point processor and is available in four standard memory configurations from 64KB to 576KB. It’s ideal for applications requiring large FFTs, execution of complex real-time algorithms, and image processing. High-speed buffered serial ports are included for interconnections of processing boards or connection to our ever-expanding line of high-performance analog I/O systems.

Add power to speed with our improved DSPlay XL DSP code generation software. It features a menu-driven diagram approach to algorithm development and generates standard executable code for both AT&T’s DSP32 and DSP32C. New version 3.19 includes over 100 DSP functions, an assembler for user-defined blocks, FIR and IIR digital filter design routines, and I/O control.

Put the power of our DSP solutions to work for you. For information on our entire line, call 1-800-548-6132, Fax (602) 741-3895, or write Burr-Brown Corp., P.O. Box 11400, Tucson, AZ 85734.

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Contribute to higher levels of EMI. The papers in Session 19 examine EMI sources and evaluate their relative importance in typical high-speed system design. The papers also highlight the most potent and common EMI problems encountered in system design and discuss potential solutions.

Before, during, or after you attend your sessions, you can visit the exhibition floor to survey the new products. This year, for the first time, semiconductor products and test and measurement instruments will appear on the exhibit floor. They will be located in the Design Automation Center. Exhibitors in the Semiconductor Center include Motorola Inc, Fujitsu America (IC and Advanced Product divisions), Micron Technology, Mitel Semiconductor, NMB Technologies, Toshiba America, and Microchip Technology Inc. In the Test and Measurement area, the exhibitors include Eastman Kodak, John Fluke Manufacturing Co, Keithley Instruments, LeCroy Corp, Martin Marietta Electronic Systems, National Instruments, Nicolet Test Instruments Division, Panasonic Factory Automation, Tektronix Inc, and WH Brady Co.

EDA companies in the Design Automation Center include Data I/O Corp, BP Microsystems, MicroSim Corp, Racal-Dana Inc, CAD Software Inc, Huntsville Microsystems Inc, Mine Inc, Omatron Inc, OrCAD, PCAD/CADAM, and Sophia Systems and Technology. Wescon/91 will also feature a comprehensive showing of components, hardware, subsystems, and manufacturing materials as well as engineering and manufacturing services.

Article Interest Quotient
(Circle One)
High 512 Medium 513 Low 514
WHY YOU NEED IT
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Bussmann makes more fuses than anyone. But during the 90’s, as your designers face increased worldwide competition, it is our solid-matrix fuses that are growing the fastest because they make your products more competitive. Our advanced PC-Tron radial lead, SMD Tron surface mount and Microtron standard subminiature fuses, all save board space. Both Bussmann high performance PC-Tron and SMD Tron fuses provide current-limiting capability never before available to designers. The solid matrix surrounding the fuse element rapidly extinguishes the arc, when a fault occurs...predictably. So for the first time, both PC board components and equipment are protected. That's a competitive edge for you. Both Bussmann high performance fuses provide for the economies of automatic insertion and are completely sealed, to withstand rigorous board washing. For designs locked into the conventional subminiature fuse footprint, Bussmann offers Microtron—the reliable standard. Contact your Bussmann distributor or Bussmann directly for samples and literature on solid-matrix fuses; 5x20mm or 1 x 1-1/4 in. glass tube fuses; fuseholders, blocks and accessories.

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CIRCLE NO. 140
What other companies' datacom controllers look like to your CPU.

The CPU overhead imposed by standard datacom controllers can be a drag on your system performance, and on your development efforts. Now there's a more intelligent solution. The Cirrus Logic CL-CD2400 single-chip datacom controller can send and receive complete packets with no host supervision. This gives you up to seven times more system performance than other serial communications controllers.

The CL-CD2400 even saves you development and debugging time, and lowers development expense. Our fast, flexible, double-buffered DMA makes buffer chaining and circular queues easy to implement. An append mode makes DMA efficient for async applications as well. Interrupt or DMA operation is selectable on a per-channel, per-direction basis. The CL-CD2400 even has much more flexible latency requirements than other controllers.

And you get all this with fewer parts. So you use less board space. At a much lower cost than you might expect.

Give your whole system and your development efforts a boost. Get the intelligent datacom controller that saves work for you and your CPU: The CL-CD2400 from Cirrus Logic.

For free product information and technical comparison
Call 1-800-952-6300.
Ask for dept. LD26.
Low-profile grid-array sockets handle as many as 484 pins

The Ampflat land grid-array (LGA) socket assembly from AMP accommodates LGA packages that have as many as 484 positions. It is configured on a 0.05-in. centerline grid and offers a mounted profile of 0.2 in. The keystone of the assembly is a contact array that is 0.009-in. high when compressed and features 10-psec max delay and a per contact thermal resistance of 200 °C/W. The unit also features a positive contact wipe, a replaceable contact array, and a choice of gold or tin/lead over nickel platings.

The socket assembly is composed of a heat-clamp pressure plate, a chip-carrier nest that holds the LGA device, a contact array, and an insulator-spacer. All of these components are sandwiched between a cover plate and a base plate. The insulator thickness is selected to match the thickness of the pc board for a given assembly. In this manner, the resultant stack thickness of the assembly yields the required normal forces under compression. You can install or remove the clamping top plate by using an ordinary screwdriver. Both top and bottom plates are made of stainless steel. The bottom plate insulator is assembled with adhesive on its top and bottom surfaces so that the bottom plate is permanently attached to the pc board after initial installation. $20 to $26.

AMP Inc, Box 3608, Harrisburg, PA 17105. Phone (800) 522-6752. Booth No 2154. Circle No. 351

Software synthesizes FPGA logic layouts

The PGADesigner family of logic-synthesis tools for field-programmable gate arrays (FPGAs) can synthesize layouts for Xilinx's XC2000 and XC3000 logic-cell arrays, Actel's ACT1010 and 10120, Altera's Max Series, and AMD's Mach 1 and Mach 2 families. Certain versions of the tools can also automatically partition some or all of your FPGA design over multiple smaller PLDs, such as the 22V10.

You can enter your design in any combination of three methods; schematics with any program that produces an industry-standard EDIF (electronic data interchange format) output file, a waveform editor, or hardware-description languages. To use the waveform editor, you draw the input and output waveforms for your circuit with a graphics editor. The software then synthesizes a synchronous circuit that accepts the specified inputs and generates the specified outputs.

The hardware-description languages let you specify your design with Boolean equations, truth tables, and state machines. The state machine tool uses a Pascal-like syntax and lets you embed Boolean equations and truth tables in the arguments of the state-machine program constructs.

The tools run on Sun-3 and Sun-4 workstations and on 286 and 386 MS-DOS machines. The company offers two configurations; one for both PLDs and FPGAs and the other for FPGAs only. Base prices include routines for one FPGA type; additional FPGA types are optional. $300 to $16,000.

Minc Inc, 6755 Earl Dr, Colorado Springs, CO 80918. Phone (719) 590-1155. FAX (719) 590-7330. Booth No 1524. Circle No. 352
SCSI-2 protocol controllers feature on-chip μP core

An on-chip μP core lets the MB86600 family of SCSI-2 ICs perform command sequences without interrupting the host CPU. The devices support the wide and fast data transfers defined by the latest version of the ANSI SCSI specification and let you implement a SCSI-host design that complies with the CAM (Common Access Method) of the LADDR (Layered Architecture Device Driver) de facto standards.

The SCSI-2 ICs support target and initiator applications. A proprietary command set features 22 initiator-specific commands and 22 target commands. Each μP-core command lets the ICs perform one or more SCSI-2 commands. The ICs automatically handle the requisite bus phases and sequences.

A 32-byte FIFO buffer paces data transfers between the SCSI bus and DMA interface. The buffer permits a transfer offset value as high as 32 bytes during synchronous data transfers. The devices also have 32-byte send-and-receive buffers that handle command, message, and status information.

The MB86601 provides signal transceivers on chip for single-ended SCSI-2 applications. The MB86602 contains control circuitry for external differential or single-ended transceivers. Both support 10-Mbyte/sec synchronous-data transfers. $19.95 (1000).

Fujitsu Microelectronics Inc, 3545 N First St, San Jose, CA 95134. Phone (800) 642-7616. FAX (408) 432-9044. Booth No 917.

Circle No. 353

Peak power meter operates to 40 GHz

The 4400 power meter is designed for microwave CW, peak power measurements, and pulse waveform characterization. With associated sensors, it ranges from 30 MHz to 40 GHz and has a -40 to +20 dBm dynamic range. Plotter, diagnostic RS-232C, and IEEE-488 interfaces (for ATE applications) are provided.

Menu-driven setup, with comprehensive help displays, allow easy and quick setup for automatic measurement and display of a variety of pulse parameters—power, time, and frequency related. Measurements are made at a rate of 40 to 70 per second. Measurement values, waveforms, and related text are displayed on a color CRT. The display-element color is user-selected. Waveforms are digitized at a 1-MHz rate, and there’s a dedicated DSP for high-speed measurements. Waveform data can be downloaded to a plotter.

The 4400 meter includes a 1-GHz precision calibrator, which ensures measurement accuracy. Sensor calibration factors are stored in each sensor and calibration-factor and sensor-temperature data are downloaded to the instrument for automatic correction of measured values. Automatic self-diagnostic routines are accessible to check operational integrity. Operating software can be reloaded or enhanced via the built-in disk drive—there’s no need to open the case or change PROMs. The meter is available in single- and dual-channel versions. $11,750 and $13,000, respectively.

Boonton Electronics Corp, 791 Route 10, Randolph, NJ 07869. Phone (201) 584-1077. FAX (201) 584-3037. Booth No 2141.

Circle No. 354
EPSON PRESENTS ANOTHER LEADING TECHNOLOGY PRODUCT:

PC COMPATIBLE REAL TIME CLOCKS

- EISA BUS COMPATIBLE (CPU and AT/XT compatible available soon)
- 4 KBYTES OF SRAM MEMORY
- CRYSTAL AND OSCILLATION CIRCUIT BUILT IN
- COMPARTMENT FOR 2 REPLACEABLE BATTERIES
- BASIC MOTOROLA RTC FUNCTION COMPATIBLE

SPECIFICATIONS

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<tr>
<th>RATING</th>
<th>VALUE</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPER. VOLTAGE</td>
<td>5 ±0.5 V</td>
<td></td>
</tr>
<tr>
<td>OPER. TEMPERATURE</td>
<td>10 TO 70 °C</td>
<td></td>
</tr>
<tr>
<td>OPER. CURRENT</td>
<td>15 (MAX) mA</td>
<td></td>
</tr>
<tr>
<td>STAND-BY CURRENT</td>
<td>2 (MAX) μA</td>
<td></td>
</tr>
<tr>
<td>BACK-UP CURRENT</td>
<td>0.5 (TYP) μA</td>
<td></td>
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EPSON AMERICA, INC.
COMPONENT SALES DEPARTMENT

TEL: 213.787.6300
FAX: 213.782.5320
**Plasma Display Module**
The Model GP01280128-01 is a dc gas-plasma display that features a 128x128-dot viewing area for graphics and text. Horizontal and vertical resolution measures 40 lines/in. The display, along with most of the drive electronics, mounts on a single pc board. Operating life is 40,000 hours. The 3.6-in. diagonal viewing area can display 16 rows of 21 characters in a 5x7 dot-matrix format. You can use this same format to display as many as 336 dot-matrix characters and graphics symbols. The module has a diffuse neon-orange display color, which features a 50-fl brightness level. Viewing angle measures 130°. $105 (100). Delivery 12 to 14 weeks ARO.

**High-Temperature Sockets**
These PGA and DIP screw-machine sockets can withstand the rigors of infra-red and vapor-phase soldering processes encountered in surfacemount and mixed (surface-mount and through-hole combinations) applications. Heat deflection ratings equal 230°C for the DIP sockets and 275°C for the PGA devices.

**Digital Voltmeters**
The four models in the AP-501 Series of dc digital voltmeters feature a 3½-digit LED display. Units in the line measure from 200 mV to 200V with an accuracy of 0.1% of reading. The input configuration of the meter depends on the model. The -11 and -12 versions (199.9 mV and 1.999V, respectively) accept a differential input. The 19.99V -13 and the 199.9V -14 models have a single-ended input. All models will operate at 2.5 conversions per sec.

Other features of the AP-501 meters include automatic zero adjustment and adjustable decimal point to any digit. An overrange indicator signals when the input exceeds the rated-input level. The meters weigh approximately 50g and operate from a single 5V supply. $71.

**VME Power Supply**
JRS Series quad-output, rack-mountable switching power supplies are designed for VME applications. The units feature true current-sharing, have parallel outputs, and can be used in N+1 redundant systems. With 110/220V ac or 48V dc input capabilities, these supplies lend themselves to telecommunications applications. They also feature a battery charger—a prime advantage in applications requiring no downtime. You can tailor each of the four outputs to develop from 5 to 48V. The units can be sold separately as modules or configured to meet most VME requirements. ALL supplies are designed to meet UL, CSA, TUV, and VDE requirements. $1 to $2/W, depending on quantities. Delivery, four to 12 weeks ARO.
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EDN November 7, 1991
Surface-Mount Relay
The G6H-2F is a surface-mountable electromechanical relay that measures 5.5 x 9.41 x 14 mm. The unit has a 2-Form C-contact arrangement and can switch voltage and current levels of 125V ac/110V dc and 1A, respectively. The maximum power-switching rating is 30W or 62.5 VA.

The operating-power requirement is 140 mW. The relay conforms to the FCC Part 68 surge-withstand requirement of 1.5 kV. Dielectric strength ratings are 1000V ac between each contact and between contacts and coil. Relay lifetime measures 200,000 operations with a 1A, 30V dc load.

The G6H-2F relay is compatible with infrared, dual-wave, and vapor-phase soldering systems. Contact resistance is 60 mΩ and operating range spans -40 to +85°C.

Omron Electronics Inc, 1 E Commerce Dr, Schaumburg, IL 60173. Phone (708) 843-7900. FAX (708) 843-7787. Booth No 2153. Circle No. 355

Virtual Disk Card
The PM-7008 virtual disk card is designed to affordably replace the floppy-disk drive in PC computer systems. The unit works just like a floppy- or hard-disk drive, except that it uses electronic components to replace the magnetic media.

Use of electronic media decreases disk-access time. You can use the PM-7008 as a 256-kbyte RAM-based virtual disk, a 512-kbyte ROM-based virtual disk, or a combination of both. The RAM-based card uses a battery to maintain data in case of power failure. The unit has the same multiple read/write cycle capability as a standard floppy-disk drive. The ROM-based card has no need for batteries because ROM is more permanent than RAM. Once you program the ROM, it can only be erased by ultraviolet light from an EPROM eraser. $125.

Acqutek Corp, Box 187, Sandy, UT 84091. Phone (801) 572-8151. Booth No 4317. Circle No. 357

Decoupling Capacitors
Memoryguard decoupling capacitors are designed for advanced memory applications and offer sufficient capacitance values for tomorrow's 16-Mbyte DRAMs. The capacitors come in a 1210 package and have capacitance values ranging to 0.47 µF in a 0.026-in.-high package or 0.39 µF in 0.023-in.-high packages. In addition, the 0.22-µF capacitor, which has become the standard for decoupling 4-Mbyte DRAMs, is now available in a 1206 package that measures 0.026-in. high. The devices mount underneath surface-mountable SOJ-packaged memories—a key feature in applications where board space is at a premium. Packaged on 8-mm embossed mylar tape, the capacitors are provided with solder-plated-nickel barrier terminations. $0.02 to $0.09 (100,000).

Johanson Dielectrics Inc, 2220 Screenland Dr, Burbank, CA 91505. Phone (818) 841-8500. FAX (818) 841-7261. Booth No 1846. Circle No. 358

Impact Printers
The PL180RM family of low-cost, impact printers is designed for panel-mounting applications. Four versions are available that feature column counts of 24 to 42. All units are packaged in an injection-molded plastic enclosure. You can load paper and change ribbon from the front panel.

Each model in the printer family is available with either a Centronics
New SLICs cut the cost of on-premises/PBX subscriber lines

Lower cost chips that need fewer external components are the latest Subscriber Line Interface Circuit offerings from Ericsson.

Designed for cost sensitive applications such as general purpose PBX/Key systems, they give you three other major advantages over alternative solutions: wide supply voltage operation from -24 V to -58 V dc, on-hook transmission and a very low on-hook power dissipation of just 35 mW with -48 V dc supply or 20 mW when running from a -24 V dc supply.

So you can reduce the cost of your power supply circuit too!

Each SLIC includes loop current and ring trip detection, together with a ring relay driver. And they work with either a conventional or programmable CODEC/filter, all of which simplifies design.

Equally important, the new circuits are available in two versions: the PBL 3766 with a programmable constant loop current, and the PBL 3767 with programmable resistive battery feed and loop current limitation for short lines.

Both come in a choice of 22-pin plastic DIP or 28-pin PLCC packages with compliant 'J' leads.

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With a full 32-bit internal architecture and a 16-bit data bus, the i960 SA/SB processors provide more performance than any other 16-bit embedded processor. And they're part of the complete i960 family, which spans 5 to 66 MIPS while preserving software compatibility.

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So get high performance, at a cost you'll be thrilled about with Intel's i960 SA/SB and development tools. For the Hamilton/Avnet branch nearest you or further information, call toll free, 1 (800) 442-6458.
or an RS-232C interface. Available power options include a choice of 5 or 12V dc, or 120V ac. Standard features include a bit-image graphics mode and a 6900-character input buffer. Overall printer dimensions are 4.45 x 4.5 x 2.5 in. $150 (100).

Telpar Inc, Box 796, Addison, TX 75001. Phone (214) 233-6631. FAX (214) 233-8947. Booth No 736. Circle No. 359

Analyzer-Support Package
The LR33000 µP-support package—a TGI-LR33K target-interface adapter (TIA) and LR33000 disassembler—interfaces with the ML4400 logic analyzer. The package features dual-clocking modes that let either every clock cycle or only complete bus transactions clock data to the logic analyzer. There's also a dynamic-cache disable feature that lets the processor run from its cache until a preset condition is met, and then forces cache misses, which lets the logic analyzer access CPU activity without affecting the long-term performance of the CPU.

The TIA plugs directly into the LR33000 PGA socket of the board being tested. This direct connection lets users collect information on CPU activity. This activity can then be disassembled by the ML4400 into LR33000 instruction mnemonics. Full disassembly of the LR33000 instruction and data cycles, with tables of as many as 10,000 symbols, is also provided. The TIA registers CPU signals to improve analyzer timing margins and minimize loading on the CPU signals support. $10,000.

American Arium, 14281 Chambers Rd, Tustin, CA 92680. Phone (714) 731-2138. FAX (714) 731-6344. Booth No 2134. Circle No. 360

Motor Driver
The RD-023MS driver executes smooth microsteps for a step motor. Working in conjunction with a 0.9° step motor, the driver can achieve as many as 160,000 steps per revolution. The RD023MS can step as small as 1/400 of a full step and thereby achieve more stable torque and also reduce resonance amplitude. Users can select from a choice of 22 microstep divisions. Idle current setting is also user adjustable. When the motor is idle, the driver can step the motor current down to 20% of rated current to reduce heat generation. The driver is housed in a 4.1 x 2.2 x 1.1-in. package. $450.

Semix Inc, 4160 Technology Dr, Fremont, CA 94538. Phone (415) 659-8800. FAX (415) 659-8444. Booth No 4328. Circle No. 361

Surface-Mount Trimmers
ST-4G side-adjust, single-turn cermet trimmers withstand wave- or reflow-soldering temperatures as high as 260°C for 10 sec and manual-soldering temperatures of 350°C max for 3 sec. Resistance value ranges from 10Ω to 2 MΩ, and resolution is infinite.

The trimmers operate over a -55 to +125°C range. Maximum input voltage is 200V dc and power rating measures 250 mW at 70°C; power-handling capability derates to 0W at 125°C. Rotational life is 100 cycles, and maximum shaft torque is 100 grams x centimeters. The ST-4G contains a precious-metal alloy-brush wiper that delivers good setting stability and 1% max contact-
resistance variation. The trimmer will withstand 100g shock and a vibration of 20g from 10 to 2000 Hz. The trimmer features an O-ring seal and tolerates temperature exposure of 125°C for 250 hours. $0.93 (1000).


Circle No. 363

Pick-and-Place System

The SMT-880 is a manual pick-and-place system designed for prototyping or low volume production of surface-mount boards. Operators select a component from the loose carousel, stick, or tape feeders, pick it up with the vacuum head and then guide it with the free-floating X-Y-Z arm to the appropriate place on the board.

A control knob on the vacuum head of the SMT-880 system provides theta rotation to ensure proper component orientation. The vacuum head automatically releases the component when contact is made with the board.

The system has an adjustable board holder and a total working area of 8 x 12 in. The unit comes complete with ESD-safe carousel vacuum pump and removable hand rest that glides over the board holder and provides the operator with a stable, fatigue-relieving platform. From $3495.

OK Industries Inc, 4 Executive Plaza, Yonkers, NY 10701. Phone (914) 969-6800. FAX (914) 969-6650. Booth No 1917.

Circle No. 364

PC-Board Connectors

These low-profile (0.25-in. mounted height) pc-board connectors are available in 2- through 40-position, dual-row (4- to 80-contact models), 0.100-in. grid configurations. The connectors are available in a choice of tail lengths—0.05 and 0.12 in. The connectors are available with contact grids of 0.1 x 0.1 or 0.1 x 0.15 in. All units are end-to-end and side-by-side stackable. The connector-insulator material is compatible with reflow-solder processes; built-in standoffs facilitate post-solder cleaning. The connectors feature gold or tin plating and mate with 0.025-in.² pin headers. The connectors are also available in surface-mount versions. $0.487 (10,000) for a 2 x 10-position version with tin plating.

Methode Electronics Inc, 1700 Hicks Rd, Rolling Meadows, IL 60008. Phone (708) 392-3500. FAX (708) 392-9404. Booth No 226.

Circle No. 365

Rotary Switches

The T-style versions of Series 50/51 ½-in. rotary switches withstand wave-soldering and board-cleaning techniques because of their process seal. You can mount a switch on a pc board along with other compo-

ments and subject it to modern assembly processes. No special handling is required—no secondary wiring or soldering is needed.

The switches are available in 4-, 6-, 8-, 10-, or 12-position versions. One- through 4-pole versions are available in a choice of shorting or nonshorting contacts. Contact resistance measures 50 mΩ max. Insulation resistance and voltage breakdown are 10³Ω and 600V ac, respectively. Termination options include a choice of solder-lug, pc-board, and water-tight panel seals. $7.50 (100) for a 1-pole model.

Grayhill Inc, Box 10373, LaGrange, IL 60525. Phone (312) 354-1040. FAX (312) 354-2820 Booth No 1241.

Circle No. 366

Audio-Frequency Board

The AT-A2150 4-channel, audio-frequency-input plug-in board is designed for IBM PC/AT and compatible computers. It is available in two versions—the A2150C is designed for general audio-frequency range measurements and the A2150S is targeted at speech and voice-band applications.

The boards feature analog and real-time digital filters to prevent aliasing. Their S/N ratio is 93 dB, and THD is –96 dB. The A2150C has ±0.015-dB amplitude flatness from dc to 20 kHz, and the A2150S has a ±0.105-dB flatness from dc to 4 kHz. Pretrigger, post-trigger, and delay-trigger modes are activated by an analog signal, which matches a programmed level and slope polarity, or by a TTL trigger pulse. The boards include an RTSI bus for synchronizing the sampling and/or triggering of multiple AT-A2150 boards and to facilitate DMA transfers. $1995.

National Instruments Corp, 6504 Bridge Point Pkwy, Austin, TX 78730. Phone (512) 794-0100. FAX (512) 794-8411. Booth No 2642.

Circle No. 367
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The main output in Series 2A supplies is rated for 5V at 30A. Two or three auxiliary outputs are rated for 12 or 15V at 10A, 12 or 15V at 3A, and 5, 12, or 24V at 3A. The line also includes models featuring user-adjustable outputs—12 to 15V at 10A, 12 to 24V at 2A, 2 to 6V at 3A, and 5 to 15V at 3A.

Standard supply features include a dc fan, internal EMI filter, input-power-fail signal, and output sense on outputs of 10A or more. There is also overvoltage protection on all outputs, overtemperature shutdown, overload protection, and soft start. All units conform to UL, FCC, CSA, EMI, and TUV safety and emission standards. $279 to $302.


Circle No. 368

Clock Oscillators

E500 Series ECL-clock oscillators are available in both through-hole and surface-mount versions. Units are available with outputs ranging from 24 to 180 MHz. The oscillators are available in two operating-range grades—an industrial range of -40 to +85°C and a standard range of 0 to 70°C.

The oscillators output a square wave, which is compatible with 100K and 10K ECL families. The output duty cycle measures 50/50, ±5%, and rise and fall times equal 2 nsec max. Output frequency stability varies with output frequency.
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Connor-Winfield Corp, 1865 Selmarten Rd, Aurora, IL 60505. Phone (708) 851-4722. Booth No 310. Circle No. 369

Industrial Keyboard
Series 19R rack-mount keyboards are designed specifically for hostile-environment applications. The units carry an IP (international protection) rating of 64, qualifying it for a dust-tight (6 out of 6) rating.

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Preh Electronic Industries Inc, 470 E Main St, Lake Zurich, IL 60047. Phone (708) 438-4000. Booth No 2000. Circle No. 370

Field Recorder
The Dash 8 is an 8-channel field recorder that can record real-time data from dc to 25 kHz at speeds ranging to 200 mm/sec. It also stores captured data for faster playback in any format at effective chart speeds ranging to 10,000 mm/sec.

The unit has built-in signal conditioning circuitry that accepts signals ranging from 50 mV to 500V full scale. Data capture and playback let you make a detailed analysis of high-speed data in slow-motion replay. The recorder can sample data at 250 kHz in real time, and at rates ranging from 0.1 to 250 kHz in playback modes. The built-in nonvolatile memory has a 32-ksample capacity.

Recorder operation is simple: Menus displayed on the 80-character screen guide the user through the entire programming sequence. Six soft keys perform different functions
Storage Oscilloscopes

COR5500U Series digital-storage oscilloscopes offer 400 point-per-division horizontal and 8-bit vertical resolution. The 100-MHz 5501 and the 60-MHz 5561 feature two channels with external trigger, 20-MHz/sec digitizing rate per channel, two 4-kbit reference memories per channel, and two 4-kbit storage memories per channel. The scopes feature digital readout and cursor measurement, 1-mV sensitivity, 2-nsec min sweep time, illuminated graticule, and level-lock auto trigger. A user-defined comment function lets the operator write alphanumerics on the screen. The scopes operate from line voltages of 100 to 240V ac. The scopes consume 55W and weigh 14 lb. An optional IEEE-488 interface provides a means of controlling the units and outputting data to a printer. From $2895 for the 100-MHz model; from $2495 for the 60-MHz model.


DC/DC Converters

The latest addition to the FW Family of dc/dc converters, the Model 48S5.1500FW, has a 20 to 60V input range and outputs 5V at 1A. Housed in a 2.02 × 2.02 × 0.37-in. package, the unit has a 10-mV p-p output noise specification and an 80% efficiency figure. Line regulation is 0.1% max and operating range spans −25 to +80°C.

The converter includes reverse polarity protection. A built-in pulse-by-pulse digital current-limit circuit protects the converter from

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**Calex Mfg Co Inc, 3355 Vincent Rd, Pleasant Hill, CA 94523. Phone (415) 932-3911. FAX (415) 932-6017. Booth No 1447. Circle No. 373**

### EEPROM Programmer

The MultiTRK-4000 is a gang-and-set EEPROM programmer. Designed for the production environment, the unit can program as many as 32 devices at one time. The unit uses the company’s multitrack design—each track supports individual socket cells. Each cell contains eight sockets that can program a broad range of memory devices. The programmer is available with options that will support all available device packages including DIP, PLCC, and PGA.

