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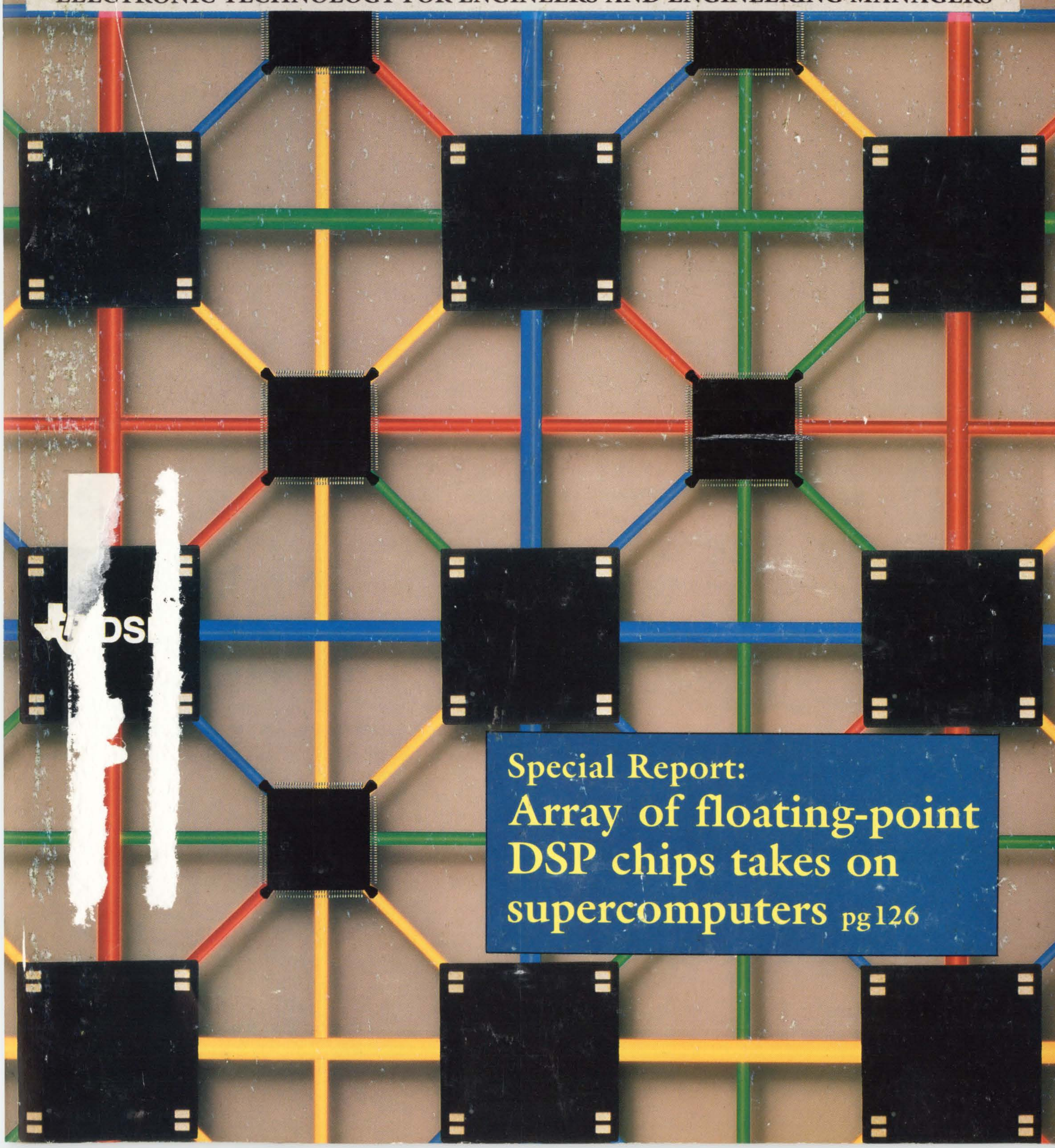
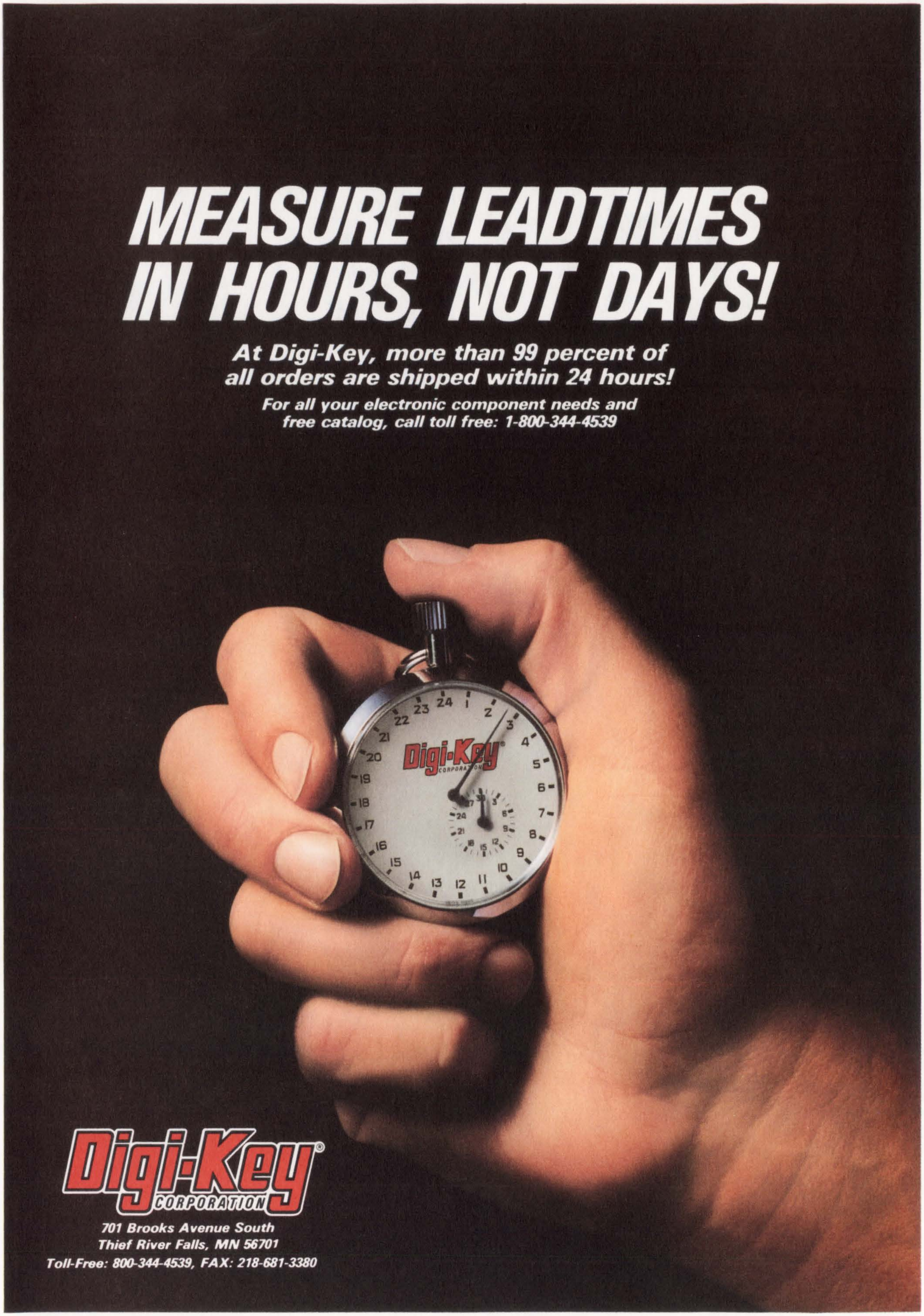
EDN®

ELECTRONIC TECHNOLOGY FOR ENGINEERS AND ENGINEERING MANAGERS



Special Report: Array of floating-point DSP chips takes on supercomputers pg126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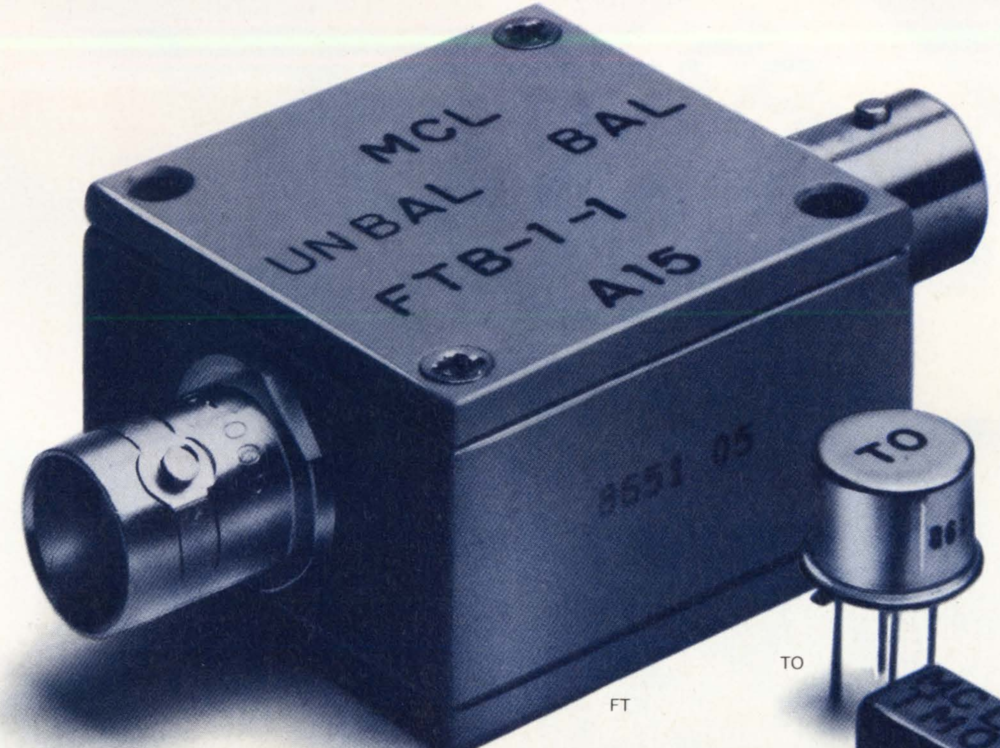

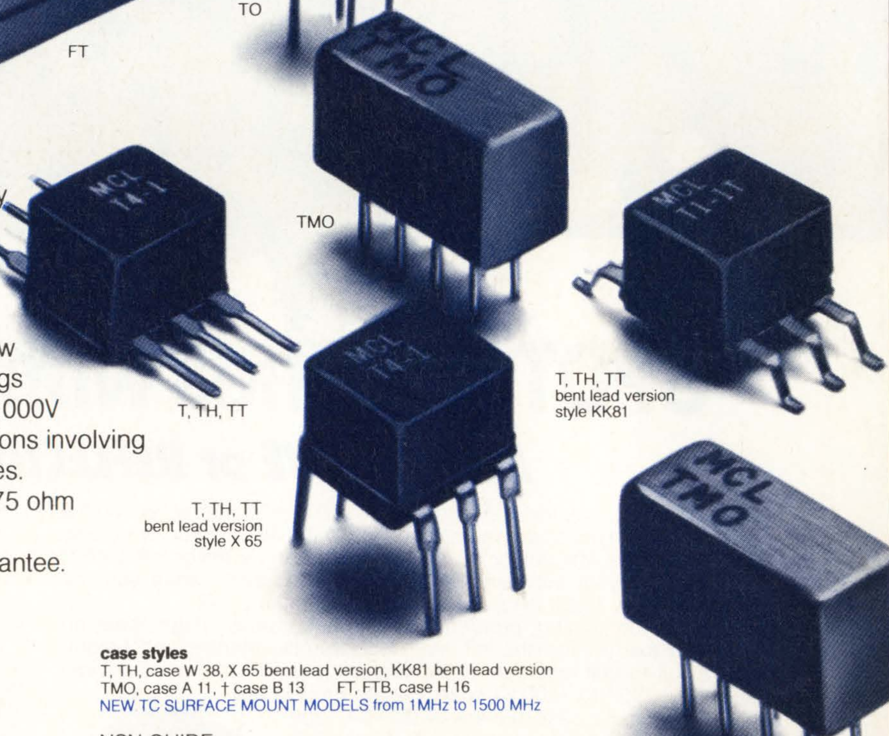

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T1-1T	5950-01-153-0668	TMO3-1T	5950-01-168-7512
T2-1	5950-01-106-1218	TMO4-1	5950-01-067-1012
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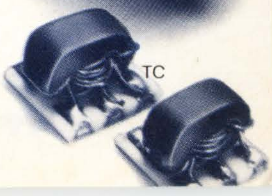

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CIRCLE NO. 3

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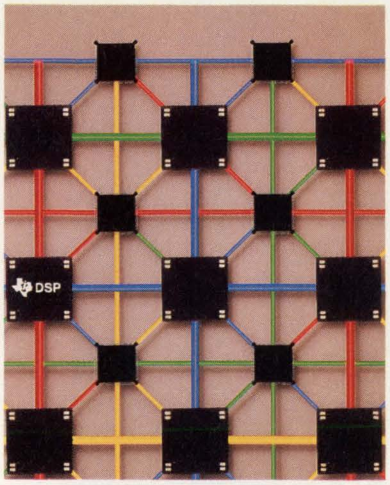
EDN Magazine Edition®

Volume 36, Number 23

November 7, 1991

ELECTRONIC TECHNOLOGY FOR ENGINEERS AND ENGINEERING MANAGERS



On the cover: *Fitted with larger memories and new multioperation architectures, 32-bit floating-point DSP processors are built to handle the toughest math and multimedia applications. See our Special Report on pg 126. (Photo courtesy Texas Instruments Inc; art direction by Mike Dennis; computer graphics by The Color Place)*

SPECIAL REPORT

DESIGN FEATURES

The Jim Williams Papers

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

Continued on page 7

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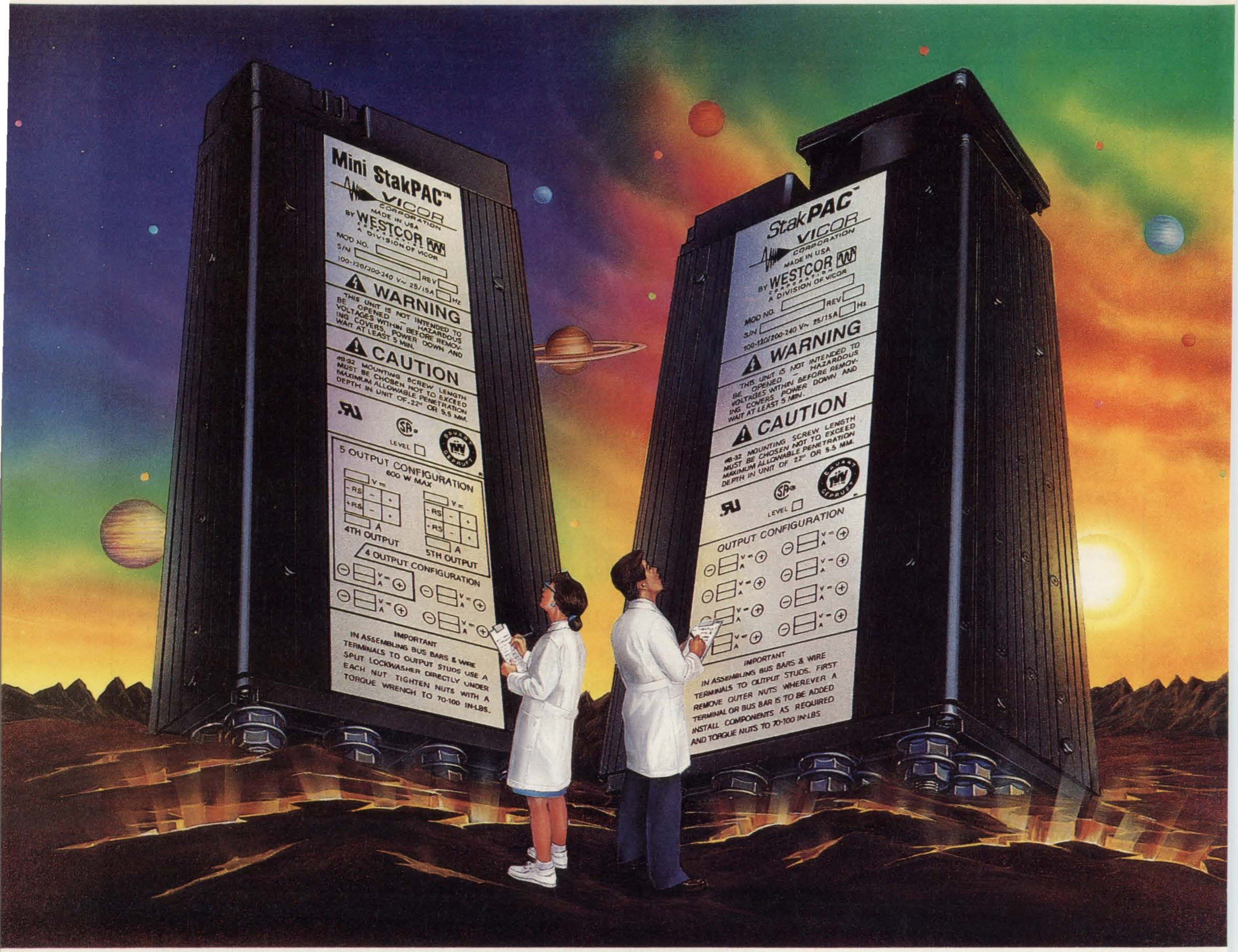
Power Revelation



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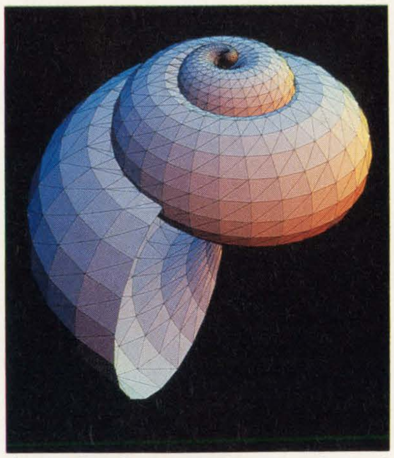
Component Solutions For Your Power System

CIRCLE NO. 5

Continued from page 5



***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.*

TECHNOLOGY UPDATES

Continued on page 9

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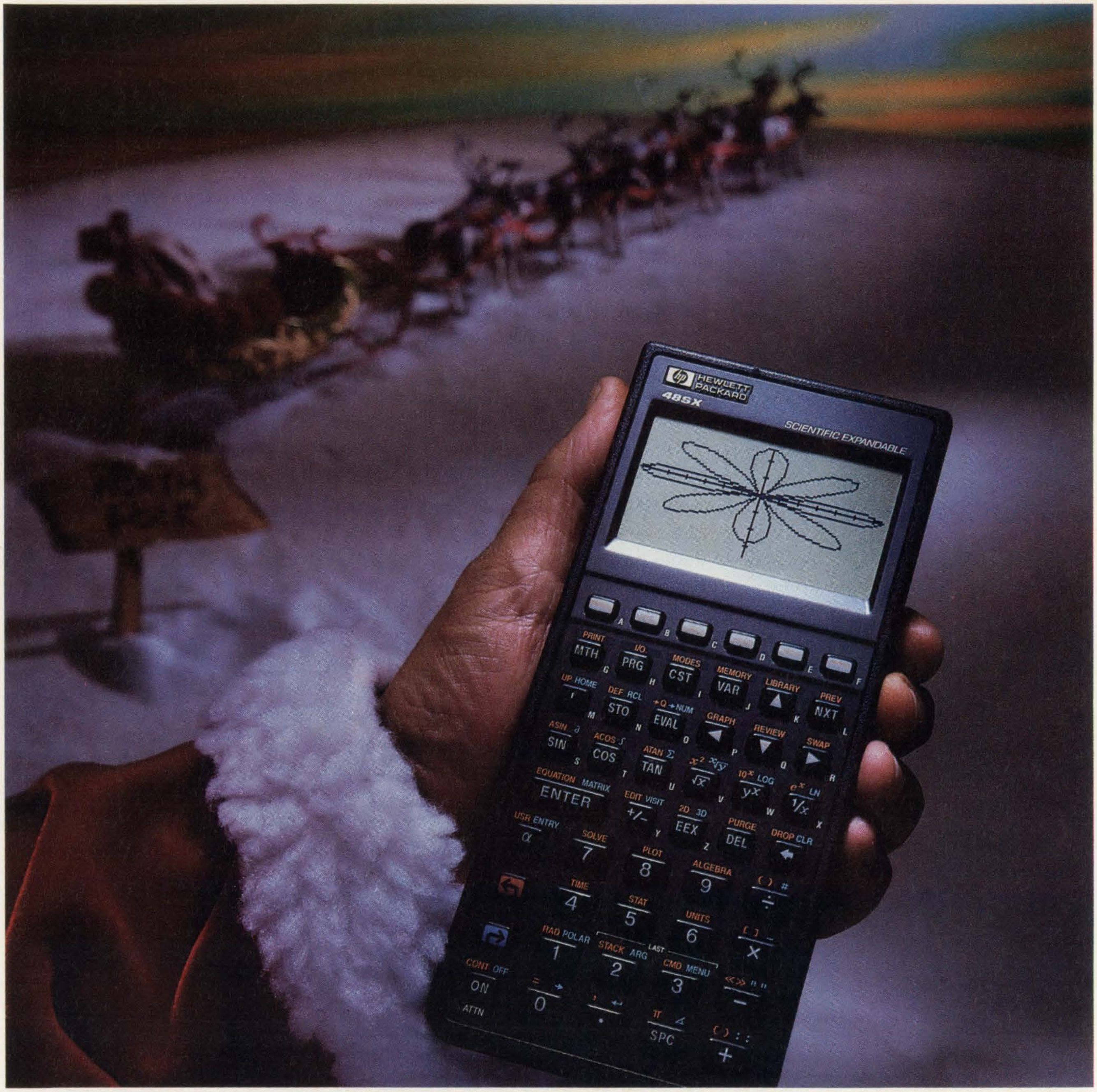

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CIRCLE NO. 6

Continued from page 7

EDN Magazine Edition

November 7, 1991

EDITORS' CHOICE

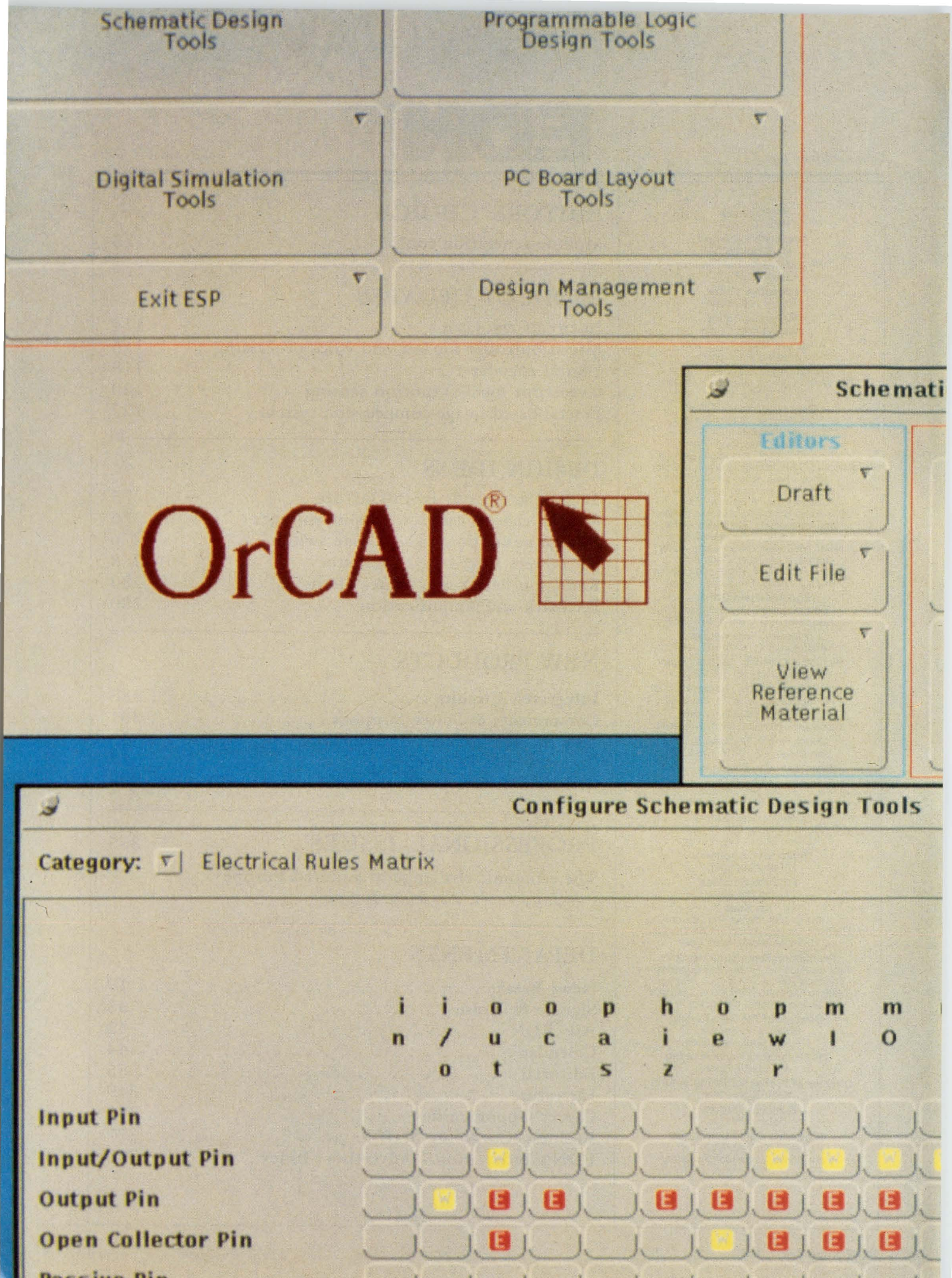
PRODUCT UPDATES

DESIGN IDEAS

NEW PRODUCTS

PROFESSIONAL ISSUES

DEPARTMENTS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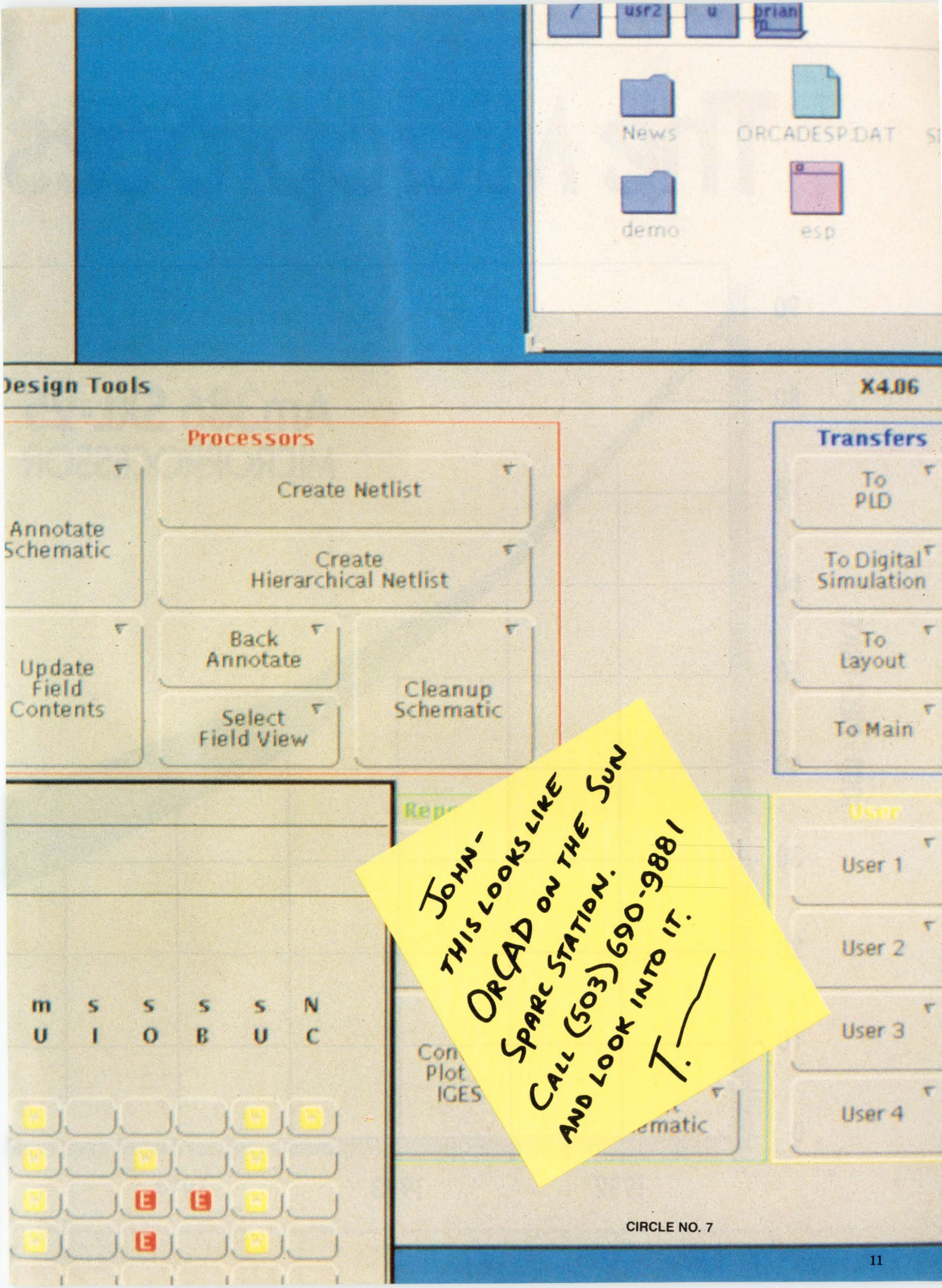
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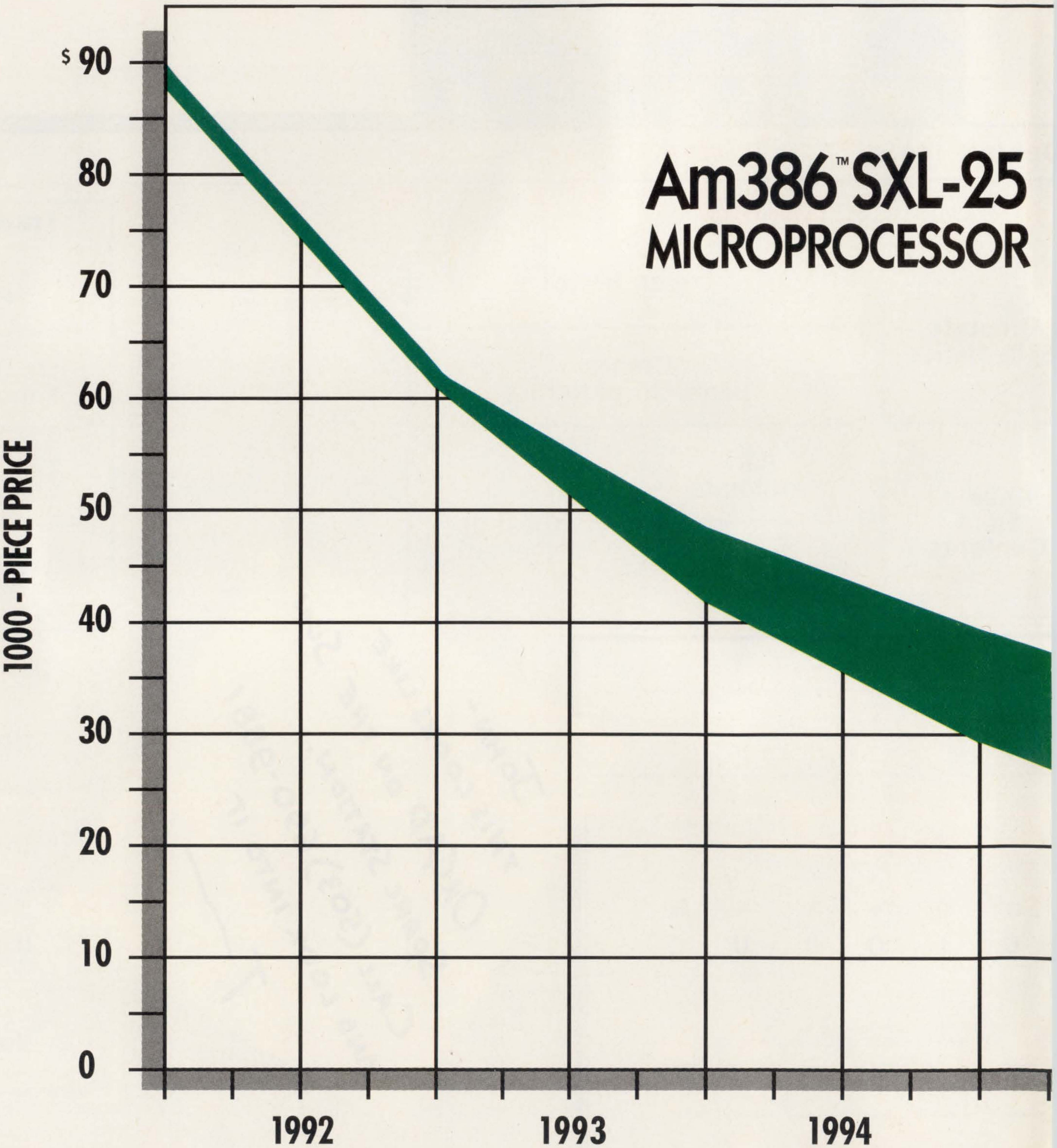

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CIRCLE NO. 17

NEWS BREAKS

EDITED BY SUSAN ROSE

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

NEWS BREAKS

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 bitblt 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 bitblt 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

Flowmeric'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. Flowmerics, Kingston-upon-Thames, UK, (81) 547-3373, FAX (81) 547-2682.—Brian Kerridge

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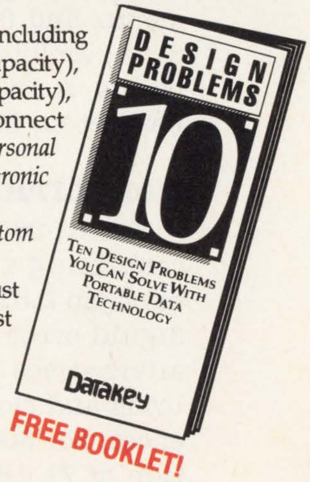

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CIRCLE NO. 19

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 (512×9 bits) and the CY7C442 and -453 (2k×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×32-bit-word dual-port static RAM (SRAM), and 128k×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

Why Settle for ½ an '040 Board?

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.

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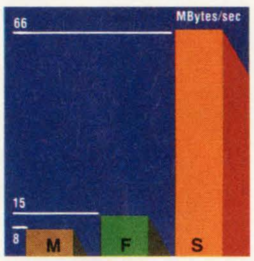
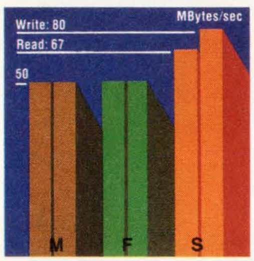


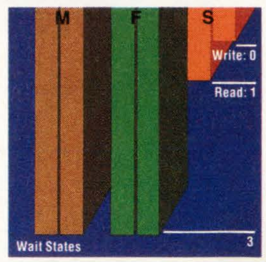
VME Transfers

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.



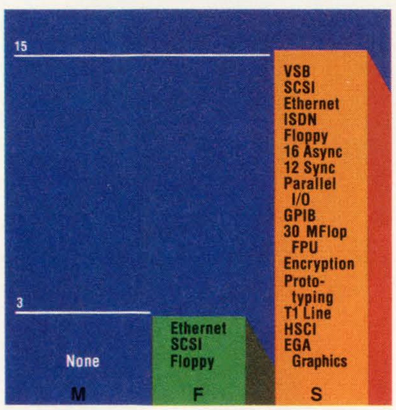
DRAM Burst Rates

A 25 MHz '040 is capable of accessing memory at 80 MB/s. The closer you are to this maximum, the more '040 performance you're gaining. SV430 bursts are 26% faster than Force and Motorola.



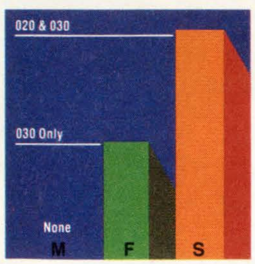
DRAM Random Accesses

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.



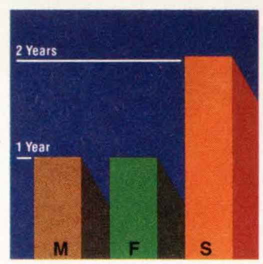
I/O Modules

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.



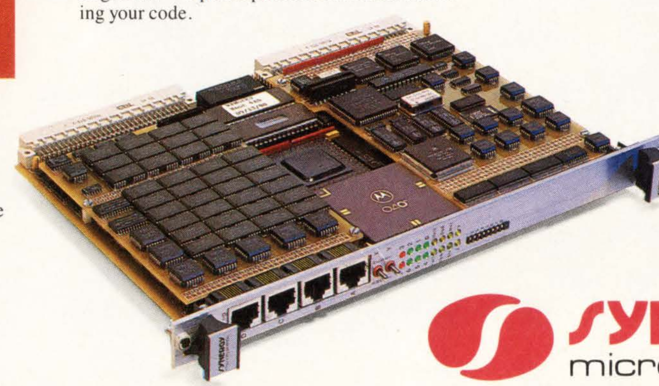
'020/'030 Compatibility

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 MVME165 data sheet dated 2/90, and Force CPU-40 data sheet A1 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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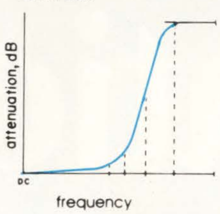
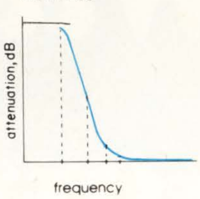


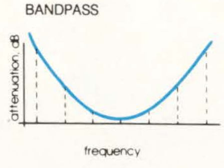
MODEL NO.	PASSBAND, MHz (loss <1dB) Min.	fco, MHz (loss 3db) Nom.	STOP BAND, MHz (loss>20dB) Max.	STOP BAND, MHz (loss>40dB) Max.	STOP BAND, MHz Min.	VSWR pass-band typ.	VSWR stop-band typ.	PRICE $ Qty. (1-9)
PLP-10.7	DC-11	14	19	24	200	1.7	18	11.45
PLP-21.4	DC-22	24.5	32	41	200	1.7	18	11.45
PLP-30	DC-32	35	47	61	200	1.7	18	11.45
PLP-50	DC-48	55	70	90	200	1.7	18	11.45
PLP-70	DC-60	67	90	117	300	1.7	18	11.45
PLP-100	DC-98	108	146	189	400	1.7	18	11.45
PLP-150	DC-140	155	210	300	600	1.7	18	11.45
PLP-200	DC-190	210	290	390	800	1.7	18	11.45
PLP-250	DC-225	250	320	400	1200	1.7	18	11.45
PLP-300	DC-270	297	410	550	1200	1.7	18	11.45
PLP-450	DC-400	440	580	750	1800	1.7	18	11.45
PLP-550	DC-520	570	750	920	2000	1.7	18	11.45
PLP-600	DC-580	640	840	1120	2000	1.7	18	11.45
PLP-750	DC-700	770	1000	1300	2000	1.7	18	11.45
PLP-800	DC-720	800	1080	1400	2000	1.7	18	11.45
PLP-850	DC-780	850	1100	1400	2000	1.7	18	11.45
PLP-1000	DC-900	990	1340	1750	2000	1.7	18	11.45
PLP-1200	DC-1000	1200	1620	2100	2500	1.7	18	11.45

high pass dc to 2500MHz



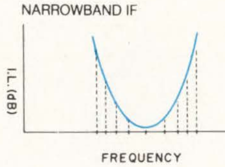
MODEL NO.	PASSBAND, MHz (loss <1dB) Min.	PASSBAND, MHz Min.	fco, MHz (loss 3db) Nom.	STOP BAND, MHz (loss>20dB) Min.	STOP BAND, MHz (loss>40dB) Min.	VSWR pass-band typ.	VSWR stop-band typ.	PRICE $ Qty. (1-9)
PHP-50	41	200	37	26	20	1.5	17	14.95
PHP-100	90	400	82	55	40	1.5	17	14.95
PHP-150	133	600	120	95	70	1.8	17	14.95
PHP-175	160	800	140	105	70	1.5	17	14.95
PHP-200	185	800	164	116	90	1.6	17	14.95
PHP-250	225	1200	205	150	100	1.3	17	14.95
PHP-300	290	1200	245	190	145	1.7	17	14.95
PHP-400	395	1600	360	290	210	1.7	17	14.95
PHP-500	500	1600	454	365	280	1.9	17	14.95
PHP-600	600	1600	545	440	350	2.0	17	14.95
PHP-700	700	1800	640	520	400	1.6	17	14.95
PHP-800	780	2000	710	570	445	2.1	17	14.95
PHP-900	910	2100	820	660	520	1.8	17	14.95
PHP-1000	1000	2200	900	720	550	1.9	17	14.95

bandpass 20 to 70MHz



MODEL NO.	CENTER FREQ. MHz F0	PASS BAND, MHz (loss <1dB) Max. F1	PASS BAND, MHz Min. F2	STOP BAND, MHz (loss > 10 dB) Min. F3	STOP BAND, MHz (loss > 10 dB) Max. F4	STOP BAND, MHz (loss > 20 dB) Min. F5	STOP BAND, MHz (loss > 20 dB) Max. F6	VSWR 1.3:1 typ. total band MHz	PRICE $ Qty. (1-9)
PIF-21.4	21.4	18	25	4.9	85	1.3	150	DC-220	14.95
PIF-30	30	25	35	7	120	1.9	210	DC-330	14.95
PIF-40	42	35	49	10	168	2.6	300	DC-400	14.95
PIF-50	50	41	58	11.5	200	3.1	350	DC-440	14.95
PIF-60	60	50	70	14	240	3.8	400	DC-500	14.95
PIF-70	70	58	82	16	280	4.4	490	DC-550	14.95

narrowband IF



MODEL NO.	CENTER FREQ. MHz F0	PASS BAND, MHz I.L. 1.5dB max. F1-F2	STOP BAND, MHz I.L. > 20dB F5	STOP BAND, MHz I.L. > 20dB F6	STOP BAND, MHz I.L. > 35dB F7	STOP BAND, MHz I.L. > 35dB F8-F9	PASS-BAND VSWR Max.	PRICE $ Qty. (1-9)
PBP-10.7	10.7	9.5-11.5	7.5	15	0.6	50-1000	1.7	18.95
PBP-21.4	21.4	19.2-23.6	15.5	29	3.0	80-1000	1.7	18.95
PBP-30	30.0	27.0-33.0	22	40	3.2	99-1000	1.7	18.95
PBP-60	60.0	55.0-67.0	44	79	4.6	190-1000	1.7	18.95
PBP-70	70.0	63.0-77.0	51	94	6	193-1000	1.7	18.95

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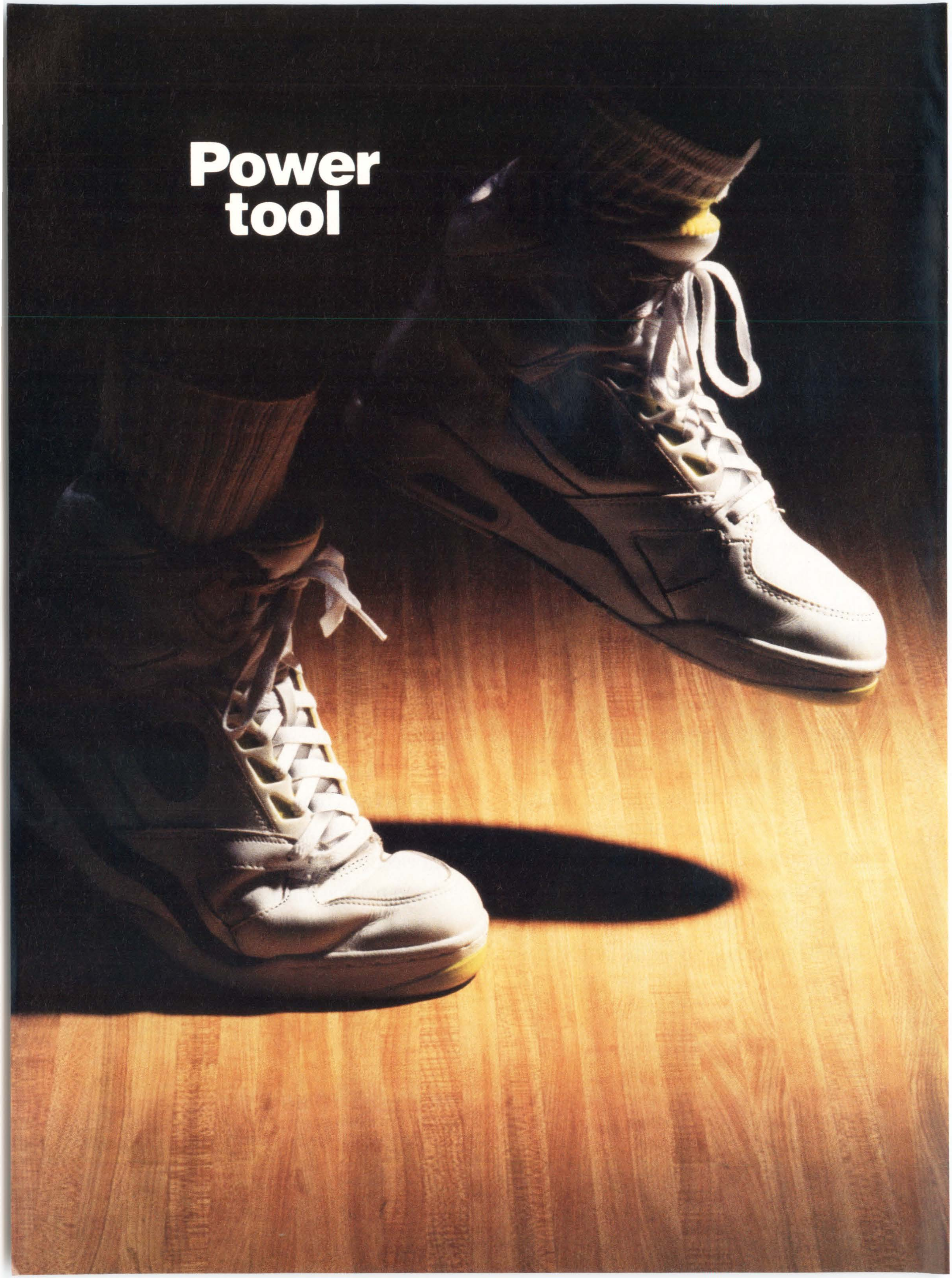
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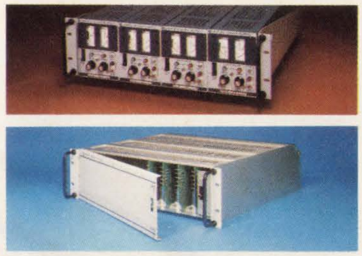

dc, unipolar power

- ☐ 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

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dc, bipolar power

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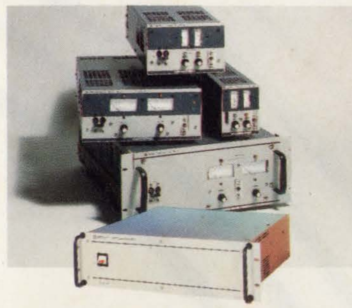
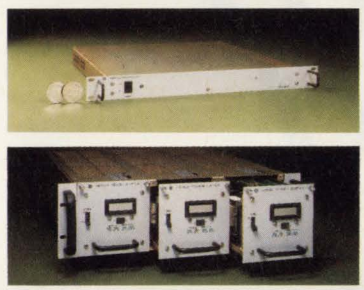
Kepco Group BIT/BOP Power Supplies



dc, unipolar power

- ☐ Listen, talk-verify, GPIB
- ☐ 12 bit control, 0-6V to 0-325V, unipolar dc
- ☐ Power: 50W, 100W, 250W, 500W, 1000W
- ☐ Control one to sixteen units, analog drive

Kepco Group TLD/ATE Power Supplies



dc (selectable polarity) power

- ☐ Talk-listen, GPIB, full read back of both voltage and current
- ☐ 12 bit control, 0-6V to 0-150V unipolar dc with polarity selection
- ☐ Power: 360W, 720W, 1080W
- ☐ 1-27 unit control, digital (bit-bus) drive

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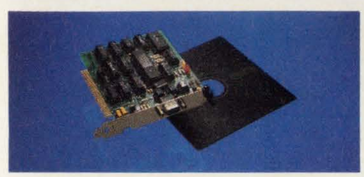

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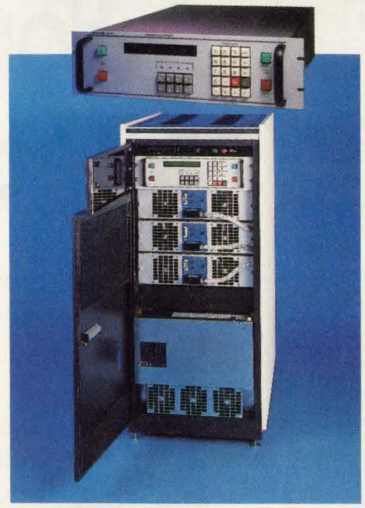

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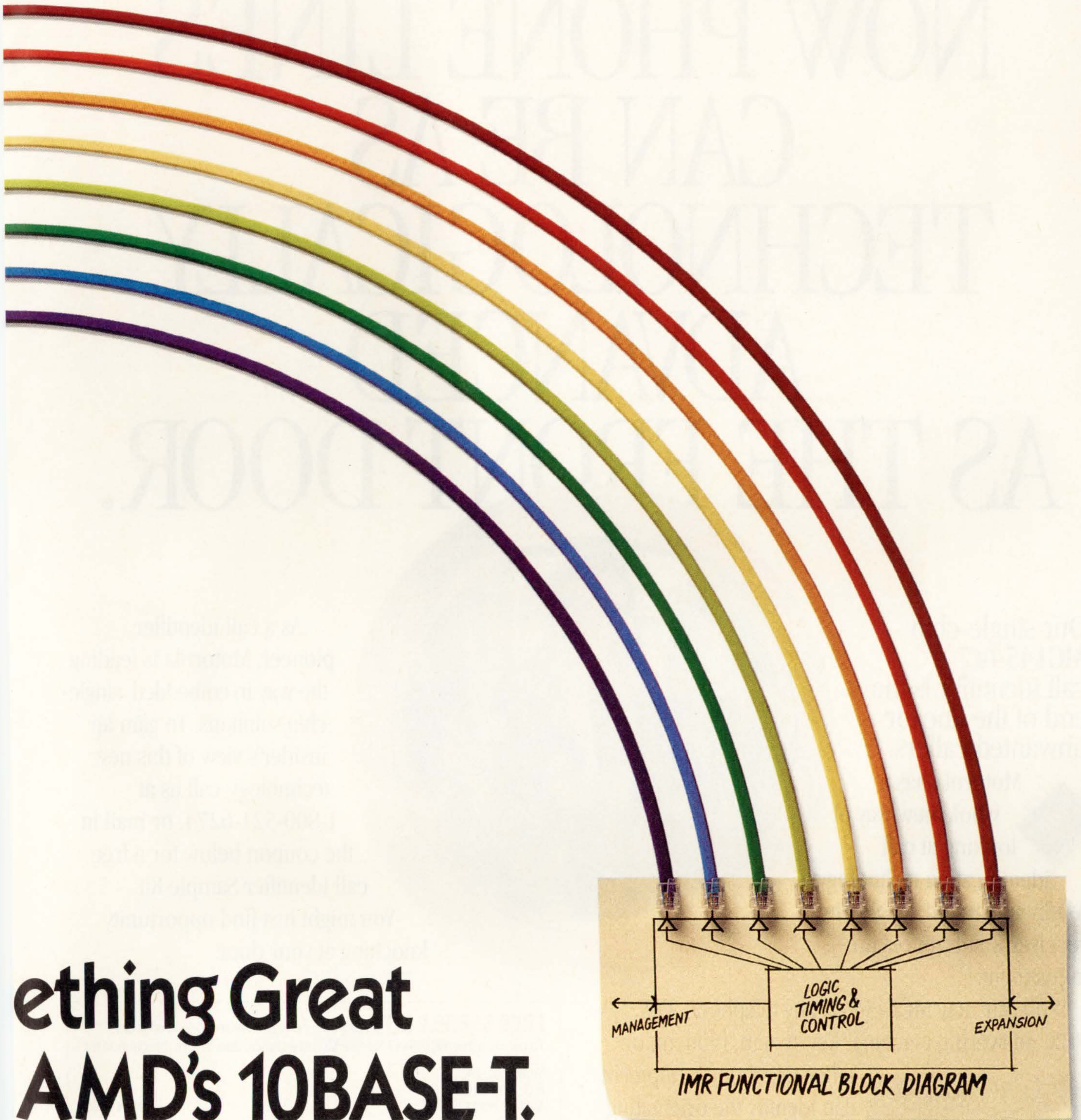

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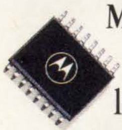

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SIGNALS & NOISE

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 $k\sigma$, 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 9 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 ($NPR = 6.02N + 20\ \log(\sqrt{3}/K)$), a loading factor of 8 will result in an NPR of 58.83 dB. This NPR is 3.87 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 bar-code 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

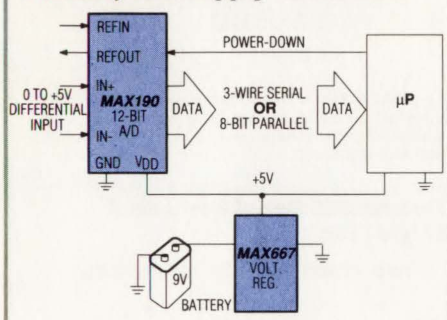
In the November 14 EDN News Edition, look for a Product Watch on SBus cards and a Career Opportunities article on ISDN.