The programmer can duplicate as many as 32 devices from on-board memory. It will support 8-, 16-, and 32-bit-wide data-path operations, including multiple set sizes. Single or multiple EEPROMs, or single or multiple sets can be downloaded into RAM and programmed simultaneously. The programmer features RS232-C and bidirectional-parallel I/O interfaces. $4995. Delivery, four to six weeks ARO.

**Bytek Corp, 543 NW 77th St, Boca Raton, FL 33487. Phone (407) 994-3520. FAX (407) 994-3615. Booth No 1528. Circle No. 374**

### Eurocard Power Supplies

APS60 Series 60W power supplies are designed specifically for VME and Multibus applications. They feature a 100-kHz switching frequency and are available in single-and multiple-output versions. The units are housed in an 8HP × 160 mm × 3U
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enclosure. The supplies meet FCC and VDE emission requirements and carry UL-1950, CSA-950, TUV-950, IEC-950, and BSI approvals. You can configure APS60 Series supplies as open-frame switchers. Custom front panels are also available. From $99 (OEM qty) for a single-output model. Delivery, stock to eight weeks.

Advanced Power Solutions, 5994 W Las Positas Blvd, Suite 211, Pleasanton, CA 94588. Phone (415) 734-3060. Booth No 256.

Circle No. 375

Optical Connectors
Series 86061 SC-type fiber-optic connectors have fewer components than the standard NTT-style connectors. Compatible with all existing SC-type connector hardware, the units feature a prepolished, prelensed ferrule—alumina or zirconia. Typical insertion loss for multimode and single-mode versions is 0.15 and 0.17 dB, respectively. An 86760 Series tool kit simplifies field termination of the connector. A bulkhead feedthrough adapter combines with a precision-molded polymeric housing and a precision ceramic alignment sleeve to optimize connector-to-connector mating. $8.20 (100) for a multimode connector with an alumina ferrule.


Circle No. 376

DC/DC Converters
HDF Series dc/dc converters output 3W and are housed in a 1.75 x 0.83 x 0.43-in. single in-line package (SIP). The units are available in single- and dual-output versions.

The 10-model family includes versions that accept inputs of 5, 12, or 24V. Available outputs include a choice of 5V at 600 mA, ±12V at 125 mA, or ±15V at 100 mA. Isolation from input to output is guaranteed at 500V dc. One model accepts a 24V input and outputs 15V at 200 mA. All models feature a total-regulation error band of ±5% for all effects including a 5 to 100% load change.

Typical efficiency for the HDF converters is specified at 70% for a unit with a 5V input and a dual output. Efficiency for units with 12 or 24V inputs and a single output measures 80%. Each converter is housed in a potted plastic

How well does Texas Instruments support TMS320C5x DSP PreviewBulletin

Futurebus-and Backplane Transceiver Logic
Resistor Chips

VSM Style bulk-metal-foil surface-mountable resistors exceed the requirements of MIL-R-55342, Characteristic Y. The units have a maximum temperature coefficient of resistance (TCR) of 5 ppm/°C over a -55 to +125°C range. The chips are available with TCR tracking figures ranging to 0.5 ppm/°C. They have resistance values of 5Ω to 150 kΩ, and standard resistance tolerance is 0.01%.

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Power Supply

The 350W PFQ350 is a 4-output switching supply that offers built-in, active power-factor correction (0.96 to 0.99 depending on load), and universal input (90 through 264V) as standard features. The supply has a 5V main-output rating of 50A. One of the three auxiliary outputs develops a 16A pk output to accommodate initial turn-on/spinup of disk drives. The other two auxiliary outputs are rated for 5A.

All three PFQ350 auxiliary outputs will provide 12, 15, or 24V; outputs two and three also offer a 5V capability. The isolation rating is 3750V ac. Overload, overvoltage, and over-temperature protection are standard. Options include power-fail detect circuitry, power-valid signal, and remote inhibit. The supply meets most international specifications for safety isolation and EMI/RFI emissions. $339 (100). Delivery, stock to 12 weeks ARO.

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— Frank Lucas
Test Engineering Manager
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Updated monthly, the CD-ROM (Compact Disc – Read-Only Memory) based CAPS system gives you fast, easy, query-driven access to technical specifications and applications data for over 575,000 ICs and semiconductors made by nearly 500 companies worldwide. Best of all, CAPS provides instant access to hundreds of thousands of pages of complete, unabridged manufacturers' datasheets, so you have everything you need right at your fingertips.
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CIRCLE NO. 153

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Simulating Multiple FPGAs

The newest release of SUSIE 6.0 facilitates simulation of multiple Xilinx, Actel and other FPGAs (field programmable gate arrays) parts at board level. With SUSIE 6.0, designers can simulate in the same run, any combination of parts and technologies, even from different vendors. Because of its real time operation, SUSIE allows simulation of partially operational FPGA designs. The improperly operating FPGA outputs can be overridden with test vectors that represent the part specification. SUSIE will simulate such test vectors as if they were generated by the FPGA itself. One of the key SUSIE features is that designers can freely move between board and component (FPGA) levels and simulate designs at either level.

The Latest Trend: Real-Time Simulation

Real time simulators allow the designer to directly interact with the design as if it were real hardware. The user can modify logic designs, replace devices, rotate switches, etc., all in real time and without any compilations. What’s more, the designer can go back to a previous simulation cycle, change design parameters and instantly compare the new design behavior with the old one. Since the real time simulators do away with lengthy engineering calculations and produce instant responses, they turn out reliable designs at a fraction of typical development costs. Because of advanced user interfaces, learning the new tools takes only hours, or days at most. A prime example of such easy to learn simulator is SUSIE 6.0 ($1,995).

If Money is an Object...

If saving money is an object, consider the new generation of CAE tools that are based on 386/486 PCs. The best example of such low-cost PC-based tools is the SUSIE logic simulator. It has been benchmarked at roughly ten times the speed of some workstation-based products, yet it is priced at only a fraction of these products. Furthermore, SUSIE comes with many patented features such as selective simulation which allows for interactive selection of design sections for analysis. Regardless of which workstation-based software is chosen, the user can expect to save at least 30% to 50% and in many cases 300% to 500% by opting for the 386/486 environment.

Fast Design Troubleshooting

Real time simulators ushered in new design methodology that makes troubleshooting of even the largest designs a simple task. The user can dynamically segment the entire design into small entities and troubleshoot them independent of each other. However, an even more powerful method is to establish a core of the design and cut off all major feeding blocks by overriding them with "test vectors", which can be any keyboard key. By toggling these keyboard keys, the user can test in real time the effect of selected blocks on the design core. This method is particularly useful with feedback loops. Overriding such feedbacks with test vectors is equivalent to both opening the feedback loop and emulating the required feedback signals. The real time troubleshooting process cuts the development time to less than 10% and is the only method of handling complex designs.

ALTERA Users Benefit Again

Altera’s programmable logic devices have found broad applications because they save design time and produce reliable, cost-effective designs. With the release of MAX/VT ($995) library by ALDEC, the ALTERA users can now test their designs in real time and have instant responses to their tests. Moreover, the users can move freely between testing the internal operation of ALTERA parts and their interaction with other components at the board level. Since testing of these parts at the board level is now performed in about 10% of the scheduled time, this adds even more incentives to using the ALTERA’s EPLD and MAX parts.

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Filters get rid of a signal's unwanted frequency components. Oscillators create signals at predictable frequencies. As you might imagine, the two types of circuits have more than a little in common.

Jim Williams, Linear Technology Corp

Filters and oscillators share a common point of view—they deal with signals in the frequency domain. You can define a filter's function as rejecting frequencies you don't want (the job of a band-reject filter, for example) or including only the frequencies you want (what a bandpass filter does). If you reorient your thinking slightly, though, you realize that all filters reject unwanted frequencies. (The bandpass filter rejects frequencies outside the band of interest.) When you view filters in this way, you see that any filter's function is the inverse of an oscillator's; oscillators synthesize individual frequencies or ranges of frequencies. Although there are more kinds of filters and oscillators than any magazine article of reasonable length can hope to touch on, herein are a few types of circuits that can meet a range of needs.

Fig 1a shows a highly selective bandpass filter using a resonant ceramic element and a single amplifier. Except at its resonant frequency, (in this case, 400 kHz) the ceramic element looks like a high impedance. For off-resonance inputs, IC₁ produces no output; it acts as a follower whose input is grounded. At resonance,
the ceramic element has a low impedance, and IC₁ behaves as an inverter with gain. The 100Ω resistor isolates IC₁'s summing point from the ceramic element's capacitance. This capacitance is quite substantial and limits the circuit's out-of-band rejection. Fig 1b, curve A shows this effect. This plot shows very steep rejection, with IC₁'s output down almost 20 dB at 300 kHz and 40 dB at 425 kHz. The device's stray parasitic capacitance causes the gentle rise in the output at higher frequencies and also sets the -20-dB floor at 300 kHz.

Fig 2 shows how to use a nulling technique to partially correct problems caused by the ceramic element's parasitic capacitance. This circuit is similar to the previous one, except that a portion of the input goes to IC₁'s positive input. The R-C network at that input has an impedance close to the ceramic resonator's off-null impedance. Therefore, out-of-band components produce similar signals at IC₁'s inputs, and, because of IC₁'s common-mode rejection, produce little output. At resonance, the added R-C network appears as a much higher impedance than does the ceramic element, and the filter response is similar to that of the circuit in Fig 1a. Fig 1b, curve B shows that this circuit has much better out-of-band rejection than does the earlier circuit. The high-frequency rolloff is smooth, and, at 475 kHz, over 20 dB deeper than that of the circuit in Fig 1a. At 375 kHz and below, on the low-frequency side of resonance, the circuits behave similarly.

By using quartz crystals, you can make filters whose high-frequency selectivity is even higher than that of filters based on ceramic resonators. Fig 3a replaces Fig 1a's ceramic element with a 3.57-MHz quartz crystal. Fig 3b shows almost 30 dB of attenuation only a few kHz on either side of resonance! The differential nulling technique used with the ceramic elements is less effective with quartz crystals. Crystals have significantly lower parasitic capacitance, making the cancellation less effective.

Oscillators use crystals and resonators

The circuit in Fig 4 places a crystal within the amplifier's feedback path, creating an oscillator. With the crystal removed, the circuit is a familiar noninverting amplifier with a grounded input. The impedance ratio of the elements associated with IC₁'s negative input sets the gain. Inserting the crystal closes a positive
feedback path at the crystal's resonant frequency, and oscillations commence.

In any oscillator, you must control the gain as well as the phase shift at the frequency of interest. If the gain is too low, oscillation will not occur. Conversely, too much gain produces saturation limiting. In this circuit, gain control comes from the positive temperature coefficient of the lamp at IC₁'s negative input. When you first apply power, the lamp's resistance is low, the gain is high, and the oscillation amplitude increases. As the amplitude builds, the lamp current increases and causes heating, which raises the lamp resistance. The increased resistance reduces the amplifier gain and the circuit finds a stable operating point. This circuit's sine-wave output has all of the stability advantages associated with quartz crystals. Although shown with a 10-MHz crystal, the circuit works well with a variety of crystal types from 100 kHz to 20 MHz. Using a lamp to control the amplifier gain is a classic technique, first described by Meacham in 1938. Electronic gain control, though more complex, offers more precise control of amplitude.

**Fig 5a**'s quartz stabilized oscillator replaces the lamp with an electronic amplitude-stabilization loop. IC₂ compares the IC₁ oscillator's positive output peaks with a dc reference. The diode in the dc-reference path compensates for the rectifier diode's temperature dependence. IC₂ biases Q₁, controlling the FET's channel resistance and influencing the loop gain. The amplitude of the oscillator's output is a reflection of the loop gain. Loop closure around IC₁ stabilizes the amplitude of the oscillator's output; the 1-µF capacitor compensates the gain-control loop.

The dc-reference network provides optimum temperature compensation for the rectifier diode, which sees IC₁'s 2V p-p, 20-MHz output waveform. IC₁'s small output swing minimizes the distortion attributable to channel-resistance modulation in Q₁. To use this circuit, adjust the 50Ω trimmer until 2V p-p oscillations appear at IC₁'s output.

**Fig 5b** is a spectrum analysis of the oscillator's output. The fundamental is at 20 MHz; the second harmonic, at 40 MHz, is 47 dB down. The third harmonic,
50 dB down, occurs at 60 MHz. Resolution bandwidth for the spectrum analysis is 1 kHz.

The circuit in Fig 6a replaces the quartz crystal with a Wien network at IC₂’s positive input. IC₁ controls Q₁ to stabilize the amplitude of IC₂’s oscillations. The operation is identical to that of the circuit in the previous figure. Although the Wien network is not nearly as stable as a quartz crystal, it has the advantage of a variable-frequency output. Normally, you vary the frequency by varying either R or C or both. The use of manually adjustable elements, such as dual potentiometers and 2-section variable capacitors is common. The circuit in Fig 6a uses fixed, 360Ω Wien-network resistors and uses varactor diodes as capacitors. The varactor diodes’ voltage-variable capacitance allows dc tuning of the oscillator. Applying 0 to 10V dc to the varactors shifts the oscillation frequency from 1 to 10 MHz. The 0.1-µF capacitor blocks the dc bias from IC₂’s positive input but lets the Wien network function normally. IC₂’s 2V p-p output minimizes the varactors’ junction effects and thereby limits distortion.

This 5V-powered circuit requires a voltage step-up to develop adequate varactor drive. IC₃ and the

---

**Fig 6—A pair of varactor diodes** lets you tune this Wien-bridge oscillator (a) from 1 MHz to 10 MHz by applying a 0 to 10V signal. Adding the components in the right half of the schematic lets you operate the circuit from a 5V supply and permits controlling the frequency with a 0 to 2.5V signal. The spectrum analysis in b shows that the sinusoidal output is quite clean.
LT1172 switching regulator form a simple voltage step-up regulator. IC₅ controls the LT1172 to produce whatever output voltage is required to close a loop at IC₅'s negative input. The 22-µF output capacitor stores L₁'s high-voltage inductive-flyback pulses after they have been rectified by the diode-and-zener-connected Q₂. The 7.5-kΩ/2.5-kΩ divider closes the loop by providing a sample of the output value to IC₅'s negative input. The 0.1-µF capacitor stabilizes this feedback action. IC₂'s zener drop allows the circuit to produce controlled outputs at voltages as small as zero. This arrangement permits a 0 to 2.5V input at IC₃ to produce a corresponding 0 to 10V varactor bias. Fig 6b, a spectral plot of the circuit running at 7.6 MHz, shows the second harmonic down 35 dB and the third harmonic down almost 60 dB. The resolution bandwidth is 3 kHz.

Fig 7a shows the schematic of an AM radio station—complete from microphone to antenna, but lacking a Federal Communications Commission license. IC₁, set up as a quartz-stabilized oscillator similar to the one in Fig 4, generates the carrier. IC₁'s output feeds IC₂, which functions as a modulated RF power-output stage. The bias applied to offset pins 1 and 8 restricts IC₂'s input range. (See the LT1194 data sheet for details.) IC₅, a microphone amplifier, supplies bias to the offset pins, resulting in an amplitude-modulated RF carrier at IC₃'s output. The dc voltage summed with the microphone output biases IC₅'s output to the appropriate level for good quality modulation characteristics. Calibrating this circuit involves trimming the 100Ω potentiometer in the oscillator for a stable 1 V p-p 1-MHz output from IC₁.

Fig 7a does not show on-air personalities—or, in keeping with current trends in AM radio—a means of providing any kind of program other than a talk show. There is no phonograph pickup or connection to the output of a compact-disc player. Nevertheless, you can connect such a music source to the microphone input. Fig 7b shows a typical AM carrier output at the antenna. In a throw-back to the days when top-40 formats reigned on the AM band, the modulating signal is Mr Chuck Berry singing the rock-'n'-roll classic “Johnny B. Goode.”

**Start with a triangle; end up with a sine**

The oscillators presented to this point have limited tuning-frequency range. Although the circuit in Fig 8a is not a true oscillator, it produces a synthesized sine-wave output over a wide dynamic range. Many applications such as audio, shaker-table driving, and automatic test equipment require voltage-controlled oscillators (VCOs) that have sine-wave outputs. This circuit meets this need, spanning a range of 1 Hz to 1 MHz (equal to 6 decades or 120 dB) for a 0 to 10V input. The circuit maintains 0.25% frequency linearity and 0.40% distortion.

To understand the circuit, assume Q₅ is on and its collector (Fig 8b, trace A₁) is at -15V, cutting off Q₁. IC₃, which inverts the positive input voltage and biases the summing node of integrator IC₁ through the 3.6-kΩ
resistor and the self-biased FET's, pulls a current, \(-I\), from the summing point. IC\(_2\), a precision op amp, provides dc stabilization of IC\(_1\). IC\(_1\)'s output, (trace B\(_r\)) ramps positive until IC\(_1\)'s input, (trace C\(_r\)) crosses zero and causes IC\(_5\)'s inverting output to go negative. The Q\(_1\)'s level shifter then turns off, and Q\(_1\)'s collector goes to +15V, allowing Q\(_1\) to come on. The values of the resistors in Q\(_1\)'s path result in a current, +2I, exactly twice the absolute magnitude of the current, \(-I\), that flows out of the summing node. As a result, the net current into the junction becomes +I, and IC\(_1\) integrates negatively at the same rate it did during its positive-going excursion.

When IC\(_1\) integrates far enough in the negative di-

Fig 8—A classic function generator, a, creates square and triangular waves whose frequency you can control with a dc voltage. A trigonometric-function generator IC converts the triangle to a sine. The traces in b show waveforms within the circuit. The lowest trace shows the residual distortion after you remove the output's fundamental-frequency component. In c, you see the circuit's quick and clean response to a command to change frequency.
FOR EMULATING THE MOTOROLA 68302, 68332*, AND 68HC16 . . . IT'S THE ADVENTURES OF

In the complex world of microcontrollers, a lot of companies make a lot of claims. It can be confusing. How do you avoid a poisoned apple? Pentica suggests that you ask a few basic questions. The following seven might appear gigantic to some, but we can help you cut them (and your development problems) down to size.

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2 Especially if you're using a high-level debugger, will the execution breakpoint you set occur before or after an instruction? And is the number of breakpoints unlimited?

3 With the bewildering situations presented by multi-use pins, the 68332 and 68HC16 challenge an emulator to be nearly clairvoyant. For instance, when using port E as I/O instead of bus control, how much emulator function is retained?

4 Can the trace buffer start and stop...then start again? Can you qualify the trace to critical functions to ensure maximum use of the trace buffer?

5 Is the emulator's event system independent of the breakpoints? Or do you have to reconfigure each situation, losing flexibility?

6 How flexible is the sequential and combinational logic of the emulator's event system? Can one event sequence re-arm another? This capability is critical when attempting to isolate spurious fault conditions.

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*Support for the 68332 will be available Q2 1992.
rection, IC₅'s + input crosses zero and the circuit's two outputs change state. The state change switches the Q₁/Q₉ level shifter's state, causing Q₁ to go off and the entire cycle to repeat. The result is a triangular waveform at IC₁'s output. The frequency of this triangle depends on the circuit's input voltage and varies from 1 Hz to 1 MHz with a 0 to 10V input. The LT1009 diode bridge and the series-parallel diodes provide a stable bipolar reference that always opposes the sign of IC₁'s output ramp. The Schottky diodes bound IC₅'s + input, ensuring its clean recovery from overdrive.

Sine of the times

The AD639 trigonometric function generator, biased via IC₄, converts IC₁'s triangular output into a sine wave, (trace D). To avoid output distortion, you must supply the AD639 with a triangular wave that does not vary in amplitude. At higher frequencies, delays in the IC₁-integrator switching loop result in late turn-on and turn-off of Q₁. Unless you minimize these delays, the triangle amplitude will increase with frequency and cause the distortion level to increase. IC₅, the Q₁/Q₉ level shifter, and Q₉ generate a total delay of 14 nsec. This small delay, combined with the 22-pF feed-forward network at IC₁'s input, keeps distortion to just 0.40% over the entire 1-MHz range. At 100 kHz, the distortion is typically less than 0.2%. The 8-pF capacitor in Q₁'s source line minimizes the effects of gate-source charge transfer, which occurs whenever Q₁ switches. Without this capacitor, a sharp spike would occur at the triangle peaks, increasing distortion. FETs Q₁ and Q₉ compensate for the temperature-dependent on-resistance of Q₁ and keep the +2I/−1 relationship constant with temperature.

This circuit responds very rapidly to input changes—something most sine-wave generators cannot do. Fig 8c shows what happens when the input switches between two levels, (trace A). IC₁'s triangle output (trace B), shifts frequency immediately, with no glitches or poor dynamics. The sine output, (trace C), reflecting this action, is similarly clean. To adjust this circuit, apply 10.00V and trim the 100Ω potentiometer for a symmetrical triangle output at IC₁. Next, apply 100 µV and trim the 100-kΩ potentiometer for triangle symmetry. Then, apply 10.00V again and trim the 1-kΩ frequency-trim adjustment for a 1-MHz output frequency. Finally, adjust the distortion-trim potentiometers for minimum distortion as measured on a distortion analyzer (Fig 8b, trace E). You may have to readjust the other potentiometers slightly to achieve the lowest possible distortion. If you won't operate the circuit below 100 Hz, you can delete the IC₂-based destabilization stage. If you make this change, you should ground IC₁'s positive input.

Many of the filter and oscillator circuits presented here are simple as well as useful. Their simplicity shows that clever circuit designers often take a minimalist approach. When you speak or write, you are more likely to get your point across if you use short words that are familiar to your audience. So it is with circuits. The simplest design that does the job usually costs the least and operates more reliably than complex alternatives.

Author's biography

For more information on this article's author, turn to pg 163 in the October 10, 1991, issue.

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The New World Of Electronics Manufacturing

The world of electronics manufacturing used to be at war. Each engineer, whether they were involved in the design, production, assembly or test of printed circuit boards, had their own battleground—their own territory. Crossing the technology borders between these different disciplines took more than a passport, it took a miracle.

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The variety of circuits that prove useful in high-speed data conversion is almost limitless. Here is a collection of circuits that can turn out to be lifesavers in several situations.

Jim Williams, Linear Technology Corp

Any reasonably complete listing of the types of circuits that you can use in data conversion and analog/digital data acquisition would be long indeed. Although books have been written just on D/A and A/D converters, such circuits are hardly the only ones that prove useful in acquiring fast-changing analog signals. You almost can’t mention ADCs without also bringing up sample and hold (S/H) circuits. Voltage-to-frequency converters offer a very attractive alternative to more conventional ADCs, especially where you need signal isolation or outstanding linearity. Comparators are the heart of any analog-to-digital conversion scheme. Trigger circuits let you view and capture waveforms that recur at intervals that aren’t perfectly periodic. Time-to-voltage converters let you see how pulse widths and time intervals vary as a function of time, and rms-to-dc converters extract an important property of ac signals—their heating value. There is a measure of commonality among the techniques you use to design such circuits. Here for your entertainment and edification is a potpourri of useful circuits that perform diverse functions.

In Fig 1a, the LT1016 comparator and the LT1122 high-speed FET amplifier combine to form a high-speed V/F converter. A variety of circuit techniques yields a 1-Hz to 10-MHz output. The circuit continues to function with a 20% overrange (V_in = 12V; f_OUT = 12 MHz). This circuit has a wider dynamic range (140 dB, or seven decades) than any unit available commercially. The 10-MHz full-scale frequency is 10x as high as that of currently available monolithic V/F converters.

The theory of operation depends on the identity Q = CV. Each time the circuit produces an output pulse, it feeds back a fixed quantity of charge (Q) to a summing node (7). The circuit’s input furnishes a comparison current at the summing node and a monitoring amplifier’s feedback capacitor integrates the difference signal. The amplifier controls the circuit’s output-pulse generator, completing a feedback loop around the integrating amplifier. To maintain the summing node at zero, the pulse generator runs at a frequency at which the pumped charge just offsets the current produced by the input signal. Thus, the output frequency is linearly proportional to the input voltage.

IC_1 is the integrating amplifier. Stabilizing IC_1 with IC_2, a chopper-stabilized op amp, produces 0.05 μV/°C of offset drift. IC_2 measures the dc value of the negative input, compares it with ground, and forces the positive input to maintain the offset balance in IC_1.
Note that IC₂ is an integrator that cannot see high-frequency signals. It functions only at dc and low frequencies.

Integrator IC₁ has a 68-pF feedback capacitor. When you apply a positive voltage to the input, IC₁’s output integrates in a negative direction (Fig 1b, trace A).

During this period, IC₃’s inverting output is low. The paralleled HCMOS inverters form a reference-voltage switch. The LT1034s (driven by the LM134 current source and the Q₆/Q₇ combination) establish the reference voltage; a small input-voltage-related term adds to the reference, improving overall circuit linearity.

Fig 1—A voltage-to-frequency converter with a maximum output frequency of 10 MHz and a 140-dB dynamic range is only moderately complex (a). In b, you see the circuit waveforms; c is an expanded view of the discharge-reset sequence upon which the circuit performance depends.
an integrator, is the actual hold amplifier. Its output feeds back to the switching bridge’s input, forming a summing point with IC₁’s output resistor. This feedback loop enhances accuracy by placing the bridge within a loop.

Driving the S/H input line switches the bridge. Q₁ and Q₂ drive L₁’s primary. L₁’s secondaries provide complementary drive to the bridge with negligible time skew.

Fig 2b shows the circuit acquiring a full-scale step. Trace A is the input command; trace B is IC₂’s output. The aberration (that is, the “hold step”) visible in IC₂’s output when the circuit switches into the hold mode is the result of minute residual ac imbalances in the bridge. Fig 2c illustrates this effect in high-resolution detail, with the “hold-step trim” deliberately disconnected. After IC₂’s output nominally settles at final value, the circuit switches into the hold mode. The bridge imbalance dumps a small parasitic charge into IC₂’s summing point, in this case causing IC₂ to step 10 mV higher. Properly connected and adjusted, the trim supplies a small compensatory charge during switching. Fig 2d shows the effect of this compensation on the output. The settled hold-mode output is the same as the acquired input voltage. To trim this circuit, ground the input while pulsing the S/H control line. Next, adjust the trim for a minimal amplitude step between the S/H states.

In contrast to low-frequency S/H circuits, this circuit, if left in the sample mode, cannot pass a signal. The transformers’ inherent ac coupling prevents the circuit from providing a dc output. Moreover, extending the sample-mode duration beyond 500 nsec will saturate the transformers, causing erroneous outputs and excessive dissipation in Q₁ and Q₂. If the control input can remain in the high state for extended periods, you should ac-couple the control signal.

**Compare currents in 15 nsec**

Fig 3a shows a way to build a high-speed current comparator with resolution in the 12-bit range. Comparing currents, which is the fastest way to compare DAC outputs with analog values, is a common technique in high-speed instrumentation, especially in high-speed A/D converters. IC₁ is a Schottky-bounded amplifier. The bounding diodes hold down the response time by preventing summing-point overdrive from causing IC₁ to saturate. Select the capacitor—it compensates for the DAC output capacitance—for the best amplifier damping; the 3-pF value shown is typical. The feedback resistor maximizes the circuit’s gain-bandwidth product; the 10-kΩ value shown is also typical. Voltage gains of 4 to 10 are common.

Fig 3b shows the circuit’s performance. Trace A, a test input, causes IC₁’s output (trace B) to slew through zero (the screen’s center horizontal line). When IC₁ crosses zero, IC₂’s input goes negative and IC₂ responds 10 nsec later with a TTL output (trace C). The total time from when the test input reaches the TTL high threshold until the comparator output level becomes a TTL high is <15 nsec.

Fig 4a is an extremely versatile trigger circuit. Designing a fast, stable trigger is not easy, and often entails a considerable number of discrete components.

---

**Fig 3**—Only two ICs yield a fast summing comparator (a). In b, you can observe key waveforms as the circuit operates.
This circuit, without level adjustment, triggers reliably from dc to 50 MHz over a 2 to 300-mV input range.

IC1, a gain-of-10 preamplifier, feeds an adaptive trigger configuration that maintains the output comparator's (IC3's) trip point at one-half the input-signal amplitude, regardless of the signal's magnitude. The self-adjusting trip point ensures reliable automatic triggering over a wide input-amplitude range, even for very low-level inputs. As an option, the network (shown in dashed lines in Fig 4a) permits changing the trip threshold. The adjustment lets you select any point on the input-waveform edge as the trigger point.

Fig 4b shows the performance for a 40-MHz input sine wave (trace A). At IC3's output (trace B), the input signal has received voltage gain with little or no phase shift. Comparator IC3 gives a clean logic output (trace C). At the highest frequencies, bandwidth limiting can occur in IC1, but it is irrelevant; the adaptive trigger threshold will simply vary in proportion to the input to maintain the circuit output.

The circuit of Fig 5a lets you determine very short pulse widths (in this case, 250 nsec full scale) with a typical error of 1%. Digital methods of achieving similar results dictate GHz clock speeds, and thus result in cumbersome implementations. In addition, processor-based approaches that use averaging techniques require repetitive pulses; this circuit does not. Circuits of the type shown in Fig 5a frequently appear in automatic test equipment and nuclear and high-energy physics work, where measuring the width of short pulses is a common requirement.

The circuit functions by charging a capacitor for the duration of the pulse. When the pulse ends, the charging ceases, and the voltage across the capacitor is proportional to the width of the pulse.

The pulse whose width is to be measured (Fig 5b, trace A) simultaneously biases the 74C221 dual one-shot and Qs. Qs, aided by Baker clamping, feed-forward capacitance, and optimized dc base biasing, turns off in a few nsec. Current source Q2's emitter becomes forward biased, and Q2 supplies constant current to the 100-pF integrating capacitor. Q1 supplies temperature compensation for Q2 and the 2.5V LT1009 provides the current-source reference. The 100-pF capacitor at Q2's collector charges in ramp fashion (trace B). IC1 supplies a buffered output (trace C). When the input

Fig 4—An extremely versatile trigger circuit (a) consists of three ICs and two pairs of transistors, each connected as a current source. The circuit adjusts its threshold as the amplitude of the incoming signal varies. In b, you see waveforms during circuit operation.
IC₃ and IC₄ provide low-drift buffering and present a low-impedance reference to the supply pins of the paralleled inverters. The HCMOS outputs give essentially error-free low-resistance switching. The reference switch's output charges the 15-pF capacitor via the path that includes Q₁.

When IC₁'s output crosses zero, IC₅'s inverting output goes high and the reference switch (trace B) goes to ground, causing the 15-pF capacitor to dispense charge into the summing node via the Q₁ base-emitter junction. The amount of charge dispensed is a direct function of the voltage that had existed across the 15-pF capacitor (Q = CV). Q₂ and Q₄ in the reference string provide temperature compensation for Q₁ and Q₃. The current that flows through the 15-pF capacitor (trace C) reflects the charge-pumping action. Removing current from IC₁'s summing junction (trace D) drives the junction negative very quickly. The initial negative-going 15-nsec transient at IC₁'s output results from amplifier delay.

The input signal feeds directly through the feedback capacitor and appears at the output. When the amplifier finally responds, its output (trace A) slews limits as the amplifier attempts to regain control of the summing node. The 1.2-kΩ pull-up resistor and the RC damper at IC₁'s output enhance the amplifier's recovery from slewing. The amount of time the reference switch remains at ground depends on the 5-pF/10000-hysteresis network at IC₁ and how long IC₁ takes to recover. A 60-nsec interval is long enough for the 15-pF capacitor to fully discharge. After the discharge, IC₁ changes state, the reference switch swings positive, the capacitor recharges, and the entire cycle repeats. The frequency at which this oscillation occurs is directly proportional to the current into the summing junction, and, in turn, to the input voltage. Any input current will dictate an oscillation frequency that holds the summing point at an average value of zero.

At MHz frequencies, maintaining a linear relationship between the input voltage and the output frequency places severe restrictions on the circuit timing. The key to achieving a 10-MHz full-scale operating frequency is the ability to transmit information around the loop very quickly. The discharge-reset sequence detailed in Fig 1c is particularly critical.

Fig 1c, trace A is the output of integrator IC₁. Its ramp output crosses zero at the first vertical graticule division on the left. A few nsec later, IC₅'s inverting output begins to rise (trace B), switching the reference switch to ground (trace C). The reference switch begins to head towards ground about 16 nsec after IC₁'s output crosses zero. Two nanoseconds later, the summing point (trace D) begins to go negative as current flows from it through the 15-pF capacitor. At 25 nsec, IC₅'s inverting output is fully positive, the reference switch is at ground, and the summing point is at its negative extreme. Now, IC₁ begins to take control. Its output (trace A) slews rapidly in the positive direction, restoring the summing point. At 60 nsec, IC₁ is in control of the summing node and the integration ramp begins again.

Come on, get going

Start-up and overdrive conditions could force IC₁'s output to go to the negative rail and stay there. The ac-coupled nature of the charge-dispensing loop can preclude normal operation and cause the circuit to latch. The remaining HCMOS inverter provides a "watchdog" function for this condition. If IC₁'s output goes to the negative rail, the reference switch tries to stay at ground. The remaining inverter goes high, lifting IC₁'s positive input, causing IC₁'s output to slew positive, and thus initiating normal circuit action. The 1-kΩ/10-µF combination and the 10-MΩ resistor in series with the inverter input limit the loop bandwidth during start-up, preventing unwanted outputs.

The LM134 current source that drives the reference string has a built-in 0.33%/°C thermal coefficient, causing a slight voltage modulation in the Q₅/Q₆ pair over temperature. This small change (±120 ppm/°C) opposes the −120 ppm/°C drift in the 15-pF polystyrene capacitor and reduces the temperature coefficient of the complete circuit.

Acronyms used in this article

ac—Alternating current
A/D—Analog-to-digital
ADC—Analog-to-digital converter
D/A—Digital-to-analog
DAC—Digital-to-analog converter
dc—Direct current
FET—Field-effect transistor
LSB—Least-significant bit
RC—Resistance-capacitance
rms—Root-mean-square
S/H—Sample and hold
TTL—Transistor-transistor logic
V/F—Voltage to frequency
VFC—Voltage-to-frequency converter
To trim this circuit, apply exactly 6V at the input and adjust the 2-kΩ potentiometer for 6.000-MHz output. Next, put in exactly 10V and trim the 20-kΩ potentiometer for a 10.000-MHz output. Repeat these adjustments until both points stay fixed. IC2’s low drift eliminates a zero adjustment. If operation below 600 Hz is not required, you can delete IC2 and its associated components.

Nonlinearity of this circuit is 0.03% and full-scale drift is 50 ppm/°C. Zero-point error, controlled by IC2, is 0.05 Hz/°C.

Fig 2a shows a simple, very fast S/H circuit. This circuit will acquire a 5V input to 8-bit accuracy in 100 nsec. The hold step amplitude is less than ¼ LSB, and hold settling time is less than 25 nsec. The aperture time is 4 nsec, and the droop rate is about ½ LSB in 1 µsec.

Inverting buffer IC1 feeds the input to a Schottky switching bridge. The Schottky bridge, which is similar to types used in sampling oscilloscopes, switches in 1 nsec and eliminates the charge pump-through that an FET switch would contribute. The switching bridge’s output feeds output-amplifier IC2. IC2, configured as

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**Fig 2a**—This very fast S/H circuit (a), acquires signals to 8-bit accuracy in 100 nsec. In b you see the waveforms within the circuit. Accurate operation depends on cancellation of the switching signals that feed through the bridge. In c, the compensation is disconnected. In d, you can see the effect of the compensation.
pulse ends, \( Q_2 \) turns on rapidly, reverse-biasing \( Q_2 \)'s emitter and turning off the current source. IC\(_1\)'s voltage is directly proportional to the input pulse width. A monitoring A/D converter can acquire this data.

After an interval set by the 74C22I's delay (a resistor and a capacitor set the delay), a pulse appears at the circuit's \( Q_2 \) output (trace D). This pulse turns on \( Q_4 \), discharging the 100-pF capacitor to zero and readying the circuit for the next input pulse.

This circuit's accuracy and resolution depend strongly on keeping the delay in switching the \( Q_1/Q_2 \) current source very short. Fig 5c provides amplitude and time-expanded versions of critical circuit waveforms. Trace A is the input pulse and trace B is IC\(_1\)'s input, showing the beginning of the ramp's ascent. Trace C, IC\(_1\)'s output, shows a delay of about 13 nsec from IC\(_1\)'s input. Traces D and E, also IC\(_1\)'s input and output, record similar delays introduced by IC\(_1\) at the ramp turn-off. The photo reflects the extremely fast current-source switching; IC\(_1\) causes most of the delay. IC\(_1\)'s delay is far less critical than the current-source-switching delays. IC\(_1\) will always settle to the correct

Fig 5—Changing pulse widths to voltages provides a convenient way to monitor changes in time intervals that occur as a function of time. The circuit in a performs this function. In b you see circuit waveforms. These waveforms appear in expanded form in c. The current-source turn-off appears in d.
value well before the one-shot resets the circuit. In practice, you should not trigger a monitoring A/D converter until about 50 nsec after the circuit’s input pulse has ceased. This delay gives IC1 plenty of time to catch up to the 100-pF capacitor's settled value.

As mentioned, fast current-source switching is essential for good results. Fig 5d details the current-source turn-off. Trace A is the circuit’s input-pulse rising edge, and trace B shows the “top” of the ramp. Turn-off occurs in a few nanoseconds. Similar speed is characteristic of the input’s falling edge (current-source turn-on). In addition, note that the circuit’s accuracy and resolution limits depend on the difference in current-source turn-on and turn-off delays. Therefore, the effective overall delay is extremely small.

To calibrate this circuit, apply a 250-nsec-width pulse and trim the 1-kΩ potentiometer for a 10V output. The circuit will convert pulse widths between 20 and 250 nsec to voltages with an accuracy that is typically 1%. The 20-nsec minimum-measurable width is the result of the 100-pF capacitor’s inability to discharge fully. If you must measure the width of pulses narrower than 20 nsec, you can replace Q4 with a lower-saturation-voltage device or you can offset IC1’s output.

Most ac rms measurements use logarithmic techniques to compute a waveform’s rms value. Such methods work with signals whose bandwidth is below 1 MHz and whose crest factor is less than about 10. Practically speaking, a waveform’s ability to heat a resistive load defines its rms value. Specialized instruments employ thermally based assemblies that compute the rms values of input signals. Compared with logarithmically based converters, thermal methods work over a substantially wider bandwidth and produce accurate results with signals that have much higher crest factors (ratio of peak to rms voltage).

Thermal rms-to-dc converters are direct acting, thermoelectronic analog computers. The thermal technique is explicit, relying on “first principles”—that is, on the definition of rms. The simple operation permits wideband performance unattainable with implicit, indirect methods based on logarithmic computing.

Fig 6 shows a classic scheme for implementing a thermally based rms-to-dc converter. Here, the dc amplifier forces a second, identical, heater-sensor pair to the same thermal conditions as the pair driven by the input. This differentially sensed, feedback-enforced loop makes ambient-temperature shifts a common-mode term, eliminating their effect. Also, although the voltage and thermal interaction is nonlinear, the input-output voltage relationship is linear and has a gain of 1.

The ability of this arrangement to reject ambient-temperature shifts depends on the heater-sensor pairs being at equal temperatures. You can achieve this condition by thermally insulating the sensors with a thermal time constant well below that of any ambient-temperature shifts. If you match the time constants of the heater-sensor pairs, ambient temperature-terms will affect the pairs equally and the dc amplifier will reject this common-mode term. Note that, even though the pairs are at equal temperatures, they are insulated from each other. Any thermal interaction between the pairs reduces the system’s thermally based gain terms. This interaction would cause unfavorable signal-to-noise performance and limit the dynamic operating range. The output of Fig 6’s circuit is linear because the matched thermal pairs' nonlinear voltage-temperature relationships cancel each other.

The advantages of this approach have made its use popular in thermally based rms measurements. Typically, the assembly consists of matched heater resistors, sensors, and thermal insulation. These assemblies are relatively large and producing them is rather expensive.

Fig 7a’s economical wide-band thermally based voltmeter uses a monolithic thermal converter. The LT1223 amplifier provides gain and drives the LT1088 rms-to-dc thermal converter. The supply biases the

---

**Fig 6**—A basic thermal rms-to-dc converter uses a pair of heating elements. The unknown ac voltage drives one; a dc voltage drives the other. By using a high-gain amplifier to provide the dc voltage, you force the heating effect of the dc to equal that of the ac. Hence the rms value of the dc and ac are equal. Thus, when you measure the dc voltage, you are measuring the rms ac voltage.
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LT1088's temperature-sensing diodes. IC₁, set up as a differential servo amplifier with a gain of 9000, extracts the diode's difference signal and biases Q₁. Q₁ drives one of the LT1088's heaters, completing a loop. The 3300-pF capacitor gives a stable roll-off. The 1.5-MΩ/0.0225-µF combination improves settling by reducing the gain during output slewing. The LT1088's square-law thermal gain makes the overall loop gain lower for small inputs. Normally, the low gain would cause slow settling for values below about 10 to 20% of full scale. The LT1004 1-kΩ/3-kΩ network provides a simple breakpoint that boosts the amplifier gain at low signal levels to improve settling. IC₂, a gain-trimmable output stage, compensates for gain variations in the two sides of the LT1088.

To trim the circuit, apply a dc signal of about 10% of full scale (that is, 0.05V) and adjust the "zero trim" so that \( V_{OUT} = V_{IN} \). Next, apply a full-scale dc input and set the full-scale trim for a full-scale output. Repeat the trims until both errors are well below 1% of full-scale. An alternate trimming scheme involves applying no input, grounding Q₁'s base, and adjusting the zero trim until IC₂'s output is active. Then you disconnect Q₁'s base from ground, apply a full-scale input, and trim the full-scale adjustment to produce a full-scale output. Fig 7b is a plot of the circuit's error vs input fre-

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**Fig 7**—A functioning rms-to-dc converter appears in a. In b, you see the circuit's error vs frequency for several input-signal amplitudes and for two values of heater resistance.
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When you apply your input to one of the 50Ω heaters, the LT1088’s error spec is 2% to 100 MHz; using a 250Ω heater, the spec is 1% to 20 MHz. Most of the error shown results from bandwidth restrictions in IC₃, but the performance is still impressive. The plots include data taken at various input levels into both a high and a low-resistance heater. The error in the response to a 500-mV input into the 250Ω heater rises to 1% at 8 MHz, and 2.5% at 14 MHz before peaking badly beyond 17 MHz. This input level forces a 9.5V-rms output at IC₃, and introduces large-signal bandwidth limitations. The 400-mV input to the 250Ω heater produces essentially flat response to 20 MHz, the LT1088’s 250Ω-heater specification limit.

The 50Ω heater provides significantly wider bandwidth, although in the circuit of Fig 7a, IC₃’s 50-mA output limits the maximum input to about 100-mV rms (1.76V rms at the LT1088).

As you can see, the circuits discussed here are useful in their own right. They are also thought provoking. You can combine and modify them virtually without limit, and in so doing, produce new circuits that perform many other useful functions.

Author’s biography
For more information on this article’s author, turn to pg 163 in the October 10, 1991 issue.

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CIRCLE NO. 157
High-speed communications circuits

High-frequency communications signals need wideband analog circuits. High-speed monolithic amplifiers let you build simple, effective circuits to meet this need for both optical and RF transmission.

Megahertz-range data transmission and communications requires wideband linear circuitry. By designing around a monolithic high-speed amplifier, you can easily implement a variety of standard high-performance communications circuits. The following circuits detail several such designs for both optical and RF transmission. All have been carefully worked out and can serve as good idea sources.

Amplifying fast photodiode signals over a wide range of optical intensity is one common optical-communications requirement. Fig 1a's fast FET amplifier gives wideband operation for 5 decades of photocurrent. You set up the photodiode in the conventional manner and use a -15V bias to aid diode response. Photocurrent feeds directly to IC1's summing point, which causes IC1's output signal to move to whatever level is required to maintain virtual ground at the negative input pin. Fig 1b details the circuit's operating characteristics when using the HP5082-4204 photodiode.

You must use care when frequency-compensating this circuit. The diode has approximately 2 pF of parasitic capacitance, which creates a significant lag at IC1's summing point. Without a feedback capacitor, the circuit's high-speed dynamics are poor. Fig 1c illustrates this point by showing the circuit's response to a photocurrent input pulse (trace A) when the 3-pF feedback capacitor is removed. IC1's output voltage (trace B) overshoots and saturates before finally ringing down to its final value. Replacing the feedback capacitor gives Fig 1d's results. The same input pulse (trace A) produces a cleanly damped output voltage (trace B). The capacitor, however, imposes a 50% speed penalty (note that the horizontal scale of Fig 1d is faster than that of Fig 1c). This penalty is unavoidable because suppressing the parasitic ringing's relatively low frequency mandates significant roll-off.

Basic amplifier has many uses

You can use the basic photodiode amplifier as the foundation for a variety of measurement and communications circuits. One such measurement circuit is Fig 2a's photointegrator. The output voltage represents the integral of the diode's photocurrent over a time period defined by the control line. This circuit is par-
particularly useful for measuring the total energy in a light pulse or pulses. The circuit is a fast integrator and uses IC₂A as a reset switch. IC₂B, which the control input signal switches simultaneously with IC₂A, compensates for IC₂A’s charge-injection error.

When the control input line is low (Fig 2b, trace A) and no photocurrent is present, IC₂A is closed and IC₁ acts as a grounded follower. Under these conditions, IC₁’s output signal (trace C) sits at 0V. When the control input line goes high, IC₁ becomes an integrator as soon as IC₂A opens. Due to the switch delay, IC₂ opens approximately 150 nsec after the control input line goes high.

When IC₂A opens, it delivers some parasitic charge to IC₁’s summing point. IC₂B provides a compensatory charge-based pulse at IC₁’s positive terminal to cancel the effects of IC₂A’s charge error. The combined effect of the two charge pulses shows up as a fast, small amplitude event in IC₁’s output, which settles rapidly back to 0V. You can see this event on trace C near the 400-nsec mark.

Once the switches have opened, the integrator is ready to receive and record a light pulse. When a light pulse (trace B) falls on the photodiode, IC₁ responds by integrating (trace C). With the circuit as shown in Fig 2a, IC₁ integrates rapidly until the light pulse ceases. IC₁’s voltage after the light event is over is related to the total energy the photodiode sees during the event. In typical operation, the control line then returns low, which resets IC₁ for the next light event.

When the circuit has only 10 pF of integration capacitance, its output droop rate is about 0.2V/µsec. You
can increase the capacitance, but the integration speed will suffer accordingly. As shown, the circuit accommodates integration times of nanoseconds to milliseconds and photocurrents ranging from nanoamperes to hundreds of microamperes. Thus, light pulses with optical-power intensities spanning microwatts to milliwatts over wide ranges of duration are practical input signals.

The primary factors restricting the circuit's accuracy are IC1's 75-pA bias current and 12V output swing and the effectiveness of the charge-cancellation network. Typically, the circuit can achieve full-scale accuracy within several percent if you trim the charge-cancellation network. To trim the network, make sure that no light falls on the diode while you repetitively pulse the control line. Adjust the trimmer capacitor to achieve a 0V output at IC1 immediately after the disturbance associated with the IC2A-IC2B switching settles.

A communications circuit that relies on the basic photodiode amplifier is the simple fiber-optic receiver in Fig 3a. IC1, a photocurrent-to-voltage converter similar to Fig 1a, feeds comparator IC2. IC2 compares IC1's output voltage to a dc level established by the

**Fig 2**—The basic photodiode amplifier is the basis for this integrator, which has a resettable output (a). When the control line is high (b, trace A), the circuit integrates (trace C) the incoming signal (trace B).

**Fig 3**—This simple optical receiver (a) has a fixed signal threshold. The outputs of IC1 (b, trace B) and IC2 (trace C) lag the input signal (trace A).
threshold-adjust potentiometer, thus producing a logic-compatible output signal. **Fig 3b** shows this circuit's typical waveforms. Trace A is a pulse associated with a light input signal. Trace B is IC1's response, and trace C is IC2's output signal. The phase shift between the photocurrent input signal and IC1's output signal is due to IC1's delay in reaching the threshold level. Reducing the threshold level will help reduce the shift but moves the circuit's operation closer to the noise floor. Additionally, the fixed threshold level cannot account for response changes in the emitter and detector diodes and the fiber-optic line over time and temperature. These response changes manifest as changes in the apparent amplitude of the signal.

Receiving high-speed fiber-optic data with such input amplitude variations is not easy, especially if the variation is wide. Unless the receiver is carefully designed, the high-speed data and uncertain intensity of the light level can cause erroneous results. **Fig 4a** addresses the previous circuit's fixed-threshold limitation and offers significant performance advantages. This receiver reliably conditions fiber-optic input signals as fast as 40 MHz. The peak-to-peak amplitude of input signal can vary by as much as 40 dB. The circuit's digital output stage has an adaptive threshold trigger that accommodates signal intensity variations due to component aging and other causes. The circuit has an analog output signal that you can use to monitor the detector's output.

The PIN photodiode detects the optical signal, which IC1 then amplifies. A second stage, IC2, further amplifies the signal. The output voltage of this second stage biases a 2-way peak detector (Q4 through Q6). Q2's emitter capacitor stores the signal's maximum peak while...
Protective circuit can save you a load

Some type of fuse or circuit breaker helps protect integrated circuits during developmental probing and expensive loads during trimming and calibration. Fig Aa shows a simple circuit that will turn off current in a load 18 nsec after that current exceeds a preset value. The circuit is especially versatile because one side of the load is grounded.

Under normal conditions, Q₁'s emitter is biased on and supplying power to the load via the 10Ω current shunt. Differential amplifier IC₁'s output signal resides below comparator IC₂'s voltage-programmed trip point, and Q₂ is off.

When an overload occurs, Q₁'s emitter current begins to increase (Fig Ab, trace A, just prior to the third vertical division). IC₁'s output voltage (trace B) begins to rise as it tracks the increase in voltage across the 10Ω shunt. The 9-kΩ, 1-kΩ voltage dividers keep IC₁'s input pins within their common-mode range. Q₁'s emitter voltage (trace C) begins to drop as the transistor beta-limits. When IC₁'s version of the load current exceeds IC₂'s trip point, IC₂ goes high (trace D), which turns on Q₂. (Local positive feedback at IC₂'s latch pin causes IC₂ to latch in this off state.) Q₂ steals Q₁'s base drive, thus turning off the load current.

Once you've cleared the load fault, you can use the push button to reset the circuit. The delay from the onset of excessive load current to complete circuit shutdown is less than 18 nsec. (When interpreting the Fig Ab waveforms, note that trace A's current probe has a 4-nsec delay.) To calibrate the circuit, ground Q₂'s base and install a 250-mA load. Adjust the 200Ω trim for a 2.5V output signal at IC₁. Next, remove the load, unground Q₂'s base, and press the reset button. Finally, set the desired trip voltage, and the circuit is ready for use.

Fig A—This circuit breaker (a) trips in as little as 18 nsec. The circuit shuts down the load (b, trace C) when the load current (trace A) exceeds the trip point. Trace B represents IC₁'s output voltage; trace D represents IC₂'s output voltage.
Q₁’s emitter capacitor retains the minimum excursion. The dc value of the midpoint of IC₂’s output signal appears at the junction of the 500-pF capacitor and the 22-MΩ resistors. This point will always be midway between the signal’s excursions, regardless of the signal’s absolute amplitude. The low-bias LT1097 op amp (IC₃) buffers this signal-adaptive voltage to set the trigger voltage at IC₁’s positive input pin. IC₁’s negative input pin is biased directly from IC₂’s output.

Fig 4b shows the results of using the test circuit of Fig 4a. The pulse generator’s output signal is trace A; IC₂’s analog output voltage is trace B; IC₁’s output signal is trace C. The waveforms were recorded using a 5-μA photocurrent at about 20 MHz as the test signal.

Fig 5—This mixer’s (a) single-ended output signal is easier to work with than differential signals. Trace B (b) is the result of mixing trace A with a 20-MHz sine wave.

Fig 6—a servo loop enables this circuit to stabilize RF signals. The loop circuit (a) uses an rms-to-dc converter (b).
Note that IC₃’s output transitions (trace C) correspond with the midpoint (plus IC₃’s 10-nsec propagation delay) of IC₂’s output signal (trace B), in accordance with the adaptive-trigger circuit’s operation.

**Mixer yields single-ended signal**

Another common communications requirement, particularly for RF work, is mixing signals for modulation or heterodyning. Analog multipliers can mix signals, but they have a drawback; their output signals take a differential form. These differential signals, which have substantial common-mode content, are frequently inconvenient to work with. You can use RF transformers to convert them to single-ended signals, but you lose dc and low-frequency information in the process. Fig 5a illustrates a better approach. The circuit uses the LT1193 differential amplifier (IC₂) to accomplish the differential-to-single-ended transition. Set up IC₁ in the configuration Ref 1 recommends. The LT1193 takes the differential signal from IC₁’s 50Ω-terminated output lines and provides a single-ended output signal. The amplifier’s gain of 2 yields an 11V output signal at full scale.

IC₁’s output signals ride on a common-mode level quite close to the device’s positive supply. This common-mode level falls outside IC₂’s input common-mode range. The diodes in the 7.5V supply rails drop the supply voltage to IC₁, which biases IC₁’s output signals within IC₂’s input range. This scheme avoids the attenuation and matching problems you’d get if you placed a level shift between the multiplier and amplifier. The impedance of the ferrite beads combine with the diodes’ impedance to ensure adequate bypassing for the multiplier.

This circuit’s performance is quite impressive. Error remains within 2% over dc to 50 MHz, and feedthrough is less than –50 dB. Trimming the circuit involves adjusting the variable capacitor at the amplifier for minimal output square-wave peaking. Fig 5b shows the circuit’s performance when multiplying a 20-MHz sine wave by trace A’s waveform. The output signal (trace B) is a singularly clean instantaneous representation of the X and Y input products.

Often in RF communications you will want to stabilize the amplitude of a waveform against variations in...
input signal strength over time and temperature. Instruments and transmitters must often provide this function, which is not easy if the instruments must also maintain waveform purity. Fig 6a shows a circuit that stabilizes waveform amplitudes while maintaining waveform purity.

You apply the RF input signal to the AD539 wide-band multiplier (IC1), which drives IC2. An LT1088-based rms-to-dc converter (Fig 6b) turns IC2’s output to dc. A servo amplifier (IC3) compares that dc output signal with a settable dc reference and biases the multiplier’s control channel, thus completing a loop. The 0.33-µF capacitor provides frequency compensation by rolling off gain at a frequency well below the response of the LT1088 servo amplifier. The loop maintains the output’s 25-MHz rms amplitude at the dc reference’s value; it rejects changes in load, input-signal strength, power-supply voltage, and other variables.