More answers.
Every week in EDN.

MAXIM
DESIGN NEWS
Analog Design Insights from Maxim Integrated Products No. 23

Analog Solutions For Tough Design Problems

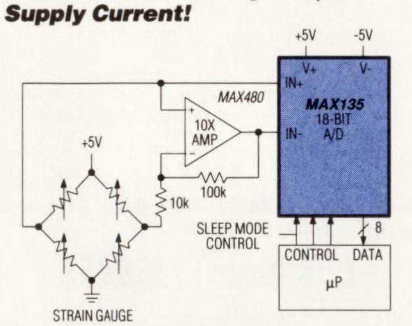
Fastest, +5V-Supply 12-Bit ADC



The **MAX190** converts rail-to-rail signals to either serial or parallel data in 7.5µs on battery power. Precision laser-trimmed reference, clock and track/hold included on-chip. The MAX190's already-low 15mW power consumption is reduced to 150µW during shutdown.

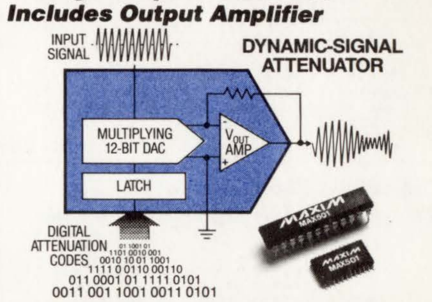
(CIRCLE 274)

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 µP interfacing. (CIRCLE 275)

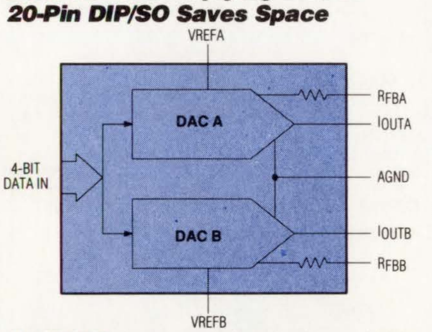
4-Quadrant Multiplying Voltage-Output 12-Bit DAC Includes Output Amplifier



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 buses.

(CIRCLE 276)

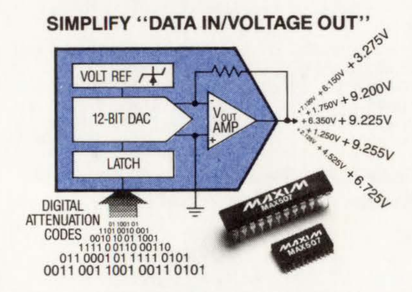
Dual 12-Bit Multiplying DAC in 20-Pin DIP/SO Saves Space



The **MX7549** current-output, four-quadrant multiplying DAC features 1% resistance match between DACs, making many dual applications possible. The new DAC has ±½LSB max integral nonlinearity, ±5ppm/°C max gain temperature coefficient, and operates from a single +5V to +15V supply. Pin compatible to AD7549.

(CIRCLE 277)

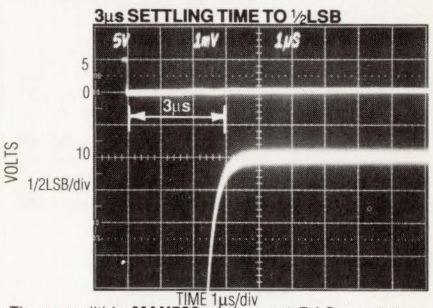
Complete 12-Bit Voltage-Output DAC Includes +5V Reference



The **MAX507/508** combine a laser-trimmed DAC, a high-performance BiCMOS output amp, and a buried-zener voltage reference on a single IC, greatly improving reliability compared to multi-chip solutions. Data is transferred into the input register in 8+4-bit (MAX508) or 12-bit (MAX507) wide data formats.

(CIRCLE 278)

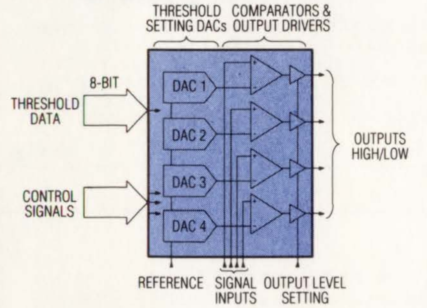
Quad 12-Bit Voltage-Output DACs Replace 8 Components!



The monolithic **MAX526** replaces 4 DACs and 4 op amps. Monotonic 12-bit performance guaranteed with ½LSB relative accuracy over temperature for all 4 outputs and 1LSB total unadjusted error with no zero- or full-scale adjustments at +25°C. Outputs settle to ½LSB in 3µs.

(CIRCLE 279)

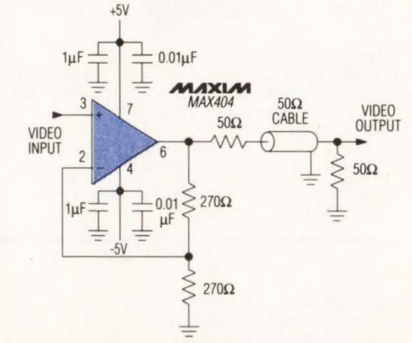
Four Comparators With On-Chip DAC Adjustable Thresholds



New **MAX516** automates calibration, minimizes part count with 4 BiCMOS comparators with DAC-programmed input thresholds in a single device. Features include 0.4% resolution, 1.5µs propagation delay and 50mW max power consumption.

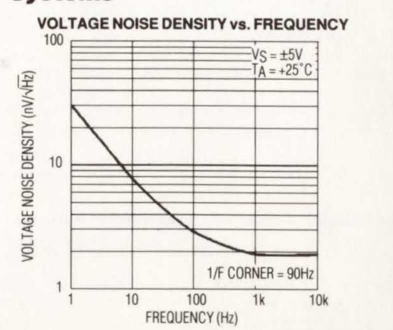
(CIRCLE 280)

Broadcast Quality Video Op Amp



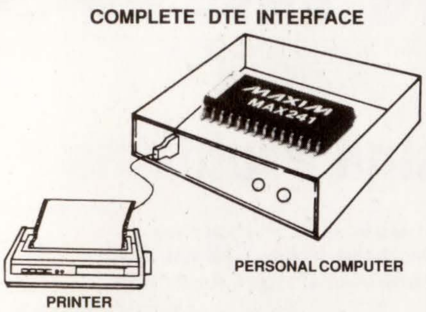
The **MAX404** video op amp has 0.01° differential phase and 0.05% differential gain while operating from ±5V supplies. Featuring 80MHz gain-bandwidth and 500V/µs slew rate, this amplifier is ideal for video and other high-speed applications. 50mA continuous output current is guaranteed. (CIRCLE 281)

Lowest Noise Dual Op Amp For 5V Systems



The **MAX412** provides the **best noise performance** — even at very low supply voltages. <2.4nV/√Hz @ 1kHz noise guaranteed! With a guaranteed output voltage swing of 7.3VPP and greater than 97dB SINAD (Signal/THD+N) while operating from ±5V supplies, the MAX412 is ideal for 5V systems. 8-pin DIP/SO. (CIRCLE 282)

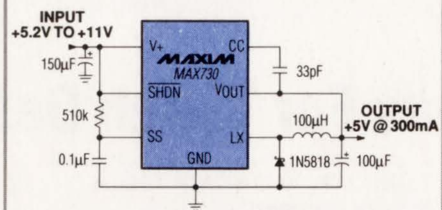
Complete +5V Serial Port IC With 1µF External Caps!



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)

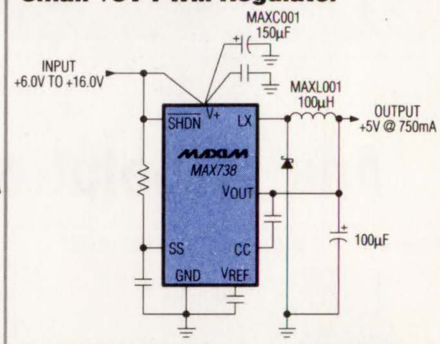
Small +5V PWM Regulator Has 94% Efficiency!



The **MAX730** is the smallest complete PWM step-down available. Its 8-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)

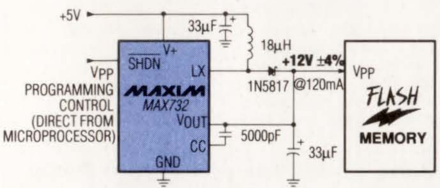
Guaranteed 750mA Output From Small +5V PWM Regulator



The **MAX738** PWM step-down switching 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 285)

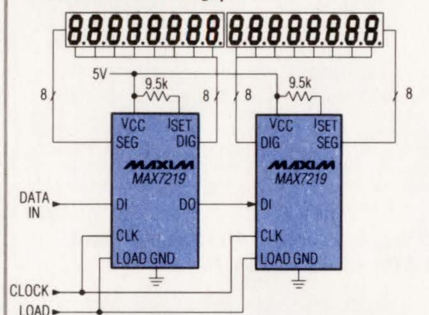
Complete Flash Memory Programmer In 1/2 Square Inch!



The **MAX732** 200mA step-up regulator is a simple, compact flash memory programming supply that has direct µP-controlled shutdown. It will step up from +5V to +12V±4% at 200mA with 88% efficiency. Pre-assembled evaluation kit available.

(CIRCLE 286)

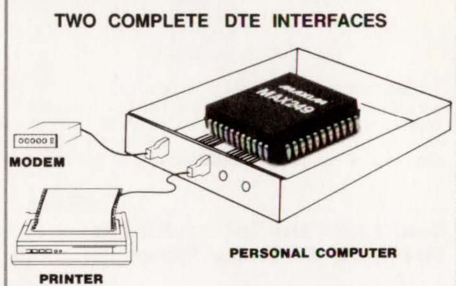
8-Digit 10MHz LED Display Driver Works With Any µP!



The new **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 287)

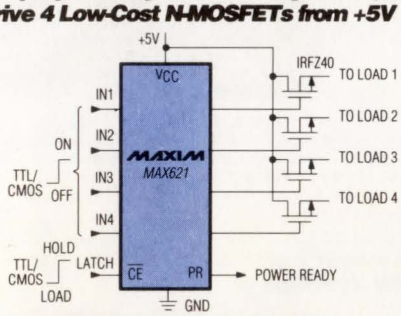
Two RS-232 Serial Ports On A Single Chip!



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 1µF capacitors and is guaranteed to operate at data rates up to 64kb/s.

(CIRCLE 288)

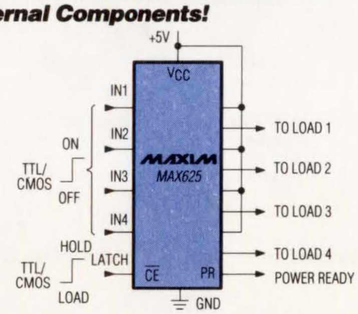
Simplify Battery Load Management, Drive 4 Low-Cost N-MOSFETs from +5V



The **MAX621/620** drive 4 low-cost 35A/0.028Ω 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 MAX621 has internal charge-pump capacitors; MAX620 costs less and requires 3 inexpensive external components.

(CIRCLE 289)

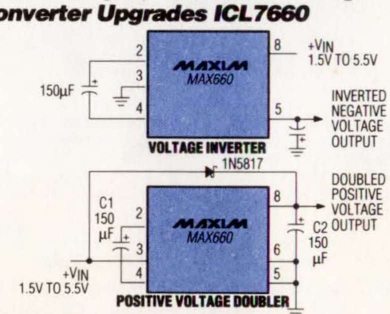
Four 0.2Ω Switches In 0.3in² — No External Components!



The **MAX625** 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 15mA with the ICL7660. Efficiency exceeds 90% for most applications.

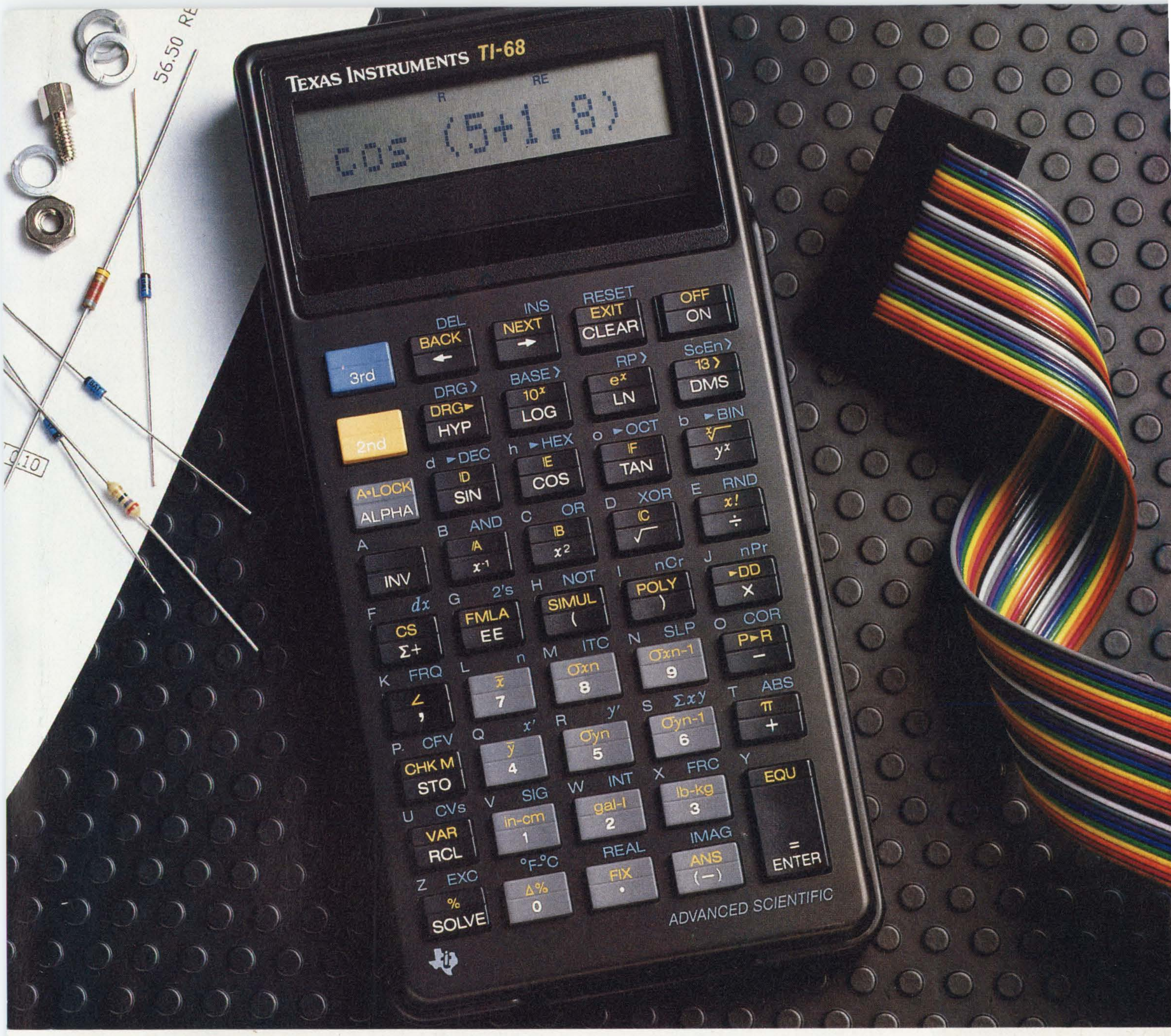
(CIRCLE 291)

★ DATA SHEETS ★

MAX190	(Circle 274)	MAX404	(Circle 281)	MAX249	(Circle 288)
MAX135	(Circle 275)	MAX412	(Circle 282)	MAX621/620	(Circle 289)
MAX501/502	(Circle 276)	MAX241	(Circle 283)	MAX625	(Circle 290)
MX7549	(Circle 277)	MAX730	(Circle 284)	MAX660	(Circle 291)
MAX507/508	(Circle 278)	MAX738	(Circle 285)		
MAX526	(Circle 279)	MAX732	(Circle 286)		
MAX516	(Circle 280)	MAX7219	(Circle 287)		

★ FREE SAMPLES ★

For applications assistance, call (408) 737-7600, FAX (408) 737-7194 or write Maxim Integrated Products, 120 San Gabriel Drive, Sunnyvale, CA 94086.



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It also lets you easily check your equations with a 12-character alphanumeric display that can scroll through up to 80 characters for long equations. And, the last equation replay feature lets you edit or check the last computation without having to go back and reenter it.

In addition, when you need to solve quadratic, cubic or quartic equations, the TI-68's polynomial root finder will calculate the real and complex roots — automatically.

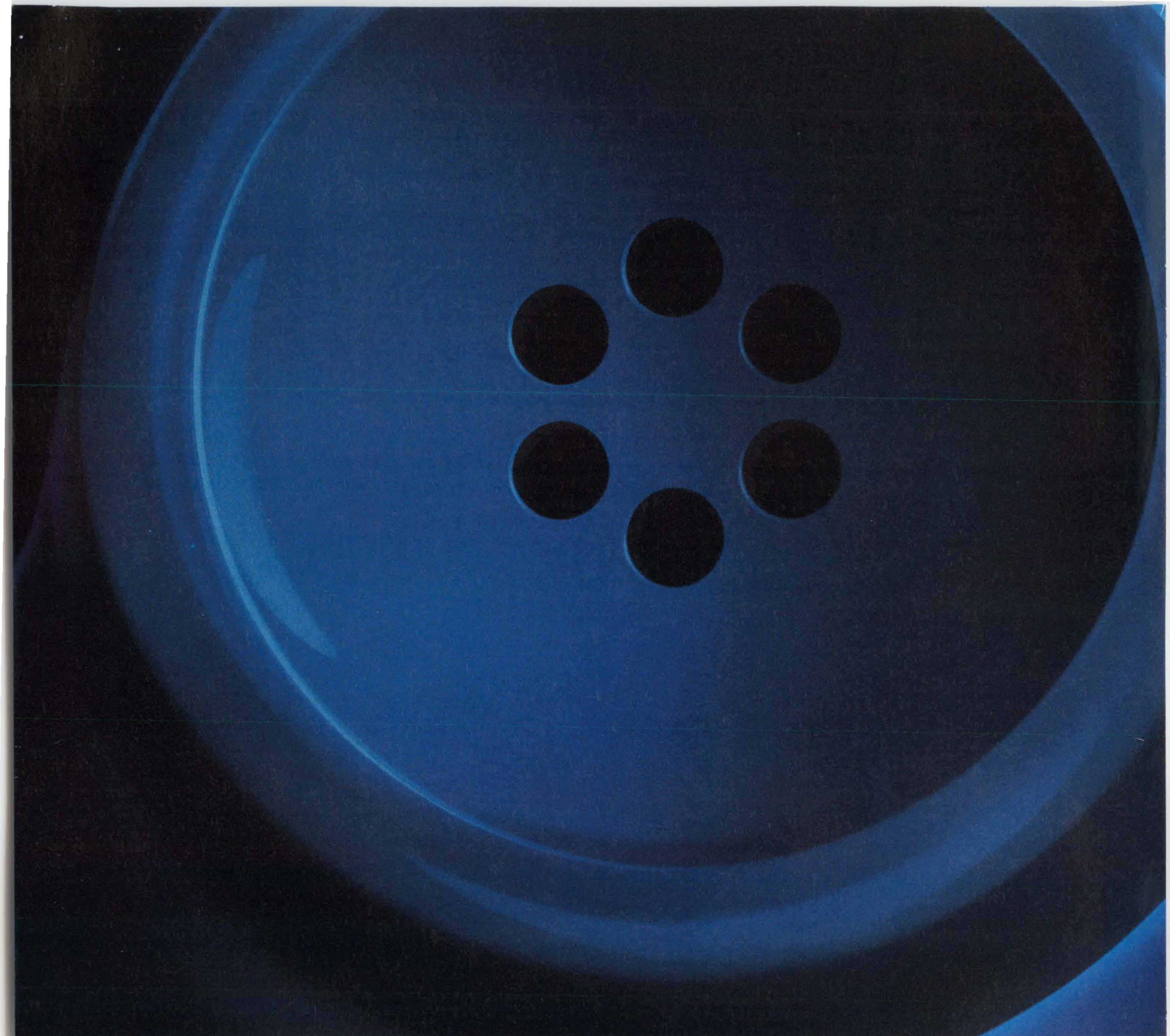
Working with number bases and conversions are also no problem. Perform arithmetic functions in decimal, hexadecimal, octal or binary. And it does Boolean logic operations, too.

The TI-68 provides up to 440 program steps for as many as 12 user-generated formulas. It even stores up to 36 values in memories with user-defined alphanumeric names.

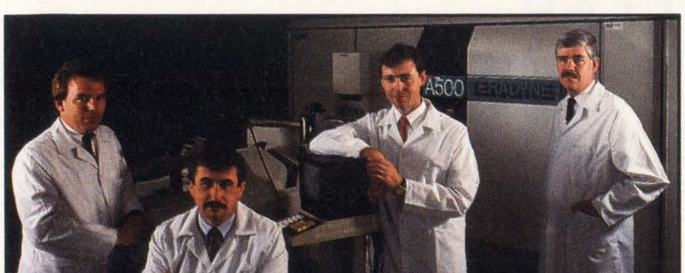
The TI-68 has what you've been looking for — the right functionality at the right price. See and try it at a nearby retailer, or call 1-806-747-1882 for additional information and to request free product literature.

TEXAS INSTRUMENTS

CIRCLE NO. 41



How Teradyne helps Northern Telecom



John Haydon, Ken Bradley, Gary Hobin, Terry Caves of Northern Telecom Electronics, Ottawa.

"To us, time is a strategic tool, a way of getting the edge it takes to gain a leadership role in world markets. With Teradyne testers, test development and manufacturing setup times are shorter, and actual test performance is far superior."

KEN BRADLEY, General Manager

Northern Telecom believes a quality message begins with a commitment: to deliver the highest performance products at the lowest cost – quickly and on time.

That's why Northern Telecom Electronics chose the Teradyne A500 Family of systems to test its most advanced mixed-signal chips. Pushing the performance envelope can be risky, but Teradyne is helping Northern Telecom avoid the pitfalls.

"Our Norstar key system is extremely silicon intensive. The A500 provided virtually unlimited test capability and reduced test time.

send the world a quality message.

I believe without it, the entire project would not be nearly as successful as it is."

GARY HOBIN, Manager,
Test & Product Engineering

Because the A500 Family's IMAGE™ programming environment permits full tester simulation at off-line workstations, test program development parallels design. That cuts product development times dramatically. And because test data is fed back quickly and early in the process, Northern Telecom engineers can eliminate bottlenecks, enhance manufacturability, and accelerate time-to-market.

"Teradyne helps us meet our high-volume production goals – on time. And they perform beyond our expectations in terms of operating costs; tester maintenance cost is 80% lower than budget – and tester uptime measures in the 98%-plus range."

JOHN HAYDON, Business Unit Manager,
Test Operations

Teradyne's A500 Family testers run reliably, producing the accurate, repeatable results that let Northern Telecom engineers ramp up fast to high-yield, high-volume production. So when a customer needs devices, Northern Telecom Electronics is ready to deliver quantity as well as quality.

"Teradyne's service continues after the sale. It's as if they take our priorities as their own. That's helped us achieve the quality it takes to succeed in such highly competitive markets as the U.S., U.K., Germany, and Japan."

TERRY CAVES, Director of Operations

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Teradyne, Inc.,
321 Harrison Ave.,
Boston, MA 02118.

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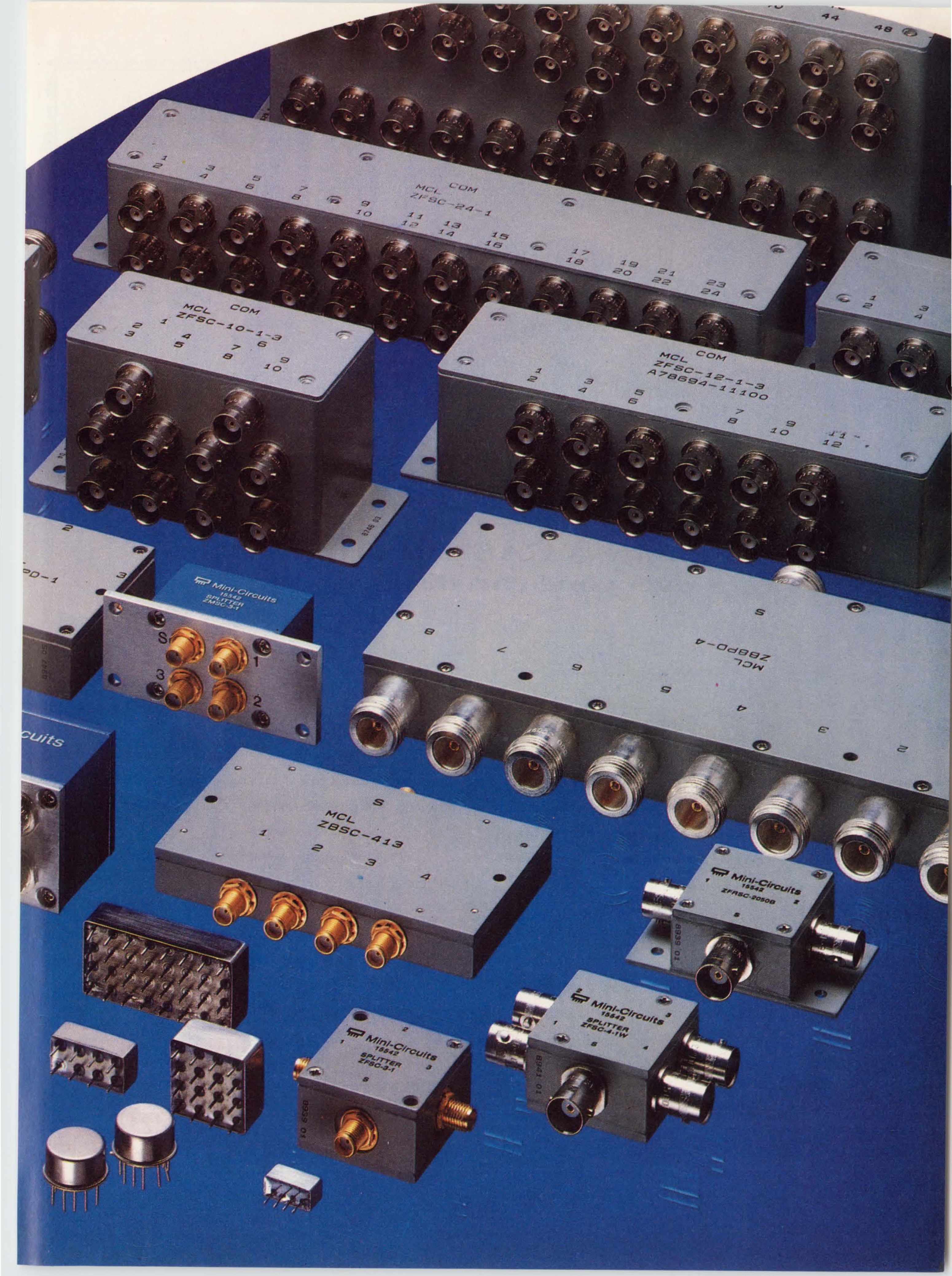
CIRCLE NO. 43

F134-1 REV. ORIG.



MCL COM
ZFSC-24-1
MCL COM
ZFSC-10-1-3
MCL COM
ZFSC-12-1-3
A78694-11100
Mini-Circuits
15542
SPLITTER
ZMSC-3-1
MCL
ZBPD-4
MCL
ZBSC-413
Mini-Circuits
15542
ZFRSC-2050B
Mini-Circuits
15542
SPLITTER
ZFSC-4-1W
Mini-Circuits
15542
SPLITTER
ZFSC-3-1

ASK EDN

EDITED BY JULIE ANNE SCHOFIELD

Tape duplicator system sought and found

I am searching for a magnetic-tape duplicating system. The tape is a ¼-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
1786 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 "orphaned" Doric C-Meter, Model 130A. Beckman 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 LXD 22-79. It is a 3½-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.

AND
770 Airport Blvd
Burlingame, CA 94010
(415) 347-9916
FAX (415) 340-1670

Hamlin
Lake and Grove Sts
Lake Mills, WI 53551
(414) 648-2361
FAX (414) 648-3001

IEE Inc
7740 Lemona Ave
Van Nuys, CA 91409
(818) 787-0311
FAX (818) 901-9046.

Ask EDN solves nagging design problems and answers difficult questions. Address your letters to Ask EDN, 275 Washington St, Newton, MA 02158. FAX (617) 558-4470; MCI: EDNBOS. Or send us a letter on EDN's bulletin-board system at (617) 558-4241; from the Main System Menu, enter ss/ask_edn and select W to write us a letter.

EDN

CALENDAR

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.

Engineering Documentation Control Seminar, Windsor Locks, CT. University of Wisconsin, Milwaukee, Center for Continuing Engineering Education, 929 N 6th St, Milwaukee, WI 53203. (414) 227-3125. November 14 to 15.

Wescon, San Francisco, CA. Electronic Conventions Management, 8110 Airport Blvd, Los Angeles, CA 90045. (800) 877-2668; (213) 215-3976, ext 252. FAX (213) 641-5117. November 19 to 21.

Hands-On Novell Networking (short course), Ottawa, Ontario. Learning Tree International, Box 45028, Los Angeles, CA 90045. (800) 421-8166; (213) 417-9700; in Canada, (800) 267-1824. FAX (213) 337-7568. November 19 to 22.

Precision Positioning & Programmable Motor Controllers (seminar), Lawrence, MA. New England Affiliated Technologies, 620 Essex St, Lawrence, MA 01841. (800) 227-1066; (508) 685-4900. FAX (508) 688-8027. November 20.

FOSE Conference: Computers and Information Systems for Government and Industry, San Antonio, TX. National Trade Productions Inc, 313 S Patrick St, Alexandria, VA 22314. (800) 638-8510; (703) 683-8500. FAX (703) 836-4486. November 20 to 21.

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.

Seagate's Low-Profile 3.5″ Drives

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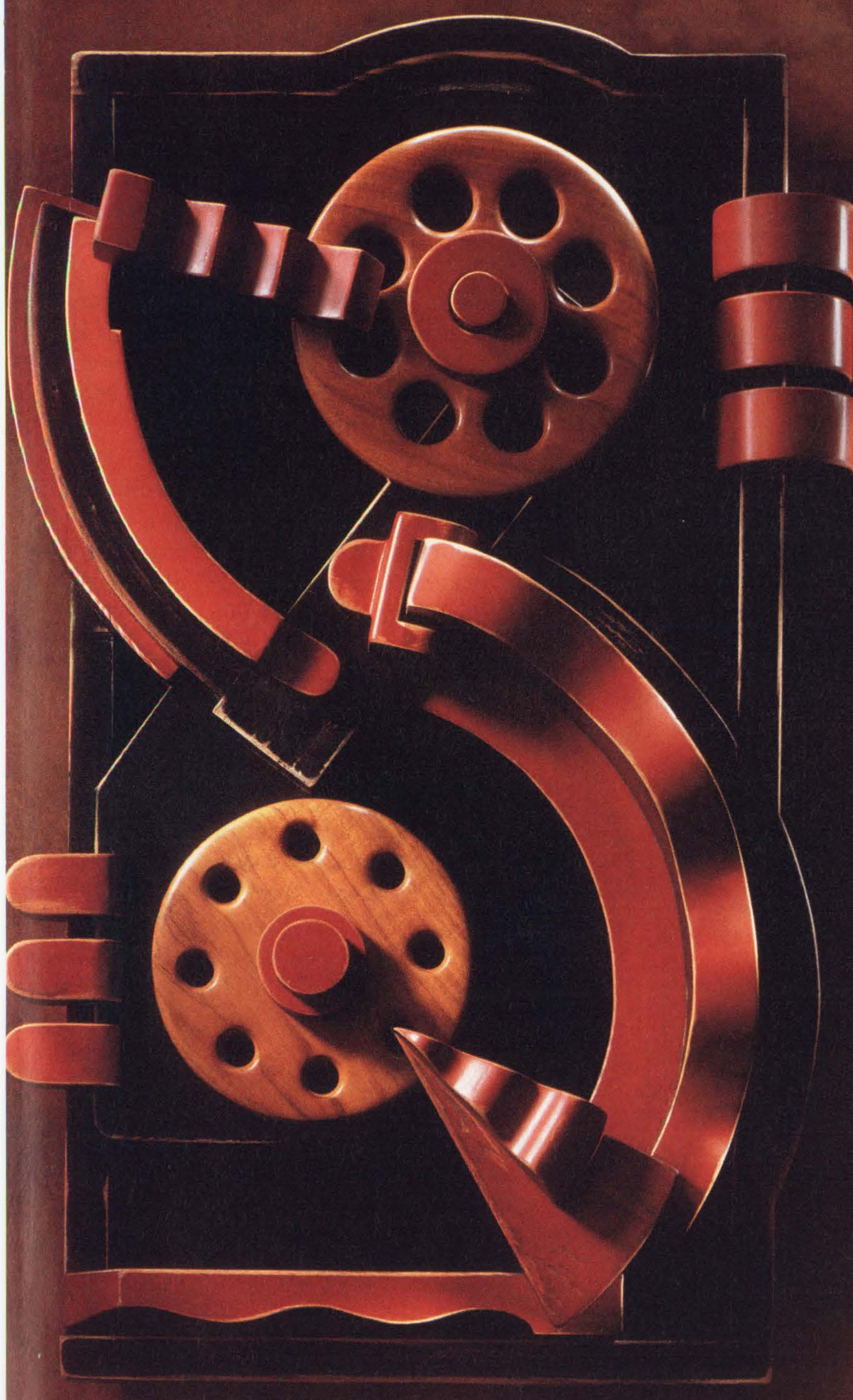

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Balance, motion, volume: the raw materials of art—and technology. At Seagate, we've consistently excelled in packing the features you want, plus the performance you need, into an elegantly compact package.

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ANOTHER QUALITY PRODUCT Seagate

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CIRCLE NO. 47

CALENDAR

MIL-STD-1553 Seminar, Phoenix, AZ. Test Systems Inc, 217 W Palmaire, Phoenix, AZ 85021. (602) 861-1010. FAX (602) 861-1082. December 3 to 4.

Troubleshooting, Upgrading, and Installing Novell (short course), San Juan, Puerto Rico. Center for Advanced Professional Development, 1820 E Garry St, Suite 110, Santa Ana, CA 92705. (714) 261-0240. FAX (714) 261-6277. December 5 to 6.

SEMI Technology Symposium, Makuhari, Japan. SEMI, 805 E Middlefield Rd, Mountain View, CA 94043. (415) 940-6903; (415) 964-5111. December 6 to 7.

IEEE International Electron Devices Meeting, Washington, DC. Courtesy Associates, Melissa Widerkehr, 655 15th St NW, Suite 300, Washington, DC 20005. (202) 347-5900. December 8 to 11.

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

International Seminar On Double Layer Capacitors & Similar Energy Storage Devices, Deerfield Beach, FL. Dr SP Wolsky, 1900 Cocoanut Rd, Boca Raton, FL 33432. (407) 391-3544. FAX (407) 750-1367. December 9 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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Computers are sometimes difficult to get along with. Each one is, well, unique. And with different operating systems and software, they can be downright peculiar.

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CIRCLE NO. 49

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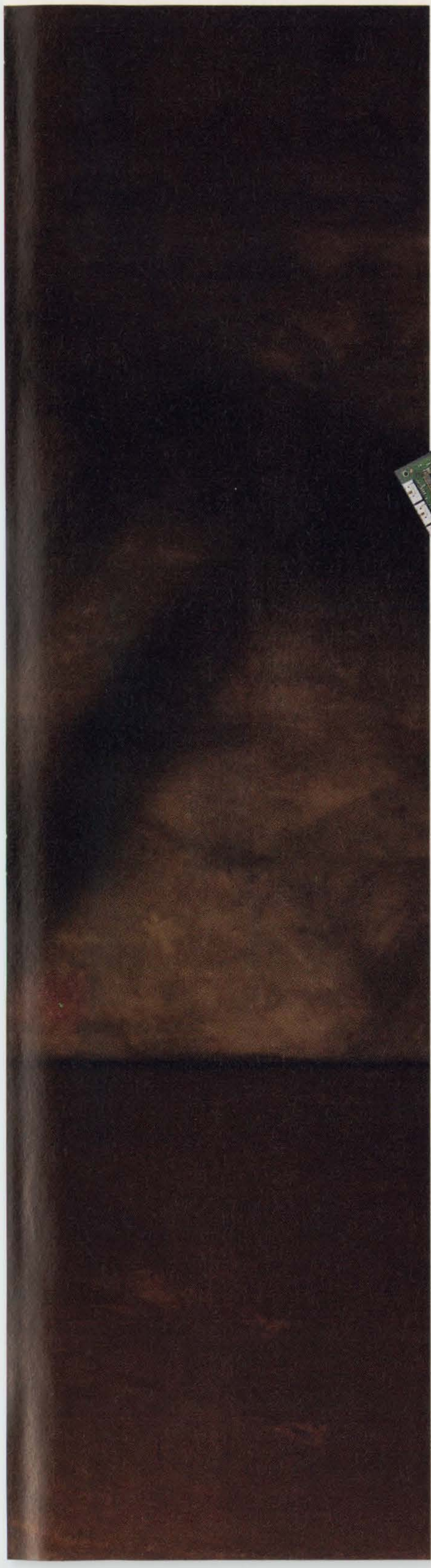
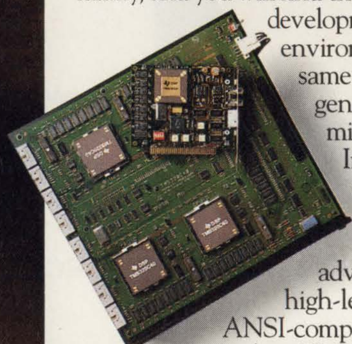


Strong, solid support is essential to your design success with digital signal processing. That's why we at Texas Instruments have developed the support for our TMS320 DSP family as carefully and extensively as the family itself.

World-class development tools

Choose any DSP in our five-generation family, and you will find that the development environment is the same as that for general-purpose microprocessors.

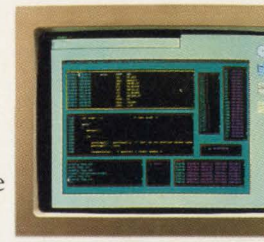


Included in the comprehensive line-up are advanced high-level-language ANSI-compatible C compilers, HLL C-source-level debuggers, scan-based emulators, a multitasking DSP operating system and a low-cost evaluation module for benchmarking.

Tap into plenty of help

Our technical hot line connects you with TMS320 specialists who can answer your questions, provide more information or discuss a fine design point. We also maintain an on-line bulletin-board service.

Hands-on workshops are a convenient opportunity for familiarizing yourself with the TMS320 family and development environment. More than 2,000 pages of applications notes and DSP code are available. In addition, there are over 100 third parties and consultants supporting the TMS320 family. And our university program includes more than 100 university labs.



When it comes to DSP support, no one in the industry gives you as strong a third leg as we do.

The right DSP at the right price

The other two legs — performance and price — are just as strong.

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We'll send you brochures on our comprehensive TMS320 support, broad TMS320 family and cDSP capability.

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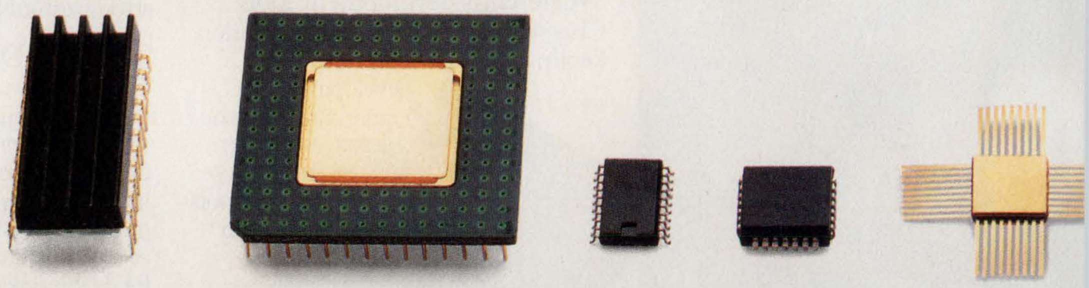
TEXAS INSTRUMENTS

Our pulse generators will test what you have.



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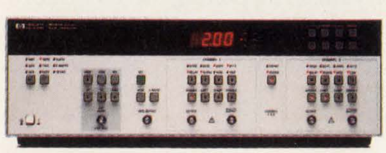
That's a big statement. But these are powerful programmable pulse generators. Combined, they deliver top speed, high resolution and pulse-parameter flexibility. So you get accurate testing of your present and future high-speed designs, whether they're ICs, PCBs, or components.

Put the 500 MHz HP 8131A to work on your hottest new devices. With a transition time of <200 ps, plus pulse widths down to 500 ps with 10 ps timing resolution, you get the stimulus you've needed for accurate testing of your fastest designs.

HP 8130A Pulse Generator



HP 8131A Pulse Generator

For the most complete testing of your high-speed devices, choose the HP 8130A. It has

And what you have in mind.

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the features you've wanted in a 300 MHz pulse generator, including variable transition times down to 1 ns, and 10 ps timing resolution. Which means you not only have the flexibility for high-speed parametric testing of digital devices, but for analog device testing as well.

So call **1-800-452-4844** today. Ask for **Ext. 2631** to get data sheets and application information. Then get the programmable pulse generators you need for the fast devices you have in hand and mind.

There is a better way.

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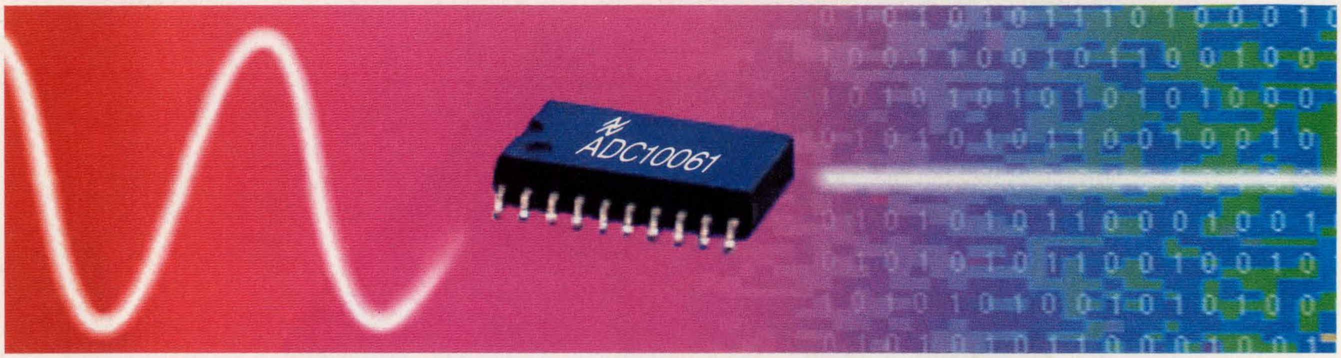
National Semiconductor

Our 10-bit multi-step conversion technique gets you from A to D in 1/64 of a flash.

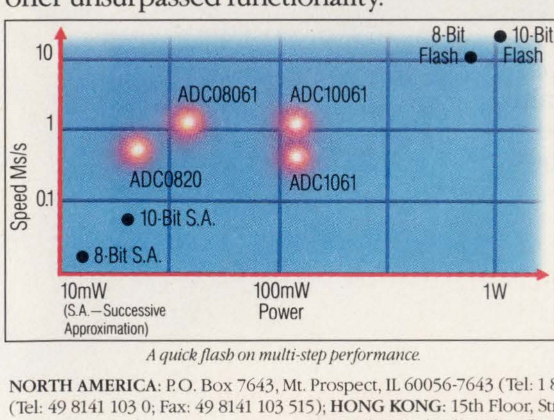


Designing ADCs with a powerful architecture and unsurpassed functionality.

Using a patented multi-step conversion technique, our 10- and 8-bit analog-to-digital converters (ADCs) now require just 1/64 as many comparators as full-flash converters.

This powerful architecture not only shrinks the number of comparators, but also reduces the power consumption and die size. So now you get low-power CMOS devices—available in military (883/SMD) and industrial temperature ranges—that are ideal for high-speed data acquisition, disk drives, and instrumentation.

What's more, our multi-step ADCs offer unsurpassed functionality.



A quick flash on multi-step performance.

Like on-chip multiplexer (including 2/4 and 8 channel) and sample-and-hold. Which means a big savings in board space and testing, and improved system reliability.

Optimizing speed and power with 10-bit ADCs.

Drawing a mere 235mW of power (1/2 that of half-flash devices), our ADC10061/2/4 still display a conversion time of 900ns. That's 1Ms/s, which is guaranteed over temperature.

They also guarantee zero and full-scale errors, with *no* missing codes, at ±1LSB. Plus, the ADC10061 is a pin-for-pin upgrade to our ADC1061. With twice the speed. And since their input range spans from 0 to 5V with single 5V operation, there's no need for a negative power supply.

Pushing the envelope on high-performance 8-bit ADCs.

Offering the same 5V system compatibility as our 10-bit ADCs, our new 8-bit families, the ADC08061/2/4/8 and the ADC08161/4/8, boast conversion times of 500ns and consume only 100mW of power. With a total error budget of ±1/2LSB.

In fact, the ADC08061 is pin-compatible with the industry-standard ADC0820. Of course, none of this would be possible if it wasn't for our ongoing commitment to high-performance mixed analog + digital technology.

Making the conversion to multi-step ADCs.

For samples, call or write us today. And discover why other conversion techniques could be just a flash in the pan.

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EDITORIAL

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.

Steven H. Leibson

Steven H Leibson
Executive Editor

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Editorial Achievement Awards
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1990 Certificate, Best Series
1987, 1981 (2), 1978 (2),
1977, 1976, 1975

American Society of
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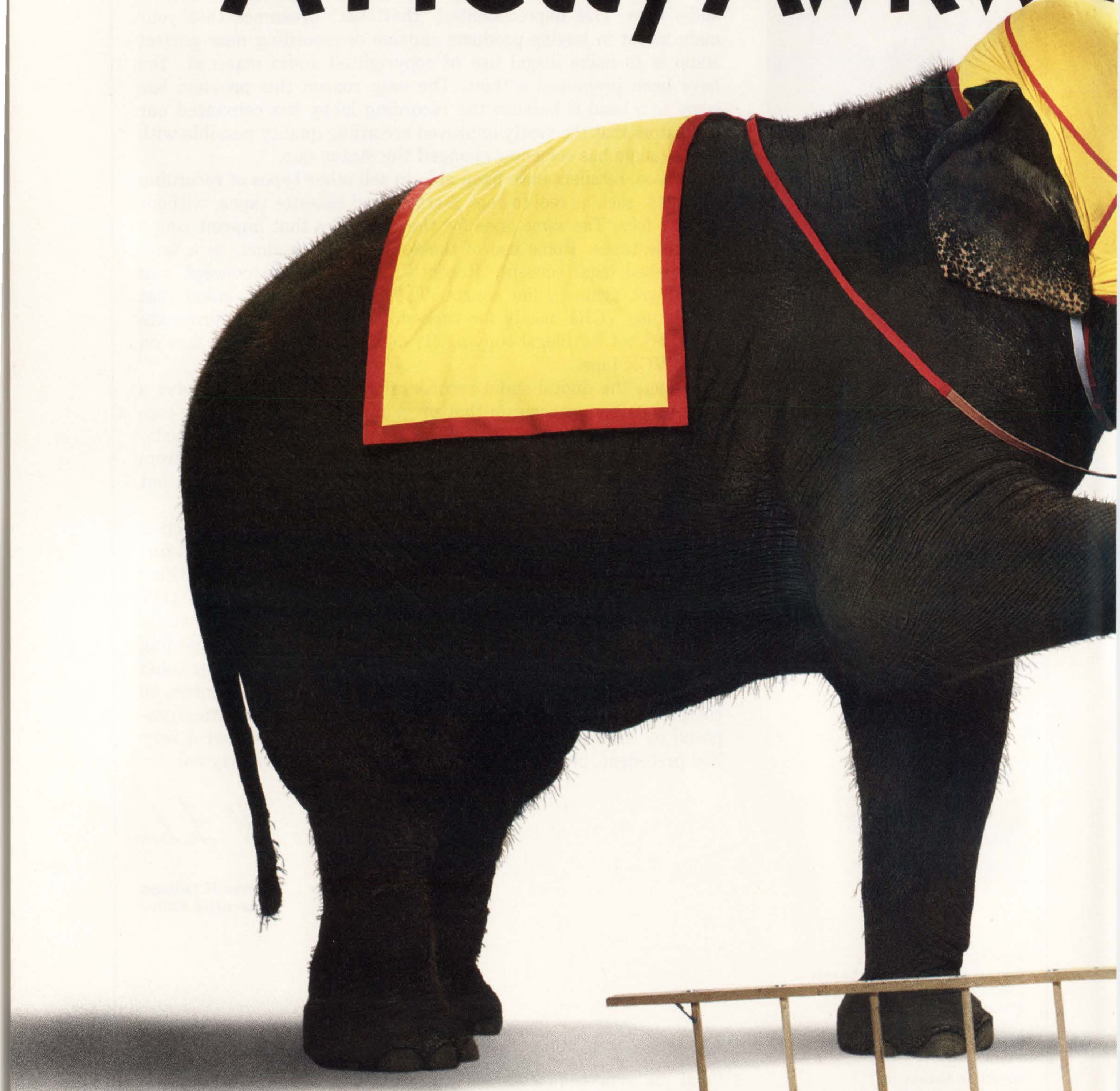
Send me your comments via FAX at (617) 558-4470, or on the EDN Bulletin Board System at (617) 558-4241 300/1200/2400,8,N,1.