All of the previous circuits have a voltage-based output signal. Sometimes, however, you’ll want your output in current form. Fig 7a shows a voltage-controlled current source that has both the load and control voltage referenced to ground. This simple, powerful circuit produces output current in accordance with the sign

Fig 7—A voltage-controlled current source (a) often comes in handy. This circuit produces a clean output current (b, trace B) 4 nsec after the input voltage (trace A).

Fig 8—A booster circuit in the middle of this voltage-to-current converter (a) provides more power to your load than does the current source of Fig 7. Trace A (b) represents voltage; trace B represents current.
and magnitude of the control voltage. Resistor R sets the circuit’s scale factor. IC₁, biased by E₁, drives current through R (in this case 10Ω) and the load. IC₂, sensing the differential voltage across R, closes a loop back to IC₁. The load current is constant because IC₁’s loop forces a fixed voltage across R. The 2-kΩ, 100-pF combination sets roll-off, and the configuration is stable. Fig 7b shows the circuit’s dynamic response. Trace A is the control input voltage, E₁, trace B is the output current. The response has a delay of 5 nsec and no slew residue or aberrations.

Fig 8a is Fig 7a’s basic current source plus a 1A booster stage to increase output power. Including the booster inside IC₁’s feedback loop eliminates the booster’s dc errors. Note that the booster needs no current-limiting features because of the circuit’s inherent current-limiting operation. Fig 8b shows that the circuit’s response is as clean as that of the lower-power version, although its delay is about 20 nsec slower. The loop stability considerations involved in placing IC₂ and the booster in IC₁’s feedback path are significant. This type of circuit receives detailed treatment in Ref 2.

References

Author’s biography
For more information on this article’s author, turn to pg 163 in the October 10, 1991 issue.

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Why can Shielding Problems Ruin a Good Design?

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Use Spice and analog circuits to model control systems

**If you already know Spice, you don’t have to learn another simulator to model control systems. You can just replace system block diagrams with equivalent circuits.**

George Ellis, *Industrial Drives*

The first step in designing a control system for the real world is to model the system. You could use software specifically designed for modeling control systems' block diagrams, or—if you're an electronic designer with Spice experience—you can use Spice.

Spice (Simulation Program with Integrated Circuit Emphasis) is an analog-circuit simulator; most lines of Spice-model code specify electronic components. In a model for a block-diagram simulator, on the other hand, most lines specify blocks. However, you can often represent blocks in Spice by using equivalent electronic circuits. For example, you might use a resistor and capacitor in Spice as the equivalent of an FIO (first-order lowpass filter) block in a block-diagram simulator. The two types of models are comparable on a higher level as well; in both cases, you describe a system as a group of elements connected at nodes.

In this case, the chief advantage of using Spice is convenience; if you're already familiar with Spice, you can model control systems without having to learn another simulator. Another benefit of Spice is that you can use one model for both the frequency domain and the time domain. With this one model, you can predict bandwidth, peaking, phase shift, settling time, rise time, and overshoot.

When you model control systems with Spice, you replace both linear and nonlinear blocks with equivalent subcircuits. Linear blocks, such as integrators and lowpass filters, require only ideal op amps, resistors, and capacitors. Nonlinear blocks require nonlinear components. For example, you can use Spice inductor coupling (K elements) to simulate saturation and hysteresis. To model deadband, you can use back-to-back diodes in series with a resistor. (In this circuit, voltage is the input and current is the output.) A simple op-amp circuit can model friction (see box 1, “Nonlinear modeling in Spice”). Behavioral modeling, a feature available on many commercial versions of Spice, enhances Spice's ability to create nonlinear models.

**Behavioral modeling adds to convenience**

Behavioral modeling allows you to describe functional blocks with algebra and look-up tables rather than forcing you to find equivalent electronic components and subcircuits. For example, with PSpice (from Microsim Corp), you can use square roots, logarithms, and sinusoids for voltage-controlled voltage and current sources. You also can use look-up tables for functions that are difficult to describe algebraically. One caution: While most versions of Spice are more or less compatible, behavioral modeling varies considerably from one vendor's software to the next.

The basic Spice tool for block diagrams is the voltage-controlled voltage source (VCVS) (Fig 1). The VCVS is an isolated voltage amplifier. The output voltage (+ OUT to − OUT) is equal to the input voltage (+ IN to − IN) multiplied by a constant gain. If the gain

---

EDN November 7, 1991
You can often represent control-system blocks in Spice using equivalent electronic circuits.

Constant is large and \( -\text{OUT} \) is connected to the power-supply common, the VCVS acts like an ideal op amp.

**Fig 2** shows a model of a simple control system that consists of a proportional controller, a lowpass filter, and an integrating plant. The plant might represent an idealized motor or a mass in a frictionless system. Suppose that you have been working with this model and have set the controller's proportional gain, \( K_p \), to 0.1 and the filter's -3-dB cutoff frequency to 2000 Hz. The filter time constant, \( \tau \), is \( 1/(2\pi \times 2000 \text{ Hz}) = 0.0796 \text{ msec} \). However, you have determined that the system output is too noisy or "busy" with those values and you want to reduce the "busyness" by lowering the filter's cutoff frequency. A Spice model can predict the effect of the lower cutoff frequency on your system.

To use Spice, you must first convert your block diagram to an equivalent electrical circuit (**Fig 3**). You can model the three blocks—the controller, the filter, and the plant—with ideal op amps (E1, E2, and E3, respectively) based on a VCVS gain of \( 10^6 \); then select resistor and capacitor values to yield **Fig 2**'s gains (transfer functions). Note that the sign of the output is inverted because of the three inverting op amps. You should number each node in your circuit. For ex-

### Nonlinear modeling in Spice

You can use simple circuits to model nonlinear effects in Spice. For instance, a simple model for dynamic friction is a constant load with an arithmetic sign opposite to the sign of the velocity. When velocity is zero, dynamic friction is also zero.

**Fig A** shows a model of a servo motor with a frictional load. The circuit uses an op amp with diodes in the feedback path to simulate dynamic friction. R1, C1, and op amp E1 simulate an unloaded, ideal motor; torque is proportional to motor current, and velocity is the integral of torque. Op amp E2, with R2 and R3, inverts the sign of "-velocity" to produce "+velocity." Op amp E3, with D1, D2, and R4, simulates dynamic friction. The diodes are assumed to have a relatively constant drop of 0.6V. The output of op amp E3 is approximately 0.6V when velocity is negative, -0.6V when velocity is positive, and 0V when velocity = 0. R5 scales the dynamic friction so that it is in proper proportion to the torque produced by the motor current.
ample, node 2 is the connection of R1, R2, R6, and the inverting input of E1. In Spice, power-supply common is always node 0.

Often, engineers are skeptical of ideal models, fearing that the models can't adequately represent their systems. Many systems have nonlinear effects that models should represent if they're going to be at all useful. For example, the torque constant of a servo motor can vary considerably over the motor's speed range. Therefore, a Spice model of a servo motor should account for this variance. However, many other components can be safely modeled as if they were ideal. For example, you almost never need to be concerned with the speed of an op amp in a temperature controller. As a designer, you must decide when a nonideal condition affects your system enough to be included in the model.

After representing your block diagram as a circuit, you must convert the circuit to a Spice model. The listing in Fig 4 is a Spice model of a circuit that has three types of lines—comments, components, and control lines. You can include a stand-alone comment by beginning its line with an asterisk, or you can add a comment to any Spice line by introducing it with a semicolon. Component lines simply begin with the component's name, and control lines begin with a period.

The listing in Fig 4 includes four types of electronic components—an independent voltage source (V1), resistors (R1 through R6), capacitors (C1 and C2), and voltage-controlled voltage sources (E1 through E3). Each component requires at least one line of code.

V1 simulates the system command. The line specifying V1 is written in the following order: the label (V1), the node list (1, 0), the types of voltage sources that comprise V1, and a comment. In this example, V1 has both AC and PULSE voltage components. The AC component, with a specified magnitude of 1V, is used to generate frequency-domain data, such as plots of gain and phase. The PULSE source is used to generate time-domain data, such as overshoot and rise time; in this example, it is specified to change from 0 to 5V at the beginning of the simulation. Spice also allows other types of sources, such as exponentials, time-domain sinusoids, and piecewise-linear waveforms.

Spice-model resistors and capacitors scale each of the blocks in a block-diagram model. In a Spice line, you specify a component with (in order) a label, a node
Behavioral modeling, a feature available on many commercial versions of Spice, enhances the use of Spice for nonlinear models.

list, and a component value. Notice that Spice allows you to use standard units; in the example, R1 appears as "10KOhm" instead of "10000Ohms." Spice allows you to prefix all units with MEG (10⁶), K (10³), m (10³), u (10⁶), n (10⁹), p (10¹²), and several other multipliers.

The listing in Fig 4 ends with two simulation control commands (TRAN and AC), two print commands, and an END command.

Use both time and frequency domains

The TRAN command controls the time-domain model. The statement .TRAN 200us 10ms specifies that the output from the time-domain model occurs every 200 μsec for 10 msec.

The AC command controls the frequency model. The statement .AC DEC 50 1 500 specifies that the output of the frequency-domain model will be printed at 50 frequencies for each decade from 1 to 500 Hz.

The two print statements command Spice to print both the transient and frequency-domain values of node 7 as the model executes. Finally, as required by Spice, the END statement appears last in the program.

The Spice model can plot several curves as it executes. Fig 5 (generated with the PROBE output of Microsim's PSpice, as were Figs 6-8) shows the transient (time-domain) response of the system in Fig 3. The lowpass filter's cutoff frequency was set to 2000 Hz (C1 = 0.0082 μF). Note that there is no overshoot.

*Proportional control system with 200 Hz Filter

VI 1 0 AC 1.0V PULSE 0 5 ;Command Signal:
; 1 volt for freq domain (AC)
; 5 volts for time domain (PULSE)
; node 1 is input node
; node 0 is always ground in SPICE

*R1 3 2 10KOhm ;Input resistor
R2 2 3 1Kohm ;Gain resistor
E1 3 0 2 9E ;Use VCVS for ideal op-amp
R4 2 7 10KOhm ;Feedback Resistor

*Low Pass Filter. Break frequency = 1/(2*pi*(C1*R4)) = 300 Hz.
R5 3 4 10Kohm ;Low pass filter input resistor
E5 5 4 0 0 4 1E ;Use VCVS for ideal op-amp
Cl 4 5 0.082uf ;Low pass filter capacitor
R6 4 5 10Kohm ;Low pass filter resistor

*Plant
B5 5 6 10Kohm ;Plant input "resistor"
E6 7 6 0 0 6 1E ;Use VCVS to form ideal integrator
C2 6 7 0.01uf ;Plant integrator constant
;Node 7 is the output node

*This statement tells SPICE to execute time domain simulations
.TRAN 200us 10ms ;Print every 200us for 10ms.

*This statement tells SPICE to execute frequency domain simulations
.AC DEC 50 1 500 ;50 points/decade from 1 to 500 Hz

*Select voltages to print out
.PRINT TRA V(7) ;Print transient response
.PRINT AC V(7) ;Print frequency domain response

.END ;Required for SPICE

Fig 5—The transient (time domain) response of Fig 3's system shows no overshoot with the cutoff frequency of the lowpass filter set to 2000 Hz (C1 = 0.0082 μF).

Fig 6 shows the response of the system with the cutoff frequency reduced to 200 Hz (C1 = 0.082 μF). The Spice plot in this case shows about half a volt of overshoot. These plots illustrate the general principle that reducing the cutoff frequencies of lowpass filters in control loops usually decreases stability.

You can also use Spice to generate frequency-domain data such as Bode plots. Fig 7 shows the Bode gain plot for Fig 3's system with a 2000-Hz filter. The plot shows that the gain is flat from low frequency to about
40 Hz; after that, the gain gradually declines. This plot indicates that the system is very stable.

**Fig 8** shows the same gain plot when the filter's cutoff frequency is reduced to 200 Hz. Notice that there is additional peaking of about half a dB. Because peaking in the frequency domain generally indicates reduced stability, the gain plots also demonstrate the undesirable effects of reducing lowpass-filter cutoff frequencies.

Notice that the Spice model in **Fig 4** makes no attempt to evaluate noise; it assumes that noise evaluation will be on the actual system. However, you can also use Spice to make noisy voltage sources by amplifying noisy components (for example, intentionally noisy diodes) and then using filters to attain the desired noise spectrum. You can then inject noise into the model and evaluate the system performance in the presence of noise.

If you want to try Spice before you buy it, Microsim...
By providing a simple way to try out ideas, Spice can save you a considerable amount of time when an actual system is difficult or impractical to modify or build.

**Acronyms used in this article**

FIO—First-order lowpass filter  
Spice—Simulation Program with Integrated Circuit Emphasis  
VCVS—Voltage-controlled voltage source

offers an evaluation version of PSpice for PCs for a handling fee of about $10. It has all the features of the production version except that it limits the number of nodes and some elements. It includes the PSpice simulator, behavioral modeling, a "simulation oscilloscope," and several other enhancements to standard Spice. This evaluation version performed the simulation and drew all the original plots for this article.

By providing a simple way to try out ideas, Spice can save you a considerable amount of time when an actual system is difficult or impractical to modify or build. Its frequency- and time-domain plots can help you evaluate stability, response, parameter sensitivity, disturbance rejection, and other important measures of control-system performance.

**References**


**Author’s biography**

George Ellis is a senior project engineer with Industrial Drives in Radford, VA, where he designs electronics and real-time software. He holds BSEE and MSEE degrees from Virginia Tech and serves on the IEEE IAS Industrial Drives Committee. George is the recent author of Control System Design Guide (Academic Press Inc, 1990).

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**Fig 8**—Additional peaking of about half a dB occurs when the filter’s cutoff frequency is reduced to 200 Hz.
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Vintage filter scheme yields low distortion in new audio designs

Digital audio systems having wide dynamic range can strain antialiasing and anti-imaging filter requirements. Increasingly, audio designers are employing an almost forgotten filter architecture, the GIC filter, to achieve simplicity while meeting adequate attenuation and low-distortion requirements.

Rick Downs, Burr-Brown Corp

Digital-audio designers are constantly concerned about noise, total harmonic distortion, and phase linearity. To prevent aliased noise and distortion, designers, using an antialiasing filter, must limit the bandwidth of the audio signal before the signal reaches the analog-to-digital converter (ADC). Using an anti-imaging filter, designers must also limit the bandwidth of the audio signal coming from the digital-to-analog converter (DAC). However, maintaining an acceptable phase linearity for a filter that matches the dynamic range of converters having 16-bit or greater resolution can be a challenging task. More and more digital audio designers are utilizing an early filter architecture, the Generalized Immittance Converter (GIC), to meet this challenge.

The GIC (Fig 1) is a 2-port network whose input impedance is:

$$Z_{in}(s) = \frac{Z_1(s) Z_3(s) Z_5(s)}{Z_2(s) Z_4(s)}$$

Fig 1—The topology of a Generalized Immittance Converter (GIC) can simulate the impedance of any passive component, including a frequency-dependent negative resistor (FDNR).
An active GIC filter can simulate the transfer characteristics of a passive LC ladder network.

where \( s \) is the standard Laplacian operator. When impedance \( Z_{2q} \) is capacitive and the other impedances are resistive, the GIC’s input impedance simulates an inductor.

\[
Z_m(s) = \frac{s R_1 C_4 R_5}{s^2 C_4 R_4 R_5}
\]

You can also simulate an inductor by making \( Z_4 \) capacitive and the remaining impedances resistive. When you make any two of the numerator impedances capacitive, such as \( Z_1 \) and \( Z_5 \), and the other impedances resistive, the GIC simulates a frequency-dependent negative resistor (FDNR).

\[
Z_m(s) = \frac{R_3}{s^2 C_1 R_2 R_4 C_5}
\]

The impedances you make capacitive have different circuit implications. If you make \( Z_1 \) a capacitor, and the filter is ac-coupled, the operational amplifier, IC, will not have a bias-current return path, which could affect the filter’s operation. When you make \( Z_3 \) and \( Z_6 \) capacitive, the op amps in the GIC all have a bias-current return path.

Audio designers generally make \( Z_1 \) and \( Z_5 \) capacitive, letting you set \( R_2 = R_3 \) (\( Z_2 = Z_6 \)) to minimize the effect of op-amp gain-bandwidth mismatch. If you configure the GIC with capacitors for \( Z_3 \) and \( Z_6 \), you should employ op amps with well-matched gain bandwidths.

An active GIC filter can simulate the transfer characteristic of a passive LC ladder network (Fig 2a). You transform an LC ladder network into an active GIC filter by multiplying each ladder network element by \( 1/s \). The transformation changes all the inductors to resistors, the capacitors to FDNRs, and the resistors to capacitors (Fig 2b). You can set \( R_1 = R_2 \) and \( C_5 = C_6 \), allowing you to trim the filter using only one component, \( R_4 \).

Because the GIC filter simulates an LC filter, it has a lower sensitivity to component value variations than other RC active filters, such as the familiar Sallen and Key topology (Ref 1). In addition, the GIC filter topology lets you design high-order filters having unity gain, whereas the Sallen and Key filter topology (Fig 3) often requires gain greater than unity to derive real resistor values.

To illustrate an active GIC filter design, consider the filter requirements in a practical digital-audio record and playback channel. Modern digital-audio channels oversample the recorded bandwidth using a sampling rate that is greater than \( 4 \times \) the Nyquist rate. Multiplying the recommended standard 48-kHz audio sampling rate by a factor of 4 produces the standard 192-kHz \( 4 \times \)-oversampling rate.

Such a high oversampling rate eliminates the need for “brick-wall” attenuation slopes and eases limitations on allowable phase distortion, hence allowing you to use lower-order—and lower-cost—anti-aliasing and anti-imaging filters. In addition, it avoids the manufacturing difficulties and nonlinear group delay associated with brick-wall filters.

**Playback devices assist anti-imaging**

The anti-imaging filter’s attenuation requirements benefit from the attenuation provided by three factors in the playback channel. The first factor is the attenuation characteristics of the digital interpolation filter that precedes the DAC. The filter interpolates the data between samples and removes most of the signal energy above 20 kHz to prevent aliasing by the DAC.

![Fig 2](image_url)—An LC ladder network generates any lowpass-filter polynomial (a). You can simulate the filter’s transfer function by multiplying each element value by \( 1/s \) and realize the filter using GICs (b).
The second factor is the frequency response and linearity of the output power amplifier. The power amplifier bandwidth is generally restricted to 20 kHz, which attenuates higher-frequency energy. A caution however: Noise-shaping DACs have significant out-of-band energy, which, if the amplifier becomes nonlinear, can create intermodulation products.

The third factor is the frequency response of the DAC. Because a DAC maintains the analog value of each digital sample, the DAC exhibits the frequency response of a zero-order-hold filter given by

$$H(f) = \frac{\sin \left( \frac{\pi f}{f_s} \right)}{\frac{\pi f}{f_s}}$$

where $f$ is the signal frequency and $f_s$ is the sampling frequency. The DAC's $\sin(x)/x$ frequency response can provide 20 dB or more of attenuation in the imaging frequency range, which is 20-kHz removed from the sampling rate.

The antialiasing filter's attenuation requirements are more stringent. Because there isn't a digital filter or a power amplifier preceding the ADC, the filter can't benefit from the additional attenuation provided by these devices. In addition, because you mathematically represent the digital samples from the ADC as impulses in discrete-time, an ADC doesn't exhibit the zero-order-hold response of a DAC.

To match the dynamic range of a 16-bit ADC, the antialiasing filter should theoretically provide 96 dB of attenuation to keep alias responses below the quantization noise level. In practice, however, the amplitude of audio signals in the 10- to 20-kHz range is significantly less than the ADC's dynamic range. Therefore, designers often use 65 dB as an adequate rule of thumb for the antialiasing filter's attenuation. Because of the help it gets in the playback channel, the anti-imaging filter can be of a lower order than the antialiasing filter.

Although you have a wide choice of lowpass filter polynomials, many of these polynomials are not suited for audio applications. Chebyshev and elliptic filters have steep cutoff characteristics, but their large passband ripple can be troublesome in some audio applications. The Butterworth filter has a maximally flat passband response, but its cutoff characteristics are less steep. Because these three types of filters don't exhibit constant group delay, passband frequencies experience unequal time delays that can cause excessive overshoot and ringing in the transient response.

The Thompson filter, also known as the Bessel filter, has constant group delay, which provides excellent transient response in audio and DSP applications. However, the Thompson filter's cutoff characteristics are even less steep than the Butterworth filter's. Therefore, you would need a high-order Thompson filter to achieve the same stopband attenuation as a lower-order Butterworth filter. And because oversampling relaxes the attenuation requirements, you can often employ a 40-kHz Butterworth filter, having tolerable group delay from 20 Hz to 20 kHz, in most 4 x oversampled digital audio systems.

Using a 192-kHz 4 x oversampling rate, a 40-kHz Butterworth antialiasing filter must attenuate the aliasing components in the 160- to 170-kHz frequency range by the rule-of-thumb 65 dB. You determine the order of a Butterworth filter using the following equation:

$$10^{20} = \sqrt{1 + \left( \frac{\omega_s}{\omega_c} \right)^n}$$

where $K_s$ is the stopband attenuation in dB, $\omega_s$ is the minimum stopband frequency, $\omega_c$ is the 3-dB cutoff frequency, and $n$ is the filter order. Solving for $n$ yields

$$n = \frac{\log \left( \sqrt{10^{20}} - 1 \right)}{\log \left( \frac{\omega_s}{\omega_c} \right)}$$
The anti-imaging filter benefits from the extra attenuation of the digital interpolation filter, the DAC, and the power amplifier's frequency response.

Fig 4—A normalized third-order Butterworth filter serves as a building block for the anti-imaging filter (a). You obtain the normalized GIC filter by multiplying each normalized element value by 1/s (b).

Substituting \( K_s = 65 \), \( \omega_s = 2\pi \times 160 \) kHz, and \( \omega_e = 2\pi \times 40 \) kHz yields \( n = 5.4 \). Therefore, you would need a sixth-order antialiasing Butterworth filter. Because the anti-imaging filter benefits from attenuation due to the digital interpolation filter, the DAC's sin(x)/x response, and the restricted power amplifier bandwidth, a third-order Butterworth filter, producing 36 dB of attenuation at 160 kHz, should suffice.

Fig 4a shows the component values for a third-order Butterworth LC filter having a normalized cutoff frequency of 1 rad/sec. You can extract the component values from standard filter tables such as those found in Ref 1. To realize the filter using a GIC, you first transform each component by multiplying each value by 1/s. Therefore, \( L_1 \) becomes \( R_1 \), \( C_2 \) becomes a FDNR having the value \( 1/(s^3C_2) \), \( L_3 \) becomes \( R_3 \), and the terminating resistor, \( R_4 \), becomes \( C_4 \) (Fig 4b). By setting the FDNR values, referring to Fig 1: \( Z_1 = R_1 \), \( Z_2 = R_2 \), \( R_1 = R_2 = 1 \); \( Z_3 = C_3 \), \( Z_5 = C_5 \), \( C_3 = C_5 = 1/s \); and \( Z_4 = R_4 = 1.333 \Omega \). Similar to the circuit in Fig 2b, a single resistor \( (R_4) \) determines the value of the FDNR.

Next you must scale the normalized cutoff frequency to the desired cutoff frequency of 40 kHz. To accomplish frequency scaling, you simply divide all capacitor values by \( \Omega_n = 2\pi \times 40 \) kHz. Finally, you must scale the large capacitor values and small resistor values by an impedance scale factor to realize practical circuit elements. The impedance scale factor is

\[
Z_n = \frac{\text{NORMALIZED C VALUE}}{\text{DESIRED C VALUE}}
\]

Choosing the desired C value to be 1000 pF yields an impedance scale factor of

\[
Z_n = 7.23 \times 10^3.
\]

Multiplying all resistor values and dividing all frequency-scaled capacitor values by \( 7.23 \times 10^3 \) produces the final filter shown in Fig 5a. Because the output impedance of the filter is high, you should buffer the output using an op-amp voltage follower. Fig 6 shows the amplitude and phase response of the final filter.

The measured noise-and-distortion and noise levels show a contrast between a third-order Butterworth filter design based on the familiar Sallen and Key architecture (Fig 5b) and this GIC realization. Noise-
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Because the Sallen and Key filter often requires greater-than-unity gain to realize component values, it can have higher noise gain than the unity-gain GIC filter.

and-distortion measurements were performed using a 1-kHz test signal and a 22-Hz to 80-kHz measurement bandwidth. The noise-only levels were measured in the same bandwidth when the circuit inputs were grounded. The GIC realization achieves a -96-dB noise-and-distortion level that matches the dynamic range of a 16-bit digital audio system.

The Sallen and Key realization achieves a -93-dB noise-and-distortion level that's adequate for most consumer audio systems, but is 3 dB higher than the GIC realization. Simple output-noise level was measured in dBu, referenced to 0 dBu, which equals 0.775 V (RMS). The GIC filter, at -104 dBu, has 7 dB less noise than the Sallen and Key filter. Because the Sallen and Key filter must have greater-than-unity gain to realize the component values, its noise gain is higher than the unity-gain GIC filter.

You can design a sixth-order GIC filter in one of two ways to achieve the 65-dB antialiasing filter requirements. You can extend the previous design procedure using standard element values for a normalized sixth-order Butterworth filter, or you can simply cascade two of the previously designed third-order GIC filters to achieve the sixth-order polynomial.

A design based on a normalized sixth-order Butterworth filter is sensitive to gain-bandwidth mismatches between all the op amps in the circuit, however. If you use this approach you should employ op amps with high gain-bandwidth products. Cascading two third-order GIC filters achieves acceptable results and has fewer op-amp matching difficulties.

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Author's biography
Rick Downs is a strategic marketing engineer in Burr-Brown Corp's component division. He has been with the company for six years, participating in audio-product planning. In the past year, he wrote the materials for one of the company's product application seminars. Rick has a BSEE from the University of Arizona (Tucson, AZ), and he is an IEEE and an Audio Engineering Society member. In his spare time he likes to compose and record music in his MIDI-controlled home studio.

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TOUGH PRODUCTS FOR TOUGH APPLICATIONS.
CIRCLE NO. 170

EDN November 7, 1991
Technique extends EEPROM life

N Kannan
Centre for Development of Imaging Technology, Trivandrum Kerala, India

EEPROMs are excellent read/write media for nonvolatile data storage, but they can handle only a limited number of write cycles. This limitation can be a liability for remote equipment that requires large numbers of write cycles. However, you can extend the EEPROM's operational life by using devices with more memory capacity than you actually need. You can extend the life of the chip by N times, where N is the number of memory banks used. Bank size depends on application requirements, and N depends on the maximum write cycles of the device and the number of cycles required for the particular application.

The technique involves dividing total memory areas into N banks, each bank area being sufficient for the application (Fig 1). Reserve some locations for use as a bank pointer, BP, and in each bank, reserve some location to use as a write-count register. The count register keeps track of the number of write cycles performed in that bank, and the bank pointer points to the current bank in use. Before installation in a system, you should initialize the EEPROM so that the bank pointer points to bank 1 and the count registers equal zero. For each write cycle to the device, memory access is directed to the bank that BP points to, and the software increments the count register by one. When the count register exceeds a certain limit value, the bank pointer advances to the next bank for the next set of write cycles. Also, data in one bank can be block-moved to the next bank when a bank-change operation takes place. 