Until Now, Density
A Pretty Awkwa



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AMD Presents The MACH™ Family Of High Speed, High Density PLDs.

Nothing can squash an elegant, high density design faster than a slow, unpredictable and expensive PLD. That's why we've developed the MACH PLD family—for both density, and speed.

The MACH family gives you everything you need in a PLD on state-of-the-art CMOS: Densities up to 128 macrocells or 3600 equivalent gates. Clock speeds up to 66.7 MHz. And absolutely predictable, worst-case delays as low as 12ns per 16 product term macrocell.

And they work for peanuts. The MACH family can bring your costs down as low as a penny per gate—up to 40% less than other high density PLDs.

Model Number	Equiv. Gates	Macro Cells	Max. Delay	System Speed	I/O Pins	Hard-Wired Option
MACH 110	900	32	12ns	66.7 MHz	44	MASC 110
MACH 210	1800	64	12ns	66.7 MHz	44	MASC 210
MACH 120*	1200	48	15ns	50 MHz	68	MASC 120
MACH 220*	2400	96	15ns	50 MHz	68	MASC 220
MACH 130	1800	64	15ns	50 MHz	84	MASC 130
MACH 230*	3600	128	15ns	50 MHz	84	MASC 230

* Available Q4 1991.

With the MACH family you'll get to market faster, too. Because it's supported by most popular design tools: Including ABEL,™ CUPL,™ LOG/iC,™ MINC, OrCad,® and AMD's own PALASM® software. There's also hardware and software support from over 20 additional FusionPLD partners.

Every MACH part migrates easily to a pin-compatible hard-wired MASC™ counterpart—for high volume orders with no redesign, no NRE, no performance glitches, no problems.

So don't horse around with slow, unpredictable, high density PLDs—start designing with the MACH family from AMD. Call **1-800-222-9323** for more information.

Advanced Micro Devices

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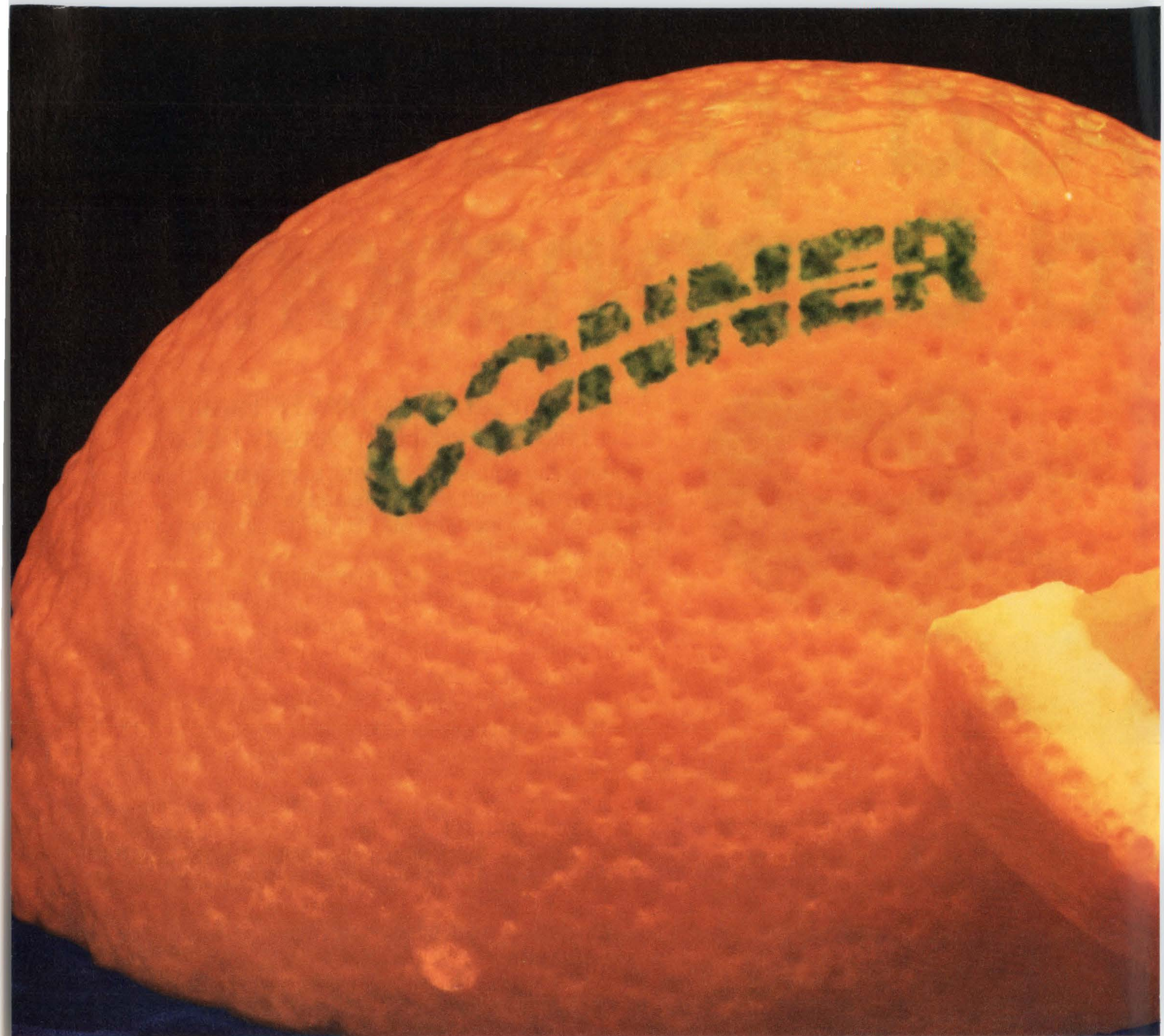
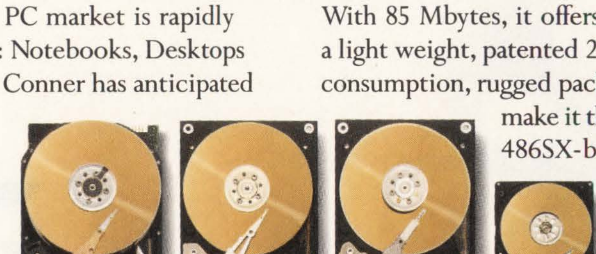


ANY WAY YOU SLICE IT, GENERATION COVERS EVERY

The squeeze is on. Today the PC market is rapidly concentrating into three segments: Notebooks, Desktops and Workstations. And once again, Conner has anticipated these changes.

Which is why we're introducing our newest wave of high-performance 2.5-inch and 3.5-inch drives to meet the needs of each of these evolving market segments.

For the notebook market, take our newest Pancho drive. With 85 Mbytes, it offers the highest capacity available in a light weight, patented 2.5-inch form factor. Low power consumption, rugged packaging and a compact form factor make it the ultimate choice for 386SX and 486SX-based notebook computers.



Summit 540MB *Cougar 210MB* *Jaguar 85/170MB* *Pancho 85MB*

Then there's our new Jaguar Series for the desktop market—3.5-inch drives offering 85 and 170 Mbytes. A 17 msec. average seek time and a light weight, patented 1-inch

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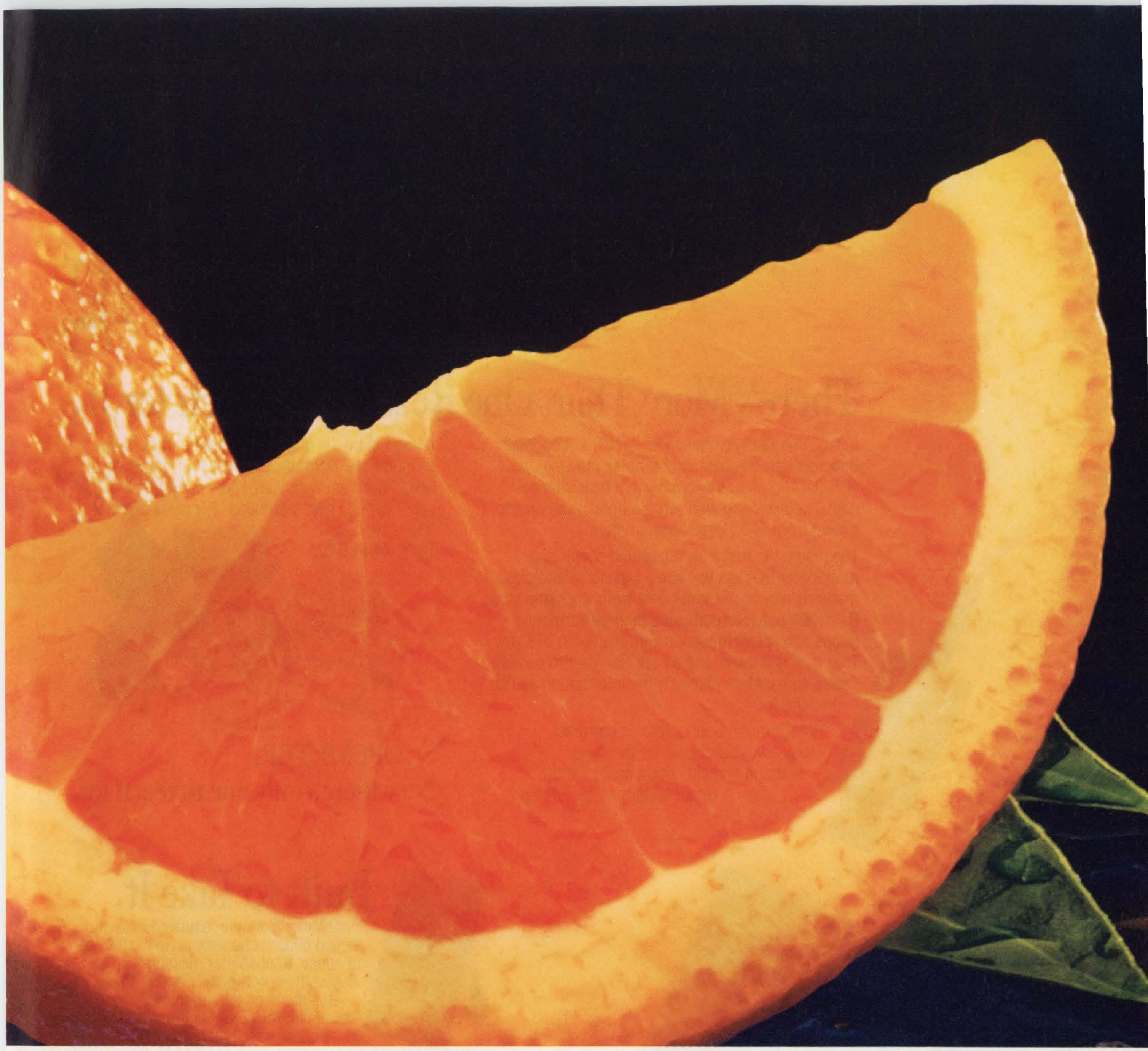

CONNER'S NEWEST SEGMENT OF THE MARKET.

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

For workstations, we're introducing two new 3.5-inch drives—the 210 Mbyte Cougar and 540 Mbyte Summit. Cougar is the highest performance low-profile drive on the market today. While Summit delivers the greatest capacity and performance of any 3.5-inch drive. Both provide a fast average seek time of 12 msec., a 2.5 Mbyte per second sustained transfer rate and a SCSI-2 interface.

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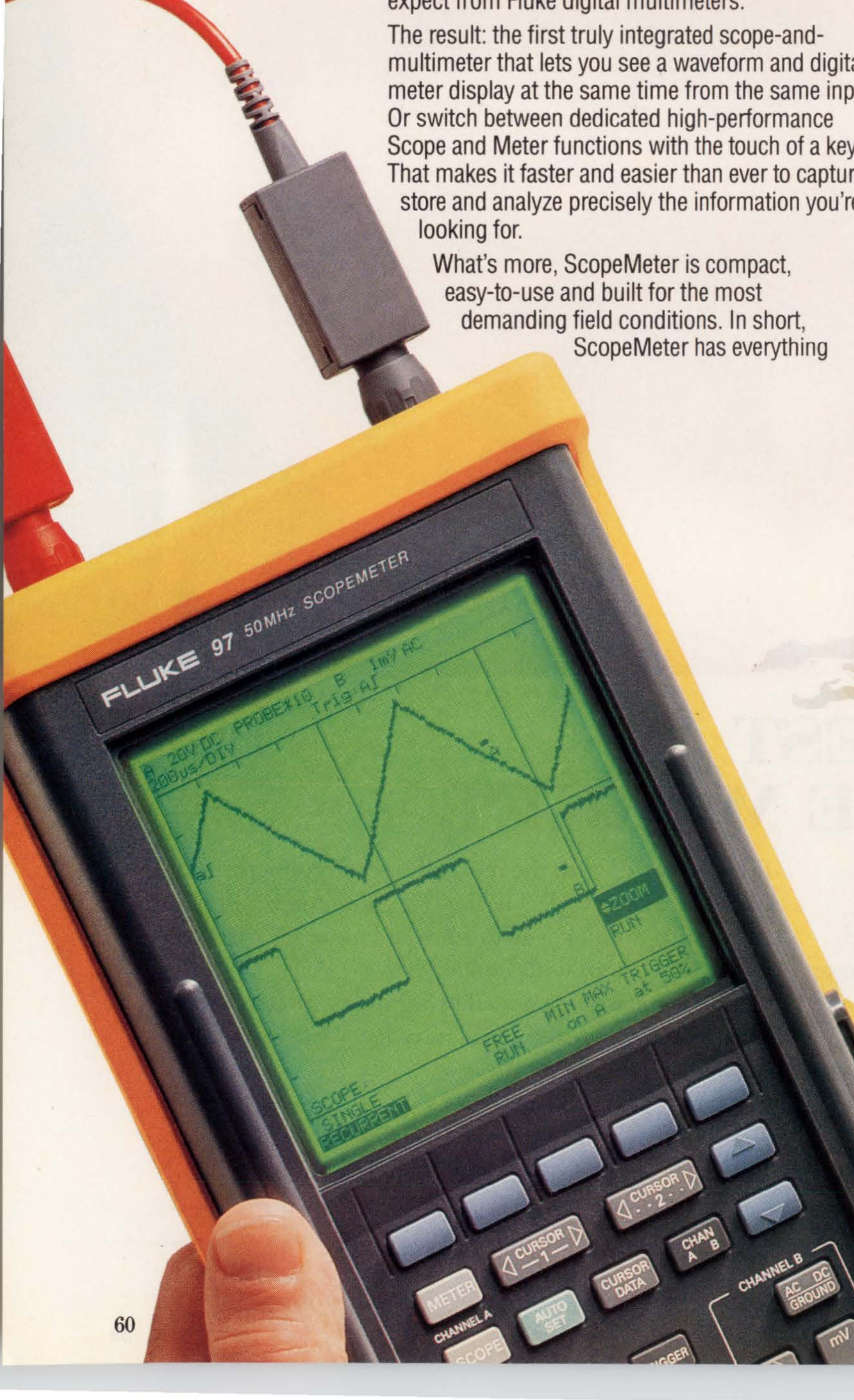
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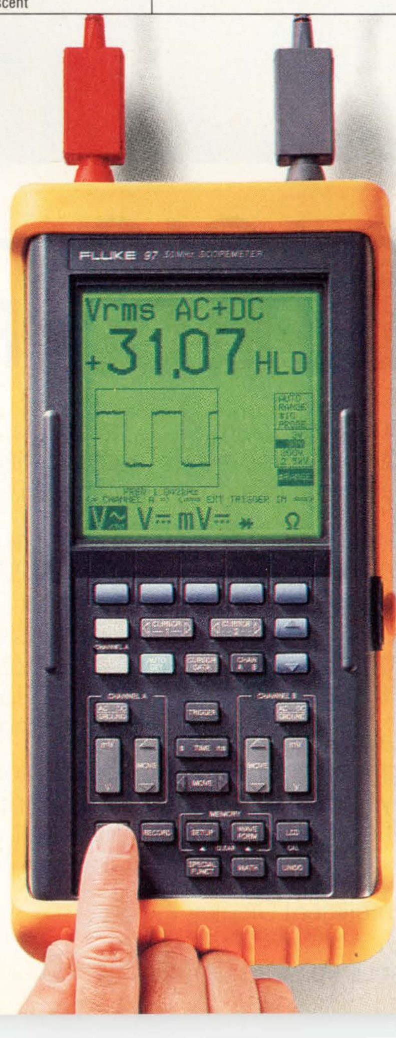
Suggested List Price	$1795	$1495	$1195
Bandwidth	50 MHz Dual Channel		
Sample Rate	25 Megasamples/second		
Autoset	Automatically sets Voltage, Time and Trigger		
Multimeter Display	3 2/3 digits (>3000 Counts)		
True RMS Volts	AC or AC+DC up to 600V (1700V Pk–Pk)		
Diode Test	Up to 2.8V		
Continuity Beeper	Yes		
Time/Division	10 ns/div to 60 sec/div		
Volts/Division	1 mV/div to 100V/div		5 mV/div to 100V/div
Digital Delay or Pre-Trigger	By Number of Cycles, Events, Time, or Zoom Mode		By Time
Special Multimeter Modes	Min Max Average Record, Relative (zero), dBm, dBV, dBW, Audio Watts, % Scale, Frequency, Smoothing,™ Change Alert™		Frequency, Smoothing™ Change Alert™
Oscilloscope Cursors	12 Measurements, Display 5 Simultaneously		
Glitch Capture	≥40 ns		
Waveform Processing	Average, Variable Persistence, Min Max Record		
Waveform Memory	Store and Recall 8 Waveforms		
Set-Up Memory	Store and Recall 10 Front Panel Set-Ups		
Waveform Mathematics	Add, Subtract, Multiply, Invert, Filter or Integrate Waveforms		
Signal Generator Output	Sinewave or Squarewave		
Component Tester Output	Voltage or Current Ramp		
Optically Isolated RS-232-C Interface	Full Operation by Remote Control		
Printer Output	Serial		
Backlit Display	Electroluminescent		



Simply Easy.

ScopeMeter's intuitive front-panel layout is simple and straightforward to use. Pop-up menus and five function keys provide quick, visible control of all your options. With one touch of Autoset, ScopeMeter automatically sets voltage, timing and triggering control. And safety-designed BNC connectors and detachable probes simplify floating measurements.

Goes Wherever You Go.

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.

FLUKE®

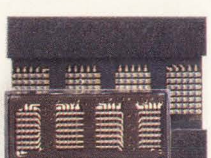
CIRCLE NO. 54

SIEMENS

We Admit This Test Of Our Slimline Display Is Stacked In Our Favor.

Our new LED dot matrix Intelligent Display® has proven once again why Siemens is at the forefront of display device technology. And has left the competition at a loss for words.

Because its package size is 60% smaller, the Siemens SLx2016 Slimline allows you to say a lot more, in a lot less space. The Slimline family features a .4-inch package height, rather than the .8-inch height industry standard, while keeping a .19-inch character height. Plus, our displays are X *and* Y stackable, to give you maximum flexibility in your design.



The SLx2016 is the first in a series of Siemens Slimline Intelligent Displays, all of which will give you on-board display drivers with control logic and easy addressability.

And it's available now, in four bright colors including red, yellow, green, and High-Efficiency Red.

So if you're looking for the slimmest Intelligent Display available, compare us to the competition. You'll see that they just don't stack up.

For more information, call (408) 725-3423, FAX (408) 725-3439, or write:
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CIRCLE NO. 55

FACTORY-AUTOMATION NETWORKS

The best LAN *may* be found off the MAP

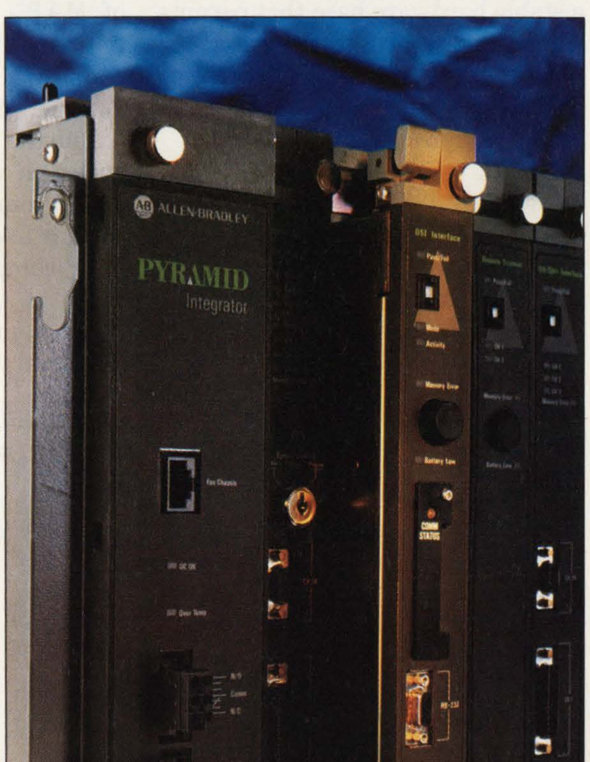
Before you select a local-area network (LAN) that will operate in an industrial environment, you must consider a variety of factors that range from the certainty of initial costs to the potential of future innovations.

J D Mosley,
Regional Editor

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.*

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 1—A comparative table of industrial LANs

Network	Proprietary	Vendor	IEEE 802.4 compatible?	Media access	Modulation	Data rate (bps)
Arcnet	Open (specs available)	Standard Microsystems	No	Token passing	Baseband dipulse	2.5M
Bitbus	Open (Intel specification)	Digital Equipment Corp, Micro/sys	No	Multidrop	Not applicable	2.4M
Data Highway Plus	Yes	Allen-Bradley	No	Token passing	Baseband	57.6k
DECnet/OSI	Open (specs available)	Digital Equipment Corp	Yes	Token ring and CSMA/CD	Binary phase-shift key; Manchester Encoding	10M to 100M
802.3/Ethernet	No	Digital Equipment Corp	Yes	CSMA/CD	Binary phase-shift key	10M
MAP	No	Motorola, Digital Equipment Corp, Hewlett-Packard, Texas Instruments, Allen-Bradley, etc	No	Polling	Phase-coherent FSK	5M or 10M
TIway	Open (specs available)	Texas Instruments	No	Poling	Nonreturn to zero, inverted	300 to 115.2k

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.

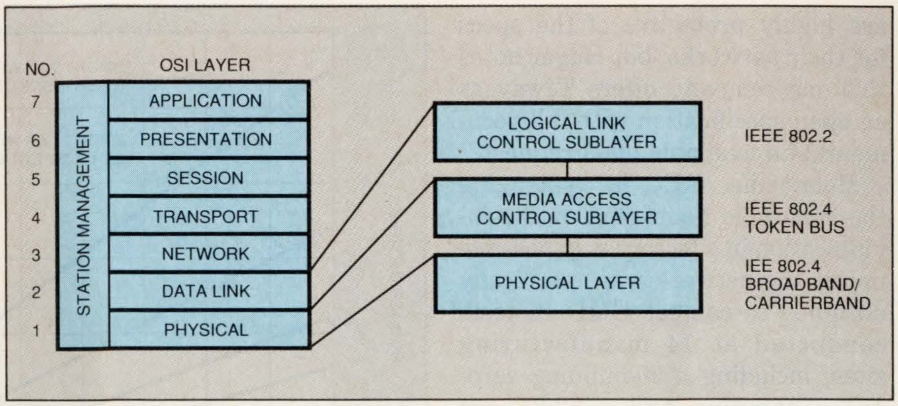


***Fig 1—Based on the 7-layer ISO/OSI communications model,** the Manufacturing Automation Protocol (MAP) was devised by system integrators at General Motors to unite the "islands of automation" created by the computerization of individual manufacturing processes. The IEEE 802 LAN standard provides the specific implementation of the first two layers of the model.*

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 6×10^{-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

Coding frequency (MHz)	Ambient noise floor	Minimum S/N ratio (dBmV)
5	Varies by implementation	Not applicable
Baseband	Not applicable	Not applicable
Proprietary	Proprietary	Proprietary
10 to 20 at 10 Mbps; 100 to 125 at 100 Mbps	2 V/m up to 30 MHz; 5 V/m above 30 MHz	26 at 10 Mbps
10 to 20 at 10 Mbps	2 V/m up to 30 MHz; 5 V/m above 30 MHz	26 at 10 Mbps
5 to 10 at 5 Mbps; 10 to 20 at 10 Mbps	2 V/m up to 30 MHz; 5 V/m above 30 MHz	20 at 5 Mbps; 23 at 10 Mbps
Baseband	Not applicable	Not applicable

Factory-automation networks

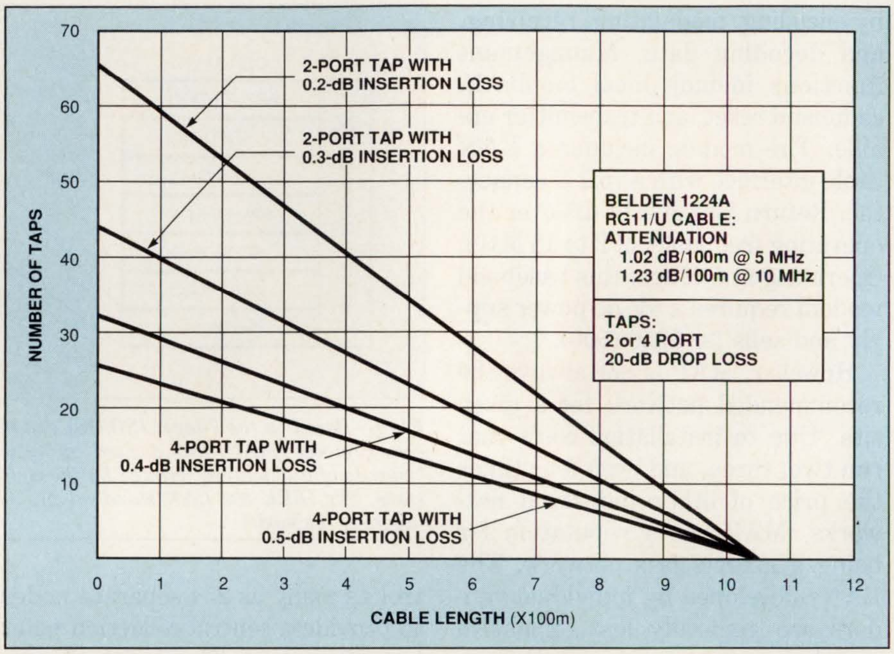
are highly protective of the specs for their networks, but Hagar notes that his company offers TIway as an open specification with full documentation available upon request.

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 monitor network performance and 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.



This graph illustrates the relationship between carrierband cable length and the number of taps in a 5-Mbps network. *Developed by IEEE 802.4 LAN design engineers at Motorola, it also shows that a 0.1-dB difference in insertion loss at each tap will significantly affect the number of taps a given length of RG11/U cable can accommodate.*

Table 2—Industrial networking characteristics

	Enterprise levels (3 and 4)	Plant levels (2 and 3)	Work cell levels (1 and 2)
Function	Integration of enterprise	Integration of work group/departments	Automation
Distance	Many miles	1000+ ft	100 ft
Type	Wide-area network	LAN	LAN subnet
Physical connection	X.25, CCITT, satellite, microwave	802.3/Ethernet, baseband, broadband, fiber	Serial lines, Bitbus, MAP, 802.3/Ethernet
Speed	5 kbps to 1.5 Mbps	10 Mbps	Less than 19.2 kbps
Protocol	DECnet/OSI, SNA	DECnet/OSI, TCP/IP	Many proprietary, MMS
Node types	Mainframes, departmental computers	Minicomputers, mainframes, PCs	Plant-floor equipment, programmable logic controllers, robots, numerical control equipment, terminals, distributed control systems
Number of nodes	Thousands	Hundreds	Less than 10
Communication services	File transfer, program to program, virtual terminal, remote data file access, network management, resource sharing		Read/write data, start/stop device, upload/download program, device status

(Data courtesy Digital Equipment Corp)

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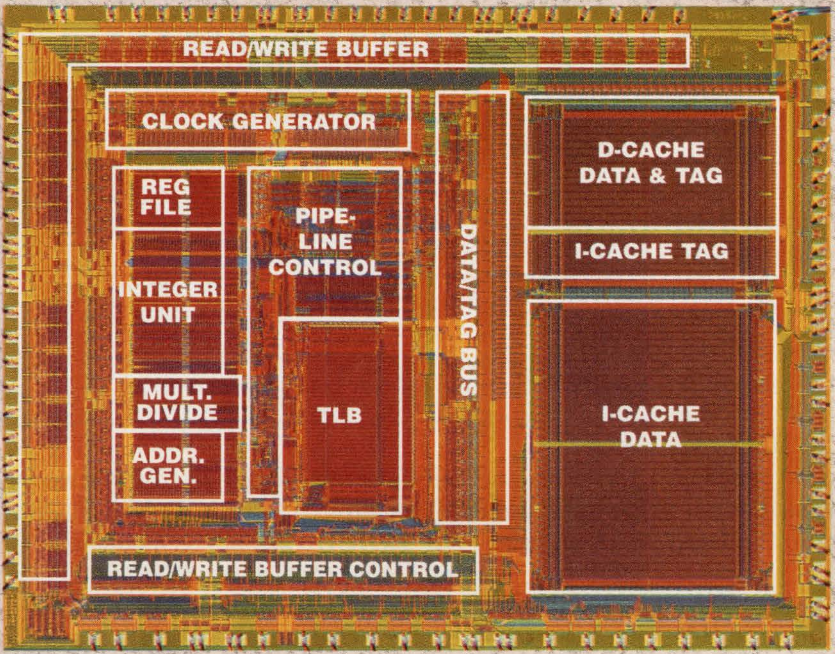

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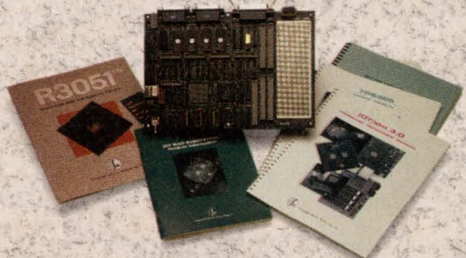

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Factory-automation networks

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.

To further reduce costs and simplify installation, Standard Microsystems Corp developed the COM20020 Arcnet controller chip that includes a LAN controller, a 2k × 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

Acronyms used in this article

ATA—Arcnet 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

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.

Allen-Bradley
Industrial Computer and Communication Group
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Circle No. 707

Digital Equipment Corp
146 Main St
Maynard, MA 01754
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Circle No. 708

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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. EDN

Acknowledgments

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

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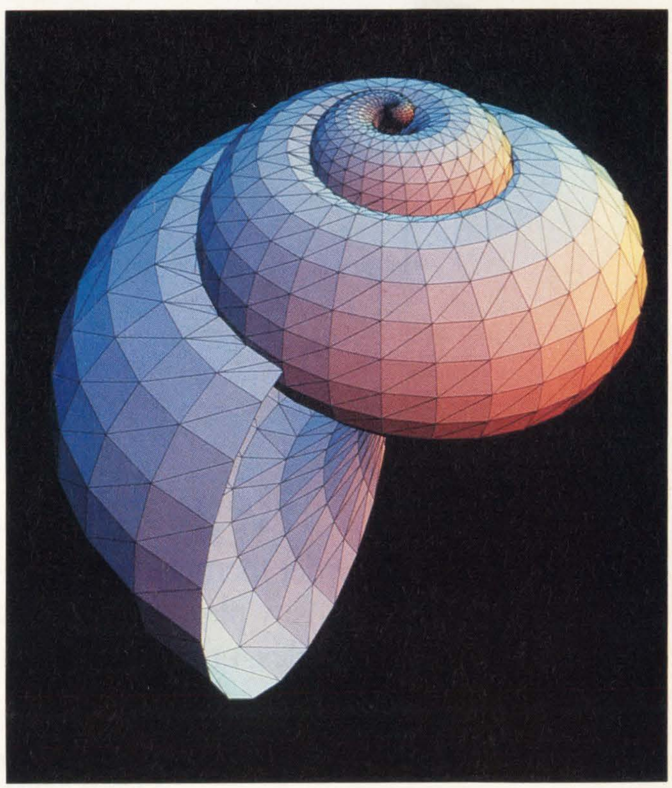
John Gallant, Associate Editor

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

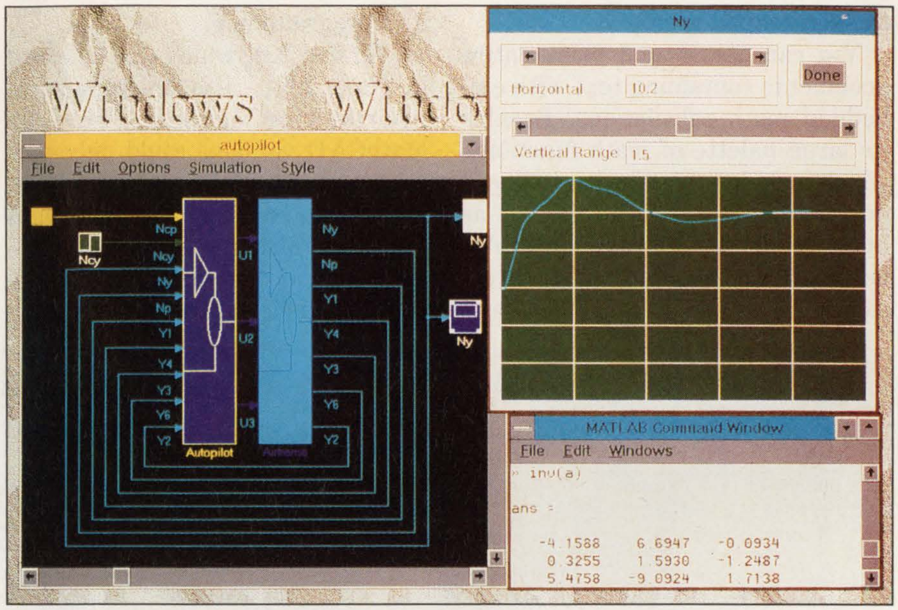
ates on an MS-DOS version-2.1-compatible computer having at least an 8086 µP and a minimum of 512 kbytes of RAM. The software employs a command-line user interface and an on-line help menu. The interface lets you enter expressions using algebraic notation.

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.



You can model linear and nonlinear *networks having multiple inputs and outputs using Simulab, an extension to Matlab.*

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.

Exact Definite Integration

```
> f := int(cos(x)^10 *
> cos(2*x)^8 * cos(4*x)^6 *
> cos(6*x)^4 * cos(8*x)^2,
> x=0..Pi/4);
```

$$f := \int_{x=0}^{\frac{\pi}{4}} \cos(x)^{10} \cos(2x)^8 \cos(4x)^6 \cos(6x)^4 \cos(8x)^2 \, dx$$

$$= \frac{5166673\pi}{536870912} + \frac{2966549762512816}{98120709987525225}$$

```
> evalf(f);
```

0.0604673534455515336647066778402200730593

Exact arithmetic means that you can get an answer to any precision. *Maple's exact arithmetic represents fractions by the ratio of 2 rational numbers.*

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

Table 1—Representative $400-and-up math software packages

Vendor	Product	Computer systems	Minimum PC configuration	Cost (DOS version)	Comments
Integrated Systems Inc	Xmath	SPARCstation	NA	$2495 (SPARCstation version)	X-Windows/Motif GUI. Object-oriented numeric computations. Mathscript high-level programming language. Postscript graphics output files. Imports and exports ASCII data files. Spreadsheet editing of data sets and matrices. Interactive 3-D plot rotation.
Mathsoft Inc	MathCAD (Version 3.0)	DOS-compatible SPARCstation Macintosh	2 Mbytes of RAM; 80286, 80386, or 80486 μP; DOS 3.1; Coprocessor; Windows 3.0; Mouse; EGA	$495	Access to formulas, constants, and diagrams in CRC electronics handbook. Symbolic computations. Windows GUI. Optional "Application Packs" libraries. Data access is via ASCII print files only.
Mathworks Inc	Matlab	DOS-compatible Macintosh SPARCstation Silicon Graphics IBM System/6000 HP 9000/300 DECstation VAXstation Alliant Convex Cray	2 Mbytes of RAM; 80386 or 80486 μP; DOS 3.1; Coprocessor; 1.2-Mbyte floppy-disk drive; Hard-disk drive	$1595 (386-Matlab)	386-Matlab uses high memory above DOS's 640-kbyte limit and has no limit on matrix or vector size. Can execute DOS commands from within the program. MEX-files let you call C and Fortran routines. Numeric computations only. Optional "Toolbox" libraries and Simulab shell ($3995) for modeling dynamic systems.
Symbolics Inc	Macsyma (Rel 417.1)	DOS-compatible HP 9000/300 SPARCstation VAXstation Symbolics Apollo	4 Mbytes of RAM; 80386 or 80486 μP; 25 Mbytes available on hard-disk drive; Windows 3.0; Coprocessor	$995	Over 1500 functions. Solves first- and second-order equations symbolically and numerically. Point-and-click 3-D object rotation. Contour plots. Optional Postscript file graphics output.
Waterloo Maple Software	Maple V	DOS-compatible Macintosh SPARCstation VAXstation IBM PS/2 Apollo Amiga	2 Mbytes of RAM; 80386 or 80486 μP; Coprocessor; DOS 3.3; 7.5 Mbytes available on hard-disk drive	$695	Symbolic computations. Command-line interface. Exact integer and ratio of rational numbers representation having arbitrary precision. Galois field arithmetic. Postscript file graphics output.
Wolfram Research Inc	Mathematica (Version 2.0)	DOS-compatible Macintosh SPARCstation Silicon Graphics Data General IBM System/6000 Convex VAXstation HP 9000/300	4 Mbytes of RAM; 80386 or 80486 μP; Coprocessor; DOS 3.0; 8 Mbytes available on hard-disk drive; Windows 3.0	$595	843 functions. Symbolic computations. 3-D color graphics with fills, animation, and shading from a light-source simulator. Commands to create and play sounds. Mathlink program communicates with an external C and Fortran routine and vice versa. Postscript file graphics output.

Note: NA = Not applicable.

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CIRCLE NO. 62

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.

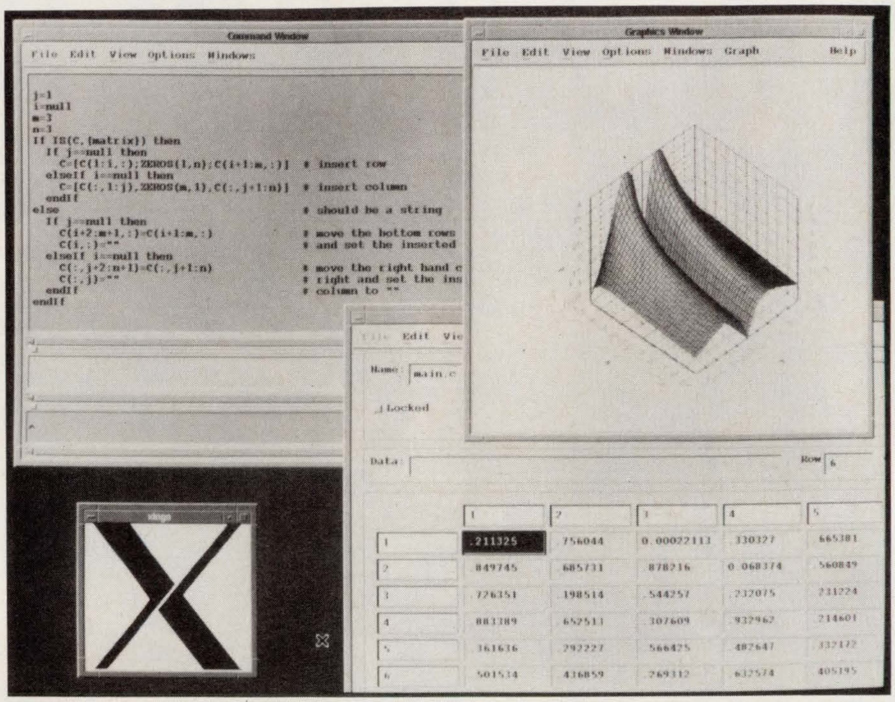
Numerics are rapid

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.



X windows provides an easy user interface that uses pull-down menus. *Xmath combines numeric computing with a Motif user interface.*

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.

PC386 has a Microsoft Windows

Over-$400 math software

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-

```
INTEGRATION
 • SYMBOLIC INTEGRATION
   - INTEGRATE (indefinite)
     (c1) INTEGRATE( 1/y^(3/4)/(y-1), y );
                    1/4              1/4           1/4
     (d1) - log(y    + 1) - 2 atan(y   ) + log(y    - 1)
   - INTEGRATE (definite, contour integral method)
     (c1) 2 * INTEGRATE( sin(x)/x, x, 0, inf );
     (d1)                  %pi
 • NUMERICAL INTEGRATION
   - ROMBERG
     (c1) ROMBERG( exp(-x^2), x, 0.0, 1.4 );
     (d1)               0.84394073
   - NEWTON-COTES
     (c1) (load(qq), QUANC8( sin(1/x), x, 0.1, 1.0 ));
     (d1)               0.515292
LAPLACE AND FOURIER TRANSFORMS
   - LAPLACE
     (c1) LAPLACE( sin(t), t, s );
                           1
     (d1)                ------
                          2
                         s  + 1
   - ILT
     (c2) ILT( dl, s, t );
     (d2)     sin(t)
   - TOTALFOURIER
     (c1) load(''fourier'')$
     (c2) TOTALFOURIER( abs(x), x, %pi );
          inf
          ====
          \        (2 (-1)^n - 2) cos(n x)
           >     ---------------------
          /                 2
                           n
          ====
          n = 1                           %pi
     (d2) --------------------------- + ---
                     %pi                   2
```

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.

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 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. EDN

References

1. Strassberg, Dan, "Taking the drudgery out of problem solving," *EDN*, March 15, 1990, pp 53-62.
2. Douglas, Richard E, "Choose PC software or scientific calculators to tame tough math," *EDN*, March 14, 1991, pp 115-132.

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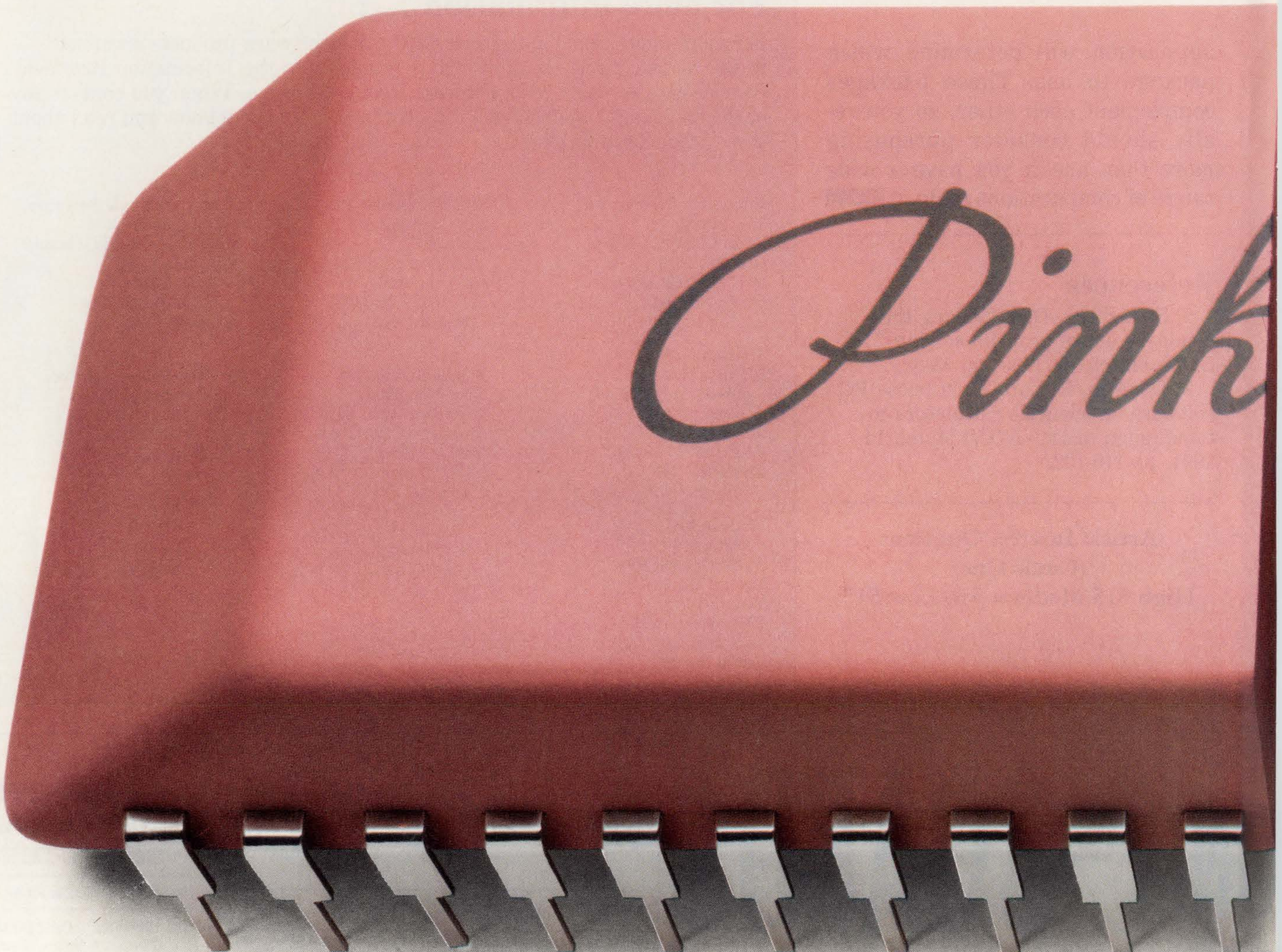

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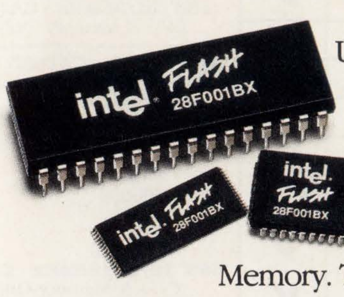

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SILICON PRESSURE SENSORS

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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

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").

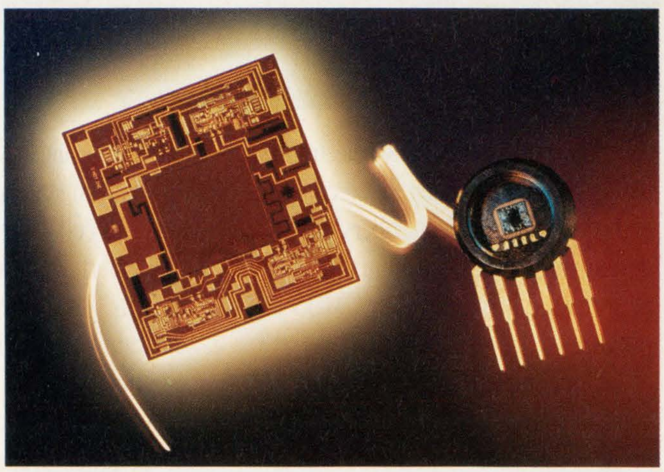
Silicon sensors are highly accurate and smaller, more reliable, and more cost effective than devices that employ more traditional technologies such as variable capacitance, potentiometric, force balance, piezoelectric, or vibrating wire. Small size provides significant advantages in such applications 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



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.*

◄ Circle No. 105

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.

Table 1—Representative sensor parameters

Manufacturer	Model	Property[1]	Full-scale pressure (psi)	Accuracy (%)	Full-scale output	Operating range (°C)	Price
Endevco	8540	A	15 to 500	0.25	300 mV	−54 to +260[2]	$950
Foxboro/ ICT	1230/1231	A, G	5 to 5000	0.125, 0.25	100 mV	−28 to +82[2]	$75/$90
Fujikura[3]	FPM	G, A	5 to 120	0.2	80 to 130	0 to 50[2]	From $14.95
IC Sensors	1431	A	15 to 300	0.25	60 mV	−40 to +125[2]	$2 (OEM qty)
Keller PSI	Series 2	A, D, G	1.5 to 300	0.25	18 to 250 mV	−10 to +80[2]	$46.50
Lucas Novasensor	NPI	A, G	15 to 10,000	1.0	100 mV	0 to 70[2]	$38 (1000)
Micro Switch	24PC	G	1.0 to 30	1.0	44 to 315 mV	−40 to +85	$15
Motorola	MPX5100A	A	15	0.2	4.5V	0 to 85[2]	$45 (100)
Sensym	SCXL004	D, G	0.15	1.0	40 mV	0 to 50[2]	$39.75 (100)

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

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.

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.

Design flexibility is the primary advantage *offered by Novasensor's NPI pressure sensors. Capable of measuring pressures of 10,000 psi, the devices provide a 100-mV output, feature a ±2% interchangeability, and are accurate to ±1% over a 0 to 70°C operating range.*

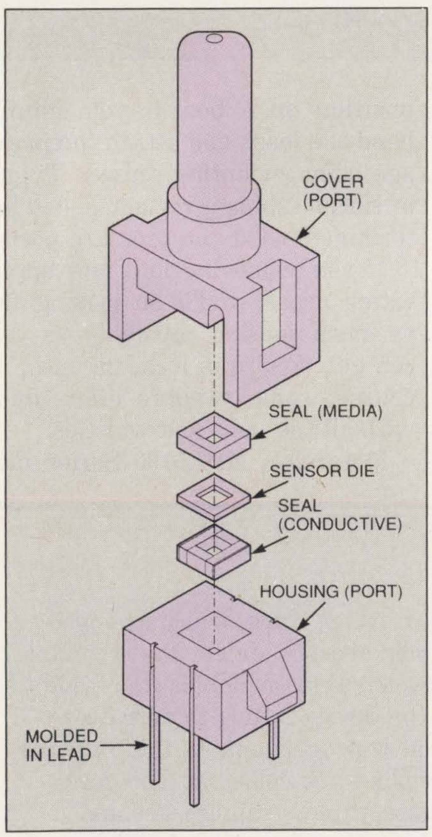


Fig 1—High reliability is a prime advantage *provided by the simplified construction of 24PC Series sensors. The conductive seal also allows Micro Switch to employ a large diaphragm area, which improves sensor stability.*

For more information . . .

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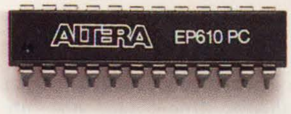

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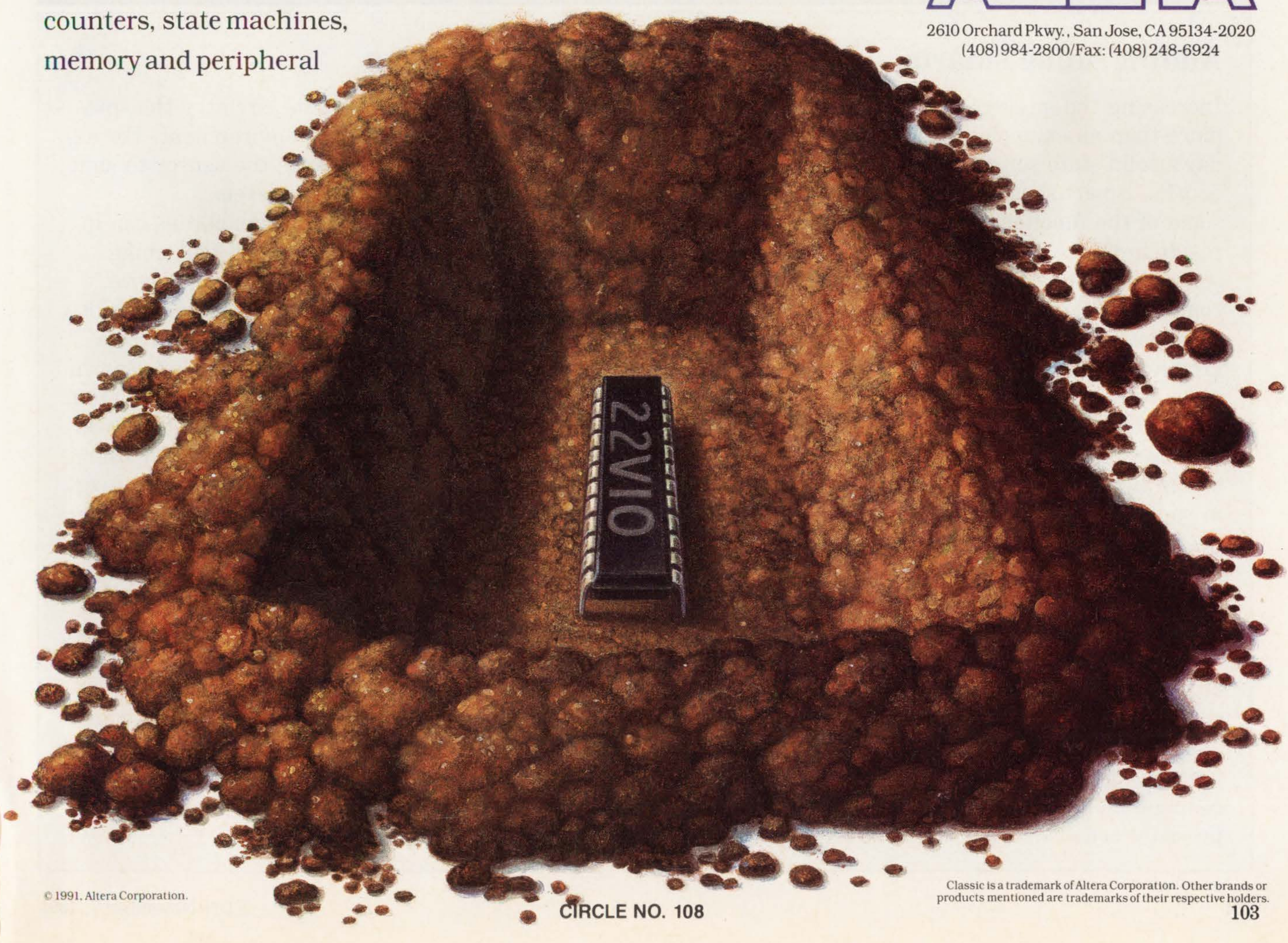


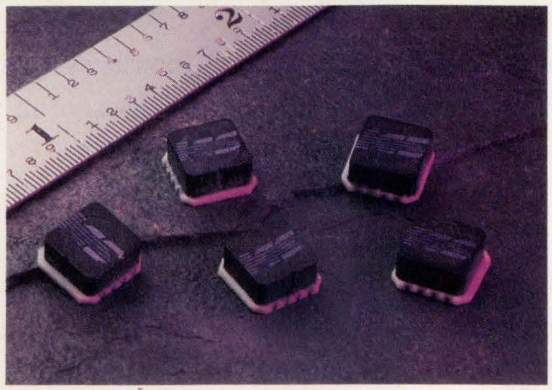
CIRCLE NO. 108

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. EDN



***Accurate to better than ±0.25%,** Model 1431 absolute pressure sensors from IC Sensors are housed in a surface-mount package measuring 0.3×0.3 in. They operate from either a constant-current or constant-voltage supply, measure pressure levels of 15 to 300 psi, and have a 60-mV typical output span.*

Article Interest Quotient
(Circle One)
High 509 Medium 510 Low 511

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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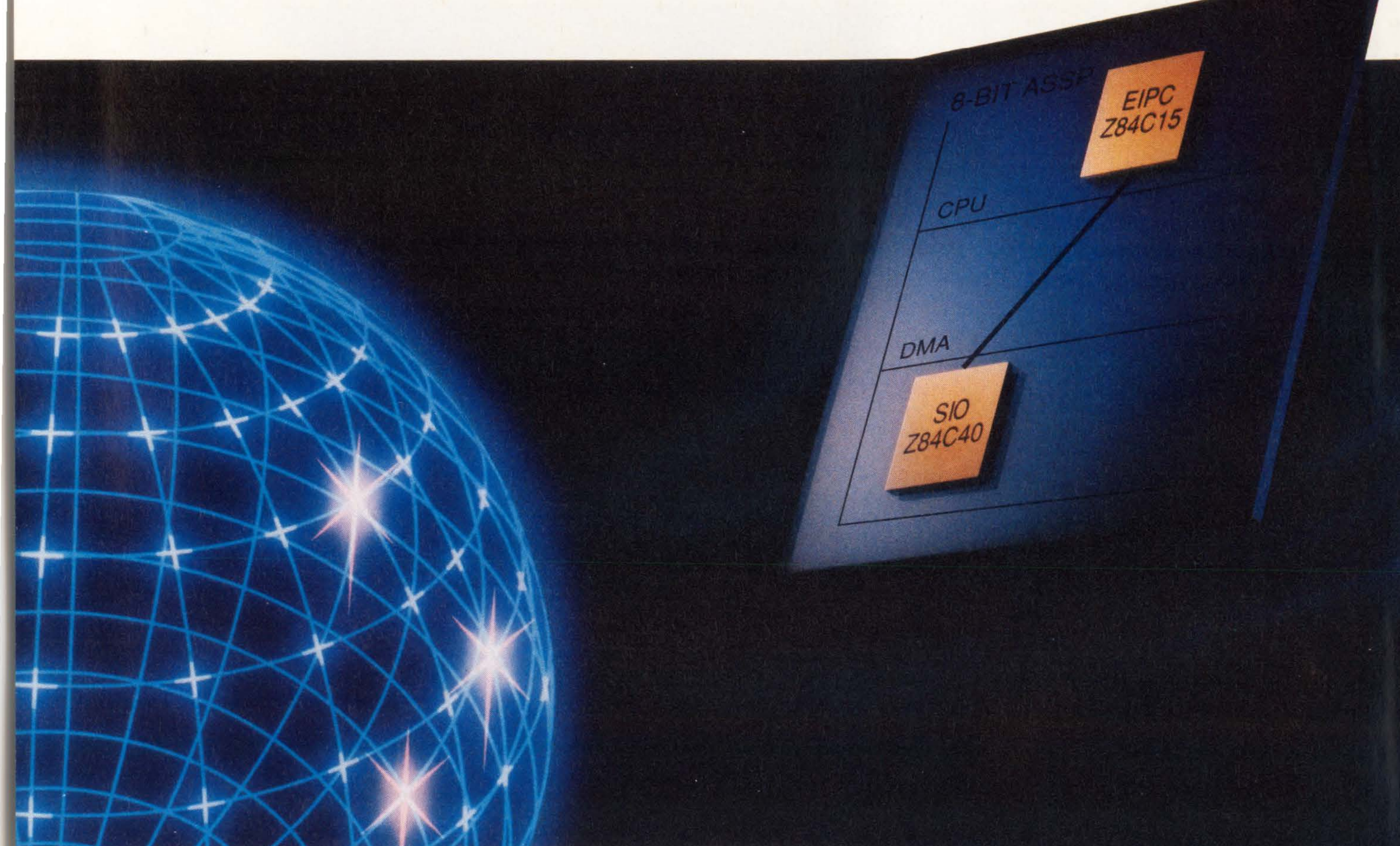

Zilog's SCC™ and USC™ datacom controller families give you a tremendous selection and the most flexibility in protocols, system interfaces and data transfer rates in the industry.

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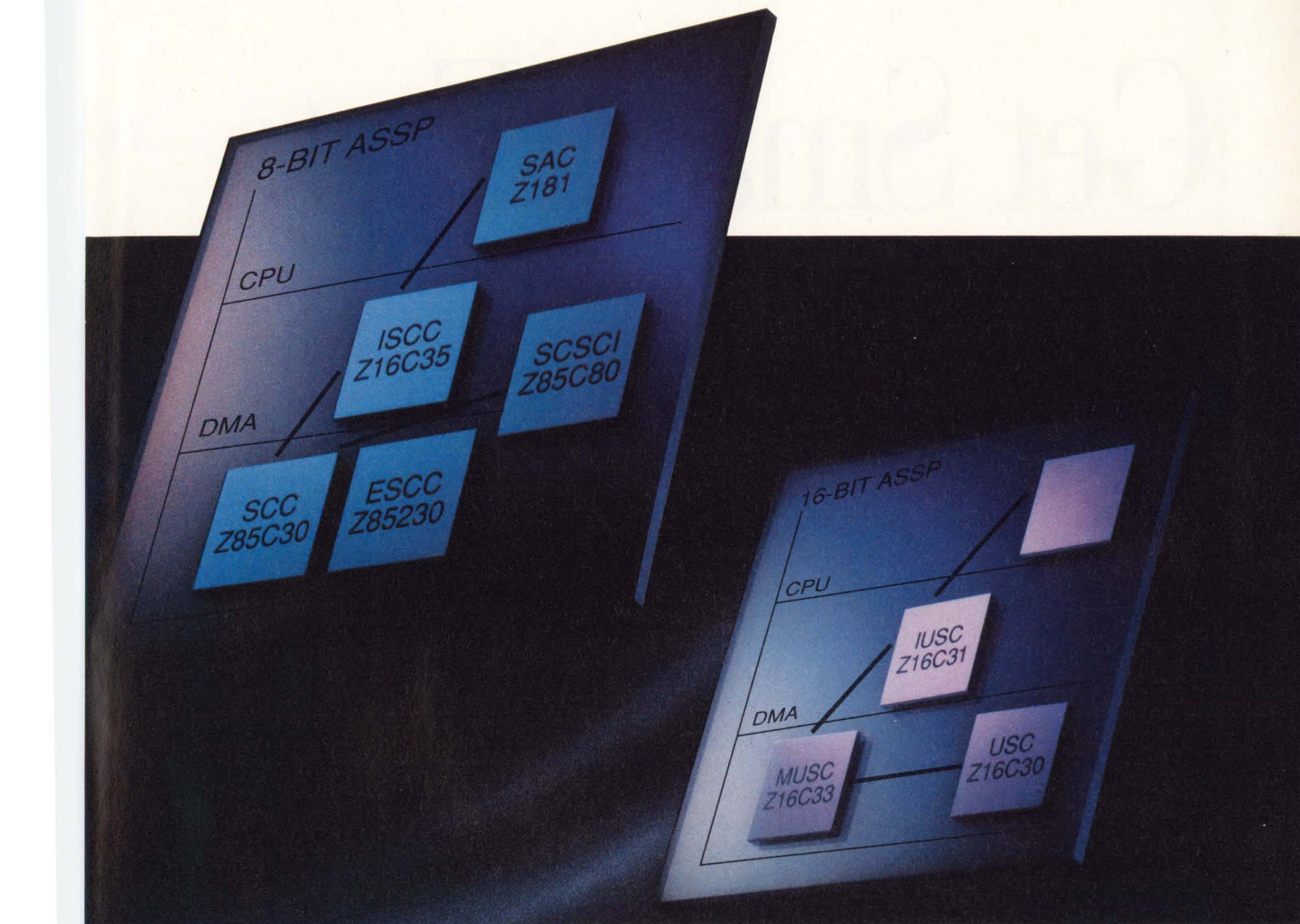

cores and cells in the industry. We're continually developing new members of Zilog's SCC and USC controller families, and, because we have the manufacturing control that comes from having our own fabrication facilities, you can rest assured that every exciting innovation will reflect the high standards of quality and reliability for which Zilog is known . . . and all the flexibility you need for today's complex designs.

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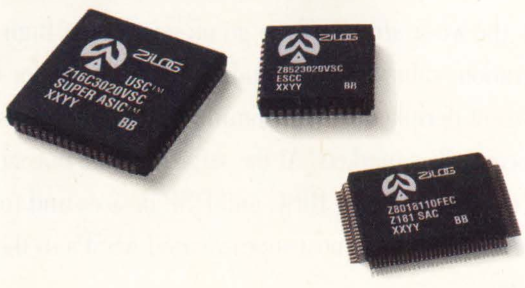

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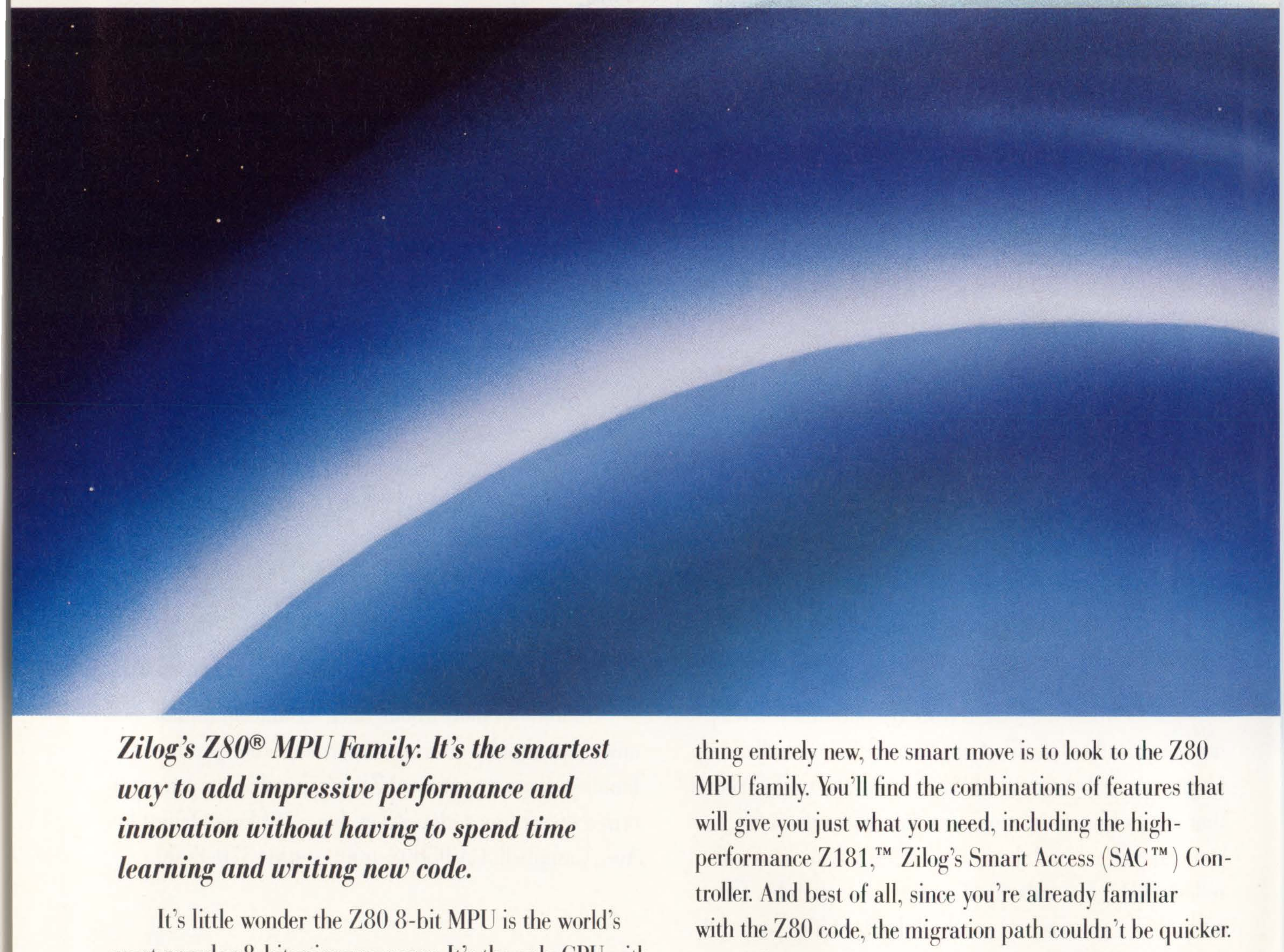

Zilog's Z80® MPU Family: It's the smartest way to add impressive performance and innovation without having to spend time learning and writing new code.

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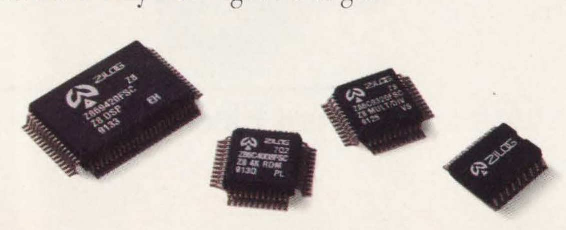

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DuPont Electronics

DU PONT

CIRCLE NO. 113

EDN EDITORS' CHOICE

INNOVATION

Module-generation tool eases top-down FPGA design

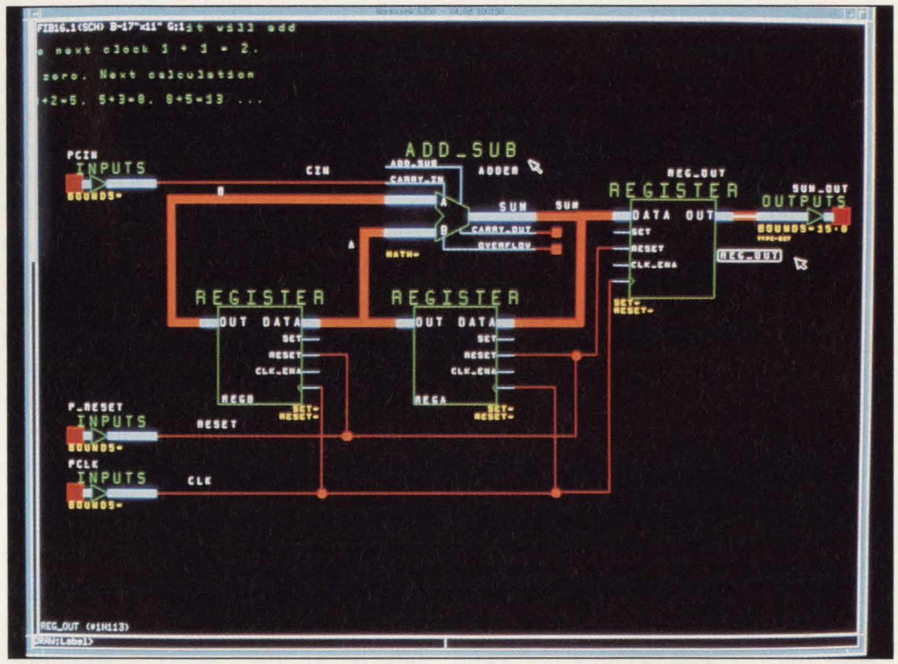
Engineers no longer need to face a Hobson's choice between low-level gate delay or high-level language for FPGA design. With Xilinx's Blox tool, which uses high-level module generation, engineers can define their designs graphically with parameterized functional blocks similar to those in silicon-module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



Engineers can define designs at a functional block level *using Blox's schematic capture.*

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-processing assembler/linker partitions code between processors. The assembler/linker has directives for mapping program and data code to specific processors.

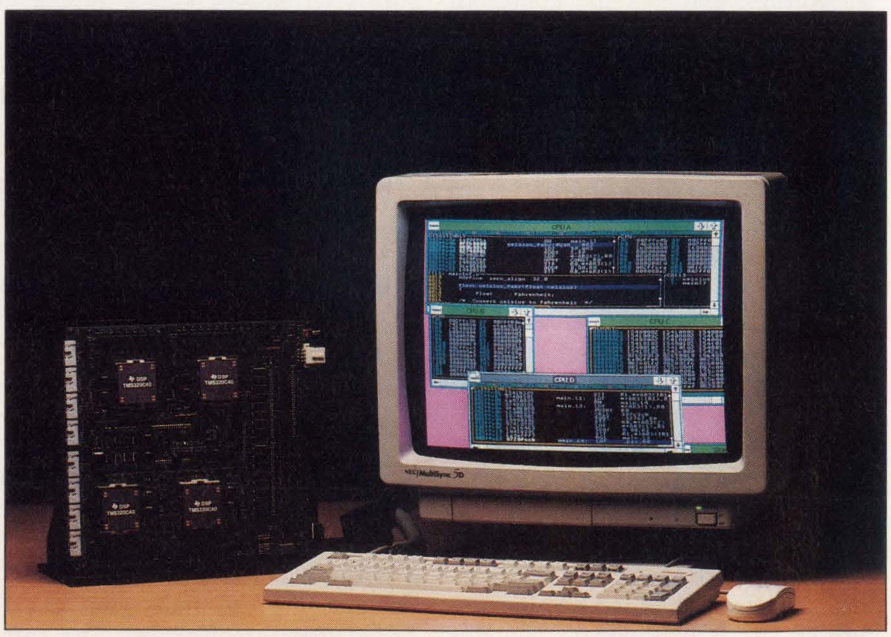
Each C40 has an on-chip DSP analysis module, which takes on key ICE-like functions. Each module has breakpoint address comparators for program, data, and DMA addresses. Discontinuities—program trace address changes—are saved in a program discontinuity stack, which holds the from, to, and PC addresses.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



You can debug multiple processors via *a JTAG serial port on the TMS32C40.*

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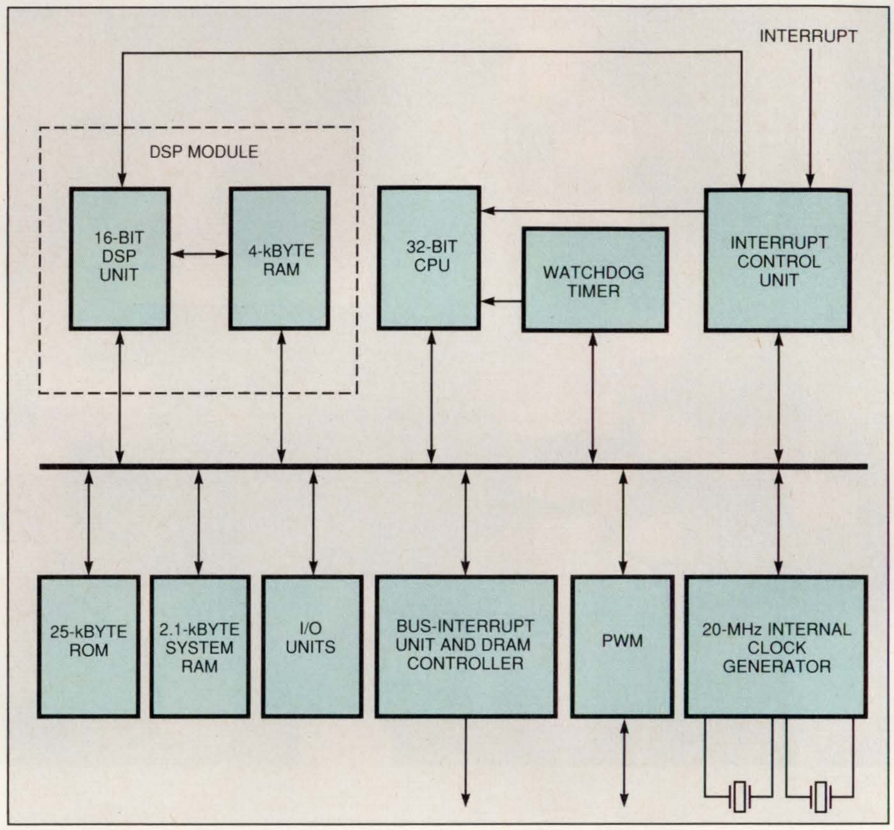
CIRCLE NO. 114

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 32AM160 microcontroller controls voice processing *by combining a 32-bit CISC CPU with a dedicated DSP module.*

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.

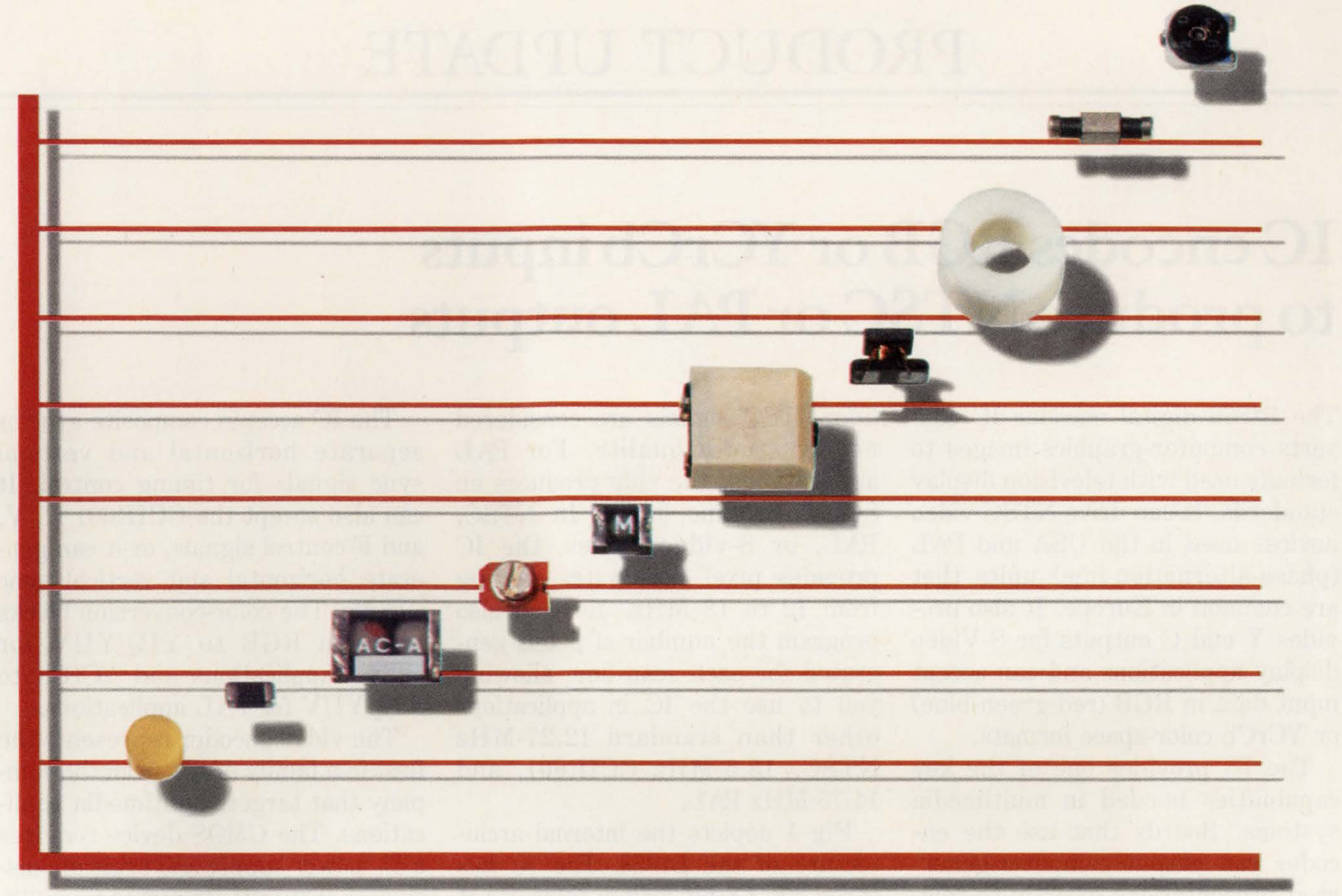
The DSP module is a pipelined, vector-processing engine. In many ways, it resembles the old-fashioned display-list processors for vector graphics. The host CPU sets up the initial program and initializes processing by setting a program pointer to nonzero. The DSP module runs the program to completion 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-leaded-chip-carrier package.—***Ray Weiss***

National Semiconductor Corp, Box 58090, Santa Clara, CA 95052. Phone (408) 721-5000.

Circle No. 735


M
AC-A

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 applicatioms, 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

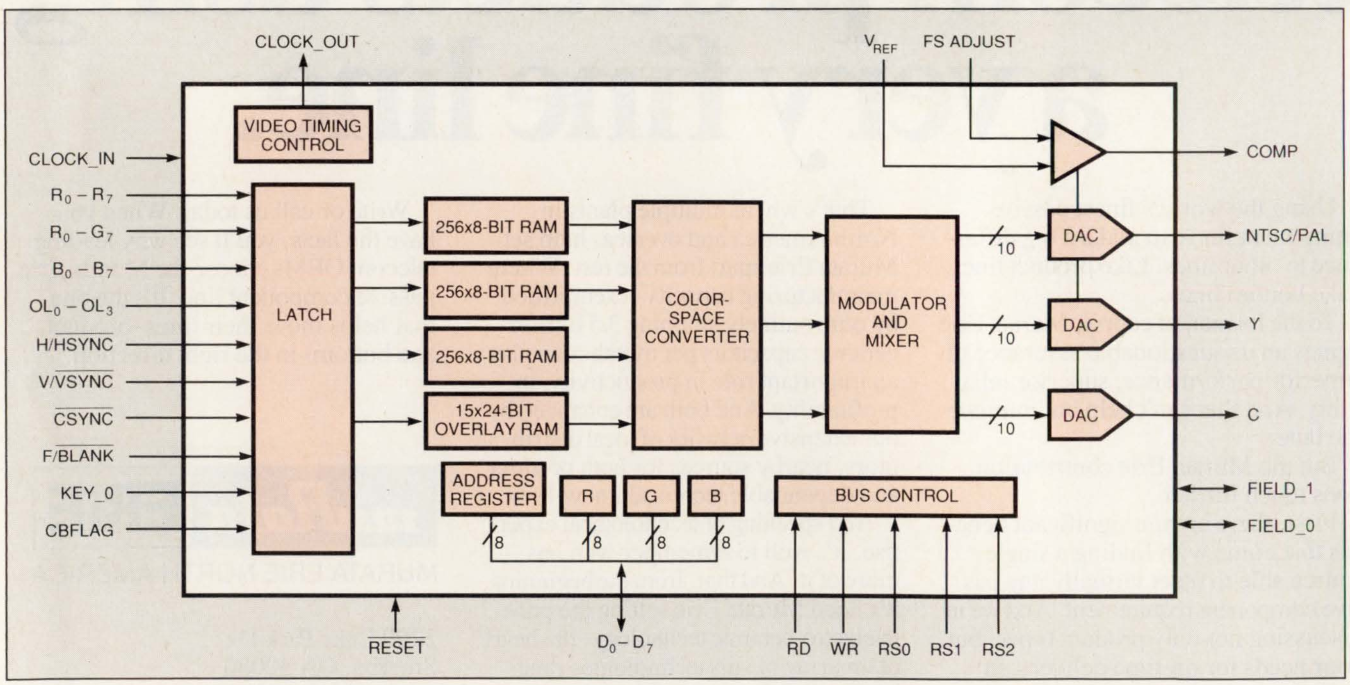


***Fig 1—A choice of S-Video, NTSC, or PAL** outputs makes the Bt858 video-encoder IC useful in applications that require compatibility with different international television standards.*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Gyroscope allows 3-D motion sensing for robotics and desktop 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.

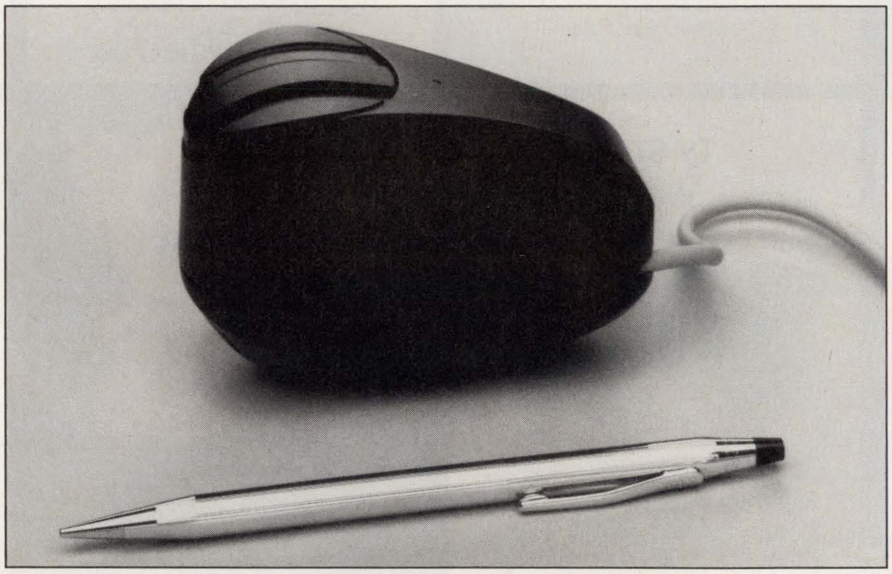
The key element of this pointer is a miniature spin gyroscope, the Gyroengine. The pointer uses two of these devices to provide three degrees of freedom. Like a conventional gyroscope, the Gyroengine uses a spinning motor inside a double-gimbaled housing to establish an inertial reference axis. The gimbals 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.

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



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.*

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

Circle No. 730

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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.

A 20-kbyte fractal-image-format (FIF) file generated these three photographs. By applying the fractal transform to successive sections of the file, the pictures display compression ratios of 154:1, 614:1, and 2456:1, while maintaining 1280×800-pixel resolution.

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 accessed 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 640×400×24-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***

Iterated Systems Inc, 5550A Peachtree Pkwy, Norcross, GA 30092. Phone (404) 840-0310. FAX (404) 840-0029.

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.

ADVERTISEMENT

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.

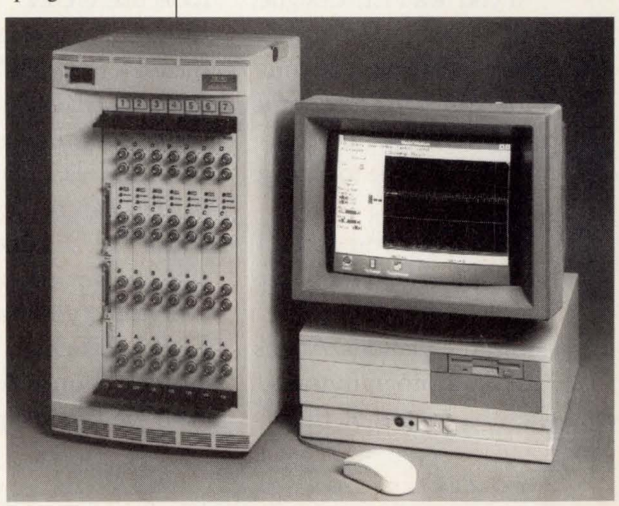
When an event's magnitude can't be known in advance, Nicolet's 12-bit digitizers allow conservation gain settings without unacceptable loss of resolution. And when timing or duration is uncertain, the optional ultra-long memories (up to 3 megawords per channel) give plenty of margin for safety.

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.

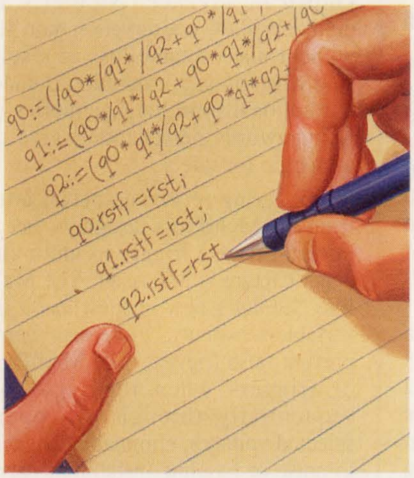
Call Nicolet Measurement Instruments (800) 356-8088



Nicolet MultiPro system with compact seven-slot tower.

CIRCLE NO. 117

You Design Actel F
You Do A PLD. But T



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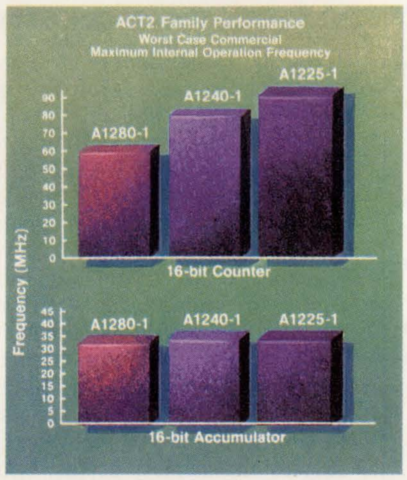
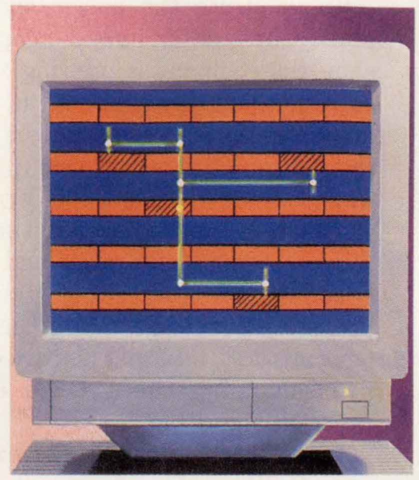
You design Actel FPGAs using the same tools as you would a PLD: ABEL,™ CUPL,™ LOG/iC™ and PGADesigner.™ But that's where the similarity ends.



Fast. Fast. Fast.

Our FPGAs are real speed demons. Whatever application you may be working on, our parts will give you the kind of performance you're looking for.



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Coupled with your PLD tools, Actel's Action Logic™ System (ALS) software lets you create your own FPGAs—using a 386 PC or workstation—right at your own desk. With Auto Place and Route that's proven in thousands of applications.

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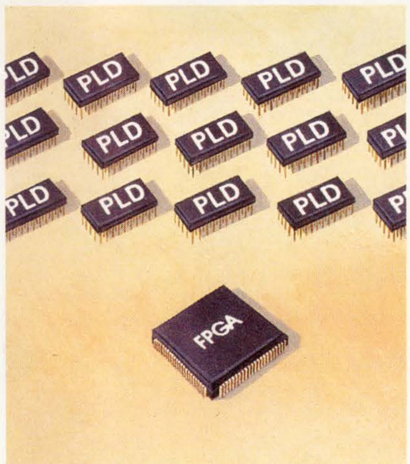
It's never been easier to make your innovative designs a reality. We offer you a complete family of powerful FPGAs, like the A1010 and A1020, available in 44, 68 and 84 pin PLCC versions and implementing up to 273 flip-flops or up to 546 latches. And the first member of our ACT 2 family, the power-

'GAs The Same Way
e Similarity Ends There.

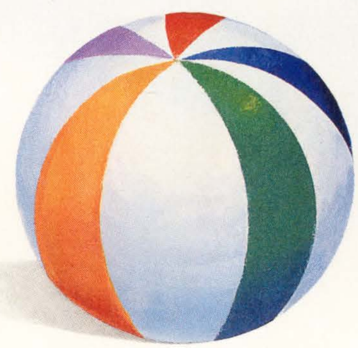
More Flexibility And Capacity.

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.



Small Footprint.

Actel FPGAs give you far more gates per square inch. As much as ten times as many as the densest PLDs. That can save a lot of real estate.



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ful A1280. With 8,000 gates, up to 998 flip-flops, and 140 I/O pins, it's the highest capacity FPGA today. And our A1240-1 is the fastest. In the A1240-1, 16-bit counters run at 75 MHz, 16-bit accumulators at 33 MHz. Enough capacity and speed to handle almost any application.

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The FPGA Design Guide

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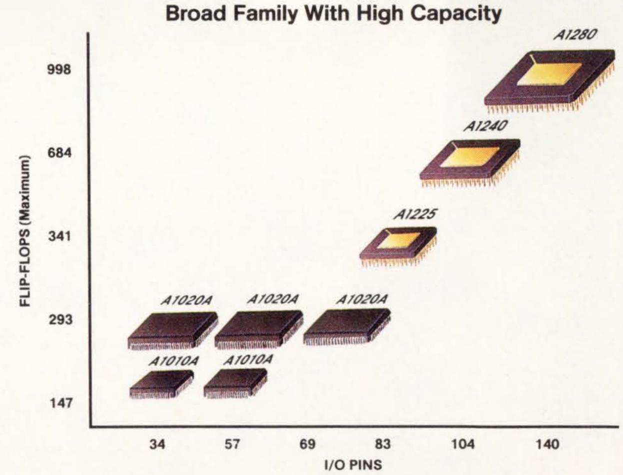

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CIRCLE NO. 118


DSP

E D N   S P E C I A L   R E P O R T

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*

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-

Thirty-two-bit, floating-point DSP processors power applications ranging from image processing to global positioning systems to multimedia computers. (Photo courtesy Motorola Inc)

"Processors like the TMS32C40 and DSP96002 are designed for large-scale multiprocessing. They don't even have a serial port." —*Tony Agnello, Ariel*

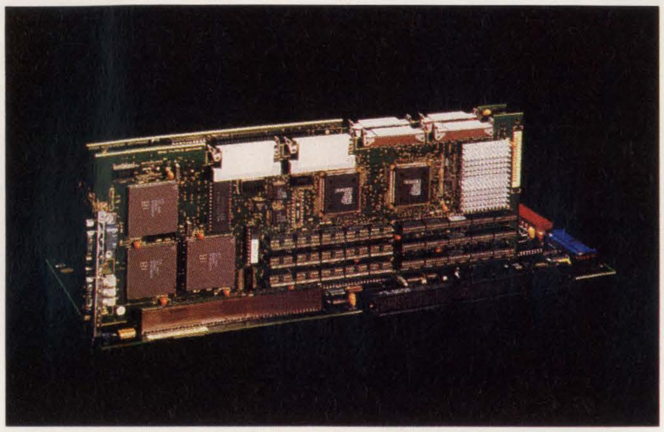
tinue to grow in raw processing power. New chips such as Analog Devices' ADSP-21020 deliver millions of floating-point operations per second running directly out of local memory.

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 mother board 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 1—RISC vs DSP floating-point CPUs

Intel i860 RISC CPU	Motorola DSP96002 and Texas Instruments TMS320C40 32-bit DSP CPUs
Designed to run Unix	Won't run Unix, no MMU
64-bit arithmetic	32-bit arithmetic
25-nsec instruction cycle (pipelined)	50-nsec instruction cycle (pipelined)
No DMA for concurrent I/O	DMA controllers for concurrent I/O
Slow context switch	Faster context switch
Standard interrupt mechanism	Faster interrupts
One external bus	Two external buses
Off-chip memory penalty	Single-cycle external memory accesses
No cache lock	Locking caches
Pipelined FPU	Single-cycle FPU multiply operations
No integer-to-floating-point conversion instruction	Single-cycle integer-to-floating-point conversion
No integer multiples	32 x 32-bit integer MAC
Graphics engine	No graphics engine
Need high-level language	Easy-to-use assemblers
C compilers	C compilers optimized for parallel operations
Long-instruction-word operation; as many as 2 instructions/word, 1 integer, 1 floating point	1 instruction/word parallel operation



A typical multiprocessing DSP design is illustrated by the IBM GT4x graphics adaptor, which has six TI TMS320C30s in a 3-card subsystem. The adapter handles 2- and 3-D wireframes and 3-D surfaces with 1280 × 1024-pixel resolution.

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

Texas Instruments TMS320C40

Clock speed	40, 50 MHz (clock is 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.

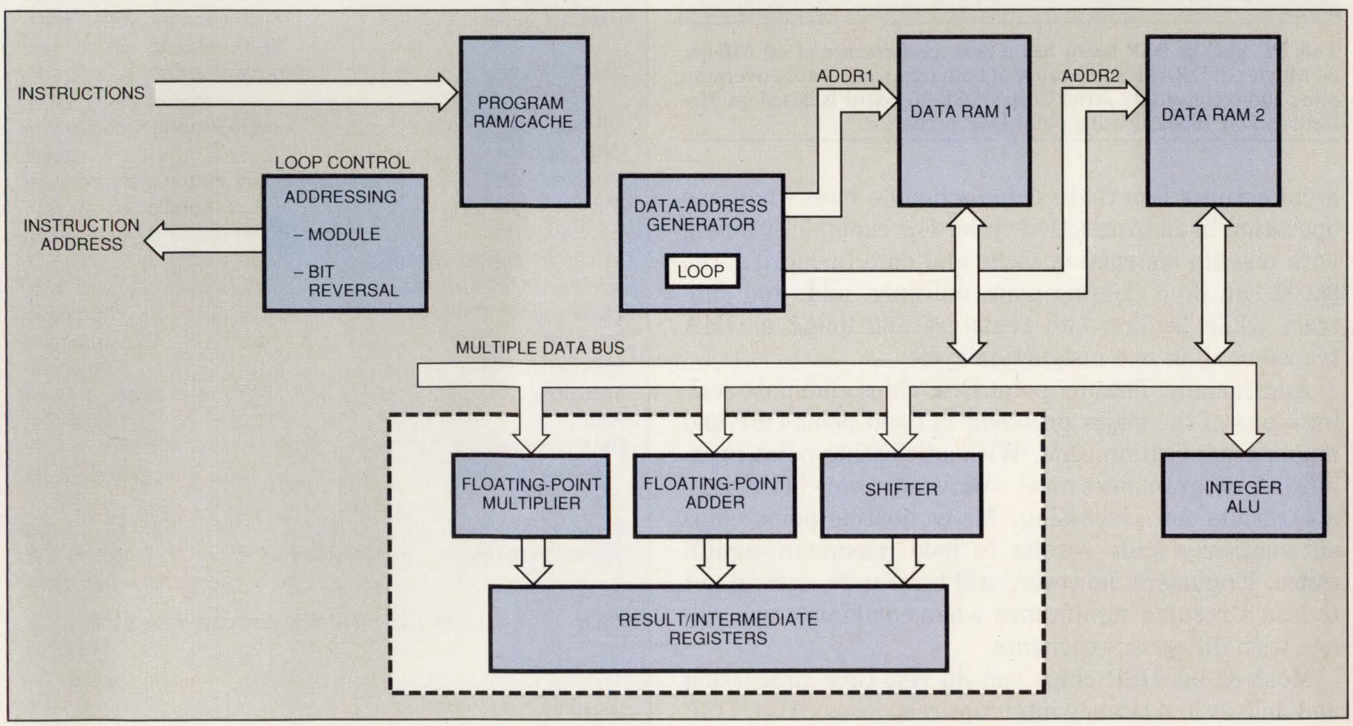
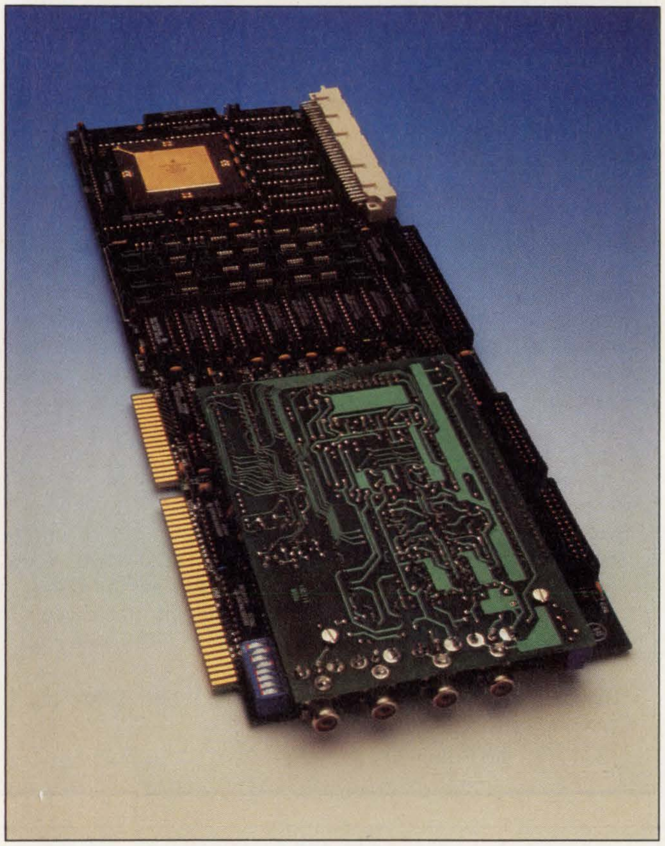


Fig 1—A generic 32-bit floating-point processor supports 3-memory addressing with automatic addressing and loop control. A low-overhead multiply/accumulate unit (MAC) calculates series.

"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



This PC plug-in DSP board has a peak performance of 60 Mflops, 64 Mbytes of DRAM, and a range of both input and output oversampling audio converters. Ariel Corp's DSP-96 board is based on Motorola's DSP96002 floating-point DSP processor.

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-

Texas Instruments TMS320C30

Clock speed	27, 33, 40 MHz (clock is divided by 2 internally)
Instruction cycle	50 nsec at 40 MHz
MAC cycle	50 nsec at 40 MHz
Accumulator size	40 bits
Floating-point formats	40 and 32 bit
Registers	twenty 32 bit and eight 40-bit precision floating point
On-chip memory	two 4-kbyte RAMs, one 16-kbyte ROM
On-chip program memory	256 bytes
External buses	24-bit address, 32-bit data; 32-bit address, 32-bit data
Internal buses	program, 2 data (2 address, shared data), DMA
Off-chip fetch	1 cycle if no bus contention
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	7
Number of instructions	135*
Floating-point divide	1560 nsec
Interrupt response	3 instructions
1024-point FFT	3.00 msec
Interrupts	4 external, 1 reset
Pins	180 (PGA)
DMA channels	1
Timers	two 32 bit
Serial ports	2
Byte addressing	word
Special features	divide-by-2 clock, 2 accesses per internal bus per cycle
Price	27-, 33-, 40-MHz versions: $92, $108, $135 (10,000)

*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 multiprocessor 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.