To Vote For This Design, Circle No. 746

Fig 1—Creating N banks of memory extends an EEPROM write-cycle life by N times. The cost is the added memory.
Battery charger straddles input voltage

Isaac Eng
University of Ottawa,
Ottawa, Ontario, Canada

At times, it's necessary to charge a variable number of cells whose total voltage can be greater or less than the input source voltage. Schemes based on linear-current regulators would be grossly inefficient if required to charge anywhere from one to 10 cells, and would be incapable of charging cells having a total voltage greater than the input voltage. You can sidestep these difficulties, however, using a switched-current regulator.

The circuit in Fig 1 is capable of charging anywhere from one to 10 AA NiCd cells—representing a total voltage from 0 to 15V—with a 5.22V input power source. The recommended charge current is 50 mA. The circuit uses the MC33063 in voltage-inverting mode and switches energy through the 55 µH inductor into the output filter capacitor (C1) and the load. The load consists of the 240 ohm reference resistor and the cells being charged. The reference resistor is normally used to regulate constant voltage, but in this case serves to maintain a constant charge current. The voltage on pin 4 rises or falls to maintain a steady charge current for the number of cells being charged. C2 filters the input, and CT is the regulator timing capacitor. D1 acts as a catch diode, and D2 protects against reverse polarity. Charge-current accuracy depends almost solely on the reference resistor. Other component values and the input voltage need only be approximate.

Charge pump powers high-side switch

Dana Davis
Maxim Integrated Products, Sunnyvale, CA

High-side switches provide a basic method for extending battery life. They eliminate unnecessary power consumption by simply removing supply voltage from peripheral devices and subsystems when the circuits are not in use. The logic-controlled switch circuit in Fig 1 provides output short-circuit protection in addition to low-loss switching and low quiescent current. The actual switch, Q1, is an n-channel MOSFET whose gate drive, which equals VBATTERY +10V, is generated by IC1, a regulated charge pump.

You turn on the circuit by applying VBATTERY to the On/Off input. VOUT (pins 9 and 10 of IC1) then pumps up, reaching VCC +10V in approximately a millisecond and providing power to op amp IC2. To ensure that Q1 remains off until sufficient gate drive is available, a threshold detector internal to IC1 triggers a 0-to-VBATTERY transition at IC1's PR terminal when the rising output equals VCC +8V. When the voltage at the PR terminal reaches VBATTERY, the voltage at IC2's inverting input equals 0.75 × VBATTERY. The transition at the PR terminal also produces a 100-msec pulse at IC2's noninverting input. The pulse, whose amplitude is VBATTERY minus one diode drop, jump-starts Q1 into
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†Midband flat | ‡Gain Compression
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conducting. The comparator-configured amplifier then
compares Q₁’s source voltage with the inverting input
voltage. As long as the source voltage is more positive,
Q₁ remains on.

Feedback through R₁ provides short-circuit protec­
tion. If excessive load current pulls the source voltage
below the reference level at IC₂’s inverting input, the
gate drive goes low and turns off Q₁. Collapsing load
voltage then latches the switch off. To reset, pull the
On/Off input to ground for at least 100 msec.

**EDN BBS /DL_SIG #1050**

**To Vote For This Design, Circle No. 748**

---

**5V powers filter-based oscillator**

Horace T Jones
Rockville, MD

The 5-kHz sine-wave oscillator in Fig 1 operates from
a single supply. For supply voltages from 4.75 to 5.25V,
the frequency shift is ±0.02%, and the change in out­
put voltage is less than 0.01 dB. The circuit can also
operate from higher positive supply voltages, depend­
ing on the particular op amp you use. The circuit is
based on a modified GIC bandpass filter with positive
feedback through the 4.7-kΩ resistor and R₄. With
R₄ = 10 × R₁, the bandpass filter has a Q of 10, which
implies low distortion. The circuit starts reliably and
shows no evidence of spurious high-frequency oscilla­
tion. For split-supply operation, remove R₇, make
R₄ = R₃, and short circuit C₃.

**EDN BBS /DL_SIG #1049**

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---

**Fig 1—A regulated charge-pump IC generates a gate drive equal to V_bATTERY + 10V for the high-side power switch Q₁, an n-channel power MOSFET.**

**Fig 1—Based on a modified GIC bandpass filter, this 5-kHz sine-wave oscillator runs off 5V.**
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TOKIN TECHNOLOGY UPDATE

EDN November 7, 1991

CIRCLE NO. 172
Radiation detector activates alarm

Jim Williams
Linear Technology Corp, Milpitas, CA

The circuit in Fig 1 produces an audible tick each time radiation or a cosmic ray passes through the detector. The LT1073 switching regulator pulses T1, T2 drives a voltage tripler, providing 500V of bias to the detector. R1 and R2 provide scaled feedback to the regulator, thereby closing a control loop. The 0.01-µF lag capacitor adds ac hysteresis, and the 1N5818 Schottky diode clamps T1's negative-going excursions. When radiation or a cosmic ray strikes the detector, its impedance drops briefly, transferring a quick negative-going spike through the 68-pF capacitor. This spike triggers the regulator's auxiliary gain block, which is configured as a comparator. Q1 and Q2 provide additional gain to drive the audible beeper (X1). About 10 to 15 cosmic rays per minute are recorded in a normal environment. The 1.5V operation permits portability and allows you to house the circuit in a small enclosure.

Fig 1—To detect radiation and cosmic rays, this circuit provides 500V of bias to the radiation detector, whose impedance drops sharply when a ray passes through it.

FEEDBACK AND AMPLIFICATION

Reader disputes 8096 shortcoming

I would like to comment on the Design Idea presented by John Liddy entitled, “Macro fixes 8096 shortcoming” in your April 11 issue. Mr Liddy complains that the 8096 clears the entire contents of the program status word (PSW) whenever a PUSHF instruction is executed, resulting in “several undesirable events, including disabling interrupts and clearing all the flags.” I claim that this idiosynrasy is actually a very valuable feature.

I agree that this characteristic may be “quite annoying when all you want to do is to save the contents of the carry flag for future use.” However, consider the more general application for which this feature was designed, namely enhancement of interrupt service routine integrity. One of the bits in the PSW that is cleared by the PUSHF instruction is the global interrupt-enable flag, bit 1. When an interrupt occurs, the 8096 guarantees that the first instruction in the service...
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ISSUE WINNER

The winning Design Idea for the July 18, 1991, issue is entitled "Capacitance meter measures to within 0.3%," submitted by M S Nagaraj of ISRO Satellite Centre (Bangalore, India).

ISSUE WINNER


FEEDBACK AND AMPLIFICATION

routine will always be executed. If this instruction is a PUSHF, then all interrupts are automatically disabled. Thus, the service routine may modify the interrupt mask register and re-enable interrupts without fear of being preempted by another interrupt. This truly wonderful feature allows the programmer to effectively create any interrupt priority structure desired. Also note that a cleared PSW assures the programmer that any instruction executed after a PUSHF will not be corrupted by invalid flag states generated by previous instructions.

Nevitt D Reesor
Woodward Governor Co
Fort Collins, CO 80522

Author replies...

I would like to respond to Mr Reesor by first saying that I agree with him. However, it's not the usefulness of the PUSHF/POPF instructions in interrupt handling that I raised the issue about.

The PUSHF/POPF instructions are the only instructions available to a programmer that allow him or her to access the 8096's PSW directly. Keeping this fact in mind, I remind the reader that a PUSH instruction by definition is not meant to be a destructive operation. The decision to destroy a register's contents should be completely left up to the programmer after he or she has saved the register. My feeling is that the designers at Intel should have given the programmer the ability to use standard PUSH/POP instructions when the programmer desires to simply save the PSW on the stack and the PUSHF/POPF instructions when wanting to use the instructions for interrupt handling.

The relevance of PUSHF/POPF's destroying the contents of the PSW is a purely application-specific issue. The application I am involved with contains many routines that return a true/false condition in one of the various PSW flags. So, the fact that the PSW is destroyed (interrupts are disabled and all flags are cleared) during the PUSHF instruction requires writing a macro to do a nondestructive PUSH of the PSW.

John H Liddy
Simplex Time Recorder Co
1 Simplex Plaza
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CIRCLE NO. 178

EDN November 7, 1991
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Circle # 5

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Free 130-page engineering catalog contains descriptions and technical data on IEC connectors, battery holders, RF/EMI filters and internationally approved power cords. All components are available for off-the-shelf delivery from stock, and are detailed with specifications, ratings and engineering diagrams.

Power Dynamics, Inc.
P.O. Box 539, 59 Lakeside Ave.
West Orange, NJ 07052
201-736-5722 FAX:201-736-8930

Circle # 6
NEW SURFACE MOUNT INTERCONNECT GUIDE

Samtec's new Surface Mount Interconnect Guide features PLCC and DIP sockets, and strips on .050", 2mm and .100" centers. A special section discusses parameters that influence solder joint reliability, lead coplanarity, manufacturability, packaging and contact quality. Additional sections feature applications and product specifications.

Samtec, Inc.
P.O. Box 1147
New Albany, IN 47151-1147
800-SAMTEC-9 FAX: 812-948-5047

Circle # 9

WORK STATIONS, LAB FURNITURE

Twenty-page illustrated guide covers the Teclab line of technical work stations and laboratory systems furniture. Included are versatile work stations of different lengths, combined with a choice of cabinets, shelves, parts drawers, partitions, and other accessories. Catalog has dimensions and shows typical arrangements. It also describes available work surfaces, and has a convenient color selection guide.

Teclab
Kalamazoo Technical Furniture, Inc.
Box 1165
Kalamazoo, MI 49005

Circle #11

FREE 756-PAGE INSTRUMENT CATALOG

Our 1991-92 catalog features over 15,000 of the latest Test, Measurement and Control Instruments available. Included are Air Velocity Meters, Flow Meters, Pressure Gauges, Sound Level Meters, Light Meters, pH Meters, Thermometers, Hygrometers, Force Gauges, Tachometers, Stroboscopes, Gas Detectors, Multimeters, Recorders, Data Loggers, Calibrators, Thickness Gauges, Vibration Monitors and many more. Representing over 150 manufacturers such as Fluke, Honeywell, Dwyer, Alnor, Quest, Simpson, Rustrak and Ametek.

Davis Instrument Mfg. Co., Inc.
4701 Mt. Hope Drive
Baltimore, MD 21215
800-368-2516 FAX: 301-358-0252

Circle #13

INTEL SOLUTIONS960 DEVELOPMENT TOOLS CATALOG

Intel's i960 superscalar architecture brings you the widest range of processors for 32-bit embedded system designs. To help you minimize development costs, we have assembled 125 tools from 50 companies. The Solutions960 catalog includes complete information on all of these tools including: boards, software, modeling & debug tools; real time operating systems; networking products; page description languages, consultants & training. For free copy call 800-548-4725 and ask for A9A23.

Intel Corporation
5000 W Chandler Blvd., CH3-61
Chandler, AZ 85226
800-548-4725

Circle #14
NEW IEEE-488 HARDWARE AND SOFTWARE

This catalog introduces CEC's newest and fastest IEEE-488 hardware and software. Support for Visual BASIC, Turbo Pascal for Windows, a Windows DLL, Turbo C++, BASIC 7, and Quick Pascal are shown. A code generator and instrument libraries for QuickBASIC, Turbo Pascal, Microsoft C and FORTRAN are described along with the latest IEEE-488.2 software.

Capital Equipment Corporation
Burlington MA 01803
Literature: 800-234-4232;
Tech Support: 617-273-1818;
FAX: 617-273-9057

Circle # 15

STD BUS CATALOG

WinSystems' free 470-page databook provides complete detailed technical information on over 200 STD and CMOS STD Bus products for both embedded and DOS compatible systems. The catalog includes non-DOS single board computers, 80-88/286/386 CPUs, memory, Ethernet and ARCNET networks, industrial I/O, card cages with power supplies, video controllers and software tools for use in harsh industrial applications.

WinSystems, Inc.
715 Stadium Drive, Suite 100
Arlington, TX 76011
817-274-7553 FAX: 817-548-1358

Circle # 16

INTERCONNECT COMPONENTS

Mill-Max offers this brand new 88-page catalog featuring America's largest selection of precision-machined PCB pins, pin receptacles, IC socket pins, solder terminals, wrapost receptacles and terminals. New products include space-saving, 0.050" grid low profile and patented compliant tall receptacles and pins. This easy-to-use catalog contains complete specs, plus a handy design guide to assist engineers and buyers in selecting the right component. Also highlighted are Mill-Max's custom design capabilities.

Mill-Max
190 Pine Hollow Road
Oyster Bay, NY 11771
516-922-6000 FAX: 516-922-9253

Circle # 32

COMPUTER VIDEO INTERFACING CATALOG AND HANDBOOK

New 1991 full-line 152 page catalog and handbook contains specifications on over 100 products for interfacing, distributing, switching, and converting computer video signals. Valuable application notes and diagrams are included. Products are available to support PC, Apple, Sun, Wang, Amiga and other computers. Free expert applications assistance and support.

Communications Specialties, Inc.
89A Cabot Court
Hauppauge, NY 11788
516-273-0404 FAX: 516-273-1638

Circle # 18

NEW ALL-PRODUCT CATALOG

A new 110-page Short Form Catalog, No. G-01-A, covering all major Murata Erie products is now available. Included in this new catalog is detailed technical information on the company's complete lines of fixed ceramic capacitors, variable capacitors and resistors. Inductors, crystal oscillators, ceramic filters and resonators, EMI filters, hybrid circuits and much more. Both surface mount and leaded components are included. Detailed distributor availability is also indicated for all product lines. To receive this new catalog, call

800-831-9172

Circle # 19

ELECTRONIC CAD

Powerful, easy-to-use electronic design with the Douglas CAD/CAM Professional System. This fully-integrated package takes you from schematic drawing to final-routed board with the advantage of the remarkable graphics and ease of use of the Apple Macintosh. Features: unlimited multilayer, SMT support and 0.001" resolution.

Douglas Electronics, Inc.
2777 Alvarado Street
San Leandro, CA 94577
510-483-8770

Circle # 20

GLASS EPOXY LAMINATES

The FGM is a rugged, accurate, highly sensitive portable hand-held instrument which can measure dc magnetic fields from 1 gamma (1nTesi) to 2 gauss. It is powered by a conventional 9 V alkaline battery commonly found in portable electronic devices. This instrument can measure dc magnetic fields to an absolute accuracy +/-0.5% on all ranges with linearity of +/- 0.2% (traceable to NIST). The full scale ranges include +/- 2000 milligauss, +/- 200 milligauss, and +/- 20 milligauss. The 3% digit LCD display provides a resolution of 0.05%.

Walker Scientific Inc.
Rockdale Street
Worcester, MA 01606
508-852-2674

Circle # 21

TRIMMER CAPACITORS

New 24 page trimmer capacitor catalog/design manual is the most comprehensive publication available on these products. Covers air dielectric, sapphire dielectric and ceramic types. All are illustrated in a wide variety of sizes, capacitance ranges and mounting configurations. Catalog also includes a section on microwave tuning elements, a device used to introduce a variable reactance to waveguides and other microwave structures.

Johnson Manufacturing Corporation
Rockaway Valley Road
Boonton, NJ 07005
201-334-2676

Circle # 22
AC/DC SWITCHING POWER SUPPLIES AND DC/DC CONVERTERS

This 48-page catalog covers International Power Sources' AC/DC switching power supplies and DC/DC converters. New products include a DC/DC converter for use with flash memory, a 35W universal input tabletop switching power supply, and a 200-650W Eurorack series. Included are 1 to 150W printed circuit board and chassis mount DC/DC converters and 15 to 200W switching power supplies including open frame and chassis mount versions.

International Power Sources Inc.
200 Butterfield Drive
Ashland, MA 01721
508-881-7434 FAX: 508-879-8669

Circle # 23

PROTOTYPE DESIGN AND FABRICATION AIDS

Your product looks better when DATAK is your design partner. Get the 1991-92 catalog of rubdown transfers for marking control panels, parts, EPROM's, circuit boards and prototype projects. Here is a broad line log of rubdown transfers for marking control panels, parts, EPROM's, circuit boards. Another section shows how to order your special transfer designs in any color.

DATAK Corporation
55 Freeport Blvd, #23
Sparks, NV 89431
702-359-7474 FAX: 702-359-7494

Circle # 25

BURR-BROWN POWER CONVERTIBLES

This selection guide provides an overview of over 500 DC/DC Converters offered by Burr-Brown Power Convertibles. It illustrates innovation in power density, small size packaging and surface mount manufacturing. Products are available in miniature SIP and DIP packages as well as other industry standard pin outs. With output power ranging from .450 watts to 25 Watts they come in regulated and unregulated units. Input voltages vary from 5, 9, 12, 15, 24, 18, 48 and output configurations are in single and dual voltages at 5, 9, 12, 15.

Circle # 27

POWER SEMICONDUCTORS & HV SUPPLIES

1991-92 Collmer catalog details Fuji Electric's power semiconductors. Ratings, specifications, outlines drawings. Modules: power Darlington (with high-performance Z-Series); new high-gain 600V and 1200V; new 600V and 1200V IGBT; diode bridge: intelligent power. Also MOSFETs, switching transistors, MOP; and Schottky, fast-recovery and high-voltage diodes. Also cataloged: Collmer's HV power supplies and multipliers.

Collmer Semiconductor, Inc.
14368 Proton Road
Dallas, TX 75255
214-233-1539 FAX: 214-233-0481

Circle # 29

PROGRAMMABLE AC POWER SOURCE

Behlman's brochure highlights the Model ACP Power Source which delivers up to 9,000 VA of clean, single phase or three phase AC power. Frequency is adjustable from 45 to 10,000 Hz, ideal for a wide range of test applications from avionics to instruments and consumer products. Build-in computer allows preprogramming of desired events and computer interfacing. Models start as low as $4430.

Behlman
6 Nevada Drive
Lake Success, NY 11042
800-456-2006 FAX: 805-642-0790

Circle # 24

PUT THE FUN BACK INTO ELECTRONICS!

From low cost test and measurement equipment to valuable additions to your stereo, TV and computer systems, ELEKTOR ELECTRONICS runs the gamut every month! Eletro's eleven yearly issues average fourteen articles each, all world class electronic construction projects from intermediate to advanced-designed, built and tested by staff professionals. Send today for a free copy. Cancel if not satisfied and owe nothing.

Elektor Electronics USA
P.O. Box 876
Peterborough, NH 03458
603-924-9464

Circle # 26

QUALITY

2- and 3-wire power cord sets manufactured to your specifications are available in a variety of NEMA plug configurations, colors, and wire-end terminations to meet your most stringent requirements. All cord sets are subjected to rigorous statistical quality inspection procedures to assure you of Zero Defects. Cord sets are U.L and CSA listed and approved. Call or FAX us your requirements for an immediate quotation.

Kord King
111 New Street
Mt. Joy, A 17552
717-755-8081 FAX: 717-653-6569

Circle # 28

ULTRA-MINI TRANSFORMERS, INDUCTORS, DC-DC CONVERTERS, AC-DC POWER SUPPLIES

New 88-page catalog from Pico Electronics, Inc. is filled with electrical specifications for their line of ultra-miniature transformers, inductors and DC-DC converters. Transformers & inductors available as plug-in, surface mount or toroidal. Inductors are offered with axial leads. More than 850 standard models of converters with single & dual outputs. Their small size (only 0.2" high) makes their encapsulated packaging attractive. Included are low profile AC to DC power supplies, 0.5" ht. up to 55 Watts.

Pico Electronics, Inc.
453 No. MacQuesten Parkway
Mt. Vernon, NY 10552
914-699-5514 (NY) Toll Free: 800-431-1064

Circle # 30

November 1991
STANDARD LOW PRESSURE SENSORS

Monolithic Sensors Inc. offers a folder fully detailing the background and capabilities of the company. MSI engineers and manufacturers standard, semi-custom and custom capacitive pressure sensing devices for a wide variety of applications. For a FREE copy, please contact:

Monolithic Sensors Inc.
2800 W. Golf Road
Rolling Meadows, IL 60008
708-437-8090 FAX:708-437-8144

Circle # 31

CROSS SOFTWARE, DEVELOPMENT TOOLS

C and Modula-2 Cross Compilers, Macro Assemblers and Source Level Debuggers for Motorola and National Semiconductor families of microprocessors and microcontrollers. Introl software runs on MSDOS systems and most workstations.

Introl Corporation,
9220 W. Howard Avenue,
Milwaukee, WI 53228
414-327-7171 FAX: 414-327-7734

Circle # 33

NEW SIMPSON TEST INSTRUMENTS CATALOG

New 44-page full color brochure by Simpson Electric is a guide to the selection of analog and digital test instruments for a wide range of applications. It details Simpson's extensive line of hand-held & benchtop multimeters, special function meters, clamp-on testers & other testers for electrical, electronic and environmental applications. Ohmmeters, voltmeters, ammeters & accessories are also covered. Write:

Simpson Electric Company
853 Dundee Ave
Elgin, IL 60120-3090
708-697-2260 FAX:708-697-2272

Circle # 35

BATTERIES—NI-CAD, ALKALINE AND LITHIUM

Dantona Industries now stocks thousands of batteries for Computers, Portable Phones, Medical, Military and Consumer uses. Our assembly capabilities have also been increased to include the manufacture of specialty packs for Medical, Military and OEM applications. Only the highest quality brand names like: Sanyo, Panasonic, Varta, Saft, Gates, Tadiran, Duraacell and others are used. Our vast inventory of single cells can allow most orders to be shipped Same Day as ordered.

Dantona Industries, Inc.
90 Horton Avenue
Lynbrook, New York 11563
516-596-1515—516-596-1776
FAX: 800-DANTONA Entire U.S.A.

Circle # 37

IC SOCKETS AND CONNECTORS

From Mill-Max comes this updated 72-page catalog of Preci-dip and EuroDip brand IC sockets and connectors. Included are DIP, SIP and PGA sockets, ultra low profile sockets, pin headers, sockets with disposable carriers and PCB connectors. New products include ultra low force PGA sockets, interstitial PGA sockets, space-saving .050" grid interconnects, plus the first machined "truly" compliant solderless press-fit sockets and connectors. Also highlighted are Mill-Max's custom design capabilities.

Mill-Max
190 Pine Hollow Road
Oyster Bay, NY 11771
516-922-6000 FAX: 516-922-9253

Circle # 17

VERS A TERM AND VERS A PRO

Our award winning text and graphics terminal emulation applications VersaTerm and VersaTerm-PRO, use Serial, LocalTalk or Ethernet (TCP/IP, Telnet, FTP, and LAT included) connections to access mainframes like DEC VAX, Cray, Prime and IBM. Our data analysis and graphing application, KaleidaGraph, supports 16 plot types, extensive curve fitting, and flexible text import facilities. All products are Macintosh System 7.0 compatible.

Synergy Software
Reading, PA
215-779-0522 FAX: 215-370-0548

Circle # 34

SIM PSON MICROPROCESSOR CONTROLLERS

New bulletin introduces Hawk series microprocessor controllers with LED display—a highly accurate digital unit for the price of a conventional panel meter. For on/off or limit applications. Hawk is front key-pad programmable with dual set points & alarms, plus dual S A relay option—all in a compact ½ DIN case with password protection & menu programming. Models are available for voltage/current, resistance, RPM & more. Write:

Simpson Electric Company
853 Dundee Avenue
Elgin, IL 60120-3090
708-697-2260 FAX:708-697-2272

Circle # 36

HIGH SPEED PULSE GENERATORS

Over 300 unique models are listed in our new 113 page Catalog No. 8 with a selection of pulse and impulse generators, laser diode drivers, monocyte generators, amplifiers, samplers, delay generators, frequency dividers, pulse transformers, power splitters, scope probes, etc., for PRF to 250 MHz, rise times as low as 40 ps, pulse widths from 130 ps to 100 us and amplitudes to 3000 volts. Over a third of the products are new and the catalog features enlarged selection guides and applications sections.

Artech Electro Systems Ltd.
P.O. Box 5120 Stn. F.
Ottawa, Canada K2C 3H4
613-226-5772 FAX: 613-226-2802

Circle # 38
EMI/RFI FILTER AND CONNECTOR SELECTION GUIDE

New six page brochure describes Spectrum Control's broad EMI/RFI filter product line including tubular filters, capacitors, solder-in filters, resin sealed filters, hermetically sealed filters, multisection filters, filter plate assemblies, filtered connectors, custom filters and EMC testing services. Brochure provides information on applications, features, performance parameters and Fed/MIL approvals for each component.

Spectrum Control
2185 West Eighth St.
Erie, PA 16505
814-455-0966

Circle # 39

UNIVERSAL INPUT POWER SUPPLIES

Universal Input (85-270 Vac) power supplies are featured in Integrated Power Designs' new catalog. Product families range from 45 to 115 watts, and offer one to four outputs. All models are UL, CSA, and TUV certified, or under evaluation. Each power supply has a VDE/FCC class "B" input filter, measures less than 1½ inches high, and offers optional chassis and cover.

Integrated Power Designs, Inc.
9C Princess Road
Lawrenceville, New Jersey 08648
609-896-2122 FAX: 609-895-1738

Circle # 40

CARBORUNDUM NON-INDUCTIVE BULK CERAMIC RESISTORS

New brochure presents high-performance ceramic resistors that exceed performance of conventional film, composition and wire-wound resistors. Designed for high voltages, energies or frequencies. Resistors are available in three types: AS—high-voltage/energy for capacitor crow bar circuits, pulse-forming networks, impulse voltage generators, snubbers, circuits; A—high resistance for grounding resistors, voltage dividers; SP—high-power/frequency loads for parasitic suppression, current limiting, snubber circuits.

The Carborundum Company
Electric Products Division
716-278-2521 FAX:716-278-6270

Circle # 41

NEW FROM MATRIX SYSTEMS A 50 PAGE CATALOG ON SWITCHING SYSTEMS AND MODULES

A full line catalog containing over 50 data sheets arranged in a convenient spiral binder is available from Matrix Systems. The catalog provides descriptions, photographs, specifications, interconnections on a variety of broadband reed relay & solid state switching modules, matrices & systems. Inputs & outputs are compatible with RS-232, RS-422, IEEE-488, 16-bit parallel, and the new VXI bus. For free copy phone:

Matrix Systems
5177 North Douglas Fir Road
Calabasas, CA 91302
818-222-2301 FAX: 818-222-2304

Circle # 42

TUSTIN TRAINING NEWS


Tustin Technical Institute, Inc.
22 East Los Olivos Street
Santa Barbara, CA 93105
805-682-7171 FAX: 805-687-6949

Circle # 43

LOW COST PC COMPATIBLE DATA LOGGER

Displays 8 channels of thermocouple output on computer monitor, saves data on disk, and drives printer. Designed specifically for laboratory and industrial monitoring. Start measuring temperature without involved installations or set-up. Data line powered RS-232 interfaced device puts digital converter at sensing site and eliminates sensor wire rat-nest at computer. Quick-Basic (R)MS source code and compiled program provided to offer user speed and flexibility.

DCC Corp.
7300 North Crescent Blvd.,
Pennsauken, NJ 08110
609-662-7272 FAX: 609-387-4413

Circle # 44

Spotlight your Latest Catalog or Brochure in the Next Issue of EDN Literature Link

1992 Mailing Schedule

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Call Heather McElkenny today at 617/558-4282 or fax at 617/558-4470 to reserve your ad.
ELECTRONIC TEST ACCESSORIES
New 130-page E-Z-Hook Catalog 65 features over 12,000 problem-solving, time-saving solutions to common testing, hook-up, and assembly applications. Products include DIP testing accessories, continuity and voltage testers, multilead assemblies, test leads, wire/cable, components and adaptors, and type N, TNC, BNC, SMA/ UHF coaxial test accessories. Catalog provides product specs, configuration diagrams, application examples, and ordering information.