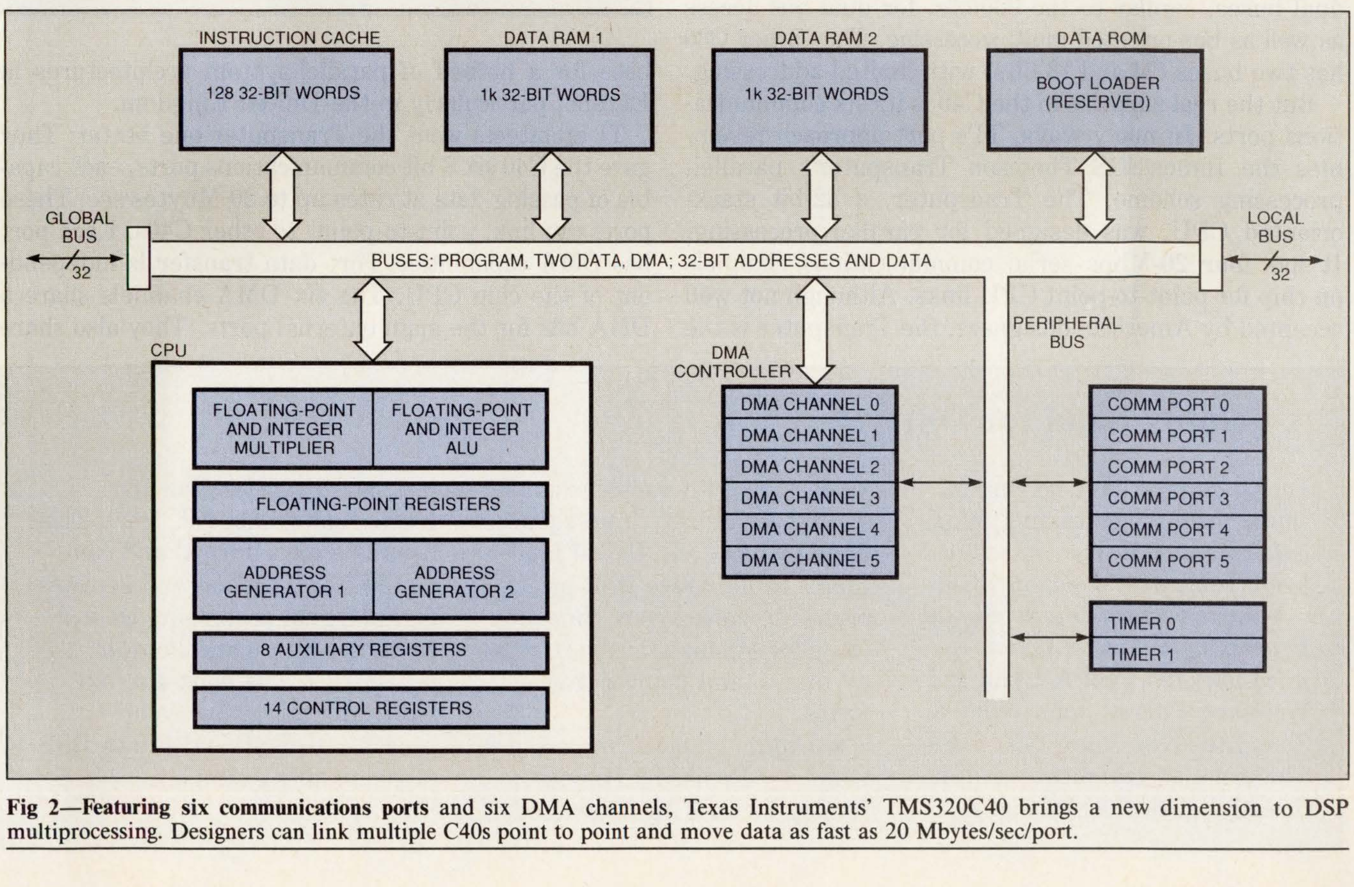


Fig 2—Featuring six communications ports and six DMA channels, Texas Instruments' TMS320C40 brings a new dimension to DSP multiprocessing. Designers can link multiple C40s point to point and move data as fast as 20 Mbytes/sec/port.

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 (pipelined)
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 4× 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:

- *Introductory Digital Signal Processing with Computer Applications*, by Paul A Lynn and Wolfgang Fuerst, John Wiley & Sons Ltd, New York, NY, 1989. This book is straightforward; it directly tackles digital signal processing with simple examples and moves quickly from equations to Basic and Pascal programs to illustrate DSP principles. The book covers time- and frequency-domain analysis, digital filters, and Fourier transforms.
- *Digital Signal Processing in VLSI*, by Richard J Higgins, Analog Devices Inc, Norwood, MA, and Prentice-Hall Inc, Englewood Cliffs, NJ, 1990. This book is a more formal and complete text. It defines and explains digital signal processing as well as digital filters and Fourier transforms. The book also explores digital hardware approaches to DSP and shows DSP programming examples.

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

Analog Devices ADSP-21020

Clock speed	15, 20, 25 MHz bus
Instruction cycle	40 nsec at 25 MHz
MAC cycle	40 nsec at 25 MHz
Accumulator size	80 bits
Floating-point format	IEEE 754 40-bit extended
Registers	two 16×40-bit, 10-port register files
On-chip memory	none
On-chip program memory	32×48 bits
External buses	two program (24-bit address, 48-bit data), data (32-bit address and data)
Internal buses	48-bit program and 32-bit data
Off-chip fetch	1 cycle, dual ports
CPU pipeline	3 stages
Pipelined MAC	1-cycle multiply and 1-cycle add
Special addressing	modulo, bit reverse
Loop controls	loop address, counter (6-deep stack)
Maximum parallel operations	7
Number of instructions	63*
Special instructions	programmable delayed branch, multiply with add or subtract; count leading 1s or 0s
External-memory interface	flexible access, runs with 35-nsec SRAM
Floating-point divide	300 nsec
Interrupt response	3 instructions
1024-point FFT	0.77 msec
Interrupts	5 hardware
Pins	223 (PGA)
DMA channels	none
Timer	32 bit
Serial port	none
Byte addressing	no
Special features	DSP/C (Numeric C); 2-bus access to external memory running from complex instruction cache; $1/\sqrt{x}$ takes 450 nsec; JTAG and chip-based ICE
Price/availability	15-, 20-, and 25-MHz versions: $185, $246, $276 (100)

*Load/store architecture.

Acronyms used in this article

ALU—Arithmetic and logic unit
API—Application program interface
ASIC—Application-specific integrated circuit
bps—Bits per second
CPU—Central processing unit
DMA—Direct memory access
DRAM—Dynamic random-access memory
DSP—Digital signal processing
EPROM—Erasable programmable read-only memory
FFT—Fast Fourier transform
FPU—Floating-point unit
ICE—In-circuit emulator
ISR—Interrupt service routine
JTAG—Joint Test Action Group
LIW—Long instruction word
MAC—Multiply and accumulate
MESI—Modified, exclusive, shared, and invalid
Mflops—Millions of floating-point operations per second
MIPS—Millions of instructions per second
MMU—Memory-management unit
N/A—Not applicable
PC—Personal computer
PGA—Pin-grid array
PQFP—Plastic quad flatpack
RAM—Random-access memory
RISC—Reduced-instruction-set computer
ROM—Read-only memory
SRAM—Static random-access memory

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 deasigns. 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

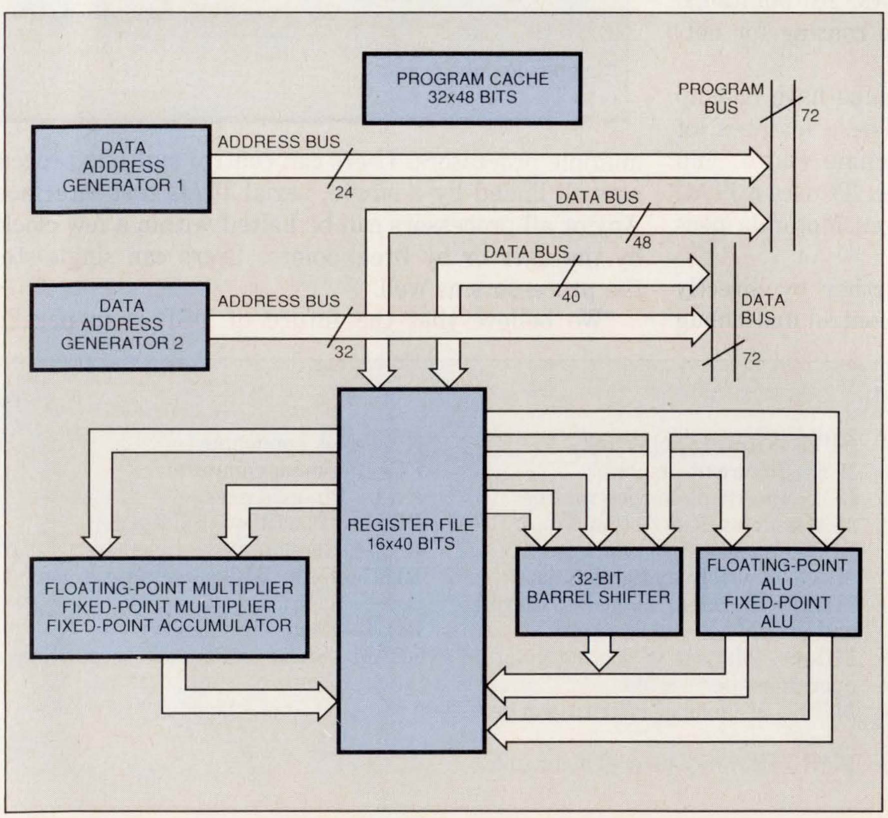


Fig 3—An on-chip cache lets Analog Devices' AD21020 do fast inner-loop processing. The processor caches complex instructions then uses the program bus as a second data bus.

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 multiprocessor 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

Motorola DSP96002

Clock speed	33, 40 MHz
Instruction cycle	50 nsec at 40 MHz (2 clocks/ instruction cycle)
MAC cycle	50 nsec at 40 MHz
Accumulator size	96 bits
Floating-point formats	IEEE-754 single precision (32 bits) and single extended precision (44 bits)
Registers	10-register file (96 bits), 24 address registers (32 bits)
On-chip memory	two 4-kbyte RAMs; X ROM for sin values, Y ROM for cos values (each ROM is 512 bytes)
On-chip program memory	4 kbytes RAM
External buses	two 32-bit (address and data)
Internal buses	5: X, Y, global, DMA data, and program bus; 3 address buses: X, Y, program
Off-chip fetch	1 instruction cycle if no bus contention
CPU pipeline	3 stages
Pipelined MAC	1-cycle multiply and add (no pipeline)
Special addressing	X and Y modulo and bit reversal
Loop controls	DO instruction with loop counter; stack for nested DO loops
Maximum parallel operations	10*
Number of instructions	133
Special instructions	floating-point multiply, add, and subtract for FFTs; graphics compare
Floating-point divide	300 nsec
Interrupt response	6 instructions (fast=2 instructions)
1024-point FFT	1.047 msec
Interrupts	3 external
Pins	223 (PGA)
DMA channels	2
Timer	none
Serial port	none
Byte addressing	none
Special features	2 parallel external buses (master/ slave); on-chip ICE—breakpoint, trace, count (program and data); 2-word interrupt service instruction
Price	33 MHz, $368; 40 MHz, $441 (100)

*Includes addressing, register operations, loops, DMA, and DMA addressing.

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.

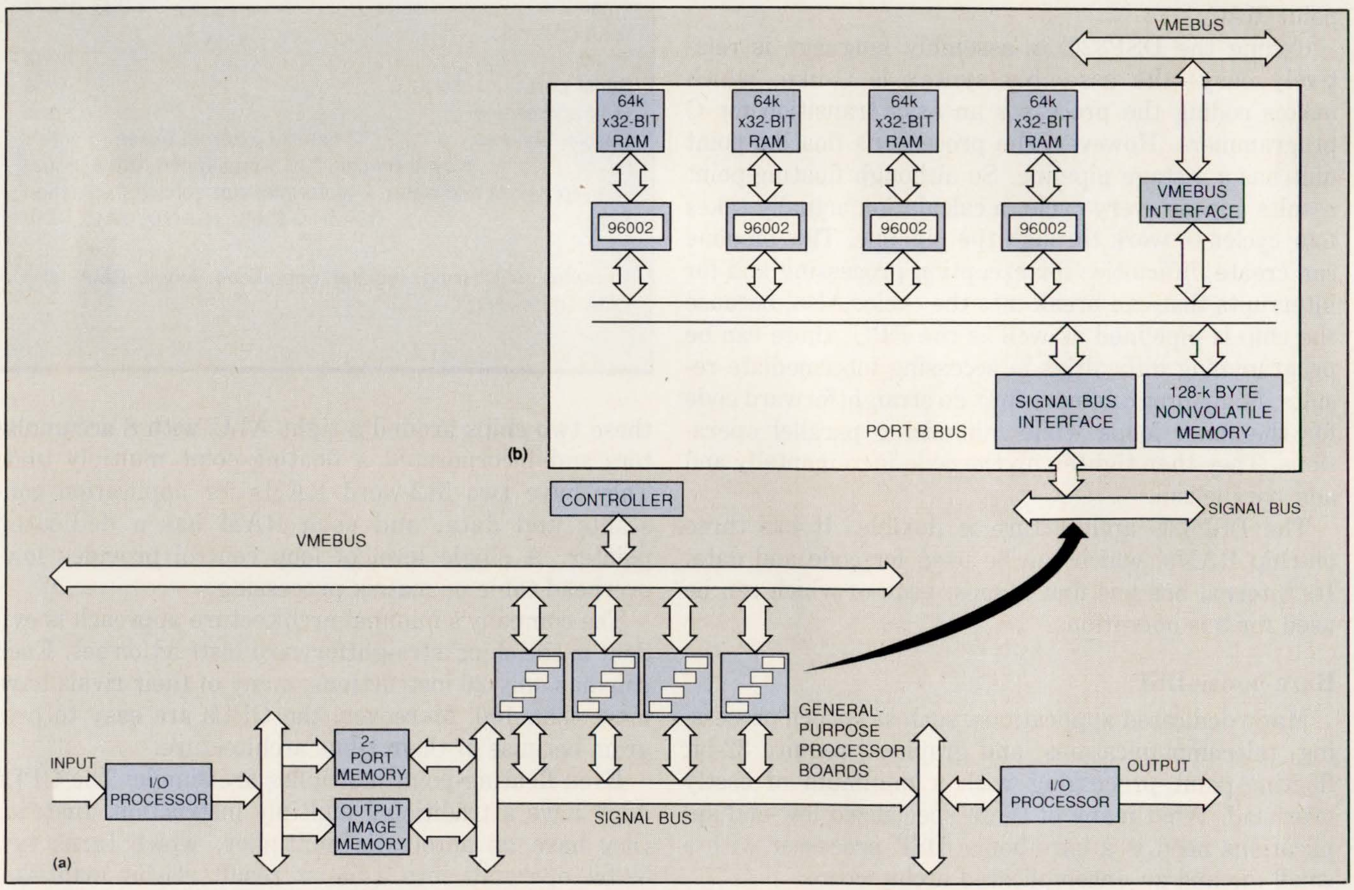
The two chips are the NEC 13.3-MHz μPD77230, which has a 150-nsec instruction cycle time, and the 11.1-MHz μPD77240, which has a 90-nsec cycle time. Each instruction cycle takes two clock cycles. The chips share a common inner architecture but have different external interfaces. The older device, the 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.

tem—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.

AT&T DSP3210

Clock speed	50, 66.7 MHz
Instruction cycle	60 nsec at 66.7 MHz
MAC cycle	60 nsec (pipelined) at 66.7 MHz
Accumulator size	40 bits
Floating-point format	32 bit (sign, 23-bit mantissa, 8-bit exponent)
Registers	twenty-two 24-bit integer, 4 floating point
On-chip memory	two 4-kbyte RAMs (for data, program)
On-chip program memory	boot ROM
External buses	32-bit address and data
Internal buses	one 32-bit bus, 4 cycles per instruction cycle
Off-chip fetch	30 nsec, (as many as 2 accesses per instruction cycle)
CPU pipeline	3 stages
Pipelined MAC	4-stage pipeline (2-stage MAC)
Special addressing	bit reverse
Loop controls	loop counter, stackable
Maximum parallel operations	9
Number of instructions	63*
Special instructions	integer-to-floating-point and pixel-to-floating-point conversion
Floating-point divide	660 nsec
Interrupt response	3 instructions
1024-point FFT	1.9 msec
Interrupts	6 (4 external)
Pins	132 (PQFP)
DMA channels	2
Timer	one 32 bit
Serial port	1 (plus 8-bit parallel port)
Byte addressing	8, 16, 32 bit
Special features	C-like assembly language, big/little endian support for Intel- and Motorola-style buses, power-down mode
Price	$60 (10,000)

*Load/store architecture

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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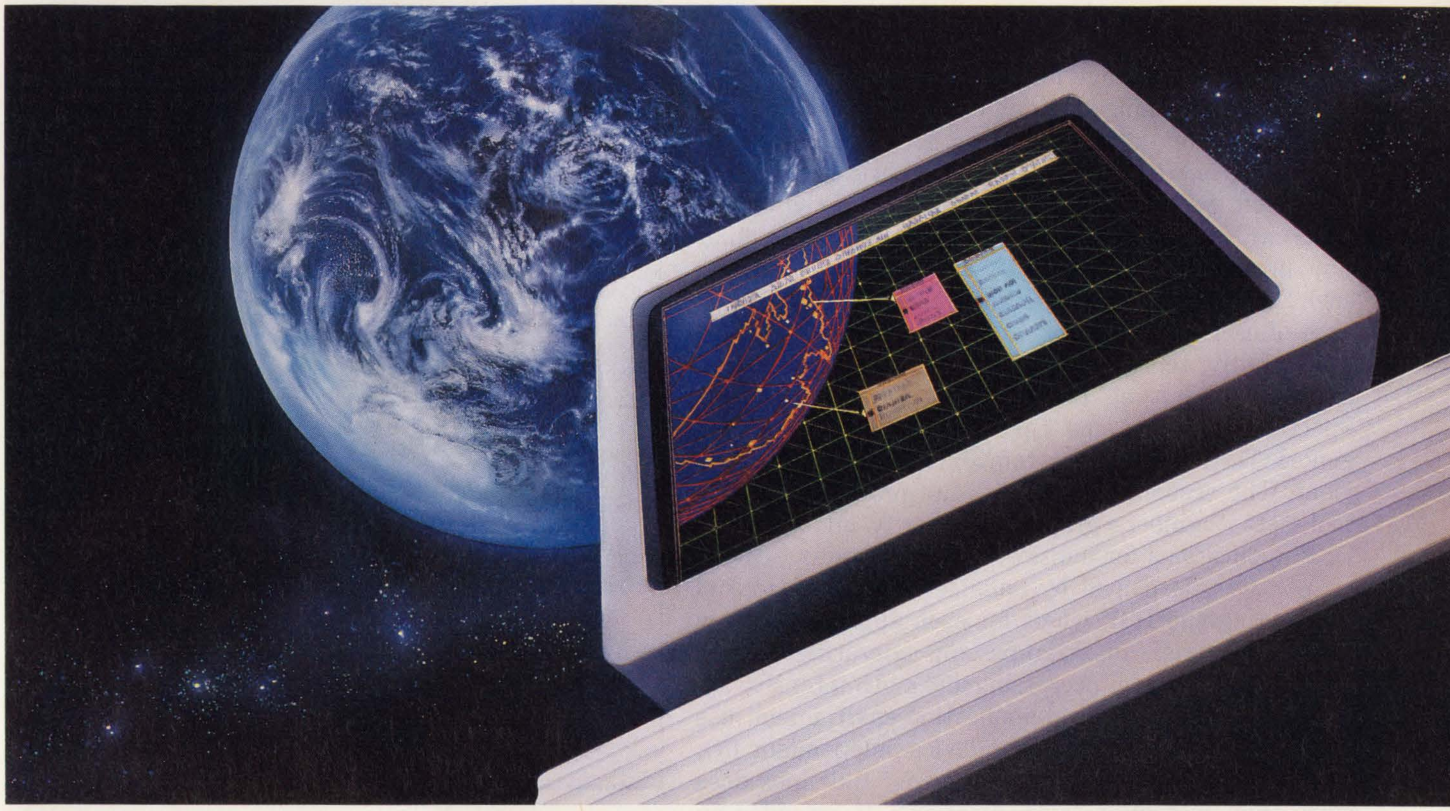

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NEC μPD77230

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	eight 55-bit accumulators, 2 multiply registers
On-chip memory	two 2-kbyte RAMs, one 4-kbyte ROM
On-chip program memory	8-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 cycle, slave mode to 16-bit microprocessor
Price	$75 (1000)

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 imaplement 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

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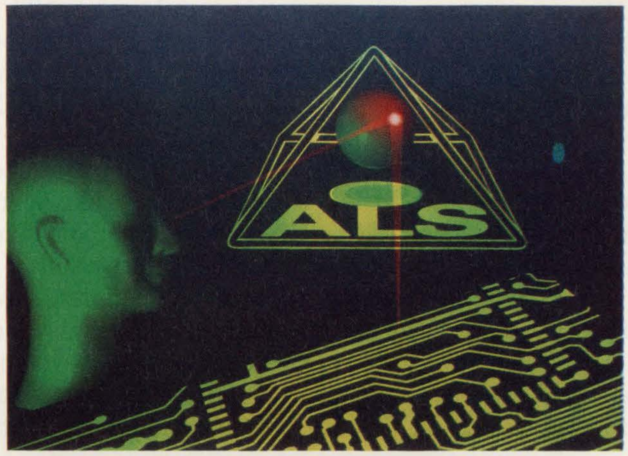

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of which subs for a DSP processor. Thus developers can use networks of workstations linked via Ethernet and TCP/IP to emulate and debug multiprocessor DSP designs.

More software changes are underway. TI's TMS32C40 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 of Intermetrics's Intertools tool set, which provides a familiar development environment and includes the XDB source-level debugger. Also, Motorola is fielding a new 96002C compiler based on the Free Software Foundation's (Cambridge, MA) GNU compiler.

Analog Devices has developed its own specialized C compiler, the DSP/C compiler, which extends C for DSP and vector processing. Taking a leaf from the Numerical C extensions (ANSI X3J11 C standards group), DSP/C extends C with vector, operator, IEEE floating-point, and math extensions. DSP/C also adds complex types, restricted pointers, and dynamic arrays. The extensions lead to far less C coding for DSP inner loops. Array, vector, and matrix data types are simplified, and the new types minimize typecasting errors.

NEC μPD77240

Clock speed	11.1 MHz
Instruction cycle	90 nsec
MAC cycle	90 nsec
Accumulator size	55 bits
Floating-point format	NEC format
Registers	eight 55-bit accumulators, 2 multiply registers
On-chip data memory	two 2-kbyte RAMs, 4-kbyte ROM
On-chip program memory	8-kbyte ROM
External buses	2 program (16-bit address, 32-bit data), 1 data (24-bit address, 32-bit data)
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, bit reverse
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	7.07 msec
Interrupts	2
Pins	132 (PGA)
DMA channels	none
Timer	none
Serial port	none
Byte addressing	none
Special features	automatic multiply cycle, built-in DSP library with more than 100 routines
Price	$85 (1000)

Intel i860XP

Clock speed	40, 50 MHz
Instruction cycle	20 nsec at 50 MHz*, as many as 2 instructions/cycle
MAC cycle	20 nsec (pipelined)
Accumulator size	64 bits
Floating-point formats	IEEE-754 single or double precision
Registers	thirty-two 32-bit integer, eight 128-bit or sixteen 64-bit floating point
On-chip memory	16-kbyte data cache
On-chip program memory	16 kbytes
External buses	32-bit address, 64-bit data
Internal buses	32-, 64-, 128-bit buses
Off-chip fetch	2 clock cycles; burst mode = 1 + n cycles
CPU pipeline	4 stages
Pipelined MAC	pipelined (3 stages); 1-cycle single, 2-cycle double precision
Special addressing	N/A
Loop controls	loop-control counter, program-status register
Maximum parallel operations	7
Number of instructions	98**
Special instructions	floating-point-to-integer, integer-to-floating-point, Z-buffer operations; 2-instruction mode
Floating-point divide	300 nsec
Interrupt response	24 instructions
1024-point FFT	76 msec
Interrupts	1
Pins	262 (PGA)
DMA channels	none
Timer	none
Serial port	JTAG boundary scan
Byte addressing	yes
Special features	pipelined graphics engine, multiprocessing cache coherency (MESI), second-level cache-control chip available, memory burst mode, breakpoint register
Price/availability	25-, 40-, 50-MHz versions: $158, $521, $652 (1000)/sampling

*Superscalar—1 or 2 instructions per cycle.
**Load/store architecture.

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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 coefficient 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

Clock speed	33-, 40-, 50-MHz bus (internal)
Instruction cycle	20 nsec at 50 MHz*, as many as 2 instructions/cycle
MAC cycle	20 nsec at 50 MHz (pipelined)
Accumulator size	64 bits
Floating-point formats	32-bit single precision, 64-bit double precision**
Registers	thirty-two 32-bit integer (32-/16-bit single-/double-precision floating point)
On-chip memory	1-kbyte data cache (locking)
On-chip program memory	4 kbytes (locking)
External buses	32-bit address, 64-bit data
Internal buses	64 bit
Off-chip fetch	64 bit (40 nsec)
Pipelined MAC	5 stages; 2 cycles per multiply for multiply/multiply sequences, 1 cycle for multiply/add sequences
Special addressing	N/A
Loop controls	N/A
Maximum parallel operations	4
Number of instructions	58***
Special instructions	integer-to-floating-point and floating-point-to-integer conversions, compare and branch
Floating-point divide	16/31 instruction cycles for single/double precision
Interrupt response	16 instruction cycles
1024-point FFT	1.025 msec
Interrupts	as many as 15 external (4-bit coded)
Pins	223 (PGA)
DMA channels	2
Timer	16 bit
Serial port	1 for on-chip ICE
Byte addressing	yes
Special features	2 pipelines, ALU, branch prediction, fault-tolerant shadow mode
Hardware debug support	6 debug registers; instruction trace, trap, count
Price/availability	$880/sampling

** IEEE-754 floating point.
*** Load/store architecture.

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 MESI (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. EDN

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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.

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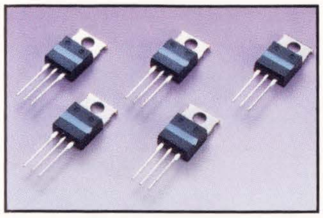

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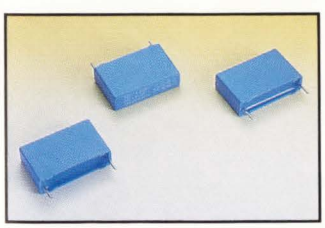

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Capacitance range 0.010 to .68 μF; tolerance is ±10%; voltage rating is 250 VAC @ 50/60 Hz @ 85 °C.

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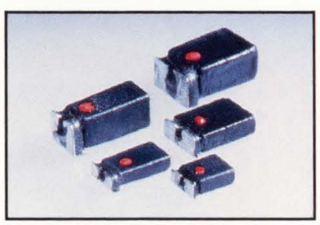

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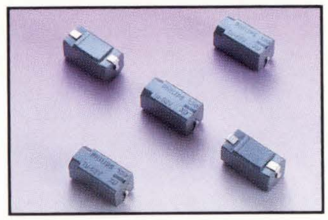

Philips 2222-139 Series Long Life SMD® Capacitors now offer longer working life as well as enhanced specifications.

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

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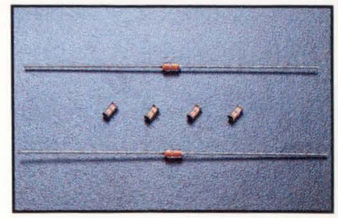

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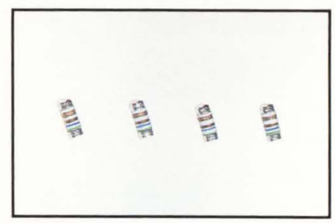

Philips 9B1406 MELF precision resistor benefits from technology used in manufacturing leaded metal film resistors — even though it comes in a surface mount package.

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.

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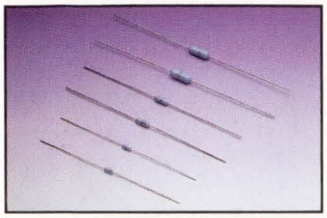

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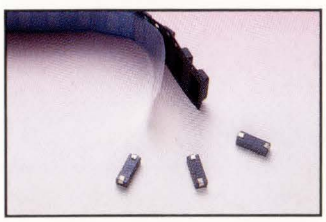

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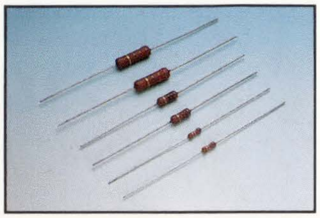
Samples now available.

New Metal Film Technology Yields Miniature-Size Power Resistors Up To 3 W.



Philips' new PR series is a miniature power resistor line of 1, 2, and 3 watt devices. The 1 watt unit is the same size as an RN55.

The new resistors have a 5% tolerance level and a temperature coefficient of 250 ppm. The devices combine high wattage capability with low hot spot parameters.

Size is .295 inches CL-CL. Packaging is RS296D Class 1 tape and reel for automatic insertion.

Availability: stock to 12 weeks ARO.

Newest Data Disk Set On Discrete Semiconductors Covers 3,600 Type Numbers.

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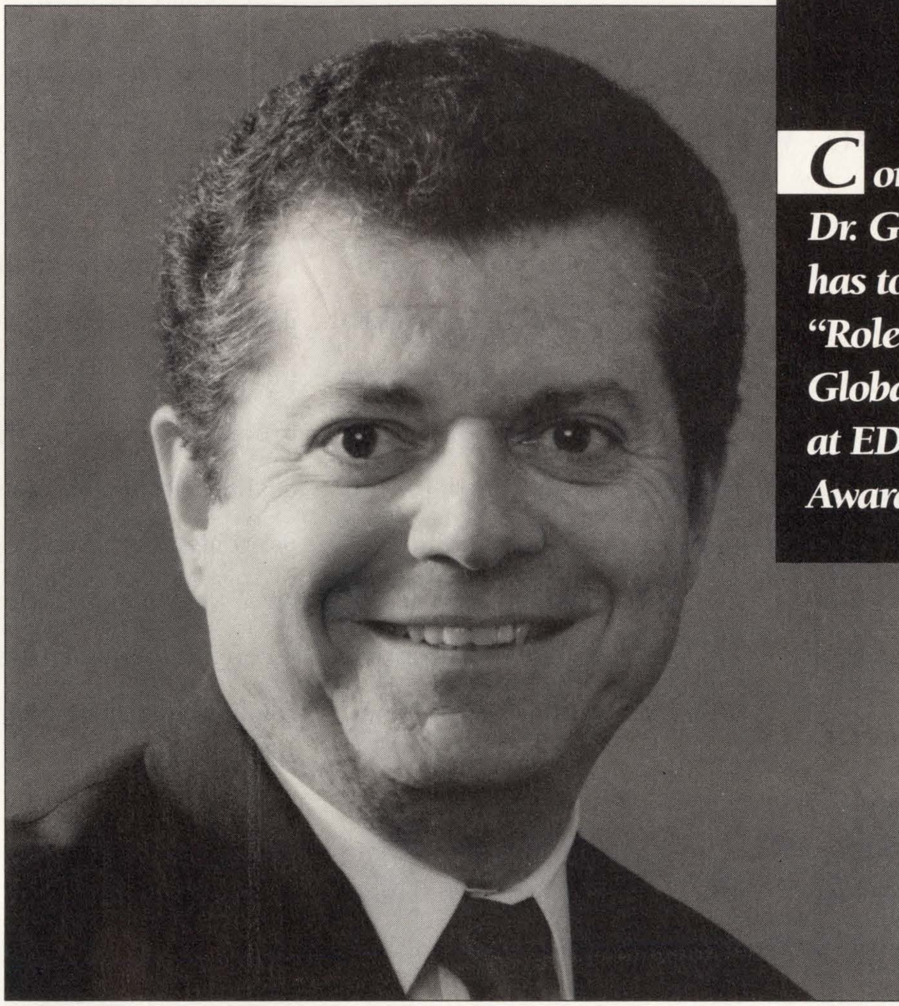


Come hear what Dr. Gilbert Amelio has to say on the "Role of Innovation in Global Competition" at EDN's Innovation Awards Banquet.

Dr. Gilbert F. Amelio,
President and Chief Executive Officer
of National Semiconductor Corporation.

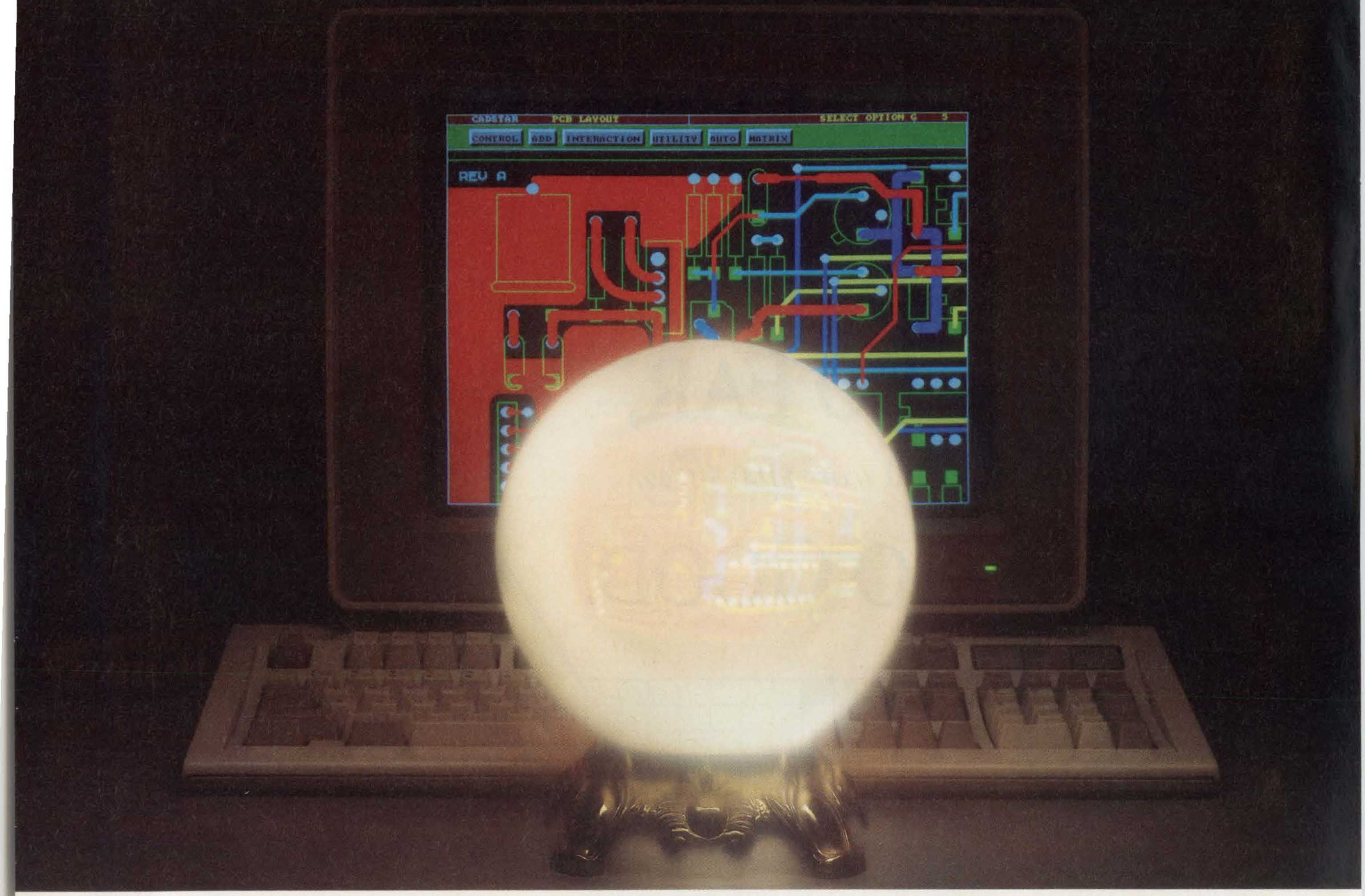
Dr. Gilbert Amelio, President and CEO of National Semiconductor Corporation, will be the keynote speaker at EDN's Second Annual "Innovation and Innovator of the Year Awards" Banquet on November 19 during Wescon in San Francisco. EDN's Innovation program recognizes the year's most innovative products 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.

EDN Magazine Edition News Edition

Introducing The New CADSTAR...



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.

CADSTAR's new Motif style graphical interface has clear, logical menus integrated across all functions. The best part is, you'll rarely need to use those menus! Imagine software so smart, it knows what you want to do next. CADSTAR is easy to learn, and it drastically reduces keystrokes, saving you hours.

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SHOW PREVIEW

WESCON/91

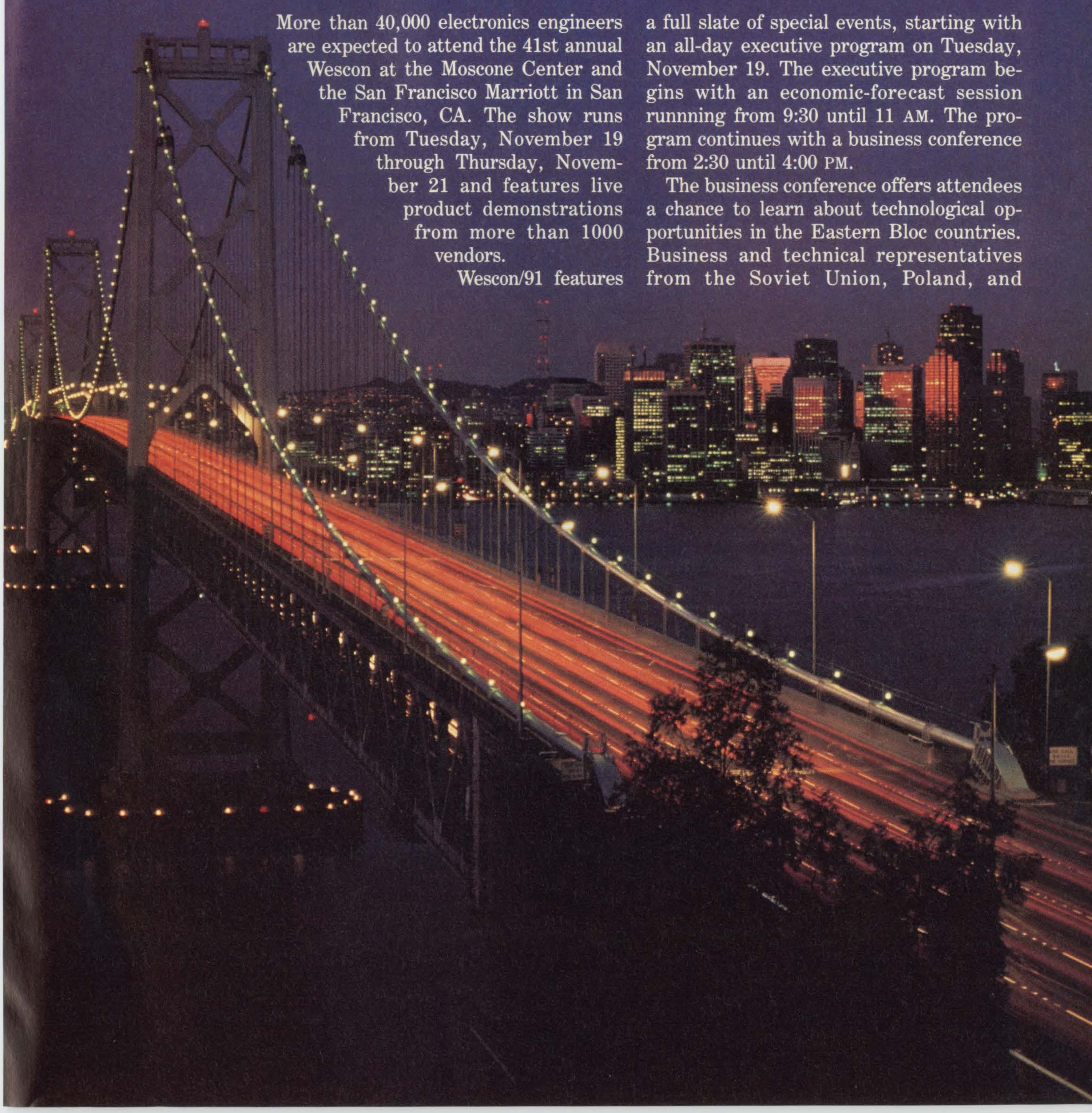
To satisfy the information needs of today's designers, Wescon/91 features programs that stress state-of-the-art information and identify future trends.

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 runnning 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



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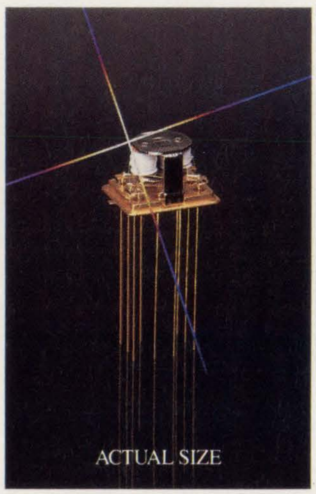

The TO-5 family of relays were always good in RF switching applications. We didn't plan it that way. It just happened. Low inter-contact capacitance. Low insertion loss. Up through 500 MHz. No problem.

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Czechoslovakia will answer questions and provide information regarding the capabilities and procedures available to nuture 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-

Table 1—Wescon/91 technical conferences and courses schedule

Tuesday November 19, 1991	**Neural networks and robotics**	**Advances in FPGAs**	**High-speed logic design**	**Memory systems**	**Image display**	**Technical courses (9:00 am to 5:00 pm)**
9:00 am to 11:00 am	**Session 1** The "new wave" in computing: Advanced technologies facilitate today's neural-network applications	**Session 3** Next-generation FPGAs accelerate system design	**Session 5** Solving clock distribution problems in high-speed systems	**Session 7** Specialty memories: A rapidly evolving set of tools for the designer of high-performance products	**Session 9** Implementation of flat-panel displays	**Short course T1** Concurrent engineering: Tying it all together
2:00 pm to 4:00 pm	**Session 2** Machine-vision systems	**Session 4** Advanced CAE tools for FPGA design	**Special session** PCs vs workstations: The software implications	**Session 8** Design advances of memory cards for portable systems		**Short course T2** Surface-mount technology: Principles and practices **Short course T3** An introduction to optical-based sensors
Wednesday November 20, 1991	**Communication networks**	**Advances in PLDs**	**High-speed logic design**	**Memory systems and sensors**	**Image display**	**Technical courses (9:00 am to 5:00 pm)**
9:00 am to 11:00 am	**Session 11** The framework of an OSI network management system	**Session 14** Innovative, high-density PLD architectures	**Session 17** High-speed logic to the rescue...	**Session 20** Hassle-free cache design (without compromising performance)	**Session 10** Image compression: A key enabler of multimedia	**Short course T4** Design for testability **Short course T5** Surface-mount/fine-pitch technology
11:30 am to 1:30 pm	**Session 12** FDDI design issues		**Session 18** Interconnect issues for high-speed electronic systems	**Session 21** Recent trends in embedded control memory		**Short course T6** Short-run statistical process control for electronics manufacturing
2:00 pm to 4:00 pm	**Session 13** The emerging 10BaseT standard: Trends in silicon and software	**Session 16** New PLD design tools enable flexible and efficient systems-level design	**Session 19** Combating EMI in high-speed electronic systems	**Session 20** Enabling sensor technologies—markets, trends, and applications	**Special session** Virtual reality	**Short course T7** 3000-series FPGA design
Thursday November 21, 1991	**Embedded controls**	**PC applications and architectures**	**ASICs and multichip modules**	**Design for testability and manufacturability**		**Technical courses (9:00 am to 1:00 pm)**
9:00 am to 11:00 am	**Session 23** Real-time and embedded systems development and deployment	**Session 25** Portable applications for PC-compatible chip sets	**Session 27** ASIC directions for the '90s	**Session 29** Electronic product design for manufacturability and testability		**Short course T8** Data storage; magnetic, optical, and systems
11:30 am to 1:30 pm	**Session 24** High-performance embedded control devices	**Session 26** PC bus architectures: Beyond the standard AT bus performance	**Session 28** The impact of multichip modules in the '90s	**Session 30** Using the IEEE boundary-scan and test-access port (JTAG)		**Short course T9** From DIPs to multichips: An introduction to high-performance packaging

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

Short courses offer variety

In addition to the special seminars, 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 management seminars—"Doing Business with the Japanese" on November 19; "The Healing Manager: Shortcuts to Total Quality and Process Improvement" on November 20; and "Protecting and Marketing Software in a Competitive Market" 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 program features four sessions—"Design for Testability", "Surface Mount/Fine Pitch Technology", "Short-Run Statistical Process Control for Electronics Manufacturing", and "3000-Series Field Programmable Gate Array Design." The program 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 conference is intended to highlight the most relevant and promising technical topics for today's electronics industry and to set the stage for tomorrow's products and markets. Emerging technologies, new developments and applications for existing 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 design—a topic discussed in five separate sessions.

As processors increase in speed, the problems encountered when distributing clock signals to various loads also increase. Skew and duty-cycle distortion, for example can reduce the cycle budget by several nsec; however, you can solve this problem by using minimum-skew clock drivers. In **Session 5**, suppliers will highlight the benefits, features, 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 fastest standard devices they can get. While speed may be the main consideration, it is not the only one—noise reduction, power consumption, and packaging are also key parameters in high-speed logic design. The discussions presented in **Session 17** will let designers compare the most recent high-speed logic offerings 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 interference is emerging as a major barrier for high-speed operation. Speakers will examine different hardware approaches to circumvent the EMI problem at various stages of the design. These approaches include the use of novel devices and interconnects, new ICs and multichip module designs, and innovative architectures.

Advanced TTL families are becoming the technology of choice for high-speed system designers. However, 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 Convention 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 Convention 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 Airport Blvd, Los Angeles, CA 90045. Phone (213) 215-3976.

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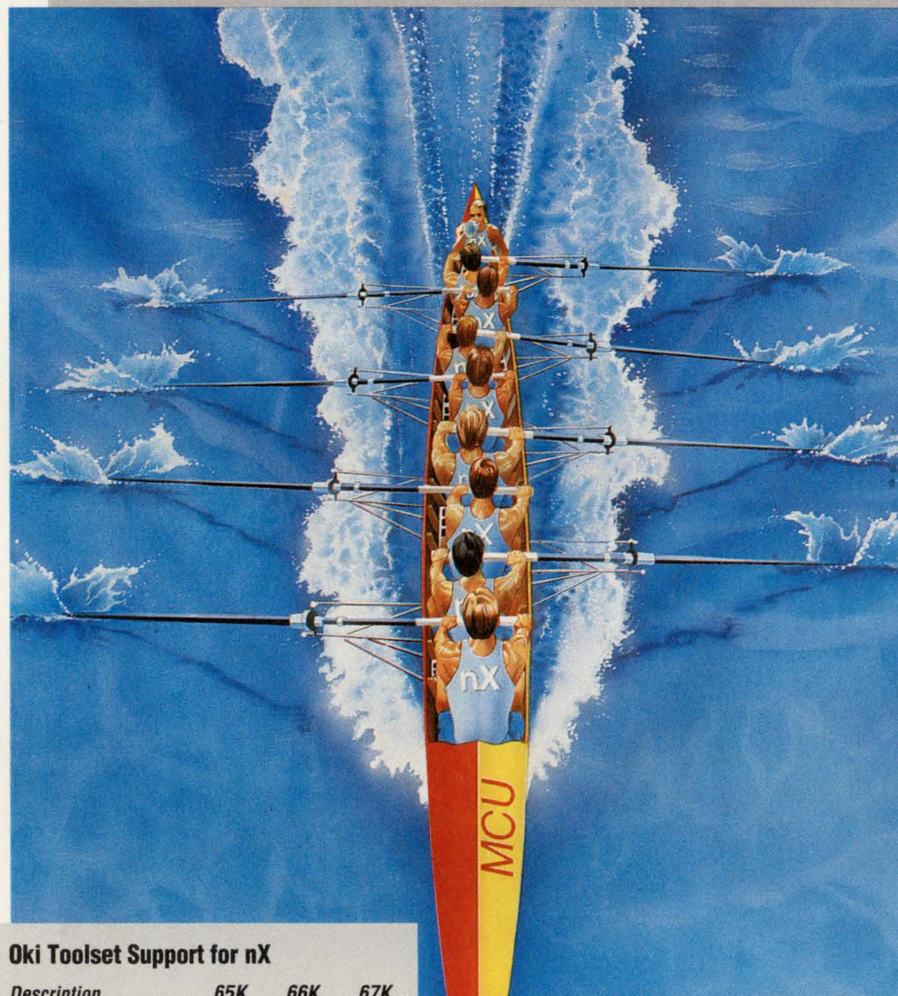

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Hardware			
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TRANSFORMING TECHNOLOGY INTO CUSTOMER SOLUTIONS contribute to higher levels of EMI. The papers in **Session 19** examine EMI sources and evaluate their relative importance in typical 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. Exhibiters 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, Minc 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. EDN

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WHY YOU NEED IT TO COMPETE IN THE WORLDWIDE '90s

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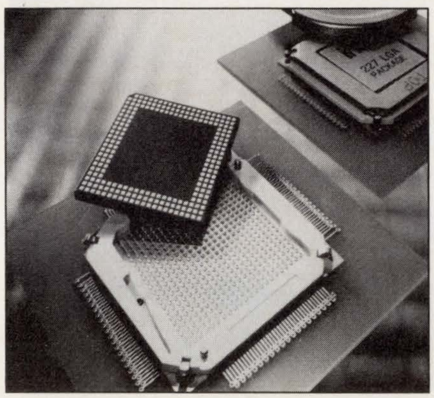


The Ampflat land grid-array (LGA) socket assembly from AMP accommodates LGA packages that have as many as 484 positions. It is configured on a 0.05-in. centerline grid and offers a mounted profile of 0.2 in. The keystone of the assembly is a contact array that is 0.009-in. high when compressed and features 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.

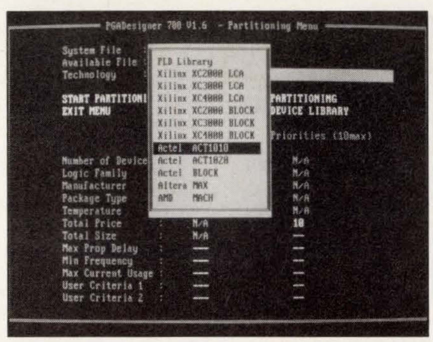
The socket assembly is composed of a heat-clamp pressure plate, a chip-carrier nest that holds the LGA device, a contact array, and an insulator-spacer. All of these components are sandwiched between a cover plate and a base plate. The insulator thickness is selected to match the thickness of the pc 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.



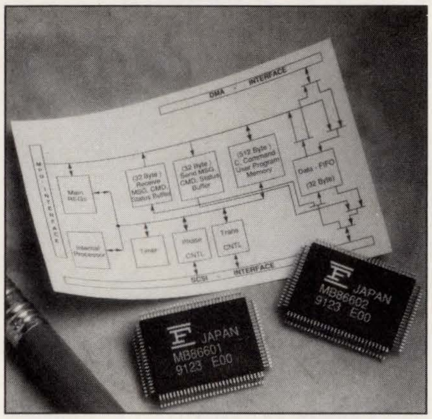
The hardware-description languages let you specify your design with Boolean equations, truth tables, and state machines. The state machine tool uses a Pascal-like syntax and lets you embed Boolean equations and truth tables in the arguments of the state-machine program constructs.

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

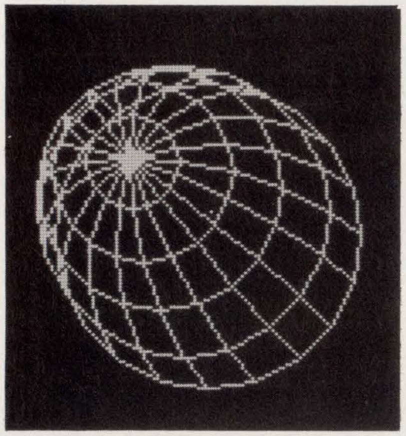
The 4400 power meter is designed for microwave CW, peak power measurements, and pulse waveform characterization. With associated sensors, it ranges from 30 MHz to 40 GHz and has a −40 to +20 dBm dynamic range. Plotter, diagnostic RS-232C, and IEEE-488 interfaces (for ATE applications) are provided.

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



Plasma Display Module

The Model GP01280128-01 is a dc gas-plasma display that features a 128×128-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 5×7 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.

Babcock Display Products Inc, 1051 S East St, Anaheim, CA 92805. Phone (714) 491-5100. FAX (714) 490-1368. Booth Nos 4203, 4205. **Circle No. 437**

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.

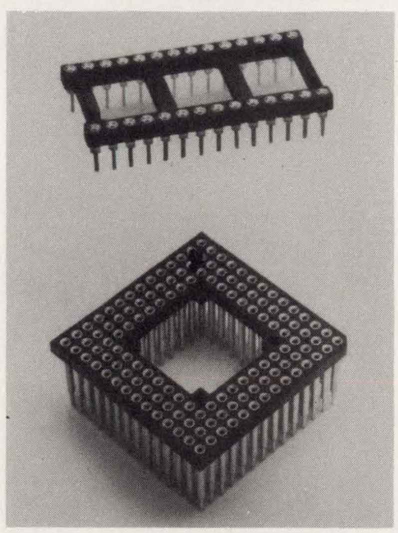
The input configuration of the meter depends on the model. The -11 and -12 versions (199.9 mV and 1.999V, respectively) accept a differential input. The 19.99V -13 and the 199.9V -14 models have a single-ended input. All models will operate at 2.5 conversions per sec.

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.

Selco Products Co, 7580 Stage Rd, Buena Park, CA 90621. Phone (213) 921-0681. FAX (714) 739-1507. Booth No 4216. **Circle No. 438**

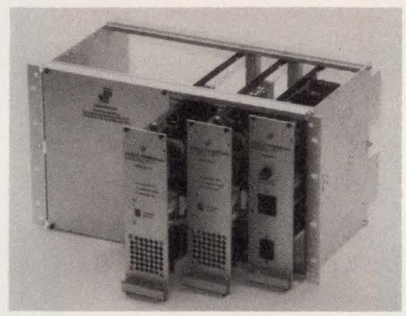
High-Temperature Sockets

These PGA and DIP screw-machine sockets can withstand the rigors of infra-red and vapor-phase soldering processes encountered in surface-mount 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.



Both devices utilize glass-filled, molded polymer construction. The DIP sockets are supplied in open or closed versions that have center-to-center spacings of 0.300, 0.400, 0.600, and 0.900 in. The models with 0.300- and 0.600-in. spacings are compatible with automatic insertion equipment. The high-temperature PGA sockets are available in more than 250 standard configurations, ranging from 9×9 through 21×21 grids. Custom PGA footprints are also available. $0.015 to $0.03 per pin for the DIP sockets; $0.02 to $0.05 per pin for the PGA models (OEM qty).

Mark Eyelet Inc, 63 Wakelee Rd, Wolcott, CT 06716. Phone (203) 756-8847. FAX (203) 755-9410. Booth Nos 950, 952. **Circle No. 439**

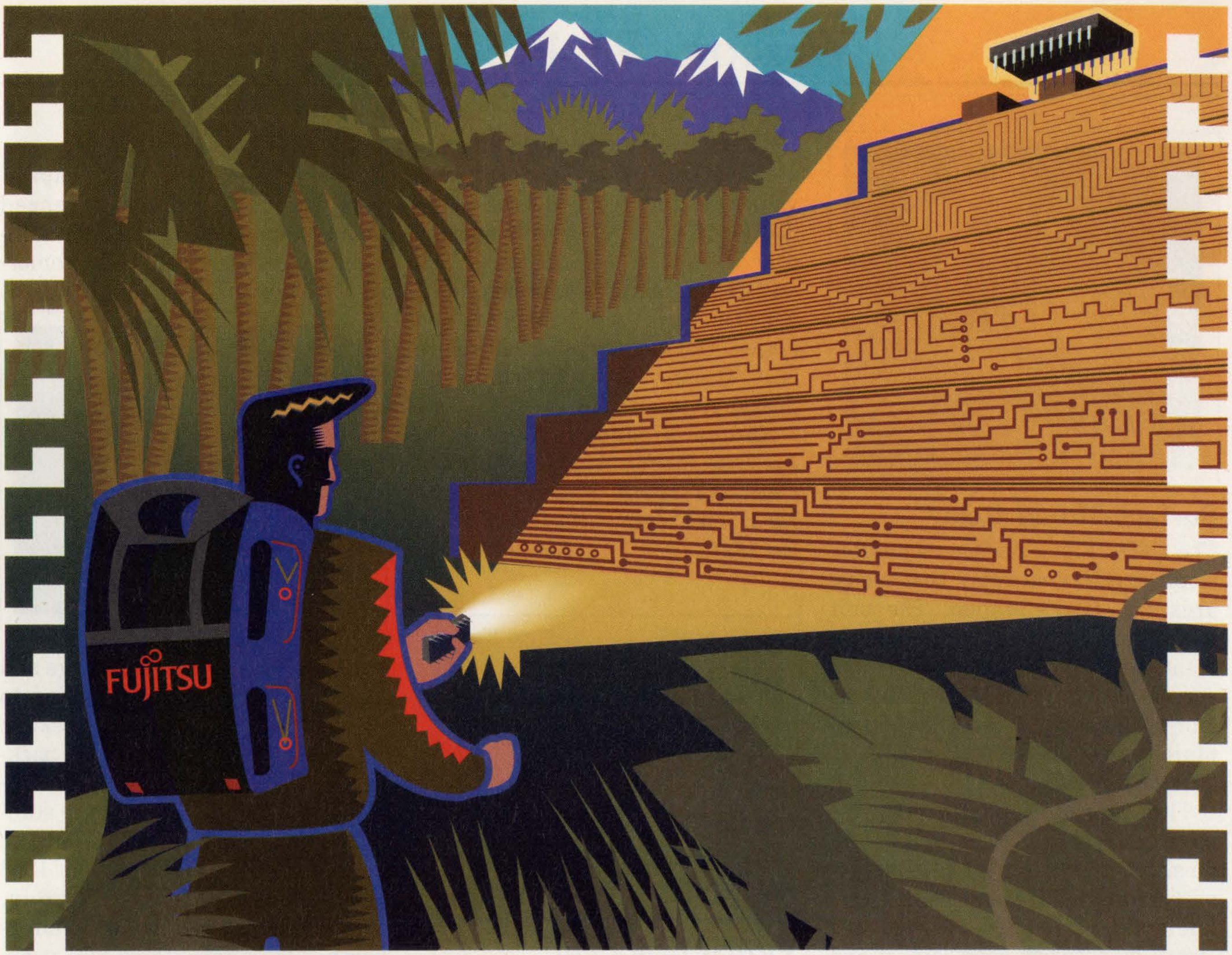


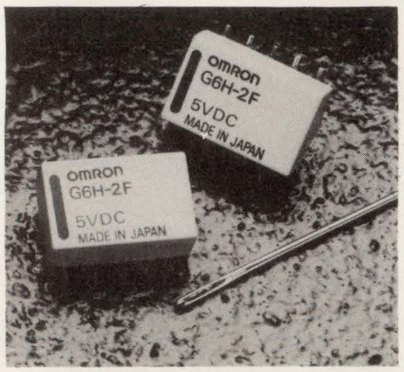
VME Power Supply

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.

Joule Power Inc, Joyce Industrial Park, Summer Rd, Boxboro, MA 01719. Phone (508) 263-9712. FAX (508) 263-9071. Booth No 3406. **Circle No. 440**


FUJITSU



Surface-Mount Relay

The G6H-2F is a surface-mountable electromechanical relay that measures 5.5×9.41×14 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. $2.45 (1000). Delivery, seven to 20 weeks ARO.

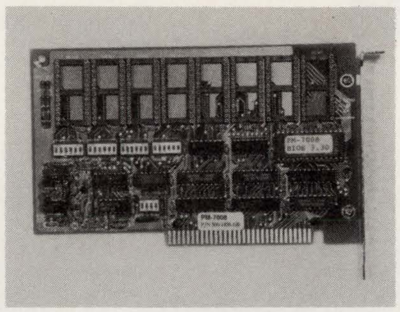
Omron Electronics Inc, 1 E Commerce Dr, Schaumburg, IL 60173. Phone (708) 843-7900. FAX (708) 843-7787. Booth No 2153.
Circle No. 355

Trimmer Capacitors

Type 9 compression-trimmer capacitors have a mica dielectric and are designed for applications requiring high-voltage ratings and high-RF power handling. The units have a 2000V-dc working-voltage rating and withstand test voltages ranging to 3000V dc.

The devices in the Type 9 family are available in eight capacitance values ranging from 10 to 48 pF to 250 to 480 pF. All models operate over a −35 to +85°C range. The unit design features a ceramic base, which encloses the mica films and plates. Device insulation resistance is $10^{11}\Omega$ min. From $3.49 (100). Delivery, 10 weeks ARO.

Sprague-Goodman Electronics Inc, 134 Fulton Ave, Garden City Park, NY 11040. Phone (516) 746-1385. FAX (516) 746-1396. Booth No 1641. **Circle No. 356**



Virtual Disk Card

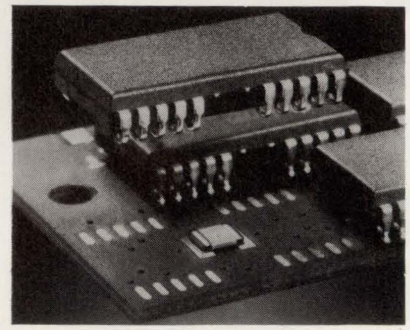
The PM-7008 virtual disk card is designed to affordably replace the floppy-disk drive in PC computer systems. The unit works just like a floppy- or hard-disk drive, except that it uses electronic components to replace the magnetic media.

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.

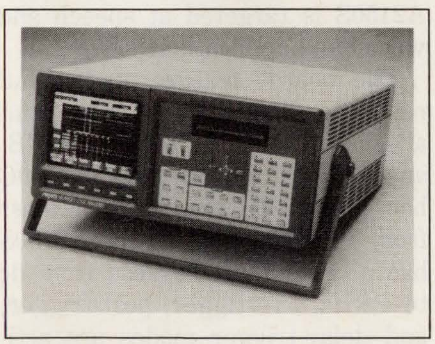
Each model in the printer family is available with either a Centronics

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 4.45×4.5×2.5 in. $150 (100).

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

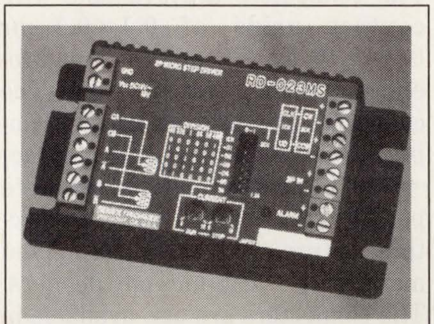
Analyzer-Support Package

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 4.1×2.2×1.1-in. package. $450.

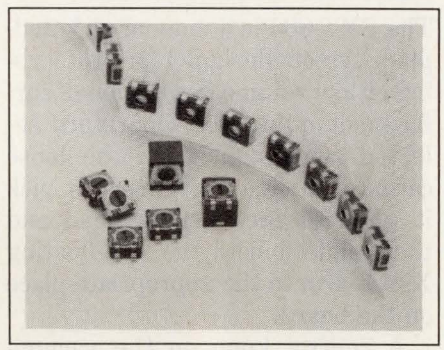
Semix Inc, 4160 Technology Dr, Fremont, CA 94538. Phone (415) 659-8800. FAX (415) 659-8444. Booth No 4328.
Circle No. 361

Digital Oscilloscopes

DCS-Series portable digital oscilloscopes feature as many as four channels. Each channel has its own digitizer that operates at 100 MHz/sec. The DCS-8200 is a 20-channel model that offers both 20-MHz/sec real time or 50-MHz/sec equivalent-time digital-scope performance and 50-MHz analog-scope performance in a single package. This unit can acquire as many as two channels at 20 MHz/sec each and store the data into 32-word memory. The scope has a peak-detect feature that allows the acquisition of glitches as small as 10 nsec at any sweep-speed setting. The unit also features vertical and horizontal Autoset.

The DCS scopes come standard with IEEE-488, RS-232C and X-Y output modes. The embedded HPGL protocol lets users plot signals directly from the DCS-8200. Front-panel memory stores 20 test steps to accommodate computer-free, semiautomatic testing applications. $3295.

Kenwood USA Corp, 2201 E Dominguez St, Long Beach, CA 90810. Phone (213) 761-8287. Booth No 2717.
Circle No. 362



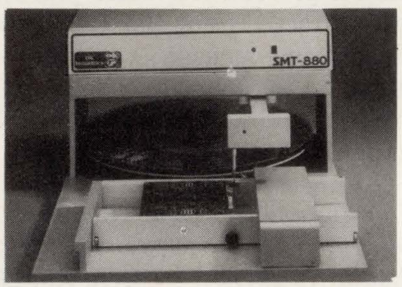
Surface-Mount Trimmers

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×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).

Mepcopal Co, 11468 Sorrento Valley Rd, San Diego, CA 92121. Phone (619) 453-0332. FAX (619) 481-1123. Booth No 1450.

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 SMT0880 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 8×12 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 0.1×0.1 or 0.1×0.15 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 2×10-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

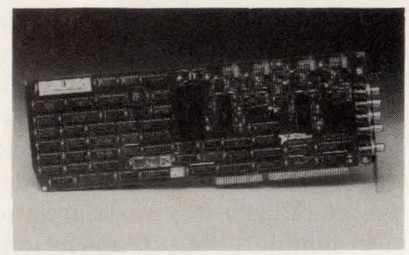
The T-style versions of Series 50/51 ½-in. rotary switches withstand wave-soldering and board-cleaning techniques because of their process seal. You can mount a switch on a pc board along with other compo-

nents 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 $10^9\Omega$ 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 −95 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

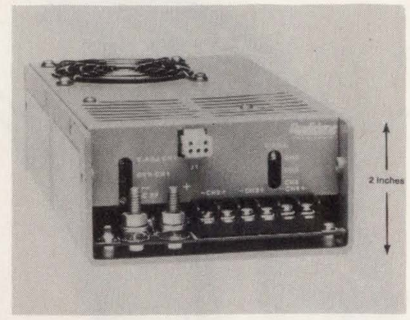
CIRCLE NO. 145

Switching Supplies

The 22 models in the Series 2A 250W power-supply family provide three or four well-regulated outputs. All models also feature an automatic universal-input range of 90 to 264V ac.

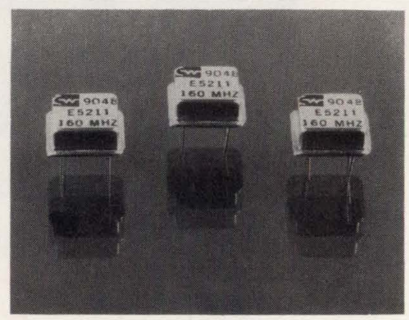
The main output in Series 2A supplies is rated for 5V at 30A. The two or three auxiliary outputs are rated for 12 or 15V at 10A, 12 or 15V at 3A, and 5, 12, or 24V at 3A. The line also includes models featuring user-adjustable outputs—12 to 15V at 10A, 12 to 24V at 2A, 2 to 6V at 3A, and 5 to 15V at 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.



Qualidyne Systems Inc, 3055 Del Sol Blvd, San Diego, CA 92154. Phone (619) 575-1100. FAX (619) 429-1011. Booth No 346.

Circle No. 368

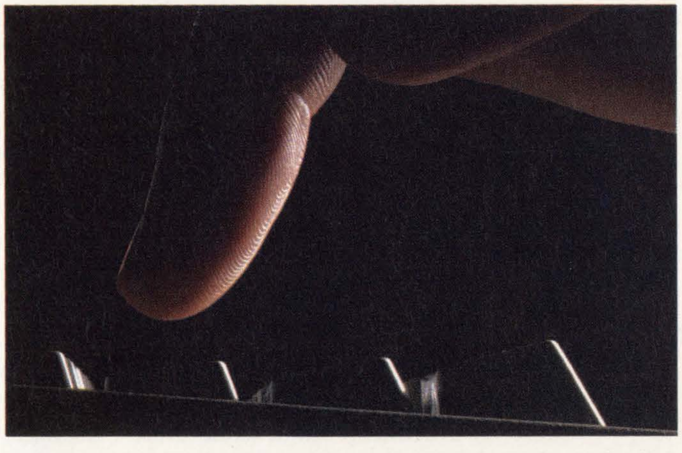


Clock Oscillators

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

IN THE TIME IT TAKES TO READ THIS AD, YOU COULD ROUTE THE WORLD'S FASTEST FPGA.



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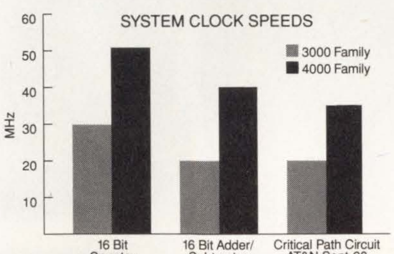

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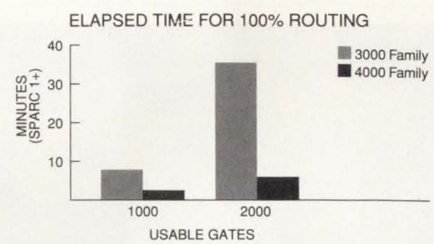

New algorithms have reduced place and route times by a factor of four.

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range and model. Models E531 and E521 operate from 24 to 180 MHz and have stabilities of ±100 and ±50 ppm, respectively. Models E511 and E631 operate over a 24- to 140-MHz range and have stabilities of ±25 and ±100 ppm, respectively. Versions are available that operate on supply levels of −5.2, −4.5, or 5V. $43.90 for a Model E531 unit with a 120-MHz output frequency. Delivery, stock to seven weeks ARO.

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.

Two configurations are available—an enclosed anodized-aluminum unit and a black-painted steel unit—mounted on ball-bearing slides. The steel-slide version is equipped with a friction latch in the in position and positive detent spring latch in the fully extended position. Either keyboard is available as a desktop stand-alone unit. $395 to $554.

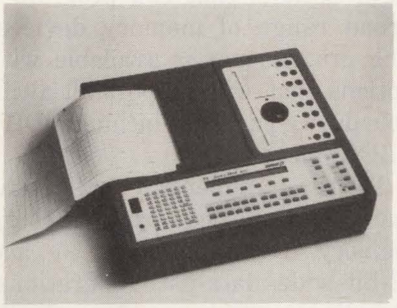
Preh Electronic Industries Inc, 470 E Main St, Lake Zurich, IL 60047. Phone (708) 438-4000. Booth No 2000. **Circle No. 370**

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



at different times as determined by the internal software. $9950. Delivery, four to six weeks ARO.

Astro-Med Inc, Astro-Med Industrial Park, West Warwick, RI 02893. Phone (401) 828-4000. *Booth No 2248.* **Circle No. 371**

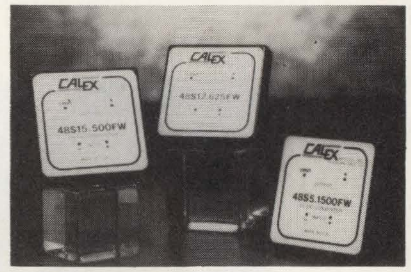
Storage Oscilloscopes

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.

Kikusui International Corp, 1980 Orizaba Ave, Signal Hill, CA 90804. Phone (213) 986-1677. *Booth No 2542.* **Circle No. 372**

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 output shorts to ground. The input and output are also protected from power surges with 500W transient-suppressor diodes. $62.90 (100).

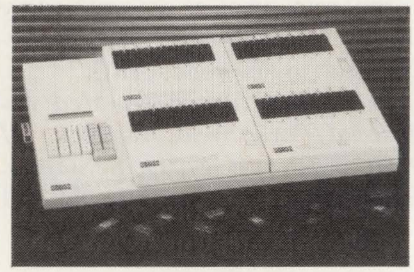
Calex Mfg Co Inc, 3355 Vincent Rd, Pleasant Hill, CA 94523. Phone (415) 932-3911. FAX (415) 932-6017. Booth No 1447.

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



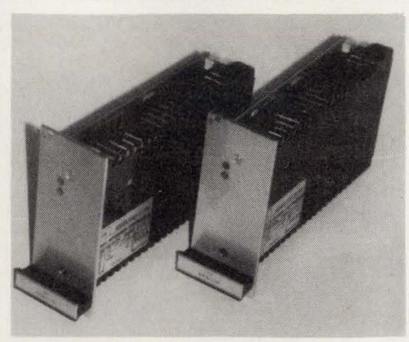
or multiple EEPROMs, or single or multiple sets can be downloaded into RAM and programmed simultaneously. The programmer features RS232-C and bidirectional-parallel I/O interfaces. $4995. Delivery, four to six weeks ARO.

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

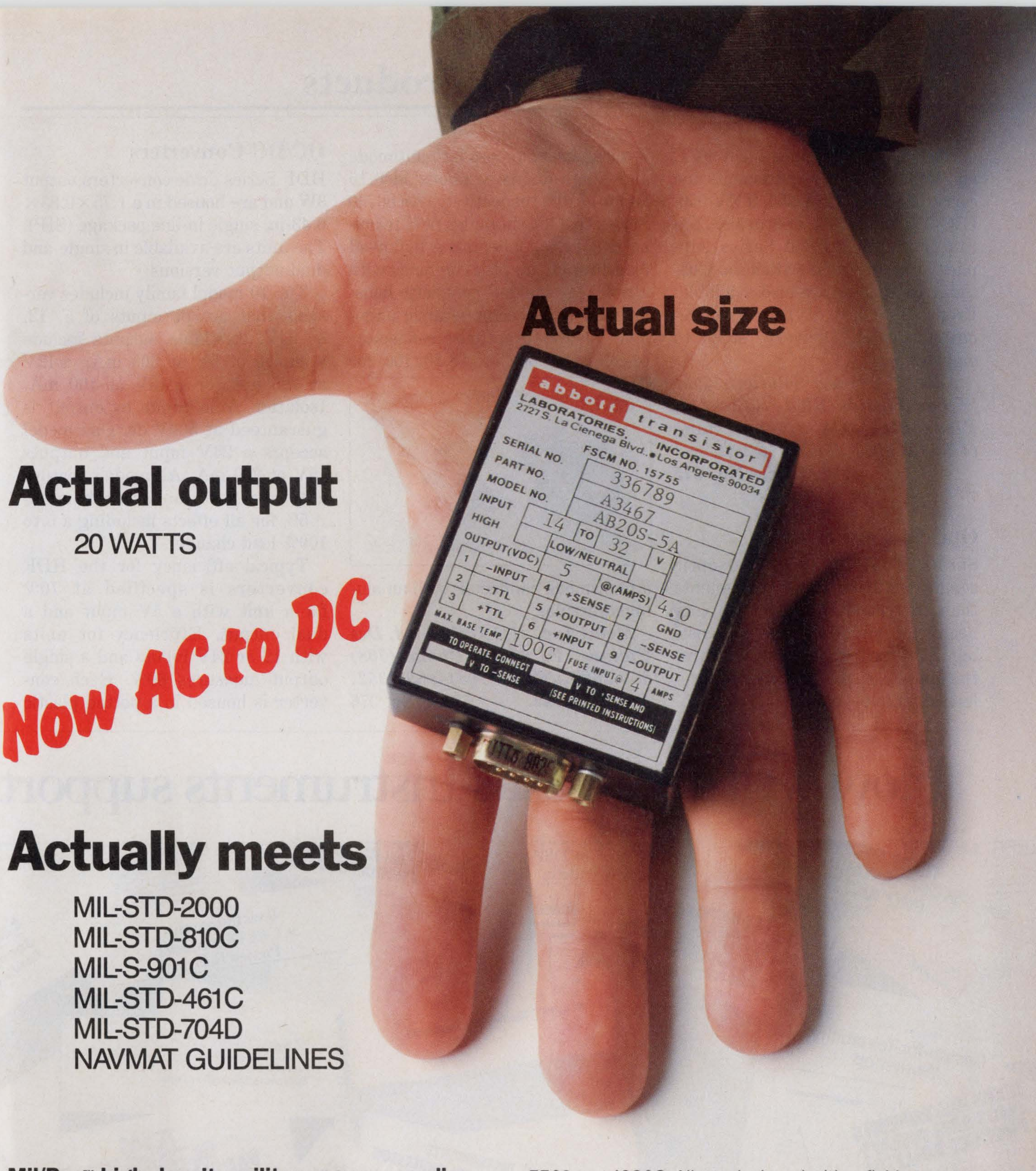
Circle No. 374

Eurocard Power Supplies

APS60 Series 60W power supplies are designed specifically for VME and Multibus applications. They fea-



ture 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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CIRCLE NO. 149

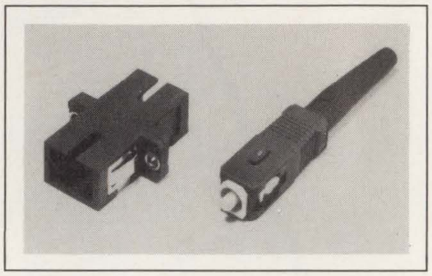
enclosure. The supplies meet FCC and VDE emission requirements and carry UL-1950, CSA-950, TUV-950, IEC-950, and BSI approvals. You can confiugre APS60 Series supplies as open-frame switchers. Custom front panels are also available. From $99 (OEM qty) for a single-output model. Delivery, stock to eight 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.

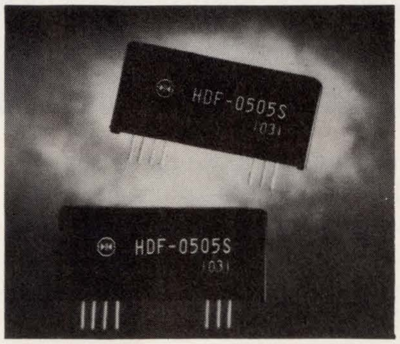
Molex Inc, 2111 Oxford Rd, Des Plaines, IL 60018. Phone (708) 803-3600. FAX (708) 969-1352. Booth No 954. **Circle No. 376**

DC/DC Converters

HDF Series dc/dc converters output 3W and are housed in a 1.75×0.83×0.43-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



package. $15.69 to $18.47 (1000).

Shindengen America Inc, 2649 Townsgate Rd, Suite 200, Westlake, CA 91361. Phone (805) 373-1130. Booth No 147. **Circle No. 377**

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%.

Other salient VSM-chip-resistor features include a 50 ppm/year max resistance shelf-life stability for nonhermetically sealed units, and 5 ppm/year for sealed versions. The chips are user trimmable for in-circuit calibration. $4.33 (100 for a 1-kΩ unit with a 0.02% tolerance. Delivery, four to six weeks ARO.

Vishay Resistors, 63 Lincoln Hwy, Malvern, PA 19355. Phone (215) 644-1300. Booth No 2610. **Circle No. 378**

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/spin-up 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 overtemperature 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.

Switching Systems International, 500 Porter Way, Placentia, CA 92670. Phone (714) 996-0909. Booth No 242. **Circle No. 379**

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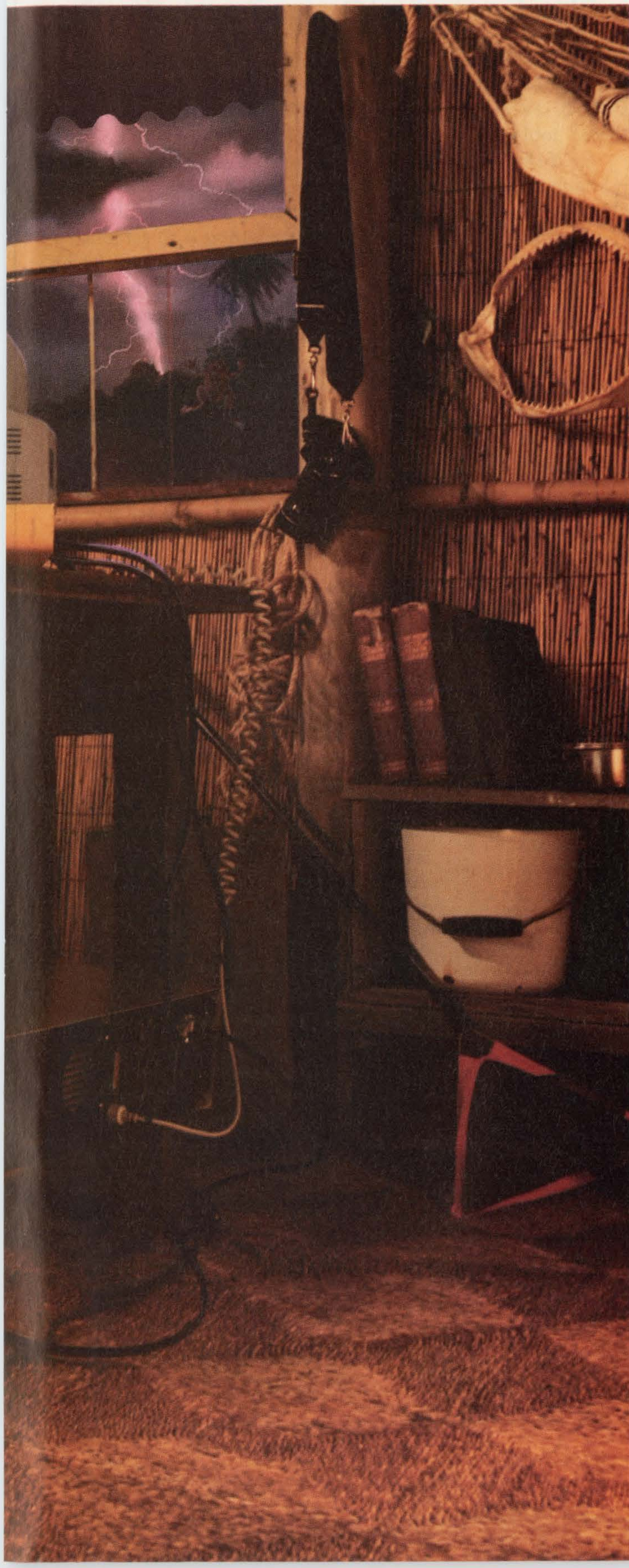

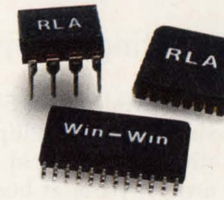

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CIRCLE NO. 153

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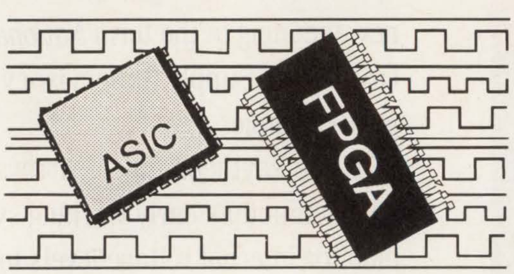
CAE Technology Report

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.

CIRCLE 10



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.

CIRCLE 12

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.

CIRCLE 14

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).

CIRCLE 11

New Modeling Capability

Simulators are only as good as their libraries, designers claim. Today, some simulators have very large IC libraries but even more importantly, they are supported by easy-to-use device modeling tools that make designers totally independent of simulator vendors. One such tool is ICMaker from ALDEC Co. This tool allows for instant cloning of new IC parts from existing models. Another tool, MOBIC 6.0 ($995) converts Boolean equations into optimized assembly language IC models. These models execute about ten times faster than any other models but provide only functional simulation. Finally, there is a score of VHDL IC modeling tools that cost from $1,995 and ensure a constant flow of high quality timing IC Models. Thanks to easy-to-use IC modeling software, logic simulators are becoming the most popular tool in engineering labs.

CIRCLE 13

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.

CIRCLE 15

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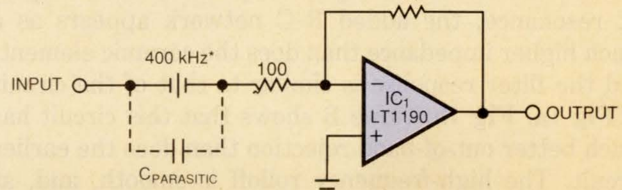
Filters and oscillators

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.

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, IC_1 produces no output; it acts as a follower whose input is grounded. At resonance,



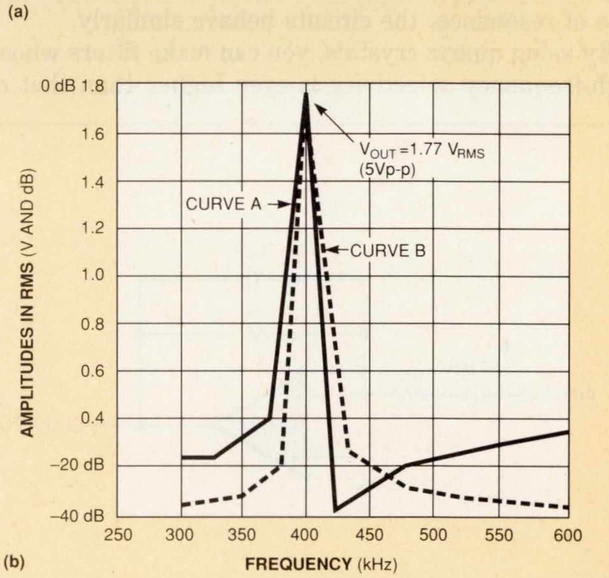


***Fig 1—One amplifier and a ceramic resonator** create a bandpass filter (**a**). The solid curve of **b** shows the filter's frequency response. Note the dip to −40 dB on the high side of resonance. The dip is the result of the resonator's parasitic capacitance.*

the ceramic element has a low impedance, and IC_1 behaves as an inverter with gain. The 100Ω resistor isolates IC_1'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 IC_1'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 IC_1'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 IC_1's inputs, and, because of IC_1'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.

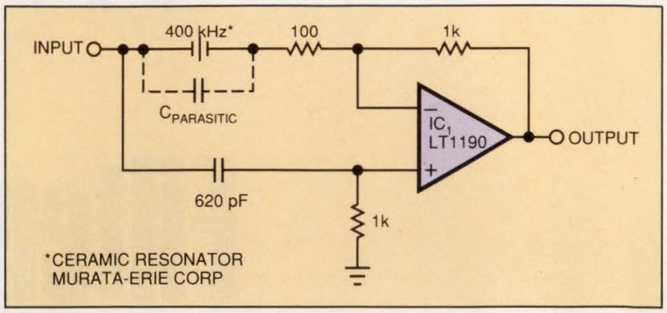


*Fig 2—**A slight modification** of the circuit in **Fig 1a** allows you to cancel out the effects of the resonator's parasitic capacitance. The dashed curve of **Fig 1b** shows the effects on the filter response. Below resonance, the modified circuit attenuates by an extra 20 dB. Above approximately 525 kHz, the improvement is even more dramatic.*

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 IC_1's negative input sets the gain. Inserting the crystal closes a positive

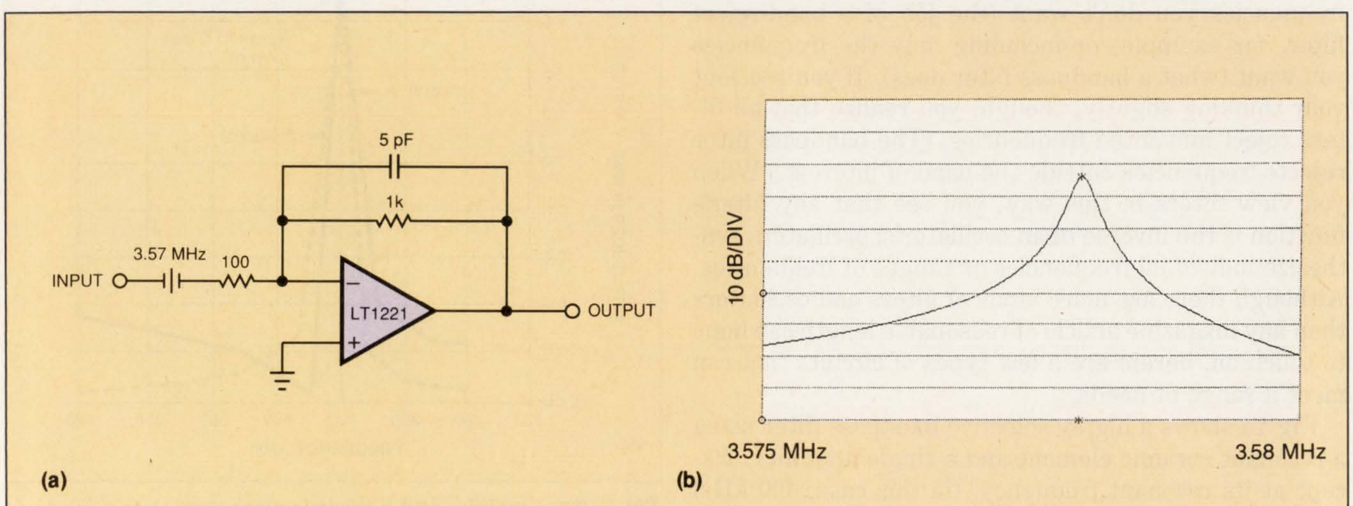


*Fig 3—**Replacing the ceramic resonator** of **Fig 1a** with a 3.57-MHz crystal is the most significant change that leads to this crystal filter (**a**). You can see the crystal filter's response in **b**.*

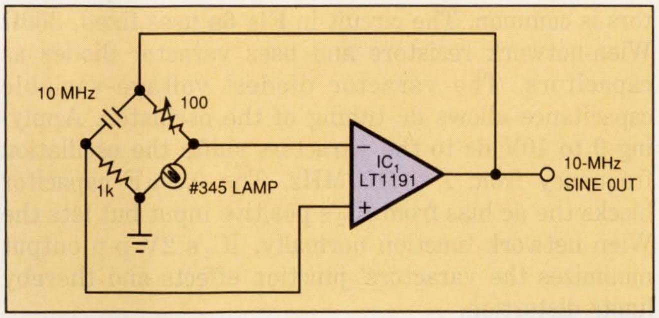


*Fig 4—**An incandescent lamp's** current-dependent resistance stabilizes the oscillation amplitude of this 10-MHz crystal oscillator.*

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 IC_1'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. IC_2 compares the IC_1 oscillator's positive output peaks with a dc reference. The diode in the dc-reference path compensates for the rectifier diode's temperature dependence. IC_2 biases Q_1, 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 IC_1 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 IC_1's 2V p-p, 20-MHz output waveform. IC_1's small output swing minimizes the distortion attributable to channel-resistance modulation in Q_1. To use this circuit, adjust the 50Ω trimmer until 2V p-p oscillations appear at IC_1'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,

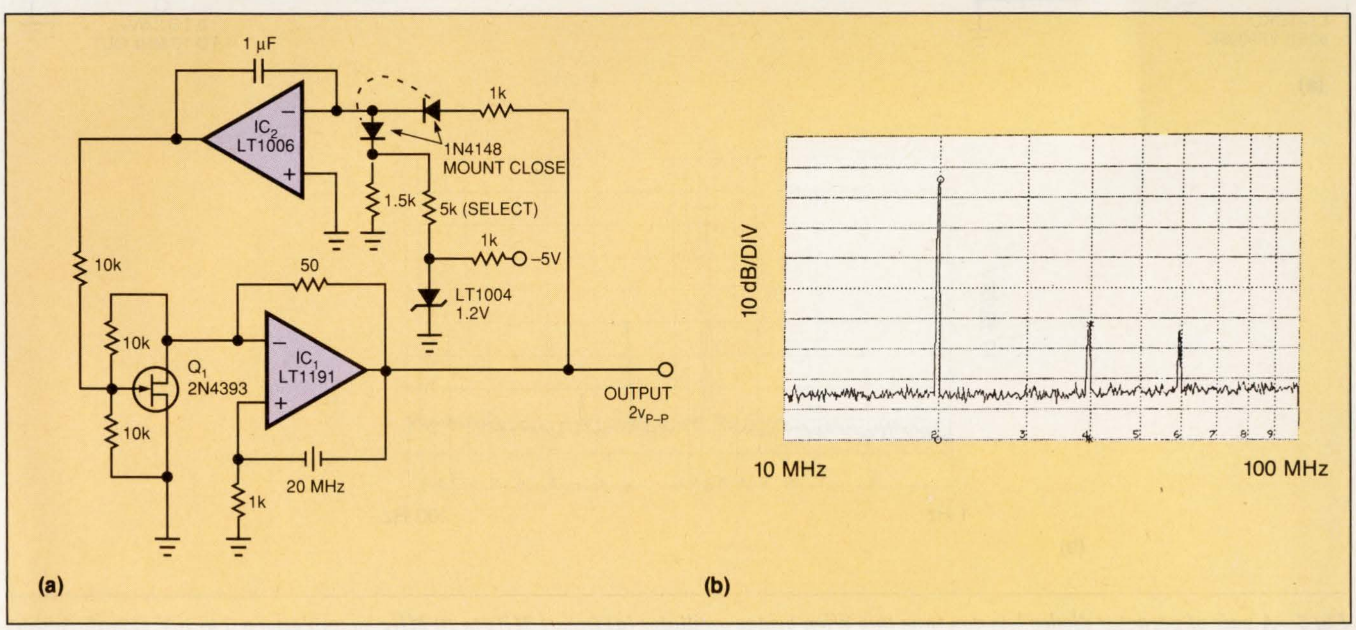


*Fig 5—**An electronic gain-control circuit** that uses the voltage-controlled on-resistance of a FET stabilizes the output amplitude of this 20-MHz crystal oscillator (**a**). In **b**, you see that the output's harmonics are at least 47 dB below the fundamental.*

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 IC_2's positive input. IC_1 controls Q_1 to stabilize the amplitude of IC_2'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 IC_2's positive input but lets the Wien network function normally. IC_2'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. IC_3 and the

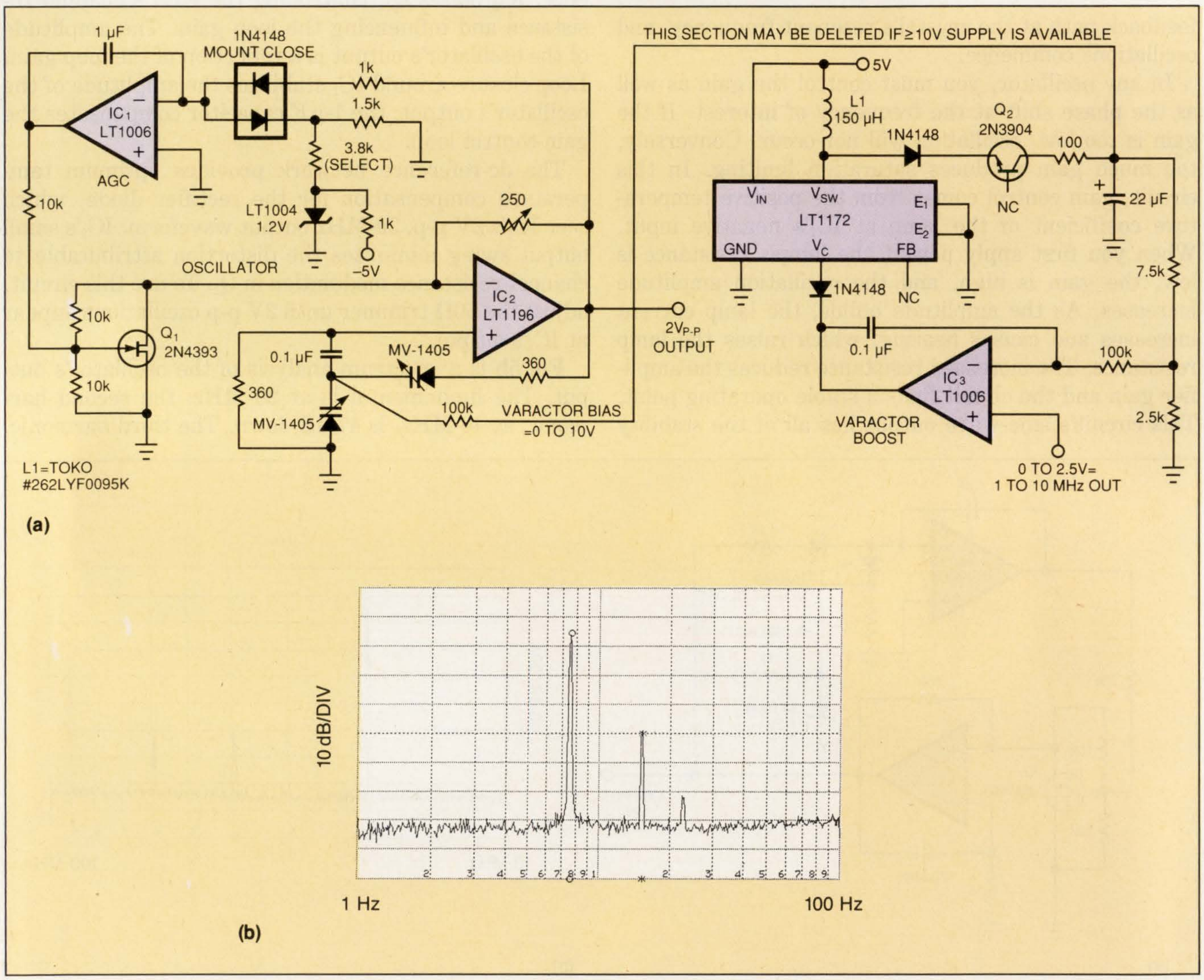


*Fig 6—**A pair of varactor diodes** lets you tune this Wien-bridge oscillator (**a**) from 1 MHz to 10 MHz by applying a 0 to 10V signal. Adding the components in the right half of the schematic lets you operate the circuit from a 5V supply and permits controlling the frequency with a 0 to 2.5V signal. The spectrum analysis in **b** shows that the sinusoidal output is quite clean.*

LT1172 switching regulator form a simple voltage step-up regulator. IC_3 controls the LT1172 to produce whatever output voltage is required to close a loop at IC_3's negative input. The 22-μF output capacitor stores L_1's high-voltage inductive-flyback pulses after they have been rectified by the diode-and-zener-connected Q_2. The 7.5-kΩ/2.5-kΩ divider closes the loop by providing a sample of the output value to IC_3's negative input. The 0.1-μF capacitor stabilizes this feedback action. IC_2'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 IC_3 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. IC_1, set up as a quartz-stabilized oscillator similar to the one in **Fig 4**, generates the carrier. IC_1's output feeds IC_2, which functions as a modulated RF power-output stage. The bias applied to offset pins 1 and 8 restricts IC_2's input-signal range. (See the LT1194 data sheet for details.) IC_3, a microphone amplifier, supplies bias to the offset pins, resulting in an amplitude-modulated RF carrier at IC_2's output. The dc voltage summed with the microphone output biases IC_3'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 1V p-p 1-MHz output from IC_1.

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 Q_5 is on and its collector (**Fig 8b**, trace A,) is at -15V, cutting off Q_1. IC_3, which inverts the positive input voltage and biases the summing node of integrator IC_1 through the 3.6-kΩ

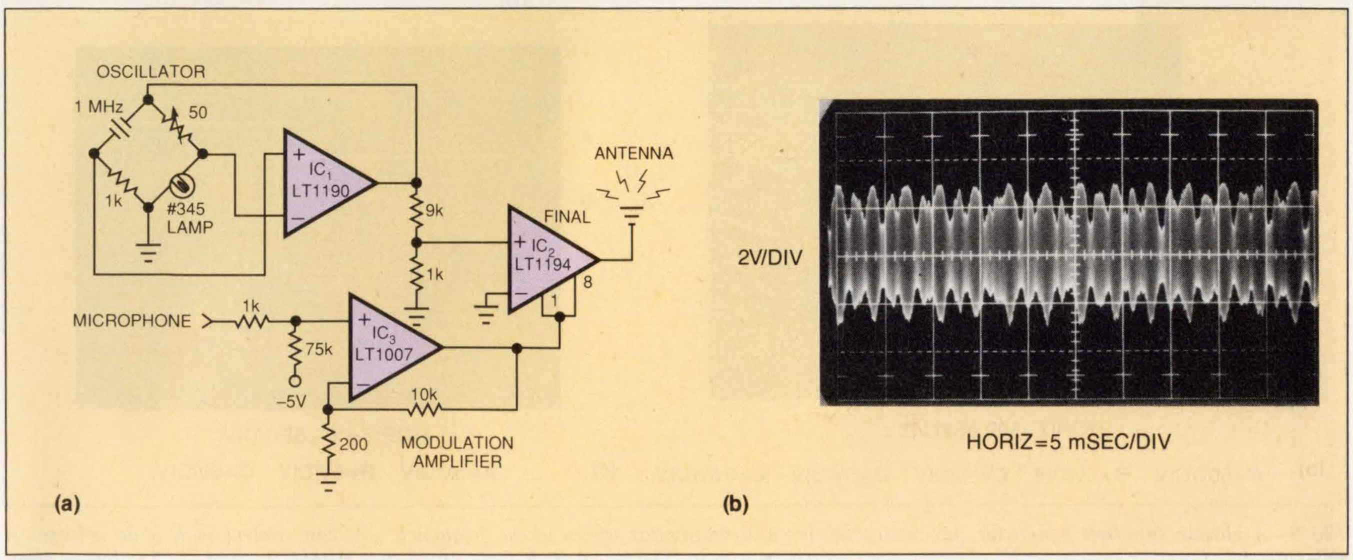


*Fig 7—**Though perhaps not worthy of Wolfman Jack** or Dick Biondi, the circuit of **a** is still a complete AM radio station. When Chuck Berry picks his guitar and belts out "Johnny B. Goode," the modulated output looks like what you see in **b**.*

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,) ramps positive until IC_5's input, (trace C,) crosses zero and causes IC_5's inverting output to go negative. The Q_4/Q_5 level shifter then turns off, and Q_5'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-

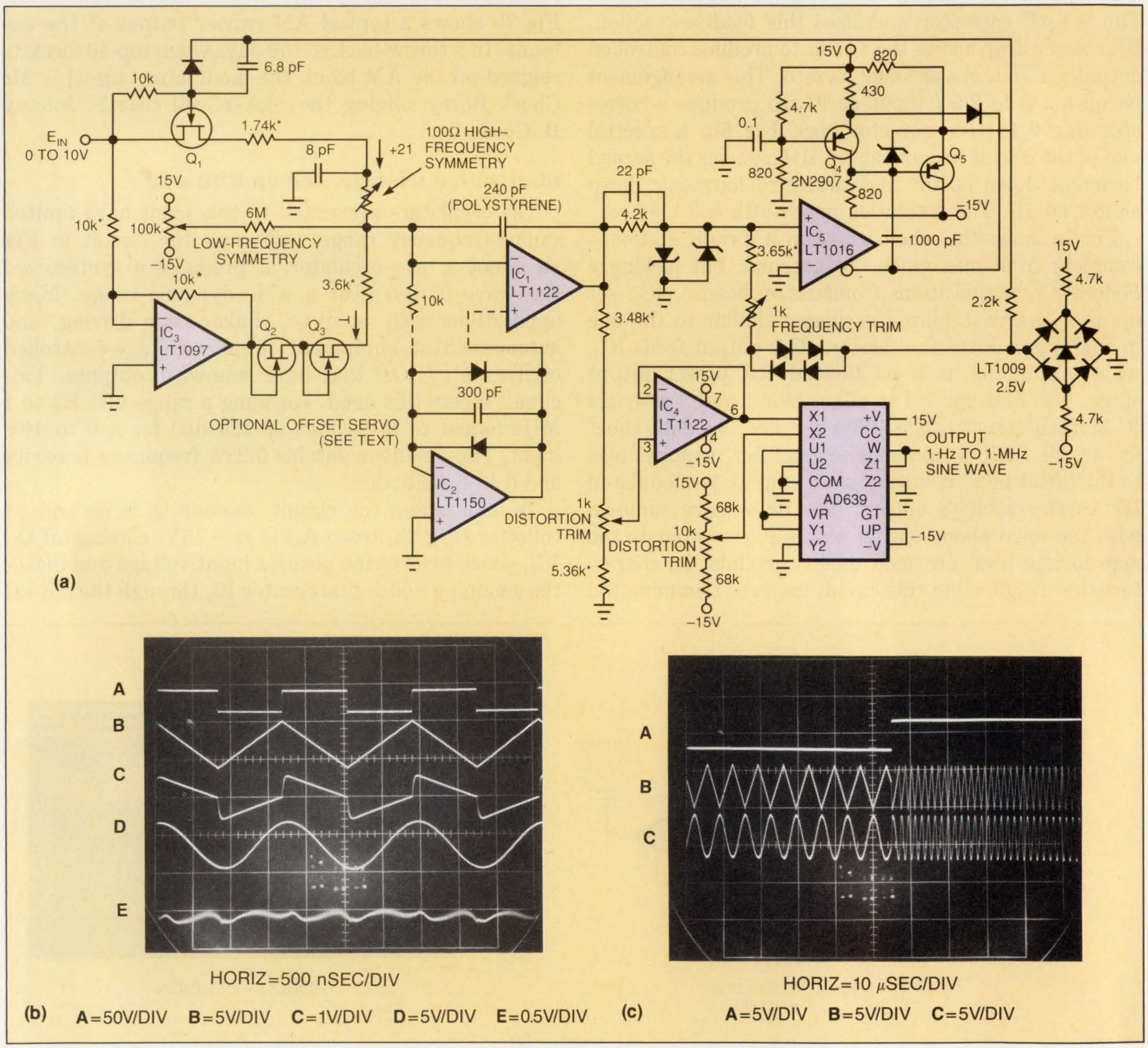


*Fig 8—**A classic function generator, a,** creates square and triangular waves whose frequency you can control with a dc voltage. A trigonometric-function generator IC converts the triangle to a sine. The traces in **b** show waveforms within the circuit. The lowest trace shows the residual distortion 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.*

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rection, IC_5's + input crosses zero and the circuit's two outputs change state. The state change switches the Q_4/Q_5 level shifter's state, causing Q_1 to go off and the entire cycle to repeat. The result is a triangular waveform at IC_1'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 IC_1's output ramp. The Schottky diodes bound IC_5's + input, ensuring its clean recovery from overdrive.