E-Z-Hook
P.O. Box 450
Arcadia, CA 91006
818-446-6175 FAX: 818-446-0972

Circle # 45

HI-REL MINIATURE DC TO DC CONVERTERS
When size is at a premium, performance is critical, and reliability is a must. Interpoint miniature DC-DC converters are the industry leaders. Interpoint's newly expanded line of over 150 converters is described in this 16-page catalog. Input voltages range from 5 to 48 volts with power outputs from 1 to 200 watts in single, dual and triple-output models. Both commercial and HI-REL military models are described. Including hermetically sealed metal components with full environmental screening options. EMI filters and custom DC-DC converters are also available.

Circle # 46

PROGRAMMABLE POSITION CONTROL
A complete 416 page engineer's guide with specifications, dimensions and performance data presents brushless servos, microstepping motor systems, indexes, linear motors and absolute encoders.

Parker Hannifin Corporation
Compumotor Division
5500 Business Park Drive
Rohnert Park, CA 94928
800-358-9070 FAX: 707-584-8015

Circle # 47

REAL-TIME ADA-PROVEN SOLUTIONS
Brochure describes the advantages of using Ada for large, real-time applications and embedded systems that demand extremely reliable code. Highlighted are Alsys products, the leading crosscompilers and tools for such applications. Products include cross-development systems for a wide range of host machines and target microprocessors and a complete set of software engineering tools.

Alsys, Inc.
67 South Bedford Street
Burlington, MA 01803-5152
617-270-0030 FAX: 617-270-6882

Circle # 48

INDUSTRIAL COMPUTERS SELECTION GUIDE
Pro-Log's Industrial Computers with modular, standard I/O schemes are ideal for environments where temperature, shock, vibration and reliability are a concern. The 224 page Selection Guide features specifications on over 60 products. An applications section guides the user through system design. Systems are available as an integrated PLC, a 286/386 PC/AT compatible, a high speed 32-bit workstation, and in real time configurations.

Pro-Log Corporation
2555 Garden Road
Monterey, CA 93940
800-538-9570 FAX: 408-646-3517

Circle # 49

DC/CAD USERS
Additions to our product:
• Edif Out and Xilinx Interface (11/91)
DC/CAD currently features:
• Schematic, PCB Layout and Autorouting
• Autoplacer and Design Rule Checker
• Two way Gerber and DXF support
• L-mil rip up and Retry Autorouter
• WINDOW 3.0 with VMS
• Opt Autoground plane and simulation

Design Computation, Inc.
1306 Highway 33
Farmington, NJ 07727
908-938-6661 FAX: 908-938-6662

Circle # 50

DAWN VME PRODUCTS FULL-LINE CATALOG
Dawn VME Products offers it's Product Catalog, filled with information on the full product line. Dawn's catalog includes both VMBus and SUNbus backplanes, extension boards, slot bypass boards, slot load boards, card cages and enclosures, power supplies, fully assembled, packaged systems, and more. The back section features technical specifications on general Eurocard, VMEbus and SUNbus requirements.

Dawn VME Products
47073 Warm Springs Blvd.
Fremont, CA 94539
800-258-DAWN FAX: 510-657-03274

Circle # 51

HOW TO PROTECT YOUR COMPUTER
FREE, money-saving literature tells you what you need to know about uninterruptible power systems (UPS). Best Power Technology's advanced technology, on-line UPS gives you complete protection from power line problems, including surges, sags, spikes, noise, brownouts, blackouts and lightning. BEST, the world's largest manufacturer of single-phase UPS, can protect your computer with models ranging in size from 500 VA through 18 KVA. For more information contact:

Best Power Technology, Inc.
P.O. Box 280
Necedah, WI 54646
608-565-7200 ext. 2876, 800-356-5794 ext. 2876

Circle # 52

November 1991
DATA CONVERSION COMPONENT DATABOOK

DATEL’s new 294 page, data sheet formatted, Data Conversion Component Databook details over 232 product models covering the latest in data acquisition technology. Sampling Analog-to-Digital Converters, Active Filters, Hybrid Data Acquisition Systems, Amplifiers, Analog-to-Digital Converters, Sample & Hold Amplifiers, Analog Multiplexers, Digital-to-Analog Converters In addition, more than 42 product models are showcased.

Datel Inc.
11 Cabot Boulevard
Mansfield, MA 02049-1184
508-339-3000 TLX: 174398
FAX: 508-339-8356

Circle # 53

F.W. BELL’S HANDHELD MULTIMETER

Versatile, hand-held and easy-to-use F.W. Bell’s C-600 Multimeter utilizes advanced Hall-effect technology to measure ac voltage and resistance. It’s jaw-like clamp permits measurement without breaking the circuit or disturbing insulation. The unit features a 3 1/2 digit LCD display and is accurate within 1%. The C-600 complies with IEC 348 Safety Requirements for Electronic Measuring Apparatus.

F.W. Bell, Inc.
6120 Hanging Moss Road
Orlando, FL 32807
407-678-6900

Circle # 54

TEMPORIC IC DATA BOOK

The complete reference tool for telecom design engineers. Contains 288 pages of specifications for:
- DTMF receivers and transceivers
- Call progress tone receivers and transmitters
- MF trunk receivers and transmitters
- Key system/PBX enhancements
- Test and demonstration equipment
- Product application notes for design-ins

Teltone Corporation
22125-20th Avenue SE
Bothell, WA 98021-4408
800-426-3926 FAX: 206-487-2288

Circle # 55

XEROX ENGINEERING SYSTEMS OFFERS FREE SUBSCRIPTIONS TO TEMPLATE MAGAZINE

Template: The Magazine of Engineering Systems and Solutions is written and designed for people involved in the creation, management and distribution of engineering documents. Topics include how engineers will create and manage their documents at the turn of the century to how the principle of concurrent engineering is becoming the status quo. Template also features a “Solutions” section that contains tutorials on how customers have improved productivity and document quality.

To order your free subscription call
800-832-6979 ext TEMP

Circle # 56

CURRENT, VOLTAGE, POWER, TRANSDUCERS

Featured in this catalog are AC and DC current sensors, AC and DC current level detectors, frequency transducers, AC/DC current sensors, AC and DC current level sensors. Specifications, descriptions, photos of these units are provided as well as application and ordering information.

American Aerospace Controls, Inc.
570 Smith Street
Farmingdale, N.Y. 11735
516-694-5100 FAX: 516-694-6739

Circle # 57

HEWLETT-PACKARD LCR METERS, IMPEDANCE ANALYZERS AND TEST FIXTURES SELECTION GUIDE

Includes HP’s new low cost LCR Meter, Milliohm and High Resistance Meters. Select the best measurement solution for a wide variety of test devices. Text fixtures are shown with cross-compatibility information and a HP Application Note guide is provided.

Hewlett-Packard,
Attn: Inquiry manager
19310 Pruneriidge Ave., Bldg 49A
Cupertino, CA 95014-9795
800-452-4844

Circle # 58

E(E)PROM PROGRAMMERS

Reliable, fast and easy to use, Needham’s Electronics E(E)Prom programmers are available in PC based or stand-alone models. Supporting 2716-4Megabit devices, Needham’s programmers are capable of support for the latest in EPROM technology. Whether your needs are development or production, Needham’s Electronics offers an affordable model to meet your programming requirements. All models are made in the USA by Needham’s Electronics

Needham’s Electronics
4539 Orange Grove Ave.
Sacramento, CA 95841
916-924-8037 FAX: 916-972-9960

Circle # 59

FREE CIRCUIT PROTECTION CATALOG

84-page catalog details the full line of circuit protection devices offered by MP (Mechanical Products, Inc.) Selected by NASA as one of the top forty out of ten thousand suppliers, MP offers reliable, high-precision circuit breakers in a variety of configurations. New to the MP line is the Series 24 switchable circuit breaker, featuring single- and two-pole protection combined with a handsome, lighted Power On/Off switch or with an optional toggle handle.

Mechanical Products, Incorporated
1824 River Street
Jackson, MI 49204
517-782-6914 FAX: 517-782-2810

Circle # 60

November 1991
8-Bit A/D Converters

- Optimized for DSP use
- Low distortion, high linearity

A family of three 8-bit A/D converters targets DSP applications such as disk drives and video processing. The TLC5502-5 and TLC5503-5 are for use in high-speed servo control, voice-coil control, and read-write circuits in disk drives. Specifications include a 0 to 5V input range, a 10-MHz sampling rate, a 50-dB S/N ratio, -51-dB THD, and ±1 LSB nonlinearity. The third device, the TLC5503-2, is for video applications such as digital TV and video processing. Specifications include a 3 to 5V input range, a 20-MHz sampling rate, ±1 LSB nonlinearity, and 0.6% differential gain and phase. The converters come in 24-pin SO packages. TLC5502-5, $10.44; TLC5503-2 and TLC5503-5, $8.34 (1000).

Texas Instruments Inc, SC-91044, Box 809066, Dallas, TX 75380. Phone (800) 336-5236, ext 700; (214) 995-6611, ext 700.

Circle No. 392

Protocol Controllers

- Meet SCSI II standards
- Feature reduced host-CPU intervention

The MB86601 and MB86602 8-bit protocol controllers are designed to meet SCSI-2 specifications. By integrating a high-speed internal processor and 256 bytes of RAM, the controllers reduce the need for host-CPU intervention. These features facilitate combination command processing and command queuing. Command processing enables the user to define a “stack” of instructions and to perform multiple SCSI operations by issuing a single instruction. Execution from internal memory makes the SCSI operation invisible to the CPU. In addition, you can implement command queue structures within the internal memory to optimize command processing. The controllers also offer a 40-bit transfer counter, with the lower 24 bits supporting variable block sizes to 16 Mbytes/block. The upper 16 bits support multiple block transfers to 64k blocks/transfer. Additional features include a synchronous bus-transfer rate of 10 Mbytes/sec, and an asynchronous transfer.

EDN November 7, 1991
Once our Fast Statics met up with Hewlett-Packard, the attraction was obvious.

With new 256K BiCMOS devices, Motorola helped unleash the speed to empower HP's hottest workstations: The HP Apollo Series 700.

What made our 64K x 4 and 32K x 8 Fast SRAMs such a design-in favorite at HP? Performance for one thing. Availability for another.

With both 10 and 12ns versions already shipping, these TTL-compatible devices provide the sheer speed required by the world's fastest workstations.

Once again, Motorola has what it takes to enhance system performance. Like preeminent technology. Relentless product support. And a growing family of BiCMOS devices to accelerate your next design.

Want to give our BiCMOS Fast SRAMs a try? Just complete and send in the coupon on the opposite page. We'll introduce your design to powerful new friends. Faster than you thought possible.

If you like what's new, wait 'til you see what's next.
INTEGRATED CIRCUITS

rate of 5 Mbytes/sec. The MB86601 is for single-ended applications; the MB86602 supports differential and single-ended applications with external transceivers. The devices are available in 100-pin quad flatpacks. $19.95 (1000).

Fujitsu Microelectronics Inc, 3545 N First St, San Jose, CA 95134. Phone (800) 642-7616; (408) 922-9000. Circle No. 393

Disk-Drive Read-Channel IC
- Has 24 Mbps speed
- Integrates all read-channel functions

Featuring a speed of 24 Mbps, the PCA2400 integrates all of the circuitry associated with read-channel functions for a hard-disk drive. These functions include a pulse detector with programmable AGC, a programmable filter, a frequency synthesizer for zone recording, a data separator, a 1/7 ENDEC with write precompensation, and a serial interface for mode control. The chip also includes quad peak detectors to support servo search and tracking. A programmable power-management feature has eight separate power-down modes. The PCA2400 operates from a 5V supply and comes in an 80-pin plastic quad flatpack. $10 (OEM).

GEC Plessey Semiconductor, 1500 Green Hills Rd, Scotts Valley, CA 95066. Phone (408) 438-2900. Circle No. 394

Dual-Port SRAM Modules
- Have parity-bit capability
- Access speeds as fast as 30 nsec

A family of four dual-port static RAM modules contains devices having either a 9-bit- or 36-bit-wide data path. The × 9 and × 36 configurations provide designers with a parity bit for error detection in telecommunication and data-communication systems. The available devices are the 8k × 9-bit IDT7M10004, the 16k × 9-bit IDT7M1005, the 1k × 36bit IDT7M1011, and the 2k × 36-bit IDT7M1012. The 9-bit modules have access times of 35 nsec; the 36-bit modules have access times of 30 nsec. Each module is tested as if it were a single monolithic component, using guard-banded ac and dc parametric tests over the operating temperature range. The 9-bit modules come in 60-pin ceramic DIPs; the 36-bit modules come in 121-pin pin-grid-array packages. From $170 to $365 (100).

Integrated Device Technology Inc, Box 58015, Santa Clara, CA 95052. Phone (408) 727-6116. FAX (408) 492-8674. Circle No. 395

EDN November 7, 1991
Killer Specs.

Panther® SCSI

Stalking system performance is your goal. That's why Maxtor's 1.2GB SCSI Panther was designed to perform a data seek in just 13ms. No other drive in its class features such lightning speed.

Panther's hunting prowess of 2ms track-to-track seek time stands out compared to Seagate's Wren 7 seek time of 2.5ms. And Panther outruns the competition with a 30Mb/sec. internal transfer rate.

Experience counts. Panther uses the reliable head disk assembly used in the Maxtor XT-8000, which boasts more than 300,000 units in the field. Panther shreds the competition with the widest range of available controllers, an MTBF of 150,000 hours, Novell certification and a highly competitive price.

Call about the full line of Panther drives that range from 1.2GB to more than 1.7GB capacity. If you're stalking performance, check out Panther's killer specs. Call your nearest Authorized Maxtor Distributor.

<table>
<thead>
<tr>
<th>1GB-plus Disk Drive Comparison Criteria</th>
<th>Maxtor Panther P0-12S</th>
<th>Seagate Wren 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity [unformatted]</td>
<td>1.2GB</td>
<td>1.2GB</td>
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<tr>
<td>Seek Time</td>
<td>13ms</td>
<td>15ms</td>
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<tr>
<td>Track-to-Track</td>
<td>2ms</td>
<td>2.5ms</td>
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<tr>
<td>Internal Transfer</td>
<td>17.4 to 29.7Mb/s</td>
<td>15-23Mb/s</td>
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<tr>
<td>Maximum Seek</td>
<td>26ms</td>
<td>34ms</td>
</tr>
</tbody>
</table>

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NEW PRODUCTS

COMPONENTS & POWER SUPPLIES

Miniature Switches
- Available in two styles
- Rated for 15.1A operation
V7 Timesaver Series miniature on-off/one switches are available in two quick-connect styles—the D8 (0.187 in. wide) and the E9 (0.250 in. wide). The line includes more than 800 configurations, which have electrical switching ratings ranging from 100 mA to 15.1A. Additional standard features include a choice of silver serrated or gold projection contacts, three operating forces, seven actuator styles, and standard or metric mounting styles. Operating range spans -40 to +85°C. The switch line is specifically designed to provide cost-effective, time-based advantages in delivery. From $0.45 to $2.90.
Micro Switch, 11 W Spring St, Freeport, IL 61032. Phone (815) 235-6600. Circle No. 380

Interconnect Assemblies
- Available with shielding
- Offer 60-position capacity
MSI multisignal interconnects are available with or without EMI/RFI shielding. The assemblies are available with standard impedances of 50 to 95Ω. The connectors will terminate with FEP, PTFE, or fluorotextile cables. Standard end-to-end or daisy-chained terminations are offered. Available in 10- to 60-position versions, the socket connectors mate with 0.025-in. square or round pins on a 0.1 x 0.1-in. grid. The connectors are compatible with lock-and-eject headers and are available in high or low profile configurations. Current rating equals 1A and contact resistance measures 5 mΩ. The beryllium copper contacts are finished with 30 μin. of gold inlay over 50 μin. of nickel. The connectors carry a UL 94V-0 rating and operate over a -40 to +105°C range. Double-ended, 50- position assembly, which includes 36 in. of EMI/RFI shielded FEP cable, $62.19 (1000).
Meritec, Box 5003, Painesville, OH 44077. Phone (216) 354-3148. FAX (216) 354-0509. Circle No. 381

Passive Delay Lines
- Designed for surface-mount applications
- Delays range to 250 nsec
All units in these three series of lumped-constant passive delay lines are designed for surface-mount applications involving TTL or ECL circuitry. SMWD Series devices are housed in 0.2-in.-high DIPs. They are available with 50, 100, 200, 350, and 500Ω impedances. This line includes 188 models with delays ranging from 1 to 250 nsec. The SMD Series includes 40 models with delays ranging from 5 to 200 nsec. These units feature delay taps at 10% increments, are also housed in 14-pin DIPs and are available in versions with 50, 100, and 200Ω. The SMMD Series includes 40 models with delays of 5 to 200 nsec. Each model in this line features three separate and isolated delay lines. These devices are housed in 16-pin DIPs and feature 50, 100, or 200Ω impedances. SMWD Series devices, $10; SMD Series, $20; SMMD Series, $22 (100).
Engineered Components Co, 8121, San Luis Obispo, CA 93403. Phone (805) 544-3800. FAX (805) 544-8091. Circle No. 382
WHEN YOU PLUNGE INTO ASIC DESIGN, YOU WANT SUPPORT TOOLS THAT WORK.

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Oki's advanced tools provide the lift you need to dive comfortably into high-level ASIC design:

- **Timing-driven layout** - for an improved design-to-silicon match.
- **Clock tree structures** - for optimized clock distribution.
- **Power calculator** - for increased overall system reliability.

Coupled with our 0.8µm SOG technology and high-level support—such as Verilog, Synopsys, and IKOS—these Oki software tools optimize ASIC performance and design time.

So take the plunge. Call 1-800-OKI-6388, Dept. 050, for Oki's ASIC capabilities brochure. See how risk-free ASIC design can be.

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<table>
<thead>
<tr>
<th>Vendor</th>
<th>Platform</th>
<th>Operating System/Application</th>
</tr>
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<tbody>
<tr>
<td>Cadence</td>
<td>Sun/Solbourne</td>
<td>Verilog: Simulation, fault grading, design verification</td>
</tr>
<tr>
<td>IKOS</td>
<td>IKOS</td>
<td>Simulation, fault grading</td>
</tr>
<tr>
<td>Mentor</td>
<td>HP/Apollo</td>
<td>Design capture, simulation</td>
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<td>Graphics</td>
<td>Sun/Solbourne</td>
<td>Parade: Layout, clock and timing structures</td>
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<td>Synopsys</td>
<td>Sun-4</td>
<td>Design synthesis, test synthesis</td>
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<td>interface to Mentor, Valid, Viewlogic</td>
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<tr>
<td>Valid</td>
<td>Sun/Solbourne</td>
<td>Design capture, simulation</td>
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<td></td>
<td>DECstation 3100</td>
<td>Design check, GED, ValidSIM, RapidSIM</td>
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<td>IBM RS6000</td>
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<td>Design capture, simulation</td>
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<tr>
<td></td>
<td>PC386</td>
<td>Design check</td>
</tr>
</tbody>
</table>

Oki ASIC Design Tool Support for 0.8µm, 1.0µm, & 1.2µm
Test Sockets

- Have a 0.50-in. contact pitch
- Feature wiping action contacts

Series 550/560 molded carrier-ring test and burn-in sockets are available with 0.5- and 0.65-mm contact pitches. The units feature normally closed contacts that provide maximum wiping action at the point of contact. The devices are available in 26- and 46-mm sizes and operate over a −565 to +150°C range. Compatible with surface mount applications, the devices meet all JEDEC specifications. They feature open-frame bodies to maximize air flow across the devices under test. A pressure plate in the socket lid prevents package damage. Support rings in both the socket base and lid eliminate the possibility of the test pads’ being damaged. Receptracks are available for all sockets in the series. A 256-lead, 46-mm version, $105.40 (250).


LED Display Module

- Measures to 199.9 mV
- Accurate to 0.1%

Model DPM5135 is an LED panel meter module that has a basic measuring range of 199.9 mV dc. Module accuracy is specified at 0.1% ±1 digit. The unit features simple snap-in mounting and a self-contained bezel. The readout features 0.56-in.-high digits. Input impedance is greater than 10Ω, and supply requirements are 5V at 130 mA. Decimal-point position is user-selectable. The unit measures 3.1 x 1.7 x 0.95 in. and weighs approximately 1.6 oz. Operating range is specified at 0 to 70°C. $22.55 (100). Delivery, stock to six weeks ARO.

DI International Inc, 95 E Main St, Huntington, NY 11743. Phone (516) 673-6866. Circle No. 384
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These days, the bottom line is the top priority. Which is why Ricoh designed our FT6750 copier to automatically feed, edit, sort, cover and staple reports. The RICOH FT6750 does it all for under $15 a day. So get your office running at top speed for less than top dollar. Call 1-800-63-RICOH, ext.1350, now.

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CIRCLE NO. 184

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LET YOU INTERFACE
WITH MICROPROCESSOR-
CONTROLLED EQUIPMENT.

ESTABLISH DATA RATE
SELECT ADDRESS
REPLACE THUMBWHEELS

- Only half-an-inch in diameter!
- Choice of 16 or 8 positions maximum
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- Shorting contacts
- Very affordably priced
- Off-the-shelf availability through your local Grayhill distributor

Ask for Bulletin Number 438 with code and truth table and detailed specs.

See us at WESCON Booth #1241-1243

CIRCLE NO. 185

COMPONENTS & POWER SUPPLIES

DC/DC Converters
- Output 15W
- Have 82% efficiency

NWS-H Series dc/dc converters accept inputs of 9 to 18, 18 to 36, or 36 to 72V and develop a 5, 12, or 15V output. The devices develop an output of 15W and have efficiencies of 79 to 82%. Maximum load- and line-regulation figures equal ±1 and ±0.5%, respectively. Maximum ripple and noise is less than 50 mV p-p, and isolation voltage equals 500V dc min. The units feature remote shutdown, and continuous short-circuit protection. The converters are housed in an EMI/RFI shielded package that measures 2 x 2 x 0.4 in. $110.

International Power Devices Inc, 155 N Beacon St, Brighton, MA 02135. Phone (617) 782-3331. FAX (617) 782-7416.

Circle No. 385

DC/DC Converters
- Provide a single output
- Feature 0.2% regulation

DC1-1-x/x series dc/dc converters accept inputs of 5 or 12V and provide an output of 5, 12, or 15V with a 1W power-output capability. Minimum MTBF, calculated per the parts-stress method outlined in MIL STD-217E, equals 10⁶ hours. Standard features include 30-mV p-p max ripple and noise, line and load regulation of ±0.2% max, and 500V dc input/output isolation. All models include indefinite short-circuit protection, reverse-voltage protection, and foldback current limiting. An input pi filter eliminates reflected ripple current. Each converter is housed in a 1.25 x 0.80 x 0.4-in. phenolic package that carries a UL 94V-O rating. Operation is specified over a −25 to +70°C range with no derating. Cooling is via natural convection. $54.

Power General, 152 Will Dr, Canton, MA 02021. Phone (617) 828-6216. FAX (617) 828-3215.

Circle No. 386

See us at WESCON Booth #1241-1243
Now there's a 12-bit Data Acquisition System that gives you easy access to the analog world.

Unsurpassed integration makes analog design easy.

When crossing the border from analog to digital the last thing you want is excess baggage.

That's why we designed the industry's first +5V 12-bit plus sign Data Acquisition System, the LM12458. A highly integrated one-chip solution that not only shrinks board space but also reduces design and debug time.

Versatility through software programmability.

Easily configured via software, the LM12458 lets you change your setup "on the fly." An eight-word instruction RAM stores your commands, which are then carried out by the on-chip sequencer.

These commands allow you to choose which input channels to access and the type of conversion to be performed. The results are then stored in a 32-word FIFO.

With conversion times of 8.8μs (12-bit plus sign), 4.2μs (8-bit plus sign), and 2.2μs ("watchdog" comparison mode) you get optimized system performance at a throughput rate of 87kS/s min. A four-channel version will be available in 1992.

Single +5V Operation.

With single +5V operation, you get all this performance while consuming just 30mW max (50µW in standby mode).

What's more, the LM12458's self-calibrating architecture ensures high accuracy over time and temperature.

Access us with one easy call.

For a free software design kit and more information, call: 1-800-NAT-SEMI, Ext. 143.

And gain duty-free passage to the analog world.
And, for those who require a +12 volt output for flash memory or other functions, the companion unit offered is a 1 MHz step-up Boost Converter.

Power Trends' Power Chipset™ drastically cuts component count and simplifies your design. This means lower costs and shorter time to market!

Last year, Power Trends' 1.5 Amp product was voted the power supply innovation of the year by EDN magazine. Recently, the Power Chipset™ has been recommended by Intel for use in their 386™SL Mustang Notebook Computer.

If you are designing notebook computers or other battery operated products, then Power Trends has the power conversion products for you. Call or write for more information about the Power Chipset™ for Notebook Computers from Power Trends. Samples are available now. Call today.
Lithium Battery
- **Develops a 9V output**
- **Has a 10-year life**

The CR 9V lithium manganese dioxide battery has a 10-year life expectancy. The unit has a 950-mAhr capacity and is built from cells with 25% more energy density than conventionally built LiMnO2 batteries. The unit is protected against overcharging or polarity reversal and is designed primarily for low-drain applications. The stainless-steel case, laser-welded fabrication, and bobbin-type configuration of the lithium cells provide for a very low self-discharge of 0.5%/year. Operating range spans -30 to +75°C. $9.99 (1000). Delivery, three to five weeks ARO.

**Varta Batteries Inc**, 300 Executive Blvd, Elmsford, NY 10523. Phone (914) 592-2500. FAX (914) 592-2667. **Circle No. 387**

Suppression Networks
- **Have a 94V-0 UL rating**
- **Rated for 250V ac operation**

XYE Series EMI/RFI ac noise-suppression networks provide normal- and common-mode attenuation. Designed for pc-board mounting, the networks feature one X and two Y suppression capacitors in a single package. The line consists of 75 models in three distinct package styles. All models meet the requirements of eight worldwide safety agencies at 250V ac. The networks feature double-wound, oil-impregnated metallized polyester construction. The case material and internal potting carry a UL 94V-0 flammability rating. The internal potting is designed to prevent expulsion of material under damaging surge conditions. $0.72 to $1.10 (OEM qty).

**Okaya Electric America Inc**, 503 Wall St, Valparaiso, IN 46383. Phone (219) 477-4488. FAX (219) 477-4856. **Circle No. 388**
No guts.

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The CCD technology that led to Sony’s leadership in color video cameras is now available to you.

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18 models including the world’s fastest. Fewer pins, smaller packages, low power consumption, and guaranteed low error rates.

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To learn more about our custom design support, our competitive prices, and our full line of components, just call us today at (714) 229-4331 or (416) 499-1414 in Canada. You can even FAX us your current requirements at (714) 229-4285 or (416) 499-8290 in Canada.

Sony Corporation of America, Component Products Company, 10833 Valley View Street, Cypress, CA 90630.

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EDN November 7, 1991  CIRCLE NO. 166  309
LITTLE FOOT.
"SIZE IS POWER"
DEBUNKING THE MYTH

The myth of mass.
Many say, "Size is power."
We say different, but understand a few of you may have doubts. Sometimes it’s just hard to believe a device so small can dissipate so much power. A full 2 watts.
But LITTLE FOOT™ does.
It also delivers the highest current rating available, up to 3.5 amps, in a tiny SOIC-8 package. This results from a combination of our unique copper lead-frame design that conducts heat directly from the backside of the die to optimize thermal performance, and our SiMOS 2.5 (2.5 million cells/sq.in.) technology that creates the industry’s highest power density and lowest on-resistance. Just what you need for motor control, load switching, and DC/DC conversion in applications where space and heat are critical constraints.

How else can you design one or two powerful MOSFETs into your system in less than five one hundredths (0.05) of a single square inch?

Use the world’s smallest evaluation board… and see for yourself.
Siliconix simplifies circuit testing by providing you with a mini-evaluation board. It’s only ⅛" x ⅛". Just solder LITTLE FOOT to the mini-board and drop it into your socket. It takes only a few minutes to prove to yourself that 2 watts can be dissipated easily by this remarkable SOIC-8 packaging technology.

LITTLE FOOT is designed for manufacturability.
LITTLE FOOT simplifies your assembly process because Siliconix’s SOIC packaging is compatible with the digital devices on your board. And its two-MOSFET capability means you use fewer components and get higher system reliability. LITTLE FOOT cuts your costs and reduces set-up time. And there are no solder voids, no lead trimming, and no tube jamming. It can also eliminate steps in your production cycle to get your product to market faster.

Get the LITTLE FOOT big advantage.
It runs cooler, saves space, improves reliability, increases efficiency, simplifies design, extends battery life, reduces costs, and cuts time to market. With this kind of designed-in performance it’s not surprising that LITTLE FOOT sales have surpassed 20 million devices.

And that’s fact — not myth.

LITTLE FOOT comes in different versions that are ideal for motor control, load switching, and DC/DC conversion.
- N-ch MOSFETs (duals & singles)
- P-ch MOSFETs (duals & singles)
- N- & P-ch MOSFETs

Voltage: 20-50 V (200 V coming)
On-resistance: 50-300 mΩ
Current Rating: 4.5 A
Power Dissipation: 2 W

Call our toll-free hot line now! 1-800-554-5565, ext 964. Ask for your LITTLE FOOT design kit and evaluation board. And remember at Siliconix we’re bringing a seamless power interface to the digital world.

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Take This Opportunity To Meet Our Distinguished Panel

The PEP™ 4286 Interactive Flat Panel Display

Ideal for Menu-Driven Applications
The PEP™ 4286 interactive flat panel display provides you with a complete touchscreen man-machine interface that is ideal for menu driven applications. PEP 4286 combines a full-dot DC gas plasma display with a highly reliable infrared touchscreen switch matrix.

Exceptional LAB-6™ Brightness... Even in Sunlight!
The display’s LAB-6™ cathode coating provides a brightness level of 200IL before filtering, and unsurpassed contrast. PEP 4286 can be used in high ambient light applications. This coating also allows the display to be used over a wide -20 to +75°C temperature range.

A Complete Touchscreen Subsystem
As a complete touchscreen sub-system, the module includes a drip proof, polycarbonate bezel which seals to your front panel, a circular polarized filter which has two side areas for fixed function switch legends, and a rear chassis cover. 14K bytes of battery backed CMOS RAM is built-in for canned messages.

Ergonomically Distinguished
• User friendly touchscreen input
• Minimize training time and errors with menu driven input choices
• Bell output for touch confirmation
• 200IL brightness is software-dimmable in 6 steps for comfortable long term viewing
• IR switch matrix means a clear, sharp display without distorting overlays
• Dedicated fixed function switch areas for most commonly used functions

Economically Distinguished
• Complete subsystem simplifies your design process and minimizes your time-to-market
• Replace banks of switches and dials with soft keys
• Display and touchscreen self-test speeds up QA and in-field diagnostics
• Compact flat panel is only 3" deep—fits where CRTs can’t
• Battery backed canned message RAM reduces host memory overhead

Display Features
• 240x120 accessible dots form a 12 line by 40 character display, using a nominal 5x7 dot matrix character
• 96-character U.S. ASCII character set in regular height-width, double height, double width, double height-width; all in regular and reverse video
• 96-character ISA Graphics character set
• 14.10x7.85x3.00" (W×H×D)

Operation
• Requires only +5.0VDC TTL supply and an unregulated 11-29VDC panel supply
• Serial I/O RS-232-C (with CTS and DTR) and RS-422 interfaces at 1200 or 9600 baud
• ANSI-standard VT100 compatible control codes

Industrial Electronic Engineers, Inc.
Industrial Products Division
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Van Nuys, CA 91409-9234
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Circle No. 215

Circle No. 30 For Immediate Response Circle No. 31 For Future Reference

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EDN November 7, 1991
VM SERIES
BUS SWITCHERS—
VME, VXI, FUTUREBUS

10 Watts/Cu.In. @ 50°C!

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- Modular High Density Construction
- FINTEGRA – Distributed Thermal Management with Cooling Fins Integral to Each Module

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INPUT
90-132 VAC or 180-264 VAC, 47-440 Hz. Strappable.

INPUT SURGE
Less than 68 Amps peak from cold start. For 1000W and 1500W units less than 136 Amps peak.

HOLDUP TIME
20 milliseconds from loss of nominal AC power.

OUTPUTS
See model selection table.

ADJUSTABILITY
±5% trim adjustment. All 5VDC outputs are adjustable up to 5.2VDC @ full output.

OUTPUT POLARITY
All outputs are floating from chassis and each other and can be referenced to each other or ground as required.

LOAD REGULATION
±0.2% or ±10mV for load changes from 50% to 0% or 100% of max. rated values.

MINIMUM LOAD
Main output requires a 10% minimum load for full output from auxiliaries.

REMOTE SENSING
On all outputs except those less than 100 watts and less than 20 Amps.

RIPPLE & NOISE
1% or 100mV pk-pk, 20 MHz bandwidth.

OPERATING TEMPERATURE
0-70°C. Derate 2.5%/°C above 50°C.

COOLING
A min. of 10 LFS cooling air directed over the units for full rating. Two test locations on chassis rated for max. temperature of 90°C. 1000 and 1500 watt units have built-in fan.

TEMPERATURE COEFFICIENT
±0.02%/°C.

EFFICIENCY
80% typical.

SAFETY
Units meet UL 1950, CSA 22.2 No. 220, CSA bulletin 1402C, EN 60 950, DIN VDE 0805/05.90. Certifications in process.

DIELECTRIC WITHSTAND
3750 VRMS input to ground.
3750 VRMS input to output.
700 VDC output to ground.

SPACING
8 mm primary to secondary.
4 mm to grounded circuits.

LEAKAGE CURRENT
0.75 mA at 115 VAC 60Hz. input.
1.5 mA for 1000 watt and 1500 watt models.

EMISSIONS
Units meet FCC 20780 Part 15 Class A and VDE 0871/6.78 Class A for conducted emissions. Compliance with Class B limits by use of additional external filter. 1000 watt and 1500 watt models require optional filter for Class A.

DYNAMIC RESPONSE
Peak transient less than ±2% or ±200mV for step load change from 75% to 50% or 100% max. ratings.

RECOVERY TIME
Recovery within 1%.
Main output – 200 microseconds.
Auxiliary outputs – 500 microseconds.

AC UNDERVERTAGE
Protects against damage for undervoltage operation.

OVERVOLTAGE PROTECTION
Standard on main output.

REVERSE VOLTAGE PROTECTION
All outputs are protected up to load ratings.

OVERLOAD & SHORT CIRCUIT
Outputs protected by duty cycle current foldback circuit with automatic recovery. Auxiliaries have additional backup fuse protection.

THERMAL SHUTDOWN
Circuit cuts off supply in case of local over temperature. Units reset automatically when temperature returns to normal.

SOFT START
Units have soft start feature to protect critical components.

FAN OUTPUT
Nominal 12 VDC @ 12 watts maximum.

INHIBIT
TTL compatible system inhibit provided.

SHOCK
MIL-STD 810-D Method 516.3, Procedure III.

VIBRATION
MIL-STD 810-D Method 514.3, Category 1, Procedure I.

MECHANICAL

<table>
<thead>
<tr>
<th>CASE</th>
<th>WATTS</th>
<th>H</th>
<th>x</th>
<th>W</th>
<th>x</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>400 W</td>
<td>2.5&quot;</td>
<td>x</td>
<td>5.05&quot;</td>
<td>x</td>
<td>9.0&quot;</td>
</tr>
<tr>
<td>2</td>
<td>750 W</td>
<td>2.5&quot;</td>
<td>x</td>
<td>5.20&quot;</td>
<td>x</td>
<td>9.63&quot;</td>
</tr>
<tr>
<td>3</td>
<td>1000 W</td>
<td>5.0&quot;</td>
<td>x</td>
<td>5.05&quot;</td>
<td>x</td>
<td>10.4&quot;</td>
</tr>
<tr>
<td>4</td>
<td>1500 W</td>
<td>5.0&quot;</td>
<td>x</td>
<td>5.20&quot;</td>
<td>x</td>
<td>11.0&quot;</td>
</tr>
<tr>
<td>5</td>
<td>960 W</td>
<td>2.5&quot;</td>
<td>x</td>
<td>5.0&quot;</td>
<td>x</td>
<td>6.85&quot;</td>
</tr>
</tbody>
</table>

POWER FAIL MONITOR
Optional circuit provides isolated TTL and VME compatible power fail signal providing 4 milliseconds warning before main output drops by 5% after an input failure. Available on units with a high current 5 volt output.

AUTO RANGER
Optional circuit provides automatic operation at specified input ranges without strapping. Not available on single output units.

PILOT BIAS
Optional circuit provides SELV output of 5 volts at 1 Amp independent of the main power converter. Output isolation compliant to safety specifications referenced above. Not available on single output units.

EMI FILTER
For Class A on 1000 and 1500 watt units.

COVER
Optional flat cover recommended when customer supplied fan cooling is directed through the length of the unit.

FAN COVER
Optional cover with brushless DC fan which provides the required air flow for full rating of VM power supplies.

POWER FACTOR CORRECTION
Refer to Bulletin FM-101 for FM Series units with 0.99 power factor and harmonic currents compliant to IEC 555-2.
DESCRIPTION

VM Series switchers comprise a line of open frame power supplies with output combinations that are required for a large variety of bus systems such as VME, VXI, and FUTUREBUS. Units in this fully modular family offer power density up to 10 watts per cubic inch. The small size and high power available permits more system hardware to be packaged in a given enclosure. The extended function without additional cabinet overhead will give your product a competitive edge in the marketplace.

VM Series feature outstanding quality, insuring full compliance to specifications, reliable field operation and long service life. This exceptional quality is a result of three major efforts.

- Meticulous innovative engineering design.
- Total modular mechanical design.
- Excellent thermal management.

VM Series are available in power ratings from 400 to 1500 watts and with 1 to 7 outputs in a single package.

FEATURES

- TUV, UL, CSA.
- 10 watts per cubic inch.
- 120 kilohertz MOSFET design.
- Current mode control.
- All outputs:
  - Adjustable.
  - Floating.
  - Overload and short circuit proof.
- System inhibit.
- Load proportional DC fan output.
- Options include:
  - Auto ranger for continuous input operation.
  - Power fail monitor.
  - Pilot bias.
  - EMI filter for 1000 and 1500 watt units.
  - Cover.
  - Fan cover – 1000 and 1500 watt units have fan built in.

SINGLE OUTPUT MODELS

<table>
<thead>
<tr>
<th>Model</th>
<th>VDC</th>
<th>Amps</th>
</tr>
</thead>
<tbody>
<tr>
<td>VM12D0-YY</td>
<td>2VDC</td>
<td>150A</td>
</tr>
<tr>
<td>VM12D1-YY</td>
<td>3.3VDC</td>
<td>150A</td>
</tr>
<tr>
<td>VM12D2-YY</td>
<td>5VDC</td>
<td>150A</td>
</tr>
<tr>
<td>VM12D3-YY</td>
<td>12VDC</td>
<td>72A</td>
</tr>
<tr>
<td>VM12D4-YY</td>
<td>15VDC</td>
<td>57A</td>
</tr>
<tr>
<td>VM12D6-YY</td>
<td>24VDC</td>
<td>36A</td>
</tr>
<tr>
<td>VM12D9-YY</td>
<td>48VDC</td>
<td>18A</td>
</tr>
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MULTIPLE OUTPUT MODELS

<table>
<thead>
<tr>
<th>Model</th>
<th>Total Power: 400 Watts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case</td>
<td></td>
</tr>
<tr>
<td>Ratings: 5VDC @ 50A</td>
<td></td>
</tr>
<tr>
<td>5VDC @ 10A</td>
<td></td>
</tr>
<tr>
<td>12VDC @ 12A</td>
<td></td>
</tr>
<tr>
<td>12VDC @ 6A</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Model</th>
<th>Total Power: 500 Watts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case</td>
<td></td>
</tr>
<tr>
<td>Ratings: 5VDC @ 80A</td>
<td></td>
</tr>
<tr>
<td>12VDC @ 12A</td>
<td></td>
</tr>
<tr>
<td>24VDC @ 6A</td>
<td></td>
</tr>
<tr>
<td>5VDC @ 10A</td>
<td></td>
</tr>
<tr>
<td>12VDC @ 6A</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Model</th>
<th>Total Power: 1000 Watts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case</td>
<td></td>
</tr>
<tr>
<td>Ratings: 5VDC @ 80A</td>
<td></td>
</tr>
<tr>
<td>2VDC @ 10A</td>
<td></td>
</tr>
<tr>
<td>5VDC @ 10A</td>
<td></td>
</tr>
<tr>
<td>12VDC @ 6A</td>
<td></td>
</tr>
<tr>
<td>12VDC @ 6A</td>
<td></td>
</tr>
<tr>
<td>24VDC @ 3A</td>
<td></td>
</tr>
<tr>
<td>24VDC @ 3A</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Model</th>
<th>Total Power: 1500 Watts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case</td>
<td></td>
</tr>
<tr>
<td>Ratings: 5VDC @ 120A</td>
<td></td>
</tr>
<tr>
<td>2VDC @ 12A</td>
<td></td>
</tr>
<tr>
<td>5VDC @ 30A</td>
<td></td>
</tr>
<tr>
<td>12VDC @ 10A</td>
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</tr>
<tr>
<td>12VDC @ 10A</td>
<td></td>
</tr>
<tr>
<td>24VDC @ 5A</td>
<td></td>
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<tr>
<td>24VDC @ 5A</td>
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</table>

OPTIONS

<table>
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<tr>
<th>Code</th>
<th>Function</th>
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<tbody>
<tr>
<td>00</td>
<td>None</td>
</tr>
<tr>
<td>01</td>
<td>Power Fail</td>
</tr>
<tr>
<td>02</td>
<td>Auto Ranger</td>
</tr>
<tr>
<td>04</td>
<td>EMI Filter</td>
</tr>
<tr>
<td>32</td>
<td>Cover</td>
</tr>
<tr>
<td>64</td>
<td>Fan Cover</td>
</tr>
</tbody>
</table>

Notes:

1. All 5VDC outputs adjustable to 5.2VDC. Others trim adjustable ±5%.
2. On models VX1E-YY and VX1F-YY the max. total power for the sum of outputs #1 to #3 must not exceed 500 watts and 750 watts respectively.
3. Models VX1E-YY and VX1F-YY include built-in fan.
4. Models VX1E and VX1F require EMI Filter option to meet FCC and VDE Class A for conducted emissions.
**DIMENSIONS**

**CASE 1 & 2**

**NOTES:**

1. WITH COVER (#6-32),
   W/O COVER (.150 DIA.)
2. W/FAN COVER UNIT HEIGHT (4.100)
3. TERMINAL BLOCKS (#6-32)
4. STUDS (1/4-20)

<table>
<thead>
<tr>
<th></th>
<th>CASE 1</th>
<th>CASE 2</th>
<th>CASE 3</th>
<th>CASE 4</th>
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</thead>
<tbody>
<tr>
<td>400/500 M</td>
<td>9.000</td>
<td>9.630</td>
<td>10.400</td>
<td>11.000</td>
</tr>
<tr>
<td>600/750 M</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000W</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1500W</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>8.250</td>
<td>8.890</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>8.260</td>
<td>8.930</td>
<td>8.260</td>
<td>8.930</td>
</tr>
<tr>
<td>D</td>
<td>4.100</td>
<td>4.25</td>
<td>4.10</td>
<td>4.25</td>
</tr>
<tr>
<td>E</td>
<td>3.820</td>
<td>4.450</td>
<td>3.820</td>
<td>4.450</td>
</tr>
<tr>
<td>F</td>
<td>3.930</td>
<td>4.560</td>
<td>3.930</td>
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<tr>
<td>G</td>
<td>5.050</td>
<td>5.200</td>
<td>5.050</td>
<td>5.200</td>
</tr>
</tbody>
</table>

**CASE 3 & 4**

**CASE 5**

---

290 WISSAHICKON AVENUE, P.O. BOX 1369, NORTH WALES, PA 19454

Intl. Units: Delaire • Sallynoggin Road, Dun Laoighaire, Co. Dublin, Ireland. Tel: (01) 851411 Prefixes - from U.K. – (0001)–Intl. + 353–(1) Telex: 30442DEL EI
Deliine • Padre Mier y Dr Mina, Reynosa, Tamps., Mexico 06866. Tel.: (932) 38723 Prefix – from USA – (01152) FAX (932) 36776

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---

**Data-Acquisition Package For Apple Macintosh**

- Consists of external ADC and software
- Provides 45 analysis functions

The SS-Pack/16 waveform-acquisition package combines Superscope data-acquisition software with the vendor's ADC488/16 ADC. It provides a data-acquisition package for those members of the Macintosh PC family that can accommodate an IEEE-488 interface. The ADC488/16 mounts outside the computer. It accepts 16 analog inputs and digitizes them at 20 rates from 0.02 to 100 ksamples/sec. The software performs 45 functions. It can display eight waveforms at once and provides virtual front panels for instrument control. It also permits saving data to journal files from which you can easily load it into a spreadsheet. $2995.

**Function Generator**

- Covers 0.002 Hz to 2 MHz
- Reads out frequency to 3½ digits

The TG230 2-MHz function generator provides a 3½-digit readout of the output waveform's frequency, amplitude, and offset. The generator includes sweep and AM (amplitude-modulation) capabilities and permits adjustment of the waveform symmetry. The sweep mode permits linear and logarithmic sweeps over ranges as great as 1000:1 and permits digital readout of the start and stop frequencies. The AM facility provides a 400-Hz signal that can produce 100% modulation. £249.

**Thurlby-Thandar Ltd**, Glebe Rd, Huntingdon, Cambs PE18 7DX, UK. Phone (0480) 412451. Circle No. 411

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**CIRCLE NO. 192**
Data-Acquisition Boards For Laptop PCs

- Plug into half-length ISA bus slots
- Include ADC and DAC units

The ADC-35 and ADC-45 are, respectively, analog input and output boards for laptop PCs. In fact, the half-length cards work in any PC that can use 8-bit ISA bus I/O boards. The ADC-35 has a 12-bit ADC and a pacer clock. The ADC-45 (despite its model number) is a 4-channel, 12-bit D/A converter.

The vendor's product line for laptop PCs also includes a 32-channel digital I/O board, a dual RS-232C board, an IEEE-488 interface, and an expansion chassis. ADC-35, $595; ADC-45, $725.

Pragmatic Instruments Inc, 7313 Carroll Rd, San Diego, CA 92121. Phone (619) 271-6770. FAX (619) 271-9567. Circle No. 413

16-Bit, 2-Msample/Sec Arbitrary-Wave Generator

- Is preprogrammed with 20 waveforms
- Lets you use a mouse and a scope to define waveforms

The 2411A device generates both predefined and arbitrary waveforms—ones you define yourself. Among the 20 signals in the unit's library are sine, square, triangle, sawtooth, pulse, exponential, sin(x)/x, and haversine waveforms. Although the generator can store $2^{16}$ waveform points, it doesn't use much of this memory for the standard functions; the unit's µP executes routines to create the signals when you need them. As with the firm's other generators, defining arbitrary waves requires only a mouse and an X-Y scope. When creating your own waveforms, you can start from scratch or edit and combine the predefined functions. The unit also produces gated and triggered bursts as well as continuous waves. A sequence generator lets you link and loop on waveform segments to extend the unit's memory manyfold. 2411A generator, $2495; optional sequence generator, $895; IEEE-488 and RS-232C ports, $495.

Pragmatic Instruments Inc, 7313 Carroll Rd, San Diego, CA 92121. Phone (619) 271-6770. FAX (619) 271-9567. Circle No. 413

Coprocessor For Micro Channel Architecture Bus

- Consists of two boards
- Switches between Basic and DOS with simple commands

A set of two boards for the Micro Channel Architecture bus of the IBM PS/2 family lets these PCs run Hewlett-Packard Basic and Basic Plus—dialects of the popular programming language tailored to instrument control. The Microcat board set lets you invoke simple commands to switch rapidly between the MS DOS and Basic environments. Installing the boards turns a PC into an HP 9000 Series 300 workstation and lets you run the workstation versions of such application packages as HP's Interactive Test Generator, Functional Test Manager, and Data Acquisition Manager. Included in the board set is an IEEE-488 bus controller that is functionally identical to the HP98624A card used in the workstations. Set of two boards, $3850. Complete controller (PC with coprocessor), approximately $7000. Delivery, eight weeks ARO.

Sejus Corp, 2618 Palisades Crest Dr, Lake Oswego, OR 97034. Phone (503) 638-9000. Circle No. 414
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The model 2300 handheld, battery-operated counter works with signals from 1 MHz to 2.4 GHz. It provides 10-mV sensitivity through 900 MHz. It has an 8-digit display. The unit features a display-hold feature that retains a reading after you remove the input signal. Model 2300 counter, $99; rechargeable 600-mAhr battery pack, $29.

Optoelectronics Inc, 5821 NE 14th Ave, Fort Lauderdale, FL 33334. Phone (800) 327-5912; (305) 771-2050. FAX (305) 771-2052.
CIRCLE NO. 415

4-Channel, 200-MHz Analog Scopes
- Have sensitivity to 2 mV/div
- Allow pairing of channels for differential input
The PM 3096 series 200-MHz analog oscilloscopes offer the convenience of µP control normally associated with digital scopes and the familiar feel and rapid display update rate of a true analog scope. Sensitivity extends from 5V/div to 2 mV/div. You can pair channels to obtain two fully differential channels. An auto-set function instantly displays a signal without requiring you to adjust control settings. PM 3094 with
4 channels, approximately $3500.
John Fluke Mfg Co Inc, Box 9090, Everett, WA 98206. Phone (800) 443-5853; (206) 347-6100.
Circle No. 416
Philips Test and Measurement, Bldg TQIII-4, 5600 MD Eindhoven, The Netherlands. Phone local office.
Circle No. 417

Customized Expansion Box
For PC Data Acquisition
• Has eight 8-bit ISA bus slots
• Includes 200W power supply
The PCI-5500H is a customizable expansion box for peripheral cards that plug into the 8-bit ISA bus. It houses eight such cards. To use it, you plug a half-length interface card into the host PC. By equipping several PCs with interface cards, you can use one expansion box with more than one PC. A Eurocard cage kit allows the box to accommodate three 3U-size Eurocards. An optional splash-proof front panel permits use of the box in many industrial locations. Each version of the box includes a 200W power supply. One version has a supply that operates between 100 and 127V ac; a second operates between 200 and 240V ac; the third operates between 90 and 110V ac. Expansion box, $995; interface card, $120; Eurocard kit, $79.

Intelligent Instrumentation, 1141 W Grant Rd, MS 131, Tucson, AZ 85705. Phone (602) 623-9801. FAX (602) 623-8965.
Circle No. 418

Programmable Power-Supply System
• Uses 7-in. space in equipment rack
• Houses eight 150W modules
The 66000A modular power system mounts in a 7-in.-high space in an equipment rack. It houses as many as eight 150W programmable-output de-supply modules. You program the modules via the IEEE-488 bus or with an optional keyboard. The system addresses the same problem that the VXI modular-instrument standard does—reduction of the size of test systems. The VXI standard does not cover power sources that produce as much as 150W, however. An unusual feature of the system is that, although the cables that carry power to the unit under test plug directly onto the power modules, they remain captive in the mainframe when you unplug modules. Mainframe, $1900; keyboard, $750; modules, $1750 each.

Hewlett-Packard Co, 19310 Pruneridge Ave, Cupertino, CA 95014. Phone (800) 752-0900.
Circle No. 419

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For more than a decade, Interpoint DC-DC converters have proven their reliability in many of the world's most advanced weapons systems — including mission-critical electronics on the Patriot and Tomahawk missiles, the Bradley Fighting Vehicle and F/A-18 aircraft. Our new generation converters are the most reliable yet. Each of them was designed with the specific intent of being qualified to the full performance and reliability standards of MIL-STD-883C.

And Interpoint continues to lead the way in power supply miniaturization. With power densities as high as 40 watts per cubic inch and package heights as low as .270 inch, this new generation of converters is built for the tightly packed boards in today's military and commercial avionics, ground vehicles and portables.

It's the hottest new technology in DC-DC converters. And it's available only from Interpoint. For more information, call 1-800-822-8782. In Europe, 44-276-26832.

Interpoint's new line of DC-DC converters features constant PWM switching frequencies from 500 to 700kHz. Built-in sync. Parallel operation. Up to 50 dB audio rejection. Line and load regulation as low as 0.1%. And full MIL-STD-704 input for 26- and 270-volt systems.

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'Fast silicon' (rise time≤1 ns) requires strict impedance control. Conventional connectors give up half their pin count for this - a sacrifice you can do without.

Our modular, scalable Stripline 100 connector system can accommodate edge rates of 250 ps (500 ps at <3% crosstalk), and still give you 40 signal lines per inch - all four rows on a .1"x.1" grid. Reference planes isolate individual signal columns within the standard grid geometry, creating an interface completely transparent to high-speed logic.

Stripline 100 connectors deliver more than raw speed, too. Each reference plane can distribute three amps, and sequenced mating is available for ground, power, and two signal levels.

Manufacturing is easier as well. ACTION PIN compliant posts (for existing 0.040" pcb holes) simplify backplane assembly, and all materials are compatible with high-temp reflow processing.

In fact, sub-nanosecond logic just got easier all around, and there's an easy way to 'bring yourself up to speed' on this exciting technology: call our Product Information Center at 1-800-522-6752 (fax 717-561-6110). AMP Incorporated, Harrisburg, PA 17105-3608. In Canada call 416-475-6222. For design assistance in characterized backplane assemblies, contact AMP Packaging Systems, 512-244-5100.
The next generation of
IDC Interconnection:
Same performance,
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System 311 is the next generation of reliable high performance IDC mass termination systems from Thomas & Betts, a pioneer in the development of IDC. A natural evolution, the new System 311 combines the finest capabilities of our proven Ansley® IDC System, downsized and precision engineered to terminate .025 pitch cable.

Performance-oriented features make System 311 the new standard in IDC fine pitch systems — a beryllium copper contact with a dual mating beam that provides greater than 100 grams normal force (150 KPSI Hertz Stress), a unique “coined-slot” IDC contact joint, one piece housing design,
Contact-to-Conductor Relationship – Thomas & Betts’ “coined-slot” contacts are designed to position the terminated conductors within a specified region for maximum conductivity and reliability.

Precision Lead-In Design – assures that repeated connect/disconnect functions are consistently smooth and without pin damage.

Our Own Vertical Eject Design – saves board real estate and ensures positive locking and easy disengagement of header from mating socket without stress to cable, contacts, or solder joints.

and high performance materials are combined to ensure excellent system integrity and maximum reliability.

System 311 incorporates these customer-requested features into a compact interconnect system with board space savings of up to 50%.

From cable to connectors to application tooling, System 311 is designed to meet or exceed the most stringent customer requirements for fine pitch IDC mass termination.