Sine of the times

The AD639 trigonometric function generator, biased via IC_4, converts IC_1'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 IC_1-integrator switching loop result in late turn-on and turn-off of Q_1. Unless you minimize these delays, the triangle amplitude will increase with frequency and cause the distortion level to increase. IC_5, the Q_4/Q_5 level shifter, and Q_1 generate a total delay of 14 nsec. This small delay, combined with the 22-pF feed-forward network at IC_5'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 Q_1's source line minimizes the effects of gate-source charge transfer, which occurs whenever Q_1 switches. Without this capacitor, a sharp spike would occur at the triangle peaks, increasing distortion. FETs Q_2 and Q_3 compensate for the temperature-dependent on-resistance of Q_1 and keep the $+2I/-I$ 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). IC_1'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 IC_1. 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 IC_2-based dc-stabilization stage. If you make this change, you should ground IC_1'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. EDN

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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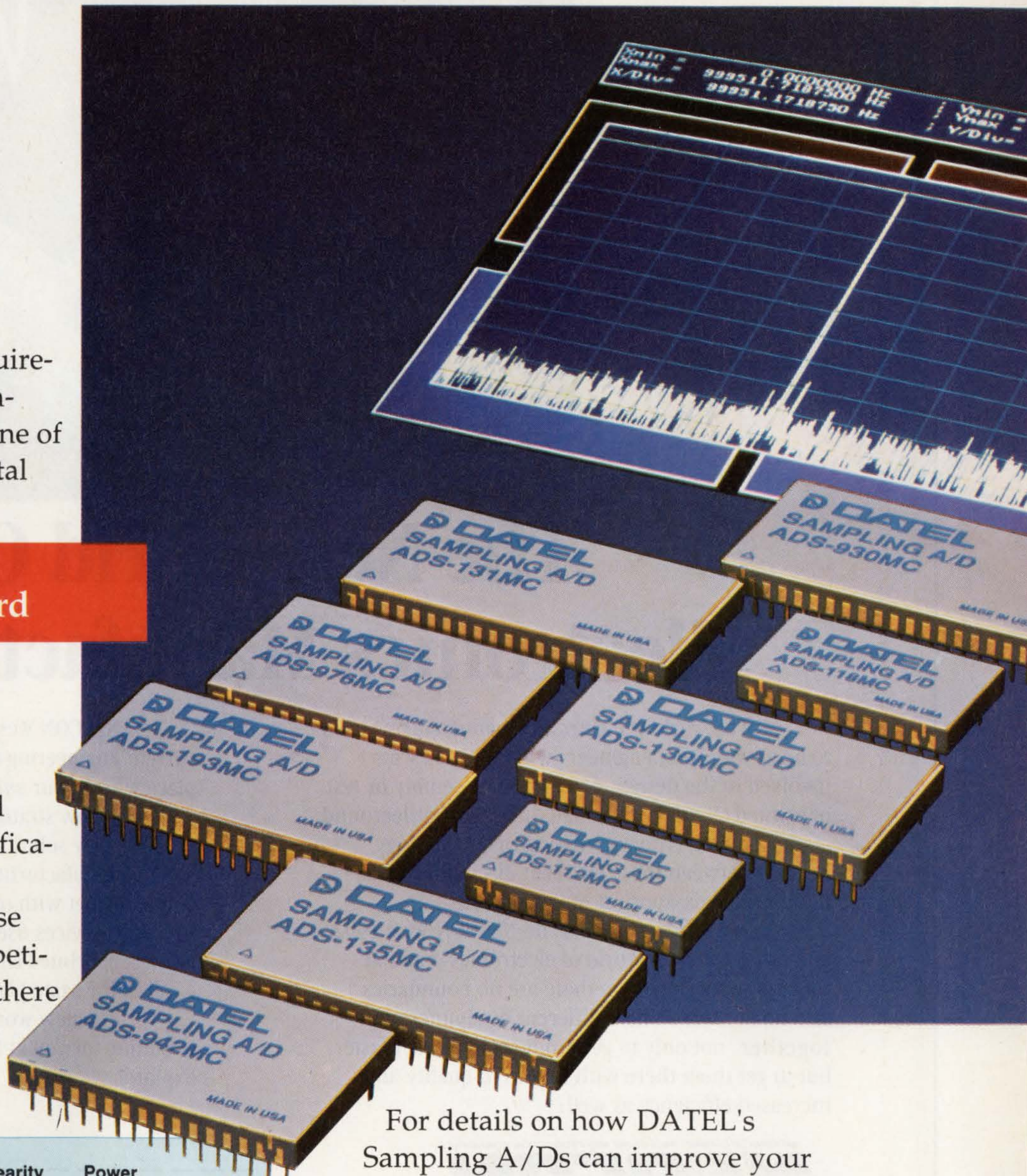

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High-speed data-conversion circuits

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.

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 10× 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 IC_2 is an integrator that cannot see high-frequency signals. It functions only at dc and low frequencies.

Integrator IC_1 has a 68-pF feedback capacitor. When you apply a positive voltage to the input, IC_1's output integrates in a negative direction (**Fig 1b,** trace A). During this period, IC_5's inverting output is low. The paralleled HCMOS inverters form a reference-voltage switch. The LT1034s (driven by the LM134 current source and the Q_3/Q_4 combination) establish the reference voltage; a small input-voltage-related term adds to the reference, improving overall circuit linearity.

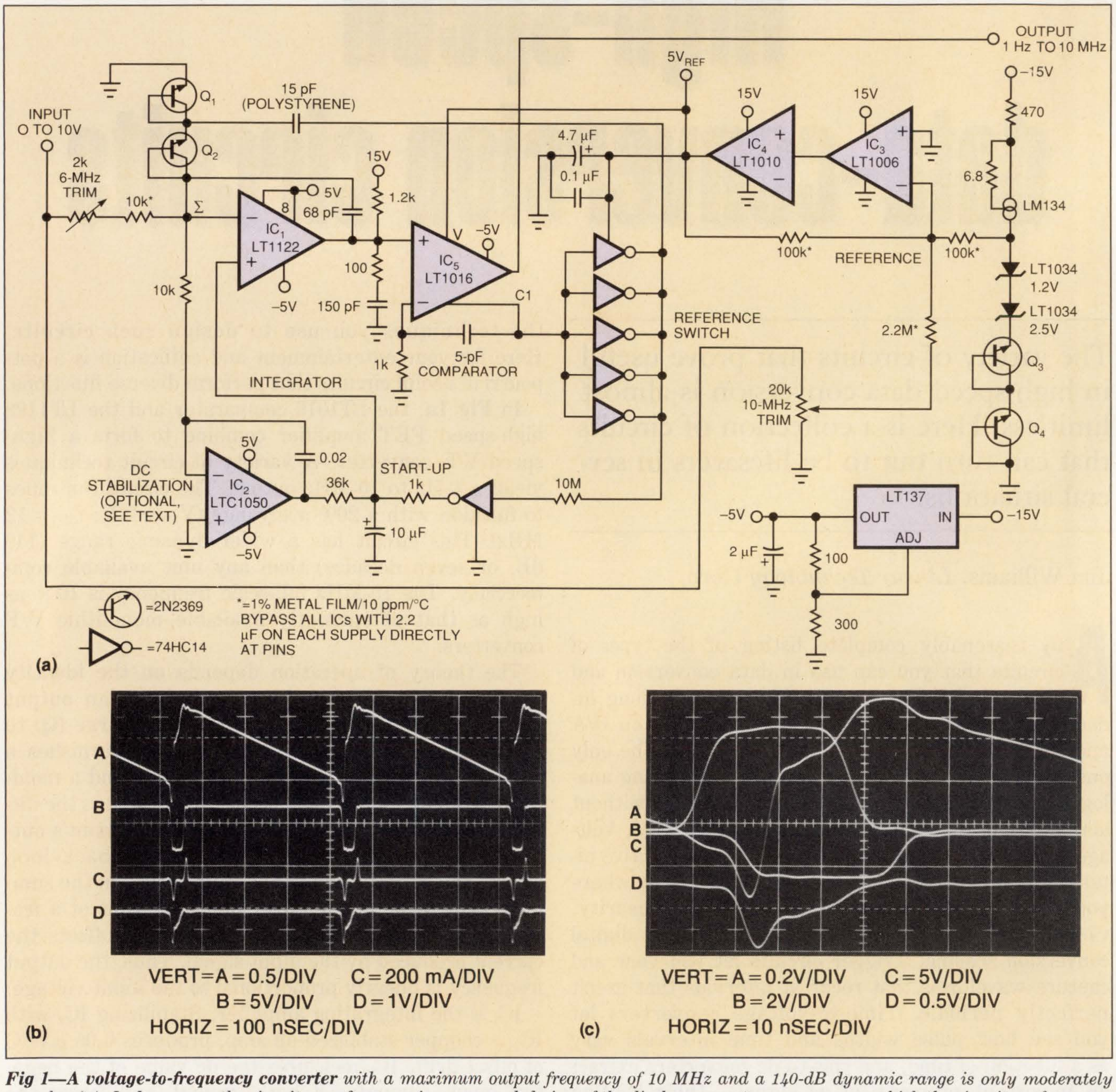


***Fig 1—A voltage-to-frequency converter** with a maximum output frequency of 10 MHz and a 140-dB dynamic range is only moderately complex (**a**). In **b**, you see the circuit waveforms; **c** is an expanded view of the discharge-reset sequence upon which the circuit performance depends.*

an integrator, is the actual hold amplifier. Its output feeds back to the switching bridge's input, forming a summing point with IC_1's output resistor. This feedback loop enhances accuracy by placing the bridge within a loop.

Driving the S/H input line switches the bridge. Q_1 and Q_2 drive L_1's primary. L_1'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 IC_2's output. The aberration (that is, the "hold step") visible in IC_2'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 IC_2's output nominally settles at final value, the circuit switches into the hold mode. The bridge imbalance dumps a small parasitic charge into IC_2's summing point, in this case causing IC_2 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 Q_1 and Q_2. 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. IC_1 is a Schottky-bounded amplifier. The bounding diodes hold down the response time by preventing summing-point overdrive from causing IC_1 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 IC_1's output (trace B) to slew through zero (the screen's center horizontal line). When IC_1 crosses zero, IC_2's input goes negative and IC_2 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.

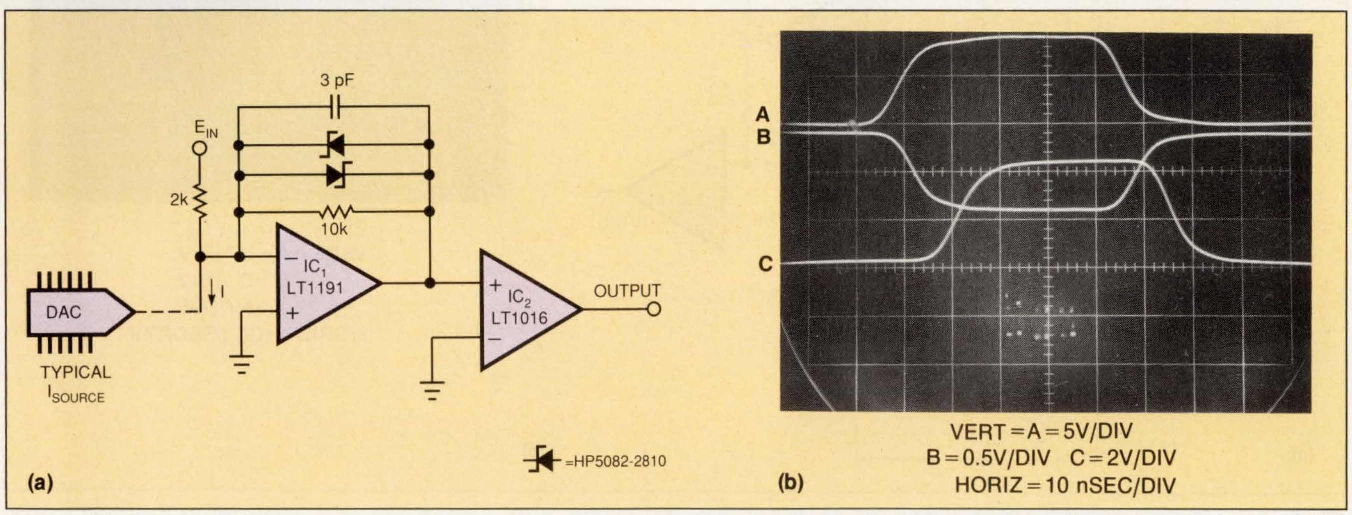


*Fig 3—**Only two ICs yield a fast** summing comparator (**a**). In **b**, you can observe key waveforms as the circuit operates.*

This circuit, without level adjustment, triggers reliably from dc to 50 MHz over a 2 to 300-mV input range.

IC_1, a gain-of-10 preamplifier, feeds an adaptive trigger configuration that maintains the output comparator's (IC_3'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 IC_1's output (trace B), the input signal has received voltage gain with little or no phase shift. Comparator IC_3 gives a clean logic output (trace C). At the highest frequencies, bandwidth limiting can occur in IC_1, 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 Q_3. Q_3, aided by Baker clamping, feed-forward capacitance, and optimized dc base biasing, turns off in a few nsec. Current source Q_2's emitter becomes forward biased, and Q_2 supplies constant current to the 100-pF integrating capacitor. Q_1 supplies temperature compensation for Q_2 and the 2.5V LT1009 provides the current-source reference. The 100-pF capacitor at Q_2's collector charges in ramp fashion (trace B). IC_1 supplies a buffered output (trace C). When the input

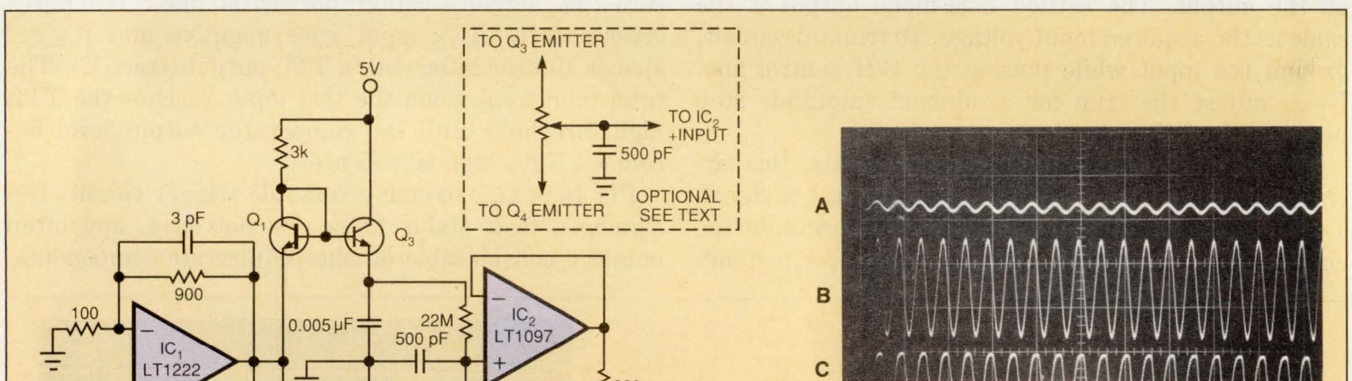


***Fig 4—An extremely versatile trigger** circuit (a) consists of three ICs and two pairs of transistors, each connected as a current source. The circuit adjusts its threshold as the amplitude of the incoming signal varies. In **b**, you see waveforms during circuit operation.*

IC_3 and IC_4 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 Q_1.

When IC_1's output crosses zero, IC_5'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 Q_2's base-emitter junction. The amount of charge dispensed is a direct function of the voltage that had existed across the 15-pF capacitor ($Q=CV$). Q_3 and Q_4 in the reference string provide temperature compensation for Q_1 and Q_2. The current that flows through the 15-pF capacitor (trace C) reflects the charge-pumping action. Removing current from IC_1's summing junction (trace D) drives the junction negative very quickly. The initial negative-going 15-nsec transient at IC_1'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) slew limits as the amplifier attempts to regain control of the summing node. The 1.2-kΩ pull-up resistor and the RC damper at IC_1's output enhance the amplifier's recovery from slewing. The amount of time the reference switch remains at ground depends on the 5-pF/1000Ω hysteresis network at IC_5 and on how long IC_1 takes to recover. A 60-nsec interval is long enough for the 15-pF capacitor to fully discharge. After the discharge, IC_5 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 IC_1. Its ramp output crosses zero at the first vertical graticule division on the left. A few nsec later, IC_5'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 IC_1'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, IC_5's inverting output is fully positive, the reference switch is at ground, and the summing point is at its negative extreme. Now, IC_1 begins to take control. Its output (trace A) slews rapidly in the positive direction, restoring the summing point. At 60 nsec, IC_1 is in control of the summing node and the integration ramp begins again.

Come on, get going

Start-up and overdrive conditions could force IC_1'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 IC_1's output goes to the negative rail, the reference switch tries to stay at ground. The remaining inverter goes high, lifting IC_1's positive input, causing IC_1'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 Q_3/Q_4 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.

Acroynms 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. IC_2's low drift eliminates a zero adjustment. If operation below 600 Hz is not required, you can delete IC_2 and its associated components.

Nonlinearity of this circuit is 0.03% and full-scale drift is 50 ppm/°C. Zero-point error, controlled by IC_2, 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 IC_1 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 IC_2. IC_2, configured as

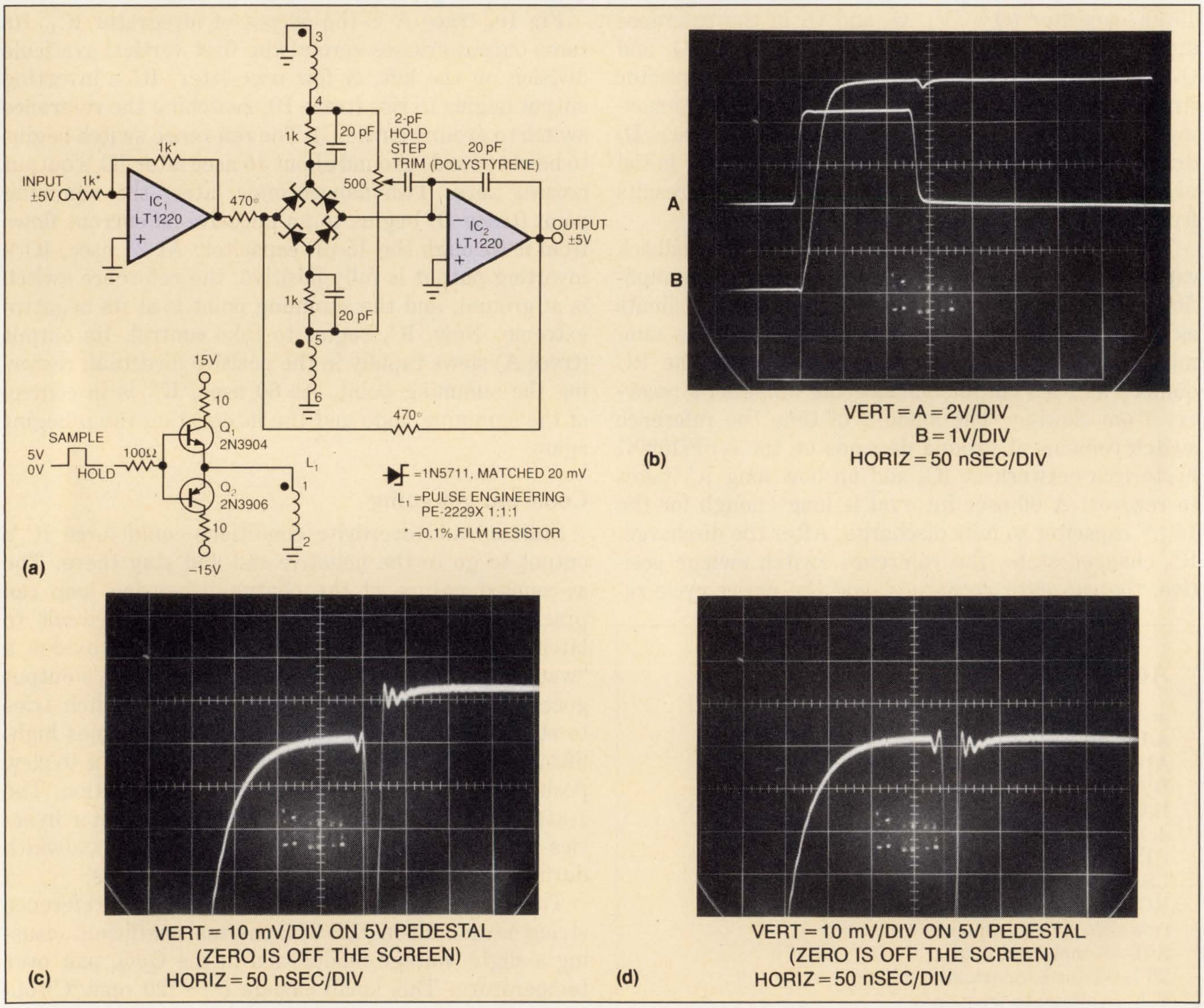
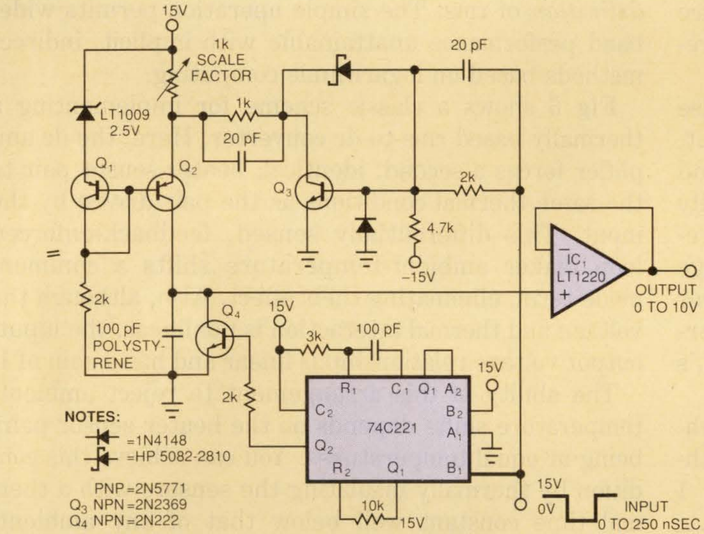


__Fig 2—This very fast S/H circuit (a),__ acquires signals to 8-bit accuracy in 100 nsec. In __b__ you see the waveforms within the circuit. Accurate operation depends on cancellation of the switching signals that feed through the bridge. In __c__, the compensation is disconnected. In __d__, you can see the effect of the compensation.

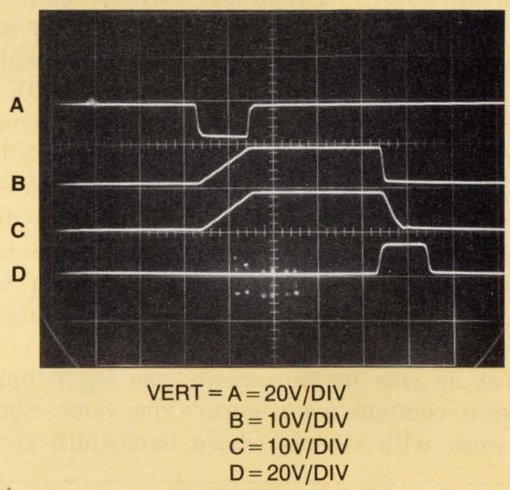
pulse ends, Q_3 turns on rapidly, reverse-biasing Q_2's emitter and turning off the current source. IC_1's voltage is directly proportional to the input pulse width. A monitoring A/D converter can acquire this data.

After an interval set by the 74C221'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



(a)



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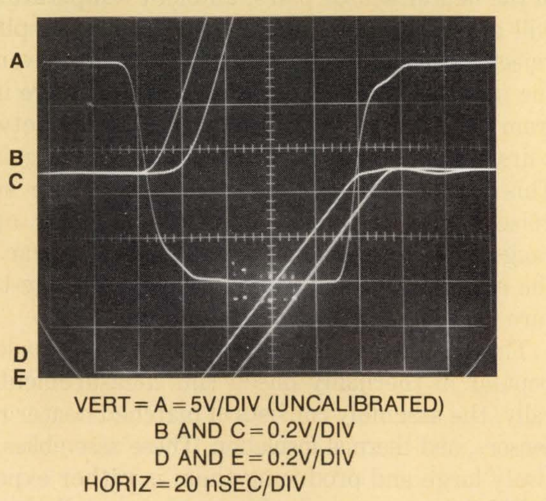

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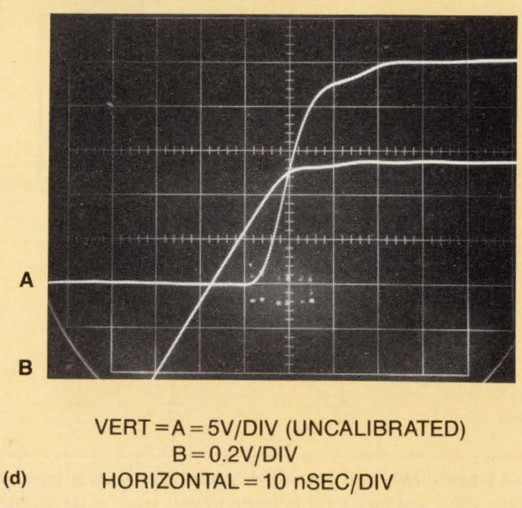

(d)

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 IC_1 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 Q_4 with a lower-saturation-voltage device or you can offset IC_1'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).

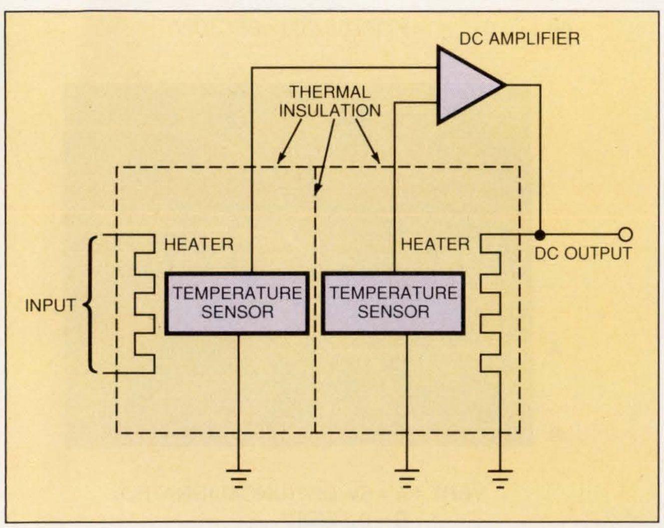

Fig 6—A basic thermal rms-to-dc converter *uses a pair of heating elements. The unknown ac voltage drives one; a dc voltage drives the other. By using a high-gain amplifier to provide the dc voltage, you force the heating effect of the dc to equal that of the ac. Hence the rms value of the dc and ac are equal. Thus, when you measure the dc voltage, you are measuring the rms ac voltage.*

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 wide-band 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

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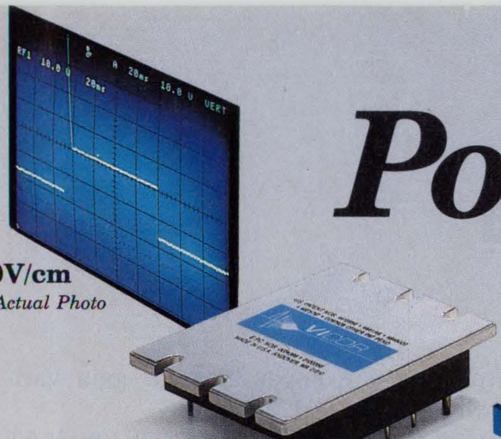

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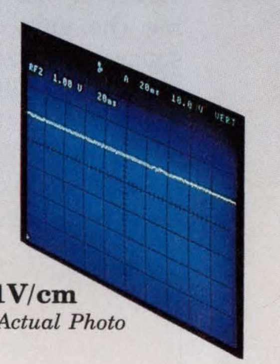

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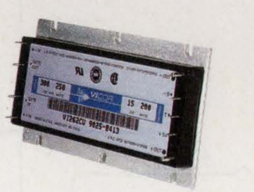

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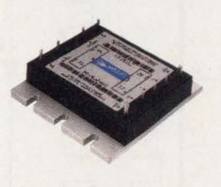

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LT1088's temperature-sensing diodes. IC_1, set up as a differential servo amplifier with a gain of 9000, extracts the diode's difference signal and biases Q_1. Q_1 drives one of the LT1088's heaters, completing a loop. The 3300-pF capacitor gives a 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. IC_2, 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 Q_1's base, and adjusting the zero trim until IC_1's output is active. Then you disconnect Q_1'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-

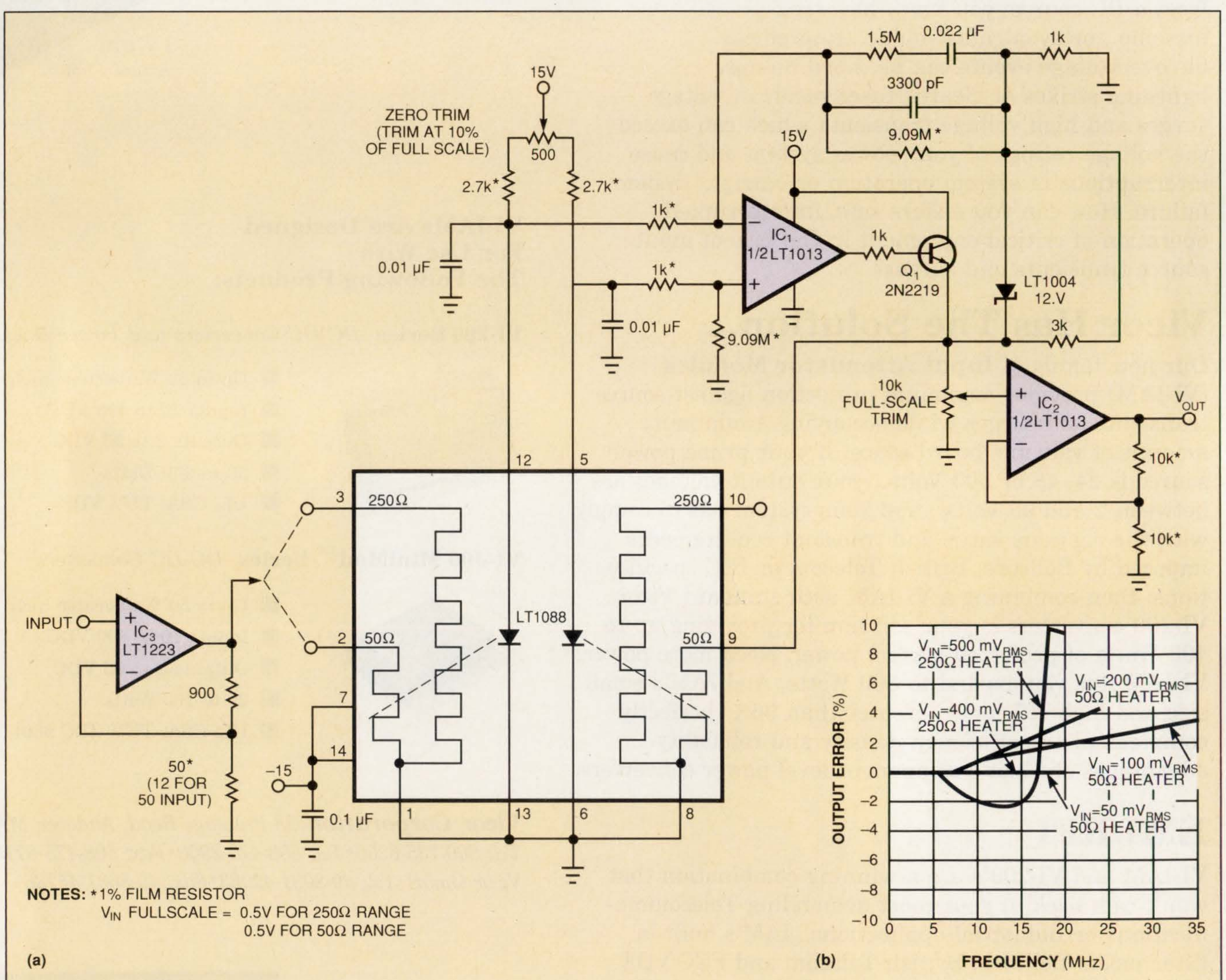

*Fig 7—**A functioning rms-to-dc converter** appears in **a**. In **b**, you see the circuit's error vs frequency for several input-signal amplitudes and for two values of heater resistance.*

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quency. 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 IC_3, 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 IC_3, 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**, IC_3'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. EDN

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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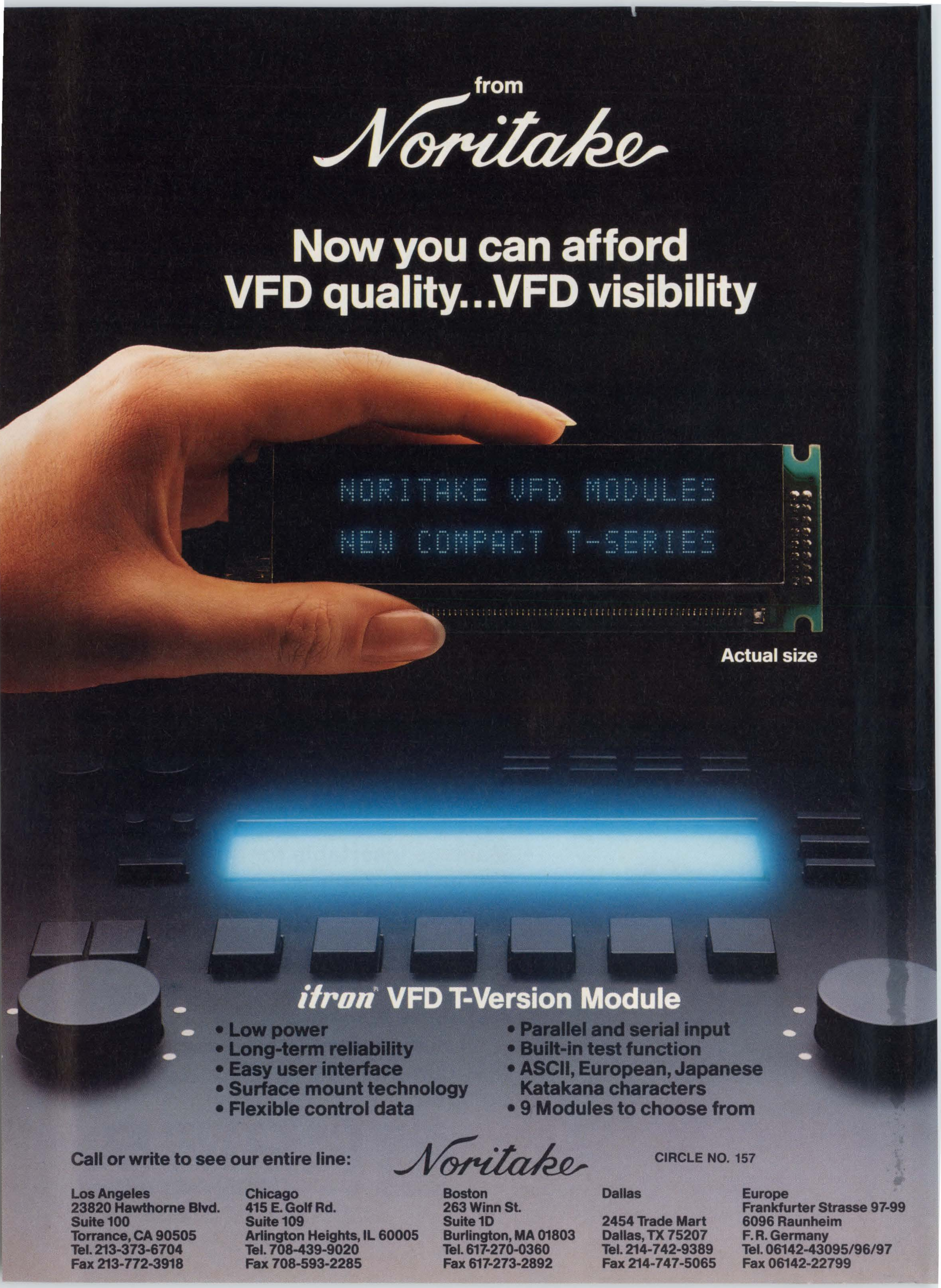

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THE JIM WILLIAMS PAPERS

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.

Jim Williams, *Linear Technology Corp*

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 IC_1's summing point, which causes IC_1'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 IC_1'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. IC_1'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

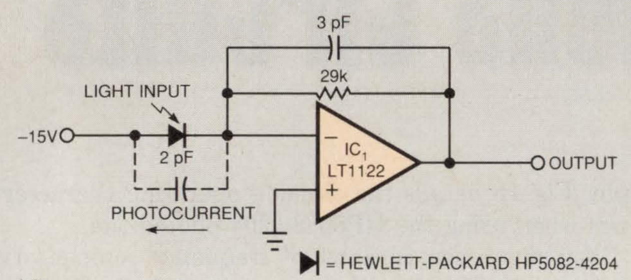
You can use the basic photodiode amplifier as the foundation for a variety of measurement and communications circuits. One such measurement circuit is **Fig 2a**'s photointegrator. The output voltage represents the integral of the diode's photocurrent over a time period defined by the control line. This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

When the control input line is low (**Fig 2b,** trace A) and no photocurrent is present, IC_{2A} is closed and IC_1 acts as a grounded follower. Under these conditions, IC_1's output signal (trace C) sits at 0V. When the control input line goes high, IC_1 becomes an integrator as soon as IC_{2A} opens. Due to the switch delay, IC_2 opens approximately 150 nsec after the control input line goes high.

When IC_{2A} opens, it delivers some parasitic charge to IC_1's summing point. IC_{2B} provides a compensatory charge-based pulse at IC_1's positive terminal to cancel the effects of IC_{2A}'s charge error. The combined effect of the two charge pulses shows up as a fast, small amplitude event in IC_1'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, IC_1 responds by integrating (trace C). With the circuit as shown in **Fig 2a,** IC_1 integrates rapidly until the light pulse ceases. IC_1'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 IC_1 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

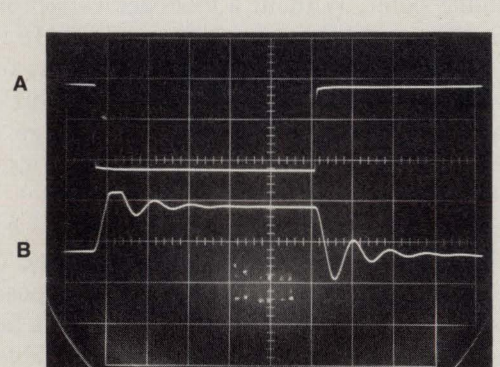


(a)

RESPONSE DATA

LIGHT (900 nm)	DIODE CURRENT	CIRCUIT OUTPUT
1 mW	350 µA	10.0V
100 µW	35 µA	1V
10 µW	3.5 µA	0.1V
1 µW	350 nA	0.01V
100 nW	35 nA	0.001V

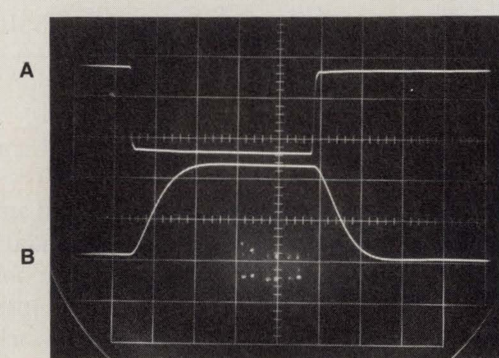
(b)



HORIZONTAL SCALE=500 nSEC/DIV

TRACE	VERTICAL SCALE
A	175 µA/DIV
B	10V/DIV

(c)



HORIZONTAL SCALE=200 nSEC/DIV

TRACE	VERTICAL SCALE
A	175 µA/DIV
B	5V/DIV

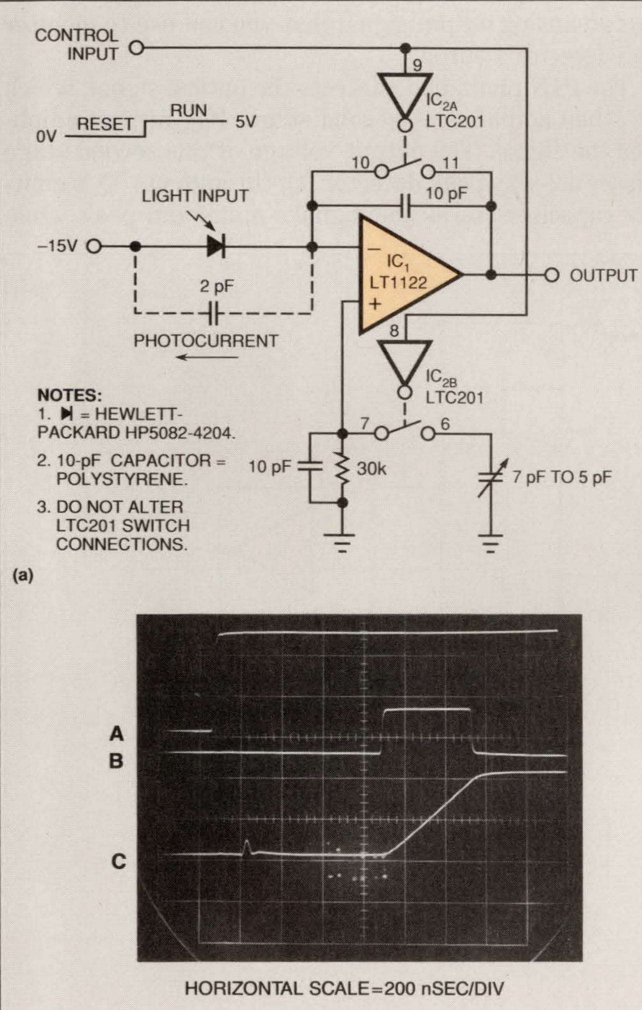
(d)

***Fig 1—This basic photodiode amplifier circuit (a)** handles 5 decades of light intensity. The table **(b)** details the circuit's operating characteristics with the HP5082-4204 diode. Parts **c** and **d** show the circuit's response (trace B) to an input signal (trace A) without and with compensation, respectively.*

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 IC_1'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 IC_1 immediately after the disturbance associated with the IC_{2A}-IC_{2B} switching settles.

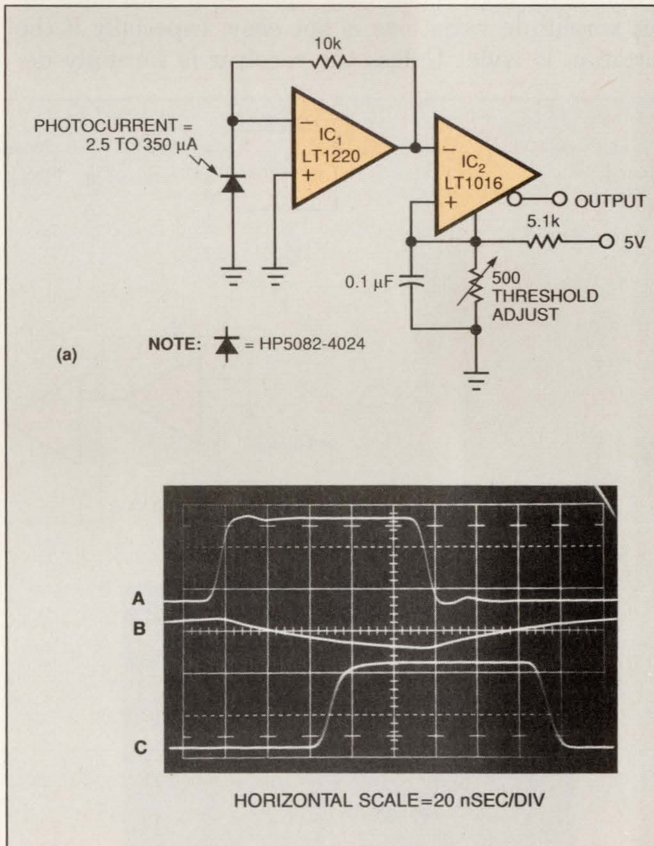
A communications circuit that relies on the basic photodiode amplifier is the simple fiber-optic receiver in **Fig 3a.** IC_1, a photocurrent-to-voltage converter similar to **Fig 1a,** feeds comparator IC_2. IC_2 compares IC_1's output voltage to a dc level established by the



TRACE	VERTICAL SCALE
A	2V/DIV
B,C	5V/DIV

(b)

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).*



TRACE	VERTICAL SCALE
A	5V/DIV
B	0.2V/DIV
C	2V/DIV

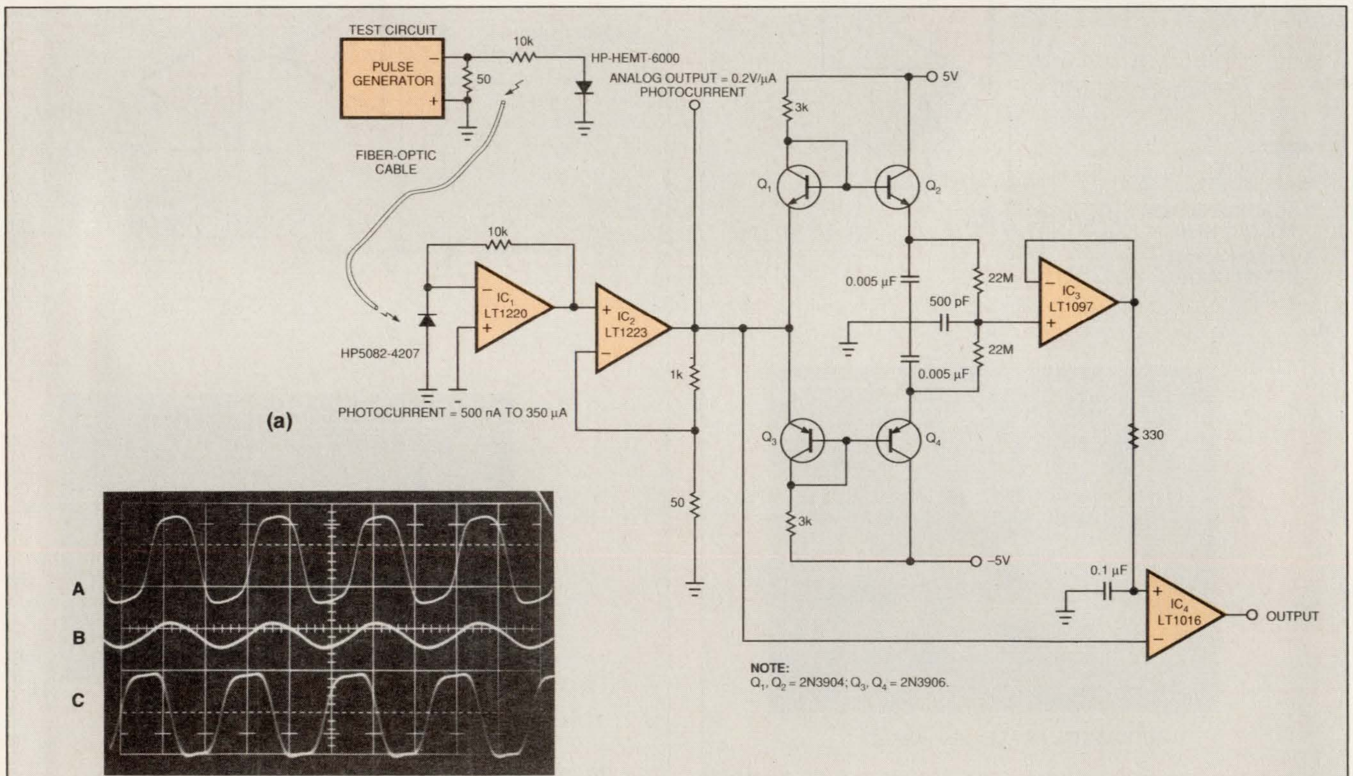
(b)

Fig 3—This simple optical receiver ***(a)*** *has a fixed signal threshold. The outputs of* IC_1 ***(b,*** *trace B) and* IC_2 *(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 IC_1's response, and trace C is IC_2's output signal. The phase shift between the photocurrent input signal and IC_2's output signal is due to IC_1'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 IC_1 then amplifies. A second stage, IC_2, further amplifies the signal. The output voltage of this second stage biases a 2-way peak detector (Q_1 through Q_4). Q_2's emitter capacitor stores the signal's maximum peak while



HORIZONTAL SCALE=20 nSEC/DIV

TRACE	VERTICAL SCALE
A	5V/DIV
B,C	2V/DIV

(b)

***Fig 4—A self-adapting threshold** is the hallmark of this optical receiver **(a)**. Driven by a test signal (**b**, trace A), the circuit lets you monitor the detector's current (trace B) in addition to producing a final output (trace C).*

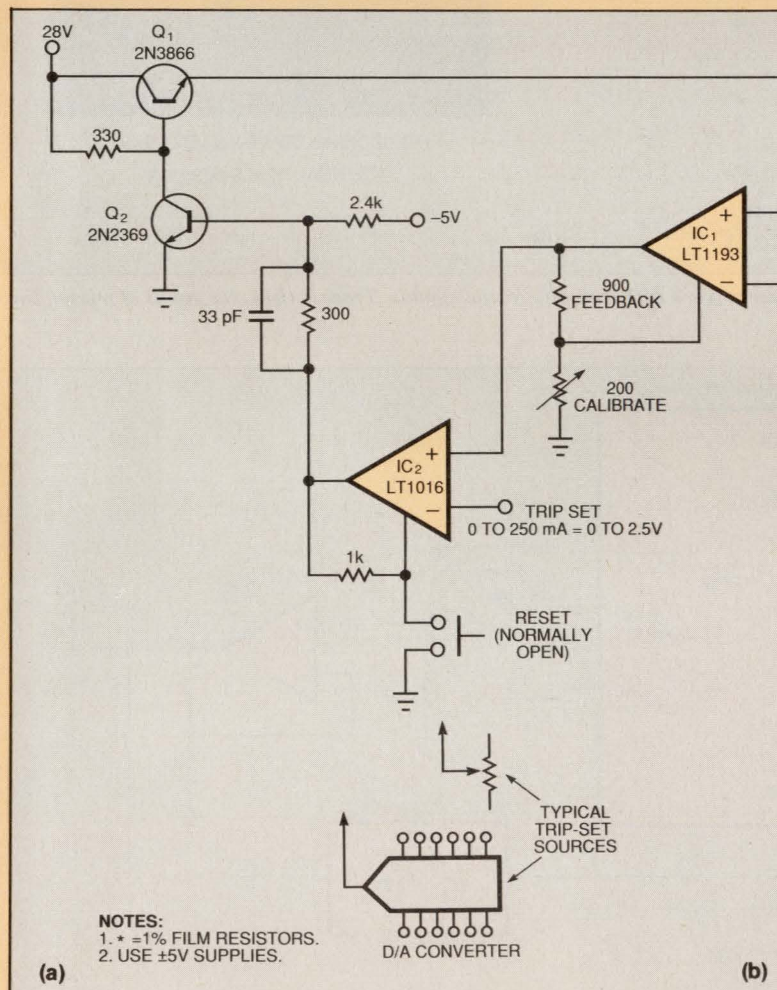
Protective circuit can save you a load

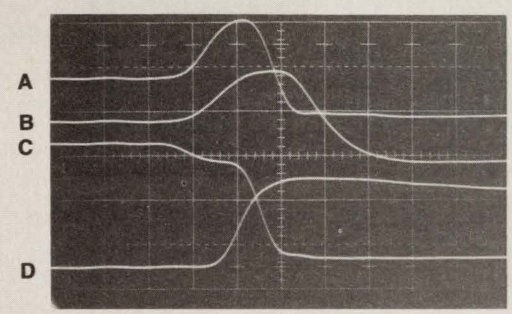
Some type of fuse or circuit breaker helps protect integrated circuits during developmental probing and expensive loads during trimming and calibration. **Fig Aa** shows a simple circuit that will turn off current in a load 18 nsec after that current exceeds a preset value. The circuit is especially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

Under normal conditions, Q_1's emitter is biased on and supplying power to the load via the 10Ω current shunt. Differential amplifier IC_1's output signal resides below comparator IC_2's voltage-programmed trip point, and Q_2 is off.