For complete information or help with a specific application, call or fax: Thomas & Betts Corporation, Electronics Division, 200 Executive Center Drive, Greenville, S.C., Phone: 803-676-2900, Fax: 803-676-2991.

For the new System 311 Catalog call 800-344-4744.

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Plus our complete PLD family is supported by industry-standard software and programmers. This allows you to eliminate the need for specialty programmers, and you can complete 100% of your design using a single software package.

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It's a user-friendly world. At least, users insist it be that way. So they look for “user-friendly” features when they shop for computers and computer products. That's why one major company introduced our Address Switch on the back panel of their personal computers. Users designate the “address” of their computers and peripherals with a simple, one-step press of the Address Switch.

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Just as users look for “IBM-compatible” on today’s computers and peripheral devices, they will soon start looking for “switch-addressable”. As local area networks continue their rapid growth, the need to change “addresses” on network devices in a quick and easy manner is becoming increasingly important.

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The Address Switch Adapts to Your Design.

Panel-mounted and easily accessible, the Address Switch adds value to your product by replacing internal DIP switches on IC boards with instant access on the external housing. Available in a variety of colors to match your product, gang-mountable in virtually any configuration, the Address Switch uses the standard SCSI design to adapt readily to any product line.

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Don’t you owe it to your product to stay competitive? Call us today at 708-360-3500, and we’ll send you a Specifications Sheet describing the Address Switch in detail. Don’t get left behind in the user-friendly race— the competition is already off and running.

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NEW PRODUCTS

COMPUTERS & PERIPHERALS

Thermal Printer
- Can print bar codes and labels
- Prints at 12 lines/sec on thermal and 2-ply paper
The DPU-5300 is a stand-alone thermal printer for point-of-sale applications. The unit can print bar codes and labels at 12 lines/sec. The data interface is via both an RS-232C and a Centronics parallel port. The unit prints alphanumerics, bar codes, and graphics on thermal paper, 2-ply paper, or label stock. The character matrix is 24 x 12 mm, and the vertical and horizontal dot pitch is 0.125 mm. Other features include a maximum 2-in./sec, 16-kbyte buffer, and a paper-out detector. The printer runs from a 110V ac adapter, and its environmentally protected housing measures 190 x 140 x 223.5 mm. $350 (1000).
Seiko Instruments Inc, Thermal Printer Group, 2990 W Lomita Blvd, Torrance, CA 90505. Phone (213) 517-7787. FAX (213) 517-7792. Circle No. 397

WAN Controller
- Lets SBus systems communicate over E1 and T1 lines
- Features 68302 processor and 256 kbytes of SRAM
The SB302 device is a wide-area-network (WAN) controller for the SBus. It provides two full-duplex serial ports on a single-width expansion card. The board lets an SBus system communicate over E1 (2.048 Mbps) or T1 (1.544 Mbps) lines. You can independently program the two serial ports. For example, one port can operate at E1 rates while the other operates at 64 kbps. Motorola's 68302 integrated multiprotocol processor implements asynchronous, high-level

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data-link control and synchronous data-link control, bisynchronous, and transparent-mode protocols. A 6800 µP executes upper-level protocols. The board also has a 256-kbyte static-RAM buffer, 2 Mbytes of dynamic RAM, and 512 kbytes of flash EPROM for program and data storage. Bit swapping allows the board to handle data from any external UART. 16-MHz version, $1240 (100).

**SBE Inc**, 2400 Bisso Lane, Concord, CA 94520. Phone (800) 347-2666; (415) 680-7722. FAX (415) 680-1427. *Circle No. 398*

**SCSI-2 Host Adapters**

- **Operate in VMEbus or VME64 systems**
- **Support 10-Mbyte/sec rates and extended command set**

The V/SCSI-2 4220 Cougar VMEbus board offers either one or two independent Fast SCSI-2 channels. The V/SCSI-2 4220 Cougar with Ethernet is a VMEbus board that has a single Fast SCSI-2 channel and an Ethernet controller. Both controllers support 10-Mbyte/sec synchronous and 2-Mbyte/sec asynchronous Fast SCSI-2 data transfer rates. Besides operating on the Fast SCSI-2 common command set, the boards operate on the extended command set, which provides error-recovery capability. The boards operate in a standard VMEbus system or a system conforming to the VME64 standard. They occupy a 6U slot, and an optional daughter card creates two controller cards occupying one slot. The Ethernet controller communi-
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CIRCLE NO. 205
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For details on the Summit 10000, and free copies of our two booklets on high-speed measurement and modeling, just write or call Ken Smith at (503) 626-8245.
DSP Board
For AT/ISA Bus
- Contains dual TMS320C40 chips delivering 80 Mflops
- Contains as much as 4 Mbytes of static RAM

The Spirit-40 AT DSP board for the 16-bit ISA bus uses dual TI TMS320C40 chips, which deliver as much as 80 Mflops. It operates in 80286, 80386, and 80486 DOS-compatible computers. Each DSP chip has access to 256 kbytes of local static RAM (SRAM), which is expandable to 1 Mbyte. Each DSP chip can also locally access 64 kbytes of EPROM and has access to as much as 2 Mbytes of global SRAM, which is also accessible to the ISA bus. The host can transfer data to and from the global memory via block I/O transfers or under DMA control. The board operates on the Spox operating system, and because the TMS320C40 is code compatible with the TMS320C30, the board can run application programs developed for the company's Spirit-30 board. Board with 1 Mbyte of SRAM, $8995. Delivery, eight weeks ARO.

Sonitech International Inc, 14 Mica Lane, Wellesley, MA 02181. Phone (617) 235-6824. FAX (617) 235-2531. Circle No. 401

Vector Processor
- Subsystem occupies one slot in a DECstation-5000
- Has one or two 40-MHz i860 µPs

The Supercard-5000 is a vector-processor subsystem for Digital Equipment's DECstation-5000 workstations. A stand-alone chassis houses one or two 4-MHz i860 µPs to deliver 160 Mflops. The subsystem interfaces to the workstation via a cable and a single-slot Turbochannel adapter card. Each µP has access to 2, 8, or 16 Mbytes of local page-mode dynamic RAM. The page-mode architecture permits the µPs to access memory at 160 Mbytes/sec. In addition, custom I/O ports operate at 160 Mbytes/sec. A 40-Mbyte/sec VSB interface is available as an option. A 3.5×16×16-in. enclosure fits on top of the DECstation enclosure. Compilers for both C and Fortran generate downloadable code. The system comes with a vector and signal-
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VMEbus DSP Board

- Contains 12 DSP32 chips delivering 300 Mflops
- Each DSP chip has access to 512 kbytes of static RAM

The VME9U12 9U VMEbus board contains 12 AT&T DSP32C chips. It provides 300 Mflops and 150 MIPS. Each DSP chip executes programs and accesses data from 128 kbytes of static RAM, which is expandable to 512 kbytes. The board operates as either a VMEbus master or slave for either DMA or memory-mapped data transfers. An optional daughter card, T1D, provides a T1-compatible communication link. The T1D can accept differential NRZ data. Because T1D supports Alternate Mark Inversion, the card interfaces directly to a T1 line. The optional C12 daughter card contains 12 8-bit companding codecs. C12 has 12 balanced input and output channels. The VME-9U12's DSP chips communicate with each other and with the daughter cards using 4-time-division, multiplexed 16-Mbps serial buses. Board with 12 DSP chips and 128 kbytes/chip, $18,800.

Communication Automation and Control Inc, 1642 Union Blvd, Allentown, PA 18103. Phone (215) 776-6669. Circle No. 403

COMPUTERS & PERIPHERALS

processing library and will be available in the first quarter of 1992. System with one i860 and 2 Mbytes of RAM, $20,000.

CSP Inc, 40 Linnell Circle, Billerica, MA 01821. Phone (617) 272-6020. Circle No. 402

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CIRCLE NO. 208

EDN November 7, 1991
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With the right combination of speed, precision, power dissipation and high output drive capability, the AD827, AD829, AD847, AD848, AD849 and OP-64 are ideal general purpose solutions. And they're ideally priced solutions—most singles are under $3, and duals are under $5.

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whatever application you're working in. Call us at 1-800-262-5643, or write to Analog Devices, P.O. Box 9106, Norwood, MA 02062-9106, for a complete high-speed op amp selection guide and a free copy of our SPICE model library.

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EDN November 7, 1991 CIRCLE NO. 211
Right Angle Pressfit
Cost-efficient ERNI Press pressfit connectors for the Eurocard sub-assembly:
• Type B & C male versions and Type Q & R female versions
• Universal press-in technique for thru hole or SMT board designs
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CIRCLE NO. 250

LDG Miniature Housing Enclosures
Multi-use, non-metallic, miniature, housing enclosures:
• Internal PCB mount terminal blocks
• Multiple connecting options (from 12 up to 70)
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CIRCLE NO. 251

Application Specific DIN Connectors
PCB process compatibility and application specific options from ERNI:
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• PCB hold-down clips
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CIRCLE NO. 252

Extended DIN High I/O Connectors
Extended DIN connectors including 120, 128, and 150 positions:
• Cost-efficient inverse (reverse) style two-piece DIN connectors
• 3 row (120 & 150) or 4 row (128) versions
• Solder, wirewrap, & pressfit options
CIRCLE NO. 253

PCB Edgecard Connectors
ERNI Edgecard connectors featuring the latest configurations and options:
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• Complete range of high-density .050" types
• Extensive options in contact style, type of termination, mounting, and plating
CIRCLE NO. 254

.050" SMC
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CIRCLE NO. 255

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Gould AMI, 2300 Buckskin Rd, Pocatello, ID 83201. Phone (208) 233-4690. Circle No. 420

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- Combines GUI builder, compiler, and Windows tools
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Microsoft Corp, 1 Microsoft Way, Redmond, WA 98052. Phone (206) 882-8080. FAX (206) 883-8101.

Circle No. 421

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Analogy Inc, 9205 SW Gemini Dr, Beaverton, OR 97005. Phone (503) 626-9700. Circle No. 422

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CIRCLE NO. 217

CAE & SOFTWARE

Floating-Point DSP Datapath Compiler/Library
- ASIC library compiles math processing structures
- Has DSP, floating point complex functions

The VDP370 compiler and cell library generates high-density, high-performance datapath circuits for advanced processing. It supports both fixed-point and floating-point DSP processing. The compiler also generates an optimized layout for either gate-array or standard-cell implementation. It uses cells from the VSP270 1-µm portable library. A high-level schematic, which graphically represents the datapath elements and buses, drives the compiler. The library's fast arithmetic units include adders, multipliers, comparators, multiplier/accumulators, and shifters. The compiler automatically generates bit-slice components to match the schematic with balanced clocks. Simulation models are generated for debugging, as well as high-coverage test vectors. $40,000.

VLSI Technology Inc, 1109 McKay Dr, San Jose, CA 95131. Phone (408) 434-7956.

Circle No. 424

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The brochure, High-Speed Linear Products, presents more than 30 high-resolution, high-speed ADCs and DACs, S/H circuits, op amps, and analog multipliers used in instrumentation, imaging, video, spectrum analysis, and direct digital-synthesis applications. The 8-pg publication provides key specification charts and application ideas. A listing of high-speed demonstration boards provides quick evaluation of many products.

Burr-Brown Corp, Box 11400, Tucson, AZ 85734. Circle No. 404

Power Transformers And Telecomm Magnetics

This 24-pg catalog features domestic and international printed-circuit power transformers, telecomm magnetics, CRT products, and inductors for switched-mode powersupply applications. It reports that the vendor's power-transformer line carries both UL and CSA listings, and the international series has approvals such as UL, IEC, VDE, CSE, and GOST. The book-

let's telecomm magnetics line includes coupling and hybrid transformers for voice and data applications. The publication shows units with features such as low profiles, small-board-area usage, "wet" or "dry" capabilities, and high-crosstalk attenuation.

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The revised Bipolar Power Transistor Selector Guide and Cross Reference (SG48/D) encompasses application categories that include application-specific devices, such as the audio and CRT deflection families. Product highlights include plastic, metal, and surface-mount packages, as well as information on a line of general-purpose Switchmode and Darlington transistors.

Motorola Inc, Literature Distri­bution Center, Box 20924, Phoenix, AZ 85063. Circle No. 407

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This 6-pg brochure highlights data-acquisition hardware and software products. It features plug-in boards for IBM PCs, PS/2, EISA, and Apple Macintosh computers. The publication explains how these boards perform various combinations of analog, digital, and timing I/O functions. It also includes driver and application-software options for programming data-acquisition hard-
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EDN November 7, 1991

CIRCLE NO. 267
The Power in Telecommunications

How component power is contributing to the future of telecom networks

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CIRCLE NO. 268
Enforcement of IEC 555-2 regulations regarding new power requirements is scheduled to take effect in Europe beginning this coming year. This means design engineers must add power factor correction to their power supplies if they expect their products to be sold or distributed into the European marketplace.

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EDN November 7, 1991
The economic challenge of a united Europe

You've probably heard the rumors by now: When Europe is economically unified in 1992 it will become an impregnable fortress. The Europeans will erect trade barriers to keep American and Japanese goods out. European companies will grow powerful by supplying their own tightly guarded market and will compete with foreign firms in every product area. European economic unification will be a serious blow to American industries and result in more unemployment here. US companies didn't realize the full implications of 1992 soon enough, and now it's too late.

All these statements are distortions, exaggerations, or outright myths. A close look at what's really happening in Europe reveals that the coming economic unification will present some dangers but many opportunities for American companies.

In 1992, the European Economic Community will be the largest market in the industrial world. Will it be a threat or an opportunity for American companies?

Jay Fraser, Associate Editor

The European Economic Community (EEC) will officially come into being on December 31, 1992. On that date all tariffs, customs regulations, and other trade barriers will be removed among 12 countries (see map). Miles of costly red tape will disappear, and state-protected monopolies will be wiped away. Products, services, finances, and workers will be able to move freely across the borders of all member nations.

The EEC will be a single market of more than 320 million people, by far the largest in the industrialized world. It will also be one of the richest. US sales to Europe last year were in excess of $600 billion, more than double the amount of sales to Japan.

In addition, the EEC headquarters in Brussels is developing a set of uniform product standards and testing and certification procedures for all member na-
When these standards are finally in place, they will be a boon for many industries, especially telecommunications and consumer electronics. After 1992, you’ll be able to buy a CD player in any one of the 12 EEC countries and plug it into a wall socket without an adapter in any other member country.

The EEC certainly looks good on paper, but some observers say it won’t fulfill all its lofty promises. Joel Kotkin is an American business analyst who has written three books on international trade and economics and has recently visited Europe. He says, “I credit the Europeans for having created a brilliant PR campaign. Nineteen ninety-two is the best PR drive since ‘Terminator 2.’ But the fact of the matter is it may have about as much reality as ‘Terminator 2,’ and it probably won’t be as profitable.

“The EEC is going to be somewhere between a moderate success and a moderate failure,” says Kotkin. “It will maybe add 10% to what the Europeans could have done without it, or it could actually screw things up because it will create a lot of artificial distortions. I don’t think it’s going to be the millennium that a lot of the Eurohustlers are trying to sell.”

A more competitive marketplace

Obviously, the creation of the EEC will make it easier for Europeans to do business with each other, but it will also make it easier for Americans and Japanese to do business in Europe. In the past, some large companies that are geared for high volume and long manufacturing runs weren’t interested in modifying their products and shortening their runs to suit the fragmented markets of Europe. After 1992, the huge, unified market and its simplified distribution procedures will induce these firms to jump in. The EEC is going to open Europe to increased competition.

Norman Weizer, senior consultant at Arthur D Little Inc (Cambridge, MA), believes the greatest economic danger for American engineers actually comes from their own companies. “[Engineers] have something to fear if the company they work for isn’t treating the EEC seriously and making an attempt to really get in there and become part of that scene,” he says. “They could see a market that their company currently has slowly disappearing to the people who are paying attention, are forming relationships, are getting into the dance.”

Some Americans fear that the EEC will erect trade barriers to protect its industries. After all, Jacques Delors, president of the European Commission, has said, “We are not building a single market in order to turn it over to hungry foreigners.”

Strong protectionist sentiment exists in some European nations, but there is very little in others. The EEC comprises 12 different countries with 10 different languages, 12 different monetary systems, and 12 different sets of national priorities.

“It’s very difficult to speak of ‘Europeans,’” says Kotkin, “because you have on one hand the French who are reactive protectionists and the Italians who are protectionists except against themselves. On the other hand, you have countries like The Netherlands and to a lesser extent Germany and Great Britain, which have a strong free-trade orientation. So it’s hard to
talk about there being a single European point of view on an issue like protectionism.”

The protectionists might someday control the EEC and try to lock foreign competitors out, but no significant trade barriers have gone up yet.

**The Japanese threat**

Many analysts point out that the Europeans are far more worried about the Japanese invading the EEC than the Americans. Edith Cresson, the new prime minister of France and a strong protectionist, has been quoted as saying, “The Japanese have a strategy of world conquest. They have finished their job in the US. Now they’re about to devour Europe.”

“The Japanese are just a total threat to them,” says Weizer. “The Europeans are much more comfortable dealing with us than with the Japanese. They know us and we’ve helped them and they’ve gotten comfortable dealing with the noisy Americans. I see it more as the Europeans and the Americans lining up together against the Japanese.”

Another factor works against the imposition of trade barriers: Europe has to export goods in order to grow. The average growth rate of the economies of the EEC countries is about 3%, well below that of the US and Japan. If the EEC imposed stiff tariffs on imported goods, the US and Japan would retaliate. In a large-scale trade war, Europe would suffer most.

Also, the EEC can’t afford to cut itself off from the rest of the world because it needs foreign investment. The reunification of Germany has turned out to be much more expensive than anyone anticipated. In 1991 the German government will pump the equivalent of $86 billion into what used to be East Germany to revive its economy. Spain, Portugal, Greece, and Italy were all hoping for an influx of German capital. That capital won’t be coming soon, and it may never come. Those countries will have to look overseas for investors.

Adding to Europe’s woes is the current recession. Unemployment in France is now above 10%. In The Netherlands unemployment has topped 14%. Philips (Eindhoven, The Netherlands), the largest and at one time most stable electronics firm in Europe, is wobbling badly. It plans to lay off 55,000 people out of a workforce of 285,000 by the end of this year. Although some European politicians make speeches about the evils of foreign companies invading the EEC, behind the scenes they often court foreign companies for the jobs they provide.

When examining the EEC closely, it doesn’t look much like a fortress. A united Europe hunkered down behind a thick wall of trade barriers hasn’t materialized yet and probably never will. As Business Week commented in a recent issue, “Europe’s fearsome fortress is beginning to look like Swiss cheese.”

**The EEC in global competition**

Another worry some American and Japanese manufacturers have is that when Brussels formally announces its new set of product standards next year, they will be purposely very different from all foreign standards. Manufacturers fear that the EEC’s standards will amount to a backhanded method of keeping American and Japanese goods out of the European market. This fear is based on a misunderstanding of the EEC’s purpose.

The EEC wasn’t formed just to make it easier for the member nations to do business with each other. It was also designed to turn Europe into a powerful competitor in world markets. If the EEC comes out with a set of standards that differs greatly from the standards other countries use, it will only be isolating itself.

As for the idea that Europeans are going to become competitors in all product areas, that’s simply unrealistic. In some high-tech fields, such as telecommunications and civilian aerospace, European companies have scored some successes, but on the whole they lag behind American and Japanese firms.

“High tech is an area where Europe is quite weak, and that means there’s an opportunity for us,” says Kotkin. “Europe is very short of engineers. Countries like Italy produce about half as many engineers a year as they need, and they’re not really encouraging immigration. The US with its immigration and its large technical workforce is much better positioned to meet the challenge.”

A persistent problem for EEC high-tech companies is a shortage of funds for research and development. Developing a new mainframe computer can cost as much as $1 billion, and most European firms can’t afford such expenditures. To keep up with American and Japanese companies, EEC firms have to depend on government subsidies or form joint ventures to pool their resources. But joint ventures don’t always work.

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Professional Issues

etti (Italy), Groupe Bull (France), and International Computers (Britain) was formed to manufacture microchips. It quickly fell apart, however, because the companies fought constantly about who was going to be in control.

Opportunities for US firms

It's not too late for American companies to take advantage of the opportunities the EEC will offer, but they had better move fast. Doing business with the EEC will require some careful planning and decisive action.

First, US firms have to stop thinking of December 31, 1992 as the day when the gate slams shut forever. Some aspects of European unification have already been finalized, but much of the process will continue after 1992. That date is partly symbolic. It is not the final cut off.

"The 90s will be a period of adjustment all over Europe," says Kotkin. "There are going to be a lot of bumps in the road, and there are going to be little spurts of economic activity such as you saw in the late 80s. We're not going to go into 1992 and come out in a different world."

Second, American companies must keep a close watch on product standards and other regulations as the EEC develops them. If they haven't already, US trade and business associations should place permanent representatives in Brussels to monitor proposed rules while they are being debated and to lobby for changes beneficial to American industries. Japanese firms currently keep more than 220 representatives and lobbyists in Brussels. These people send a continuous stream of reports back to Japan.

In addition, American companies should be flexible. Markets for different products within the EEC will require different approaches. Some markets will be relatively open. American companies will be able to enter them directly or set up European subsidiaries. In more competitive markets, US firms might have to form partnerships or acquire existing companies to gain a foothold.

American companies that want to become involved in the EEC will also have to adjust their thinking. US firms have been rightly criticized for going after quick profits and paying too much attention to quarterly reports. The economy of the EEC will grow much more slowly than the US economy, especially at first. American companies doing business within the EEC shouldn't expect instant gratification.

However, American companies will have some advantages when it comes to dealing with the EEC. US firms are familiar with methods of large-scale, continent-wide distribution. Most European firms aren't. And, American companies have seen certain industries, such as airlines, deregulated. They have a good idea of what might happen in Europe and know which mistakes to avoid.

The methods American companies use to establish themselves in the EEC are not as important as the fact that they do establish themselves. "I believe that US companies are going to have to become insiders to take the maximum advantage of the opportunity," says Weizer. "Just sitting on the outside and taking pot shots, just throwing something over the wall and hoping they'll buy it, not getting in there and forming relationships and taking the market seriously is the worst thing Americans can do."

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EDN November 7, 1991
For a career to be exciting, you need some diversity in the assignments you tackle. And fresh challenges to generate new insights. That’s what you’ll find at ESL.

A subsidiary of TRW, ESL offers the chance to experience a variety of projects in a flexible, informal environment. If you’d like to join our efforts in advanced technologies like reconnaissance, intelligence, digital systems, and signal processing, contact us about the following:

**Hardware Assistant Program Manager**
Manage a team in the development of signal processing and communications hardware including technical, cost and schedule objectives. In doing so, you’ll plan, organize and monitor all hardware development tasks. A BS/MSEE plus a minimum of 5 years’ experience in hardware design, including CMOS, TTL and ECL logic at rates up to 25 MHz as well as 2+ years’ as a lead engineer is required. Prior management experience and strong interpersonal skills are essential.

**Senior Strategic Signal Processing Engineer**
You’ll develop state-of-the-art, strategic signal processing systems and provide technical leadership for other design engineers. A BS/MSEE and 5-10 years’ experience in hardware and software design is required. Three plus years’ working with signal processing systems including z transforms, transmultiplexers and sampling theory along with communications systems and prior supervisory experience is also required.

**Senior Hardware Design Engineers**
Provide technical leadership and take responsibility for the development of signal processing and communications hardware and firmware including proposals, requirements definition/allocation, design, test and integration. We require a BS/MSEE and 5-10 years’ experience in hardware design and programmable logic design. A minimum of 3-5 years’ experience in firmware design using C, TMS320, 860 or DSP16/32 assembly language, as well as previous technical leadership experience is also required. Prior experience with Mentor CAE simulation and familiarity with digital signal processing is essential.

**Software Engineers**
You’ll address a wide range of applications including direction finding, mission planning, resource and data management, and signal processing. We require a BS/MS in CS, EE, Physics, Applied Math, or the equivalent and experience in a UNIX* system environment working in Ada, C, Assembler, or FORTRAN. Knowledge of MMI, X-Windows, networks, and distributed computing systems along with DoD standards is also required.

**Senior RAM Engineer**
Provide reliability/availability/maintainability (RAM) support proposals, programs and studies. Ability to perform RAM modeling and testing; allocations and predictions; FMEA; and circuit, thermal and failure analysis is essential. Experience in system safety, human factors and component engineering is a plus.

**Systems Engineers**
You’ll need prior experience in the development of airborne and/or ground based reconnaissance systems operating in the HF, VHF/UHF, and P-band frequency ranges. Ability to perform system analysis activities including system sensitivity, dynamic range and antenna performance is a must. A digital signal processing background is preferred.

**Logistic Engineer**
You’ll provide logistic support for various programs. Ability to perform maintenance analysis; prepare technical manuals, training materials and documentation; and deliver classroom training is a must.

U.S. Citizenship is required for these positions; EB1 is preferred. Please mail your resume, indicating your area of interest and expertise, to Patricia Ashmore, Professional Employment Dept. EDN-2028, ESL, 1345 Crossman Ave., P.O. Box 3510, Sunnyvale, CA 94088-3510. An equal opportunity employer.

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Openings now exist for individuals with expertise in the following areas. Positions require a BSEE/CS or advanced degree with emphasis on computer engineering. Experience in RISC architecture, microprocessor, and CMOS VLSI design is essential, as well as strong circuit and logic design skills. Proficiency in C and UNIX would be a plus.

LOGIC DESIGNERS
Responsible for definition, logic design and verification of high performance RISC microprocessor. Expertise in specifying, modeling and design is essential.

SYSTEM VERIFICATION ENGINEERS
Develop verification programs/behaviorals to verify RISC microprocessor functions and perform failure analysis at system and chip levels. Proficiency in Card UNIX is required.

CIRCUIT DESIGNERS
Design CMOS circuitry for RISC based microprocessor functions. Must be able to design complex CMOS circuits and perform circuit analysis, verification and design for test.

CAE DESIGNERS
Develop an integrated VLSI CAD platform based on vendor tools and design/code. Includes evaluation, design methodology and tool support. Requires experience in workstation tool development and software integration. Knowledge of relational database and graphical user interfaces (X, motif) would be a plus.

PRODUCT ENGINEERS
From wafer probe and assembly through final test, will ensure effective product yield/cost management. Involves customer interface and characterization of products to support design, manufacturing and quality improvements for RISC microprocessors.

SYSTEM ADMINISTRATORS
Administer a distributed UNIX workstation environment of multivendor platforms. Will also provide network management and system software support to engineering programming departments. Familiarity with installation/maintenance of VLSI CAD tool software preferred.

There's no company—or opportunity—in the world like this one. Be a part of it. For consideration, send your resume to: Motorola Recruitment, Dept. ATX—9118, 505 Barton Springs Rd., One Texas Center, Suite 400, Austin, TX 78704. (800) 531-5183; (512) 322-8811 FAX. Equal Opportunity/Amiritive Action Employer.

MOTOROLA
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**Advertiser in European edition

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<th>Category</th>
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<th>Actual No. Copies of Single Issue Published Nearest to Filing Date</th>
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<tr>
<td>2. Mail Subscriptions (Paid and/or Requested)</td>
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<td>E. Total Distribution (Sum of C &amp; D)</td>
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<td>2. Returns from news agents</td>
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<td>G. Total</td>
<td>145,340</td>
<td>160,372</td>
</tr>
</tbody>
</table>

I certify that the statements made by me above are correct and complete. John Scheunemann, Distribution Manager.

COMING JANUARY 20, 1992

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