When an overload occurs, Q_1's emitter current begins to increase (**Fig Ab,** trace A, just prior to the third vertical division). IC_1'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 IC_1's input pins within their common-mode range. Q_1's emitter voltage (trace C) begins to drop as the transistor beta-limits. When IC_1's version of the load current exceeds IC_2's trip point, IC_2 goes high (trace D), which turns on Q_2. (Local positive feedback at IC_2's latch pin causes IC_2 to latch in this off state.) Q_2 steals Q_1'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 Q_2's base and install a 250-mA load. Adjust the 200Ω trim for a 2.5V output signal at IC_1. Next, remove the load, unground Q_2's base, and press the reset button. Finally, set the desired trip voltage, and the circuit is ready for use.





HORIZONTAL SCALE=10 nSEC/DIV

TRACE	VERTICAL SCALE
A	001A/DIV
B	1V/DIV
C	2V/DIV
D	10V/DIV

(b)

***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 IC_1's output voltage; trace D represents IC_2's output voltage.*

Q_4's emitter capacitor retains the minimum excursion. The dc value of the midpoint of IC_2'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 (IC_3) buffers this signal-adaptive voltage to set the trigger voltage at IC_4's positive input pin. IC_4's negative input pin is biased directly from IC_2's output.

Fig 4b shows the results of using the test circuit of **Fig 4a**. The pulse generator's output signal is trace A; IC_2's analog output voltage is trace B. IC_4's output signal is trace C. The waveforms were recorded using a 5-μA photocurrent at about 20 MHz as the test signal.

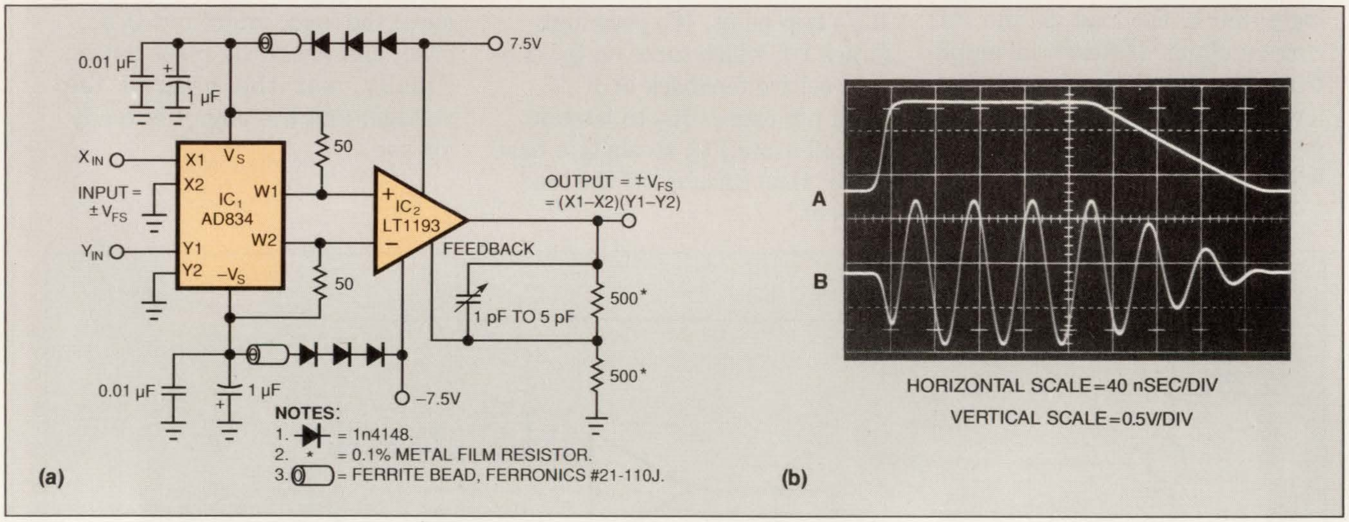


*Fig 5—**This mixer's (a) single-ended output signal** is easier to work with than differential signals. Trace B **(b)** is the result of mixing trace A with a 20-MHz sine wave.*

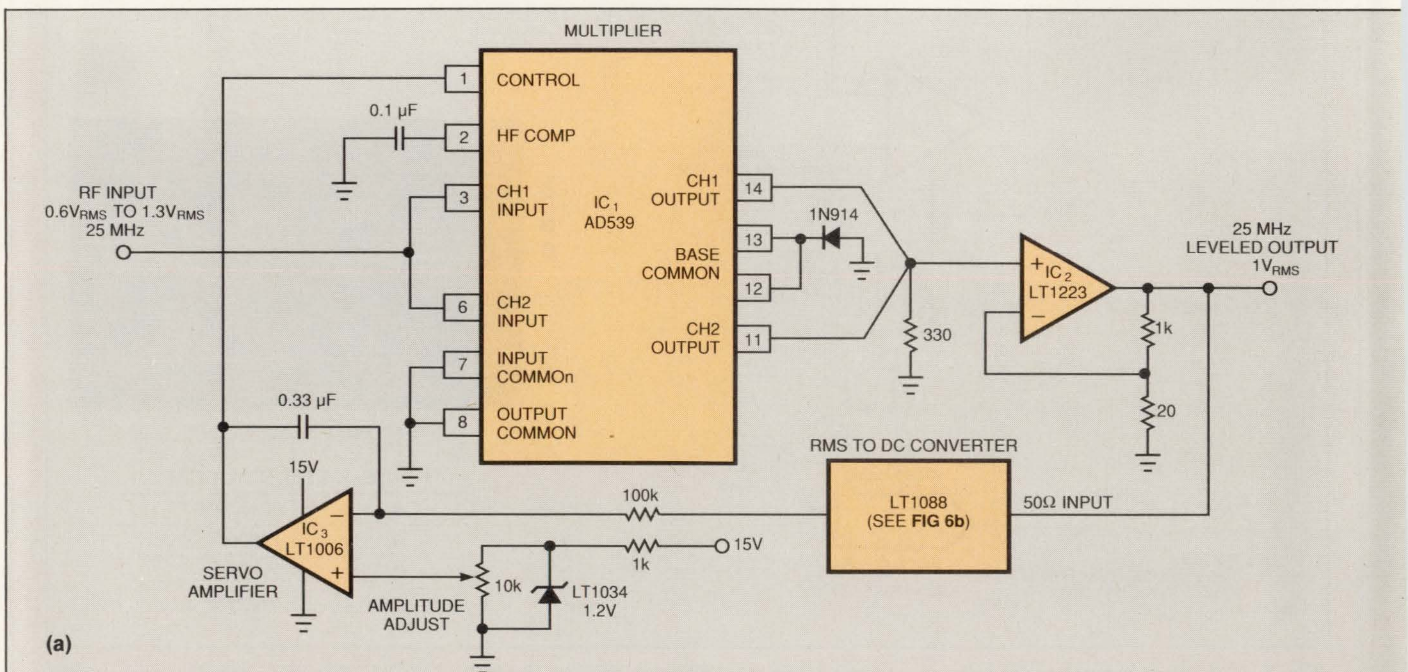


*Fig 6—**A servo loop enables this circuit to stabilize** RF signals. The loop circuit **(a)** uses an rms-to-dc converter **(b)**.*

Note that IC_4's output transitions (trace C) correspond with the midpoint (plus IC_4's 10-nsec propagation delay) of IC_2's output signal (trace B), in accordance with the adaptive-trigger circuit's operation.

Acronyms used in this article

FET—Field-effect transistor
RF—Radio frequency
rms—Root mean square

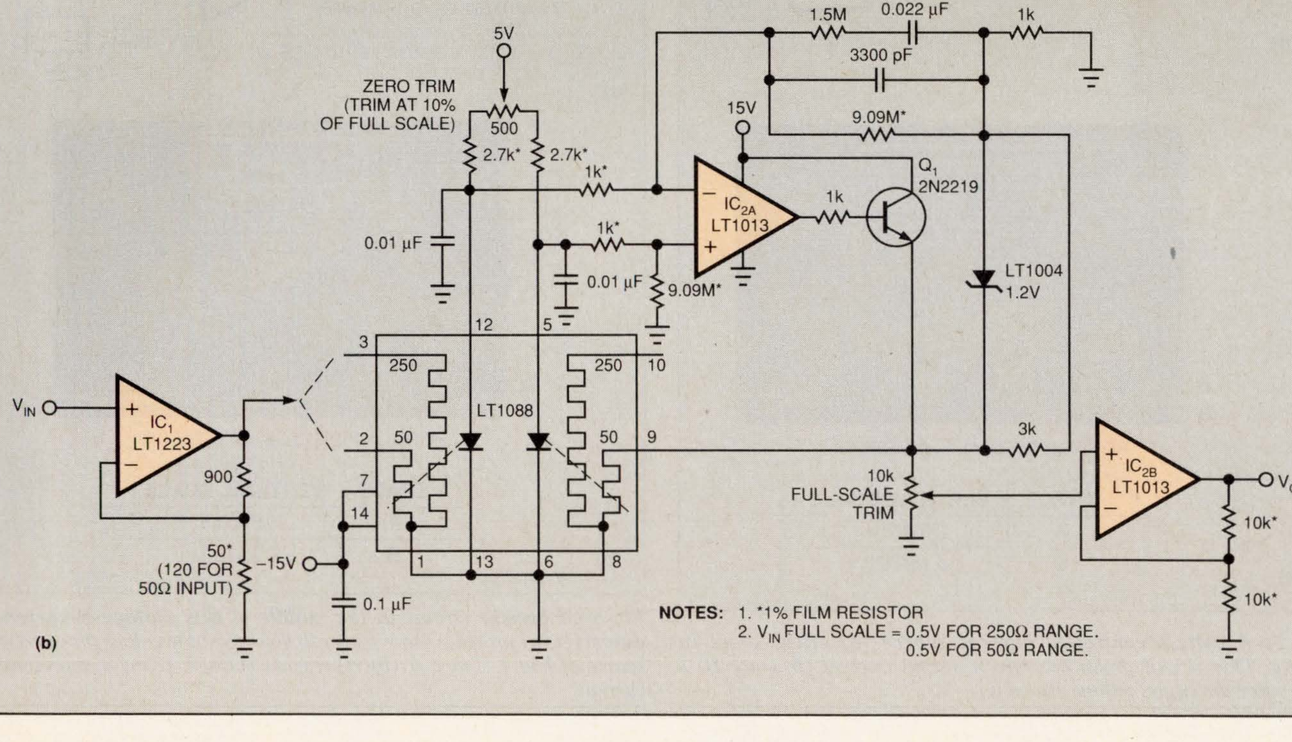
Mixer yields single-ended signal

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 (IC_2) to accomplish the differential-to-single-ended transition. Set up IC_1 in the configuration **Ref 1** recommends. The LT1193 takes the differential signal from IC_1'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.

IC_1's output signals ride on a common-mode level quite close to the device's positive supply. This common-mode level falls outside IC_2's input common-mode range. The diodes in the 7.5V supply rails drop the supply voltage to IC_1, which biases IC_1's output signals within IC_2'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 wideband multiplier (IC_1), which drives IC_2. An LT1088-based rms-to-dc converter **(Fig 6b)** turns IC_2's output to dc. A servo amplifier (IC_3) 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

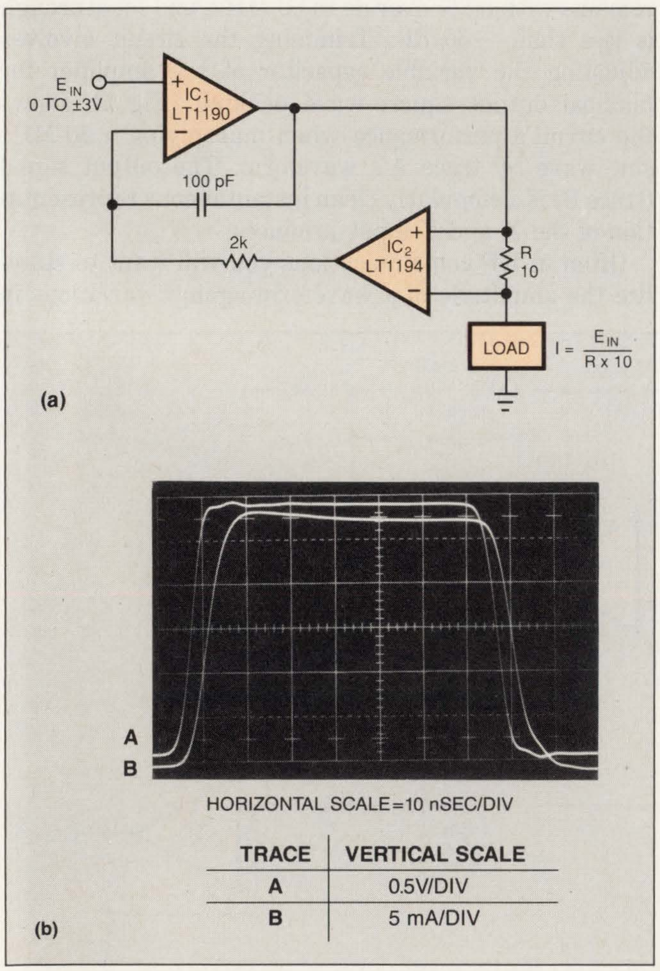


*Fig 7—**A voltage-controlled current source (a)** often comes in handy. This circuit produces a clean output current (**b**, trace B) 4 nsec after the input voltage (trace A).*

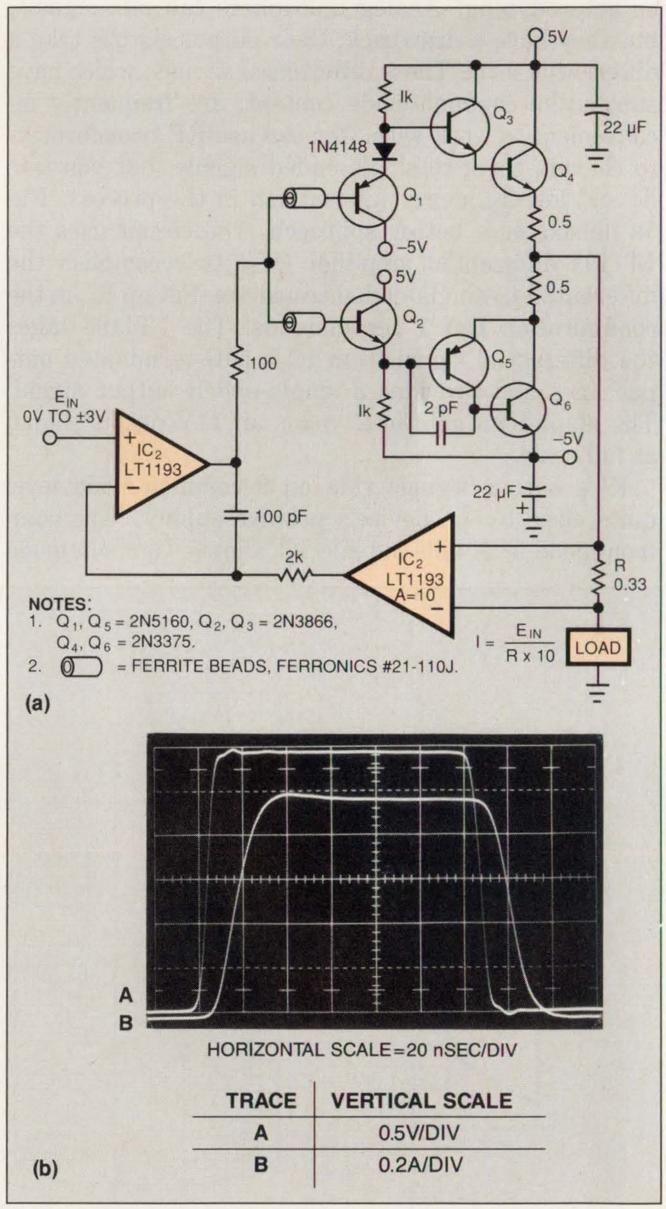


*Fig 8—**A booster circuit in the middle of this voltage-to-current converter (a)** provides more power to your load than does the current source of **Fig** 7. Trace A **(b)** represents voltage; trace B represents current.*

and magnitude of the control voltage. Resistor R sets the circuit's scale factor.

IC_1, biased by E_{IN}, drives current through R (in this case 10Ω) and the load. IC_2, sensing the differential voltage across R, closes a loop back to IC_1. The load current is constant because IC_1'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, E_{IN}; 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 IC_1'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 IC_2 and the booster in IC_1's feedback path are significant. This type of circuit receives detailed treatment in **Ref 2.** EDN

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Author's biography

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

Article Interest Quotient (Circle One)
High 497 Medium 498 Low 499

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

You can often represent control-system blocks in Spice using equivalent electronic circuits.

constant is large and −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, τ, is $1/(2\pi\times 2000\ \text{Hz})=0.0796$ 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-

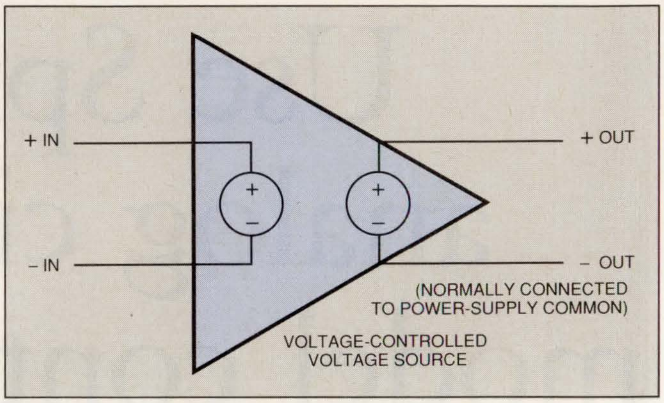

Fig 1—The voltage-controlled voltage source (VCVS) *is the basic Spice tool for block diagrams. If the gain constant is large and −OUT is connected to power-supply common, the VCVS acts like an ideal op amp.*

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.

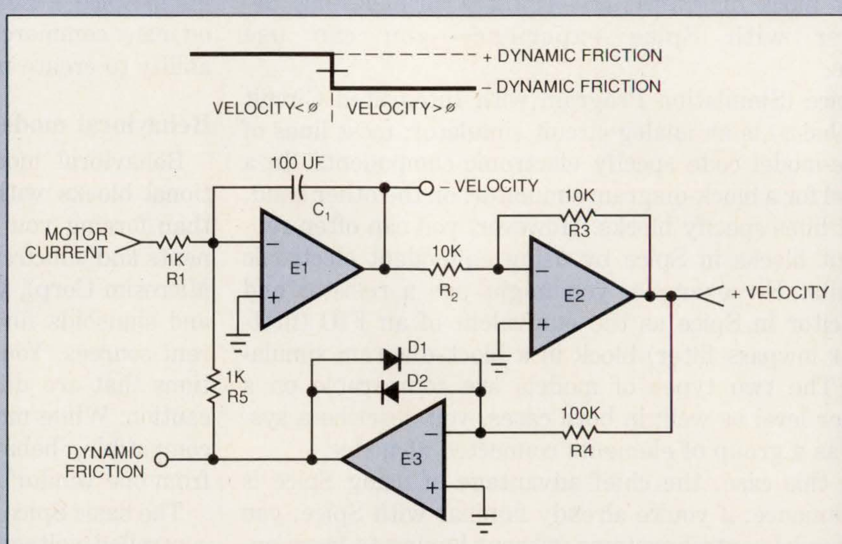

Fig A—This model of a servo motor *with a frictional load uses an op amp with diodes in the feedback path to simulate dynamic friction.*

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 or *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.

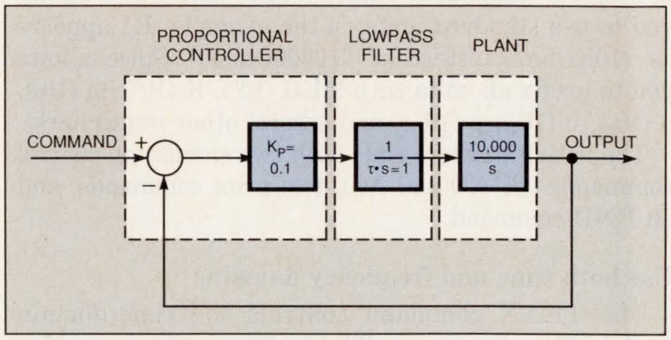

Fig 2—This simple control system *consists of a proportional controller, a lowpass filter, and an integrating plant. The plant might represent an idealized motor or a mass in a frictionless system. K_P is the proportional gain, and τ is the cutoff frequency in radians/sec.*

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

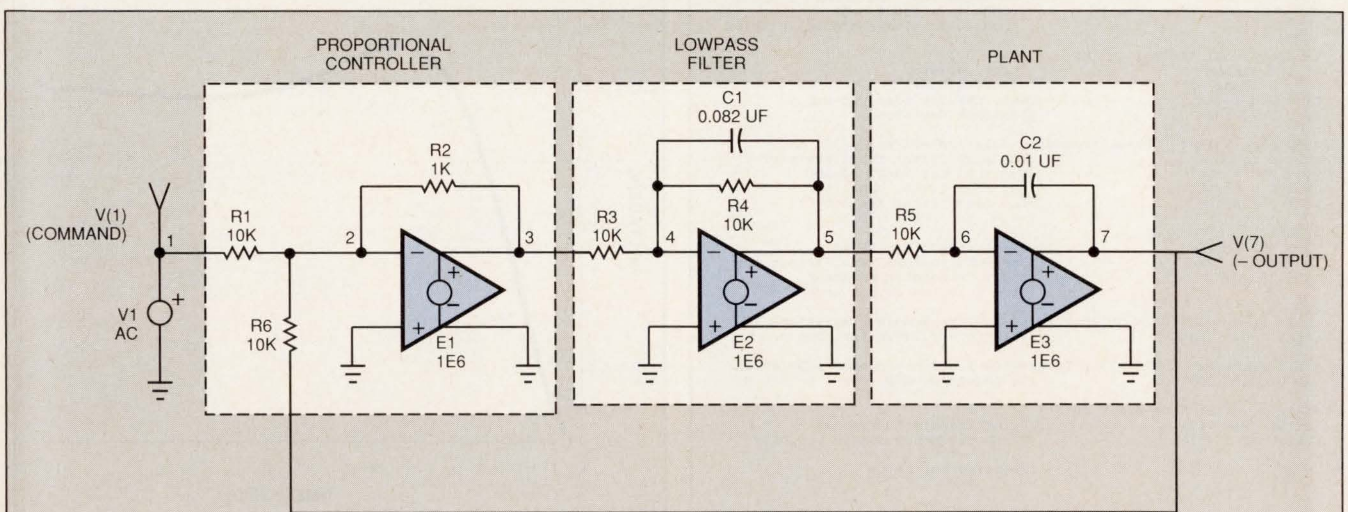

Fig 3—Op amps and other components *model each of the three blocks—the controller, the filter, and the plant—of* **Fig 2**'s *control system.*

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 (10^6), K (10^3), m (10_3), u (10_6), n (10_9), p (10_{12}), 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

V1 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

*Proportional Controller (Kp = R2/R6 = 0.1)
R1 1 2 10Kohm                     ;Input resistor
R2 2 3 1Kohm                      ;Gain resistor
E1 3 0 0 2 1E6                    ;Use VCVS for ideal op-amp
R6 2 7 10Kohm                     ;Feedback Resistor

*Low Pass Filter.  Break frequency = 1/(2*pi*C1*R4) = 200 Hz.
R3 3 4 10Kohm                     ;Low pass filter input resistor
E2 5 0 0 4 1E6                    ;Use VCVS for ideal op-amp
C1 4 5 0.082uF                    ;Low pass filter capacitor
R4 4 5 10Kohm                     ;Low pass filter resistor

*Plant
R5 5 6 10Kohm                     ;Plant input "resistor"
E3 7 0 0 6 1E6                    ;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 TRAN V(7)                  ;Print transient response
.PRINT AC   V(7)                  ;Print frequency domain response

.END                              ;Required for SPICE
```

Fig 4—This Spice model, *representing the circuit in* **Fig 3**, *has three types of lines—comments, components, and control lines.*

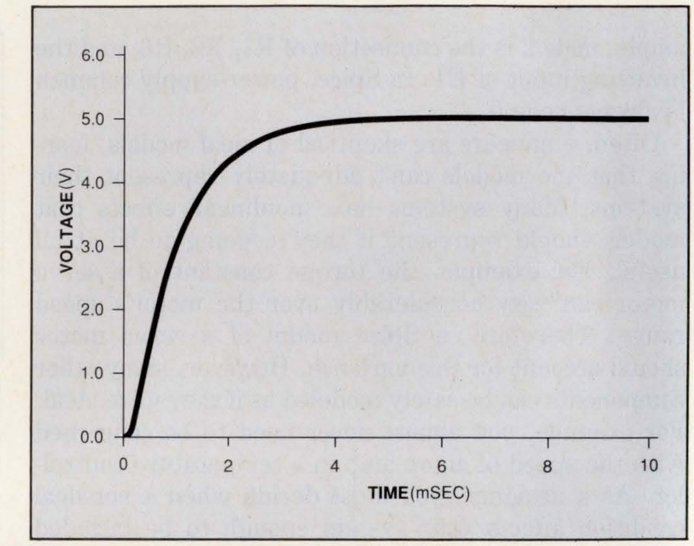

Fig 5—The transient (time domain) response *of* **Fig 3's** *system shows no overshoot with the cutoff frequency of the lowpass filter set to 2000 Hz (C1 = 0.0082 μF).*

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

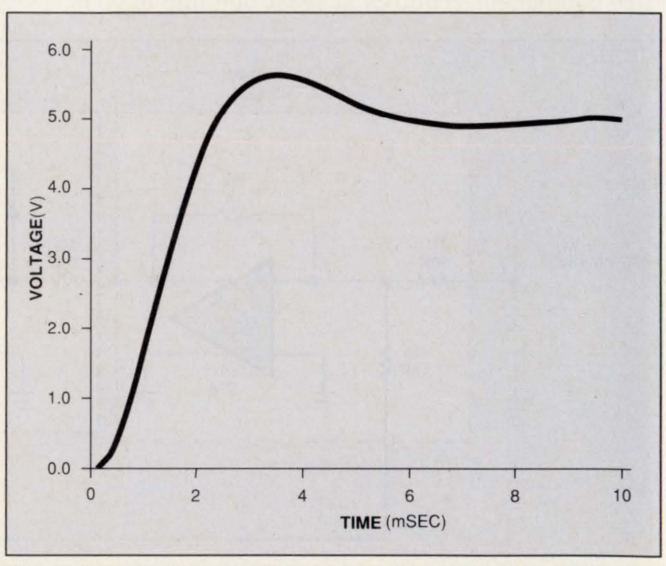

Fig 6—About half a volt of overshoot *occurs in* **Fig 3's** *system when the cutoff frequency is reduced to 200 Hz (C1 = 0.082 μF).*

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

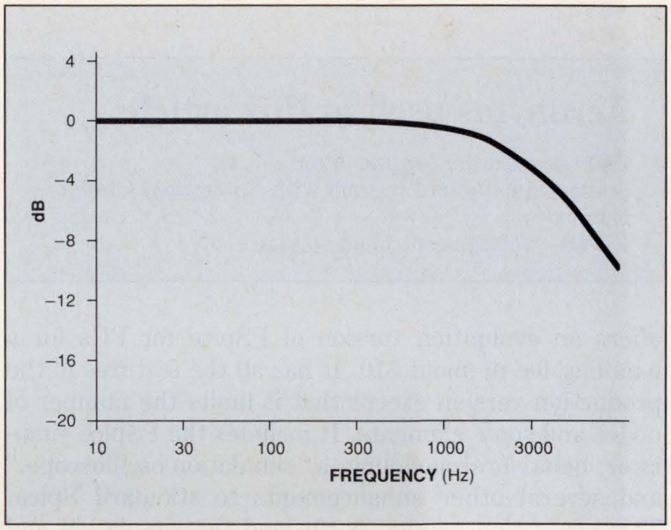

Fig 7—The Bode gain plot for **Fig 3**'s *system, with a 2000-Hz filter, shows that the gain is flat to about 40 Hz; after that, the gain gradually declines. This plot indicates that the system is very stable.*

Suppliers of analog-simulation software

For more information on analog-simulation software packages 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.

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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. EDN

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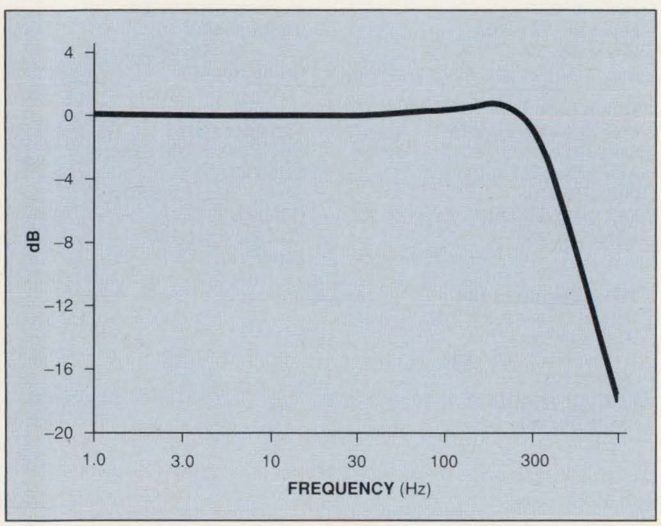
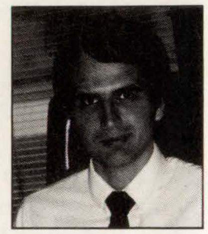


***Fig 8—Additional peaking of about half a dB** occurs when the filter's cutoff frequency is reduced to 200 Hz.*

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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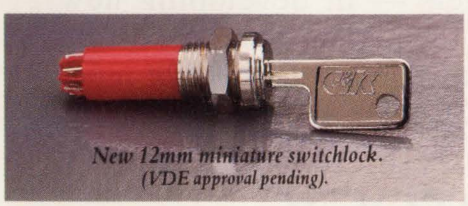

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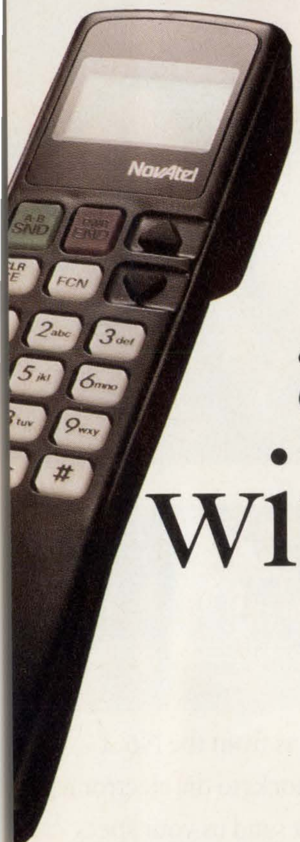

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CIRCLE NO. 293

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:

$$Z_{in}(s) = \frac{Z_1(s)\,Z_3(s)\,Z_5(s)}{Z_2(s)\,Z_4(s)}$$

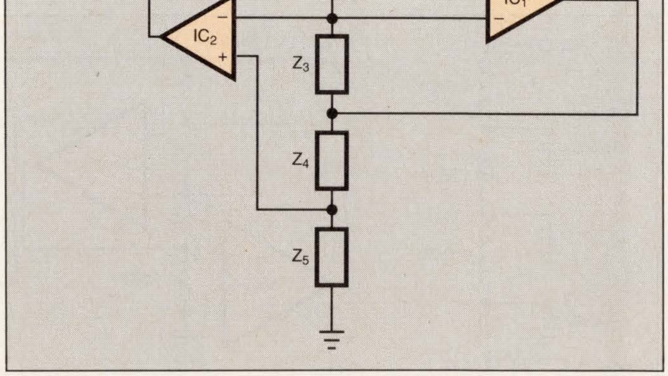

***Fig 1—The topology of a Generalized Immittance Converter (GIC)** can simulate the impedance of any passive component, including a frequency-dependent negative resistor (FDNR).*

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_{s2} is capacitive and the other impedances are resistive, the GIC's input impedance simulates an inductor.

$$Z_{in}(s) = \frac{s\,R_1\,C_2\,R_3\,R_5}{R_4}\ .$$

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).

$$Z_{in}(s) = \frac{R_3}{s^2\,C_1\,R_2\,R_4\,C_5}\ .$$

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_1 will not have a bias-current return path, which could affect the filter's operation. When you make Z_3 and Z_5 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 $R_2 = R_3$ ($Z_2 = Z_3$) to minimize the effect of op-amp gain-bandwidth mismatch. If you configure the GIC with capacitors for Z_3 and Z_5, 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 $C_3 = C_5$, 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× the Nyquist rate. Multiplying the recommended standard 48-kHz audio sampling rate by a factor of 4 produces the standard 192-kHz 4×-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—antialiasing 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.

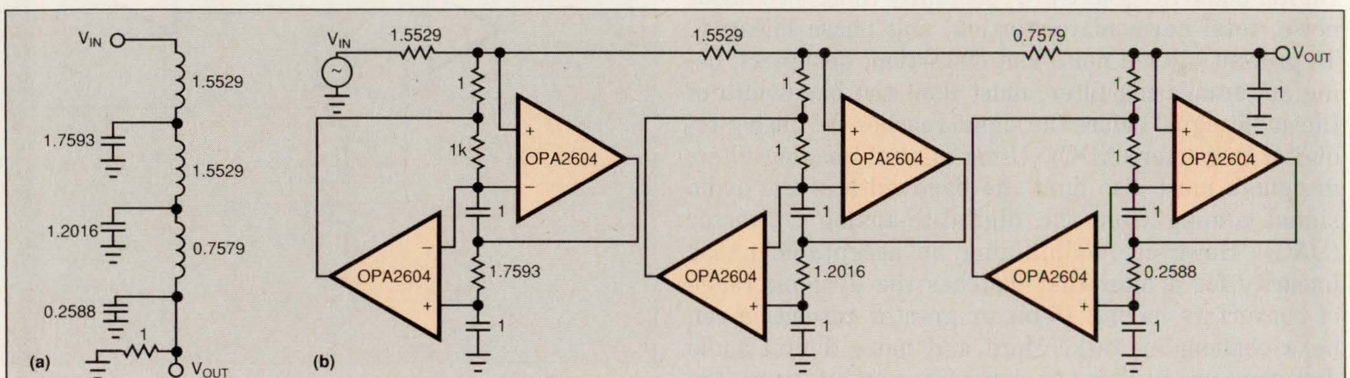

*Fig 2—**An LC ladder network generates any lowpass-filter polynomial (a).** You can simulate the filter's transfer function by multiplying each element value by 1/s and realize the filter using GICs (**b**).*

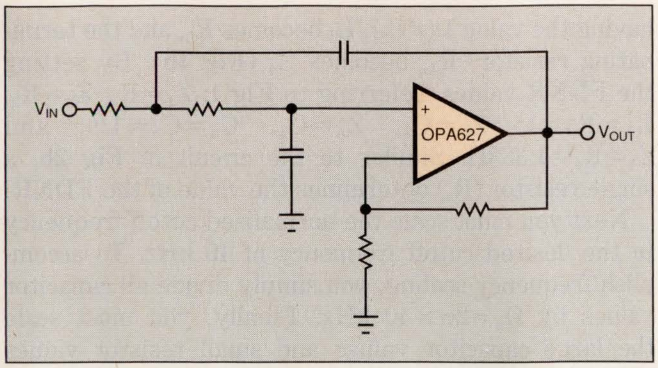

Fig 3—Active-filter handbooks contain many "cookbook" designs for the familiar Sallen and Key lowpass architecture. *The topology often requires greater-than-unity gain to realize the filter.*

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

$$H(f) = \frac{\text{SIN}\left(\pi \frac{f}{f_s}\right)}{\left(\pi \frac{f}{f_s}\right)},$$

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× oversampled digital audio systems.

Using a 192-kHz 4×-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:

$$10^{\frac{K_S}{20}} = \sqrt{1 + \left(\frac{\omega_s}{\omega_c}\right)^{2n}},$$

where K_s is the stopband attenuation in dB, ω_s is the minimum stopband frequency, ω_c is the 3-dB cutoff frequency, and n is the filter order. Solving for n yields

$$n = \frac{\text{LOG}\left[\sqrt{10^{\frac{K_S}{10}} - 1}\right]}{\text{LOG}\left[\frac{\omega_s}{\omega_c}\right]}.$$

The anti-imaging filter benefits from the extra attenuation of the digital interpolation filter, the DAC, and the power amplifier's frequency response.

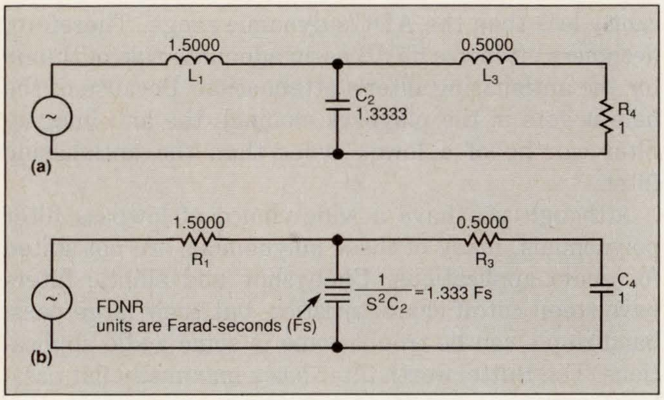

Fig 4—A normalized third-order Butterworth filter serves as a building block for the anti-imaging filter (a). *You obtain the normalized GIC filter by multiplying each normalized element value by 1/s (**b**).*

Substituting $K_s=65$, $\omega_s=2\pi\times160$ kHz, and $\omega_c=2\pi\times40$ 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 $1/(s^2C_2)$, 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 $\Omega_n=2\pi\times40$ 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

$$Z_n=7.23\times10^3.$$

Multiplying all resistor values and dividing all frequency-scaled capacitor values by 7.23×10^3 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-

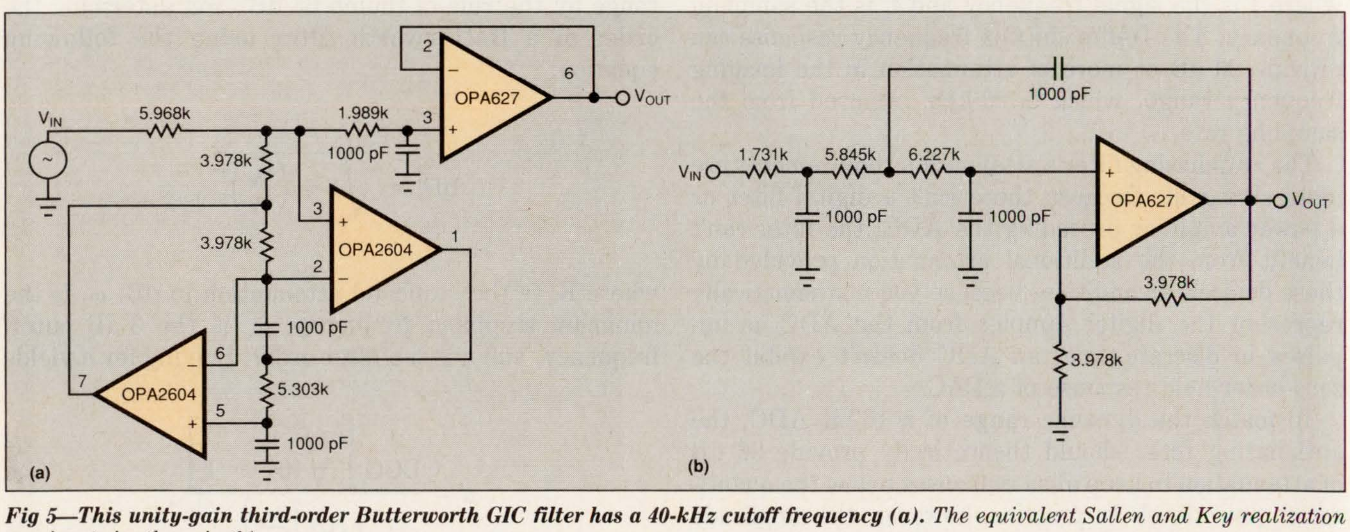

Fig 5—This unity-gain third-order Butterworth GIC filter has a 40-kHz cutoff frequency (a). *The equivalent Sallen and Key realization requires twice the gain (**b**).*

CIRCLE NO. 164

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.

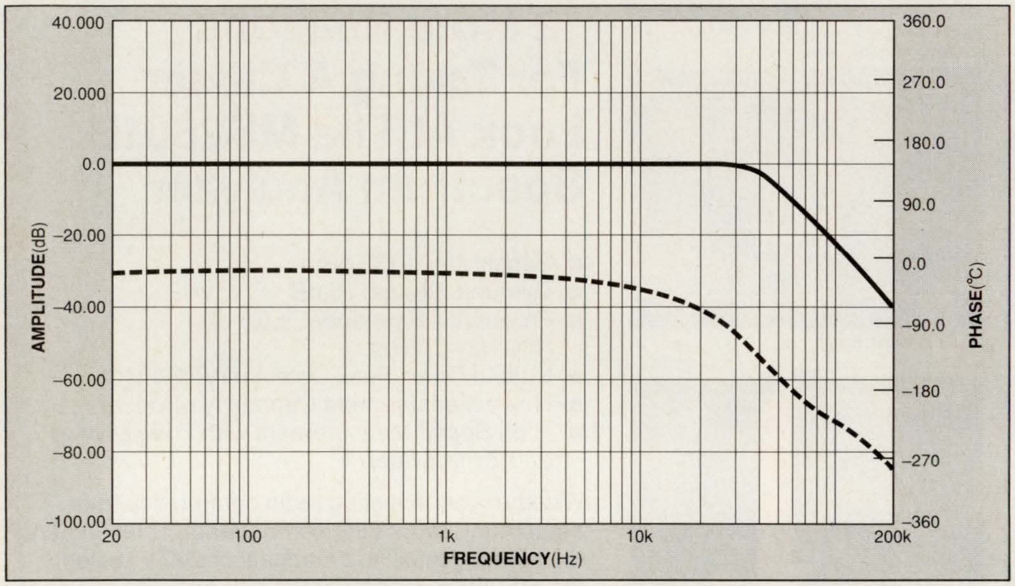

***Fig 6—The amplitude (solid line) and phase response (dotted line) of the third-order Butterworth GIC filter** are nearly constant throughout the audio-frequency band.*

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. EDN

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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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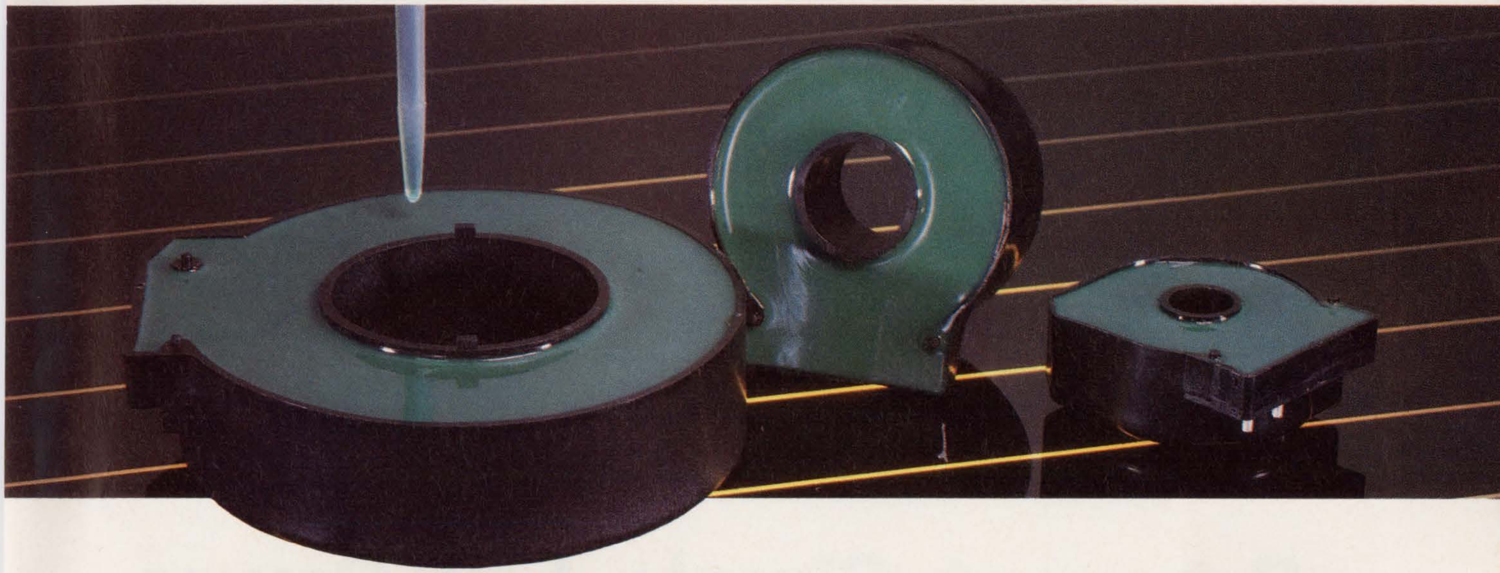

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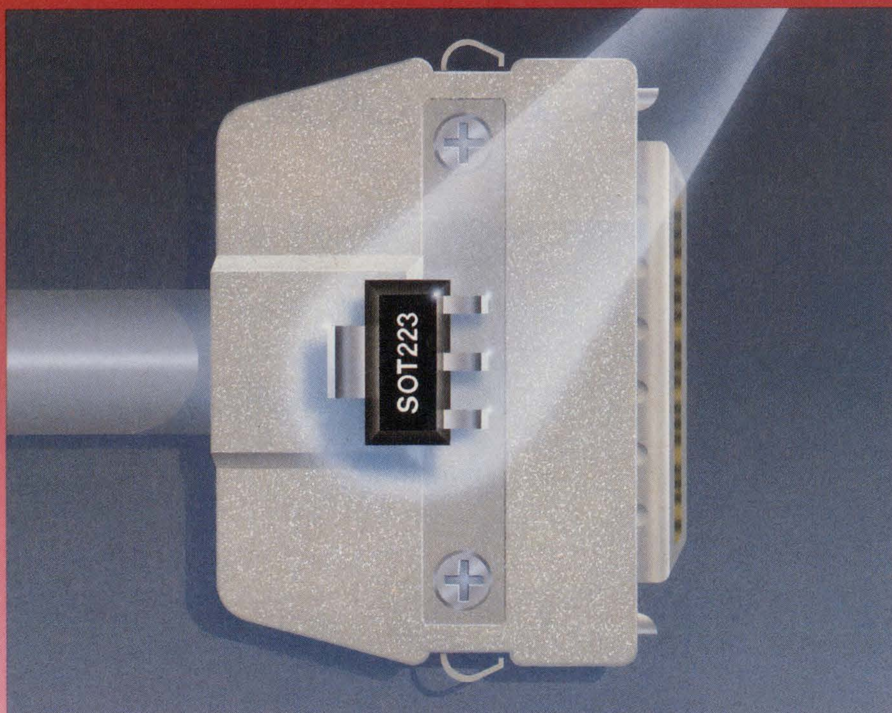

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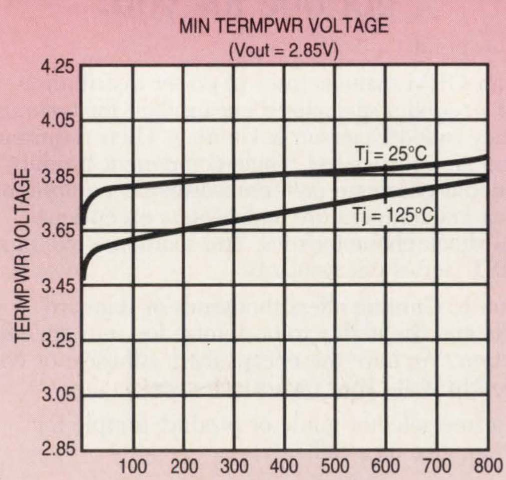

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LINEAR TECHNOLOGY

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CIRCLE NO. 170

EDITED BY ANNE WATSON SWAGER

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. **EDN BBS /DI_SIG#1051**

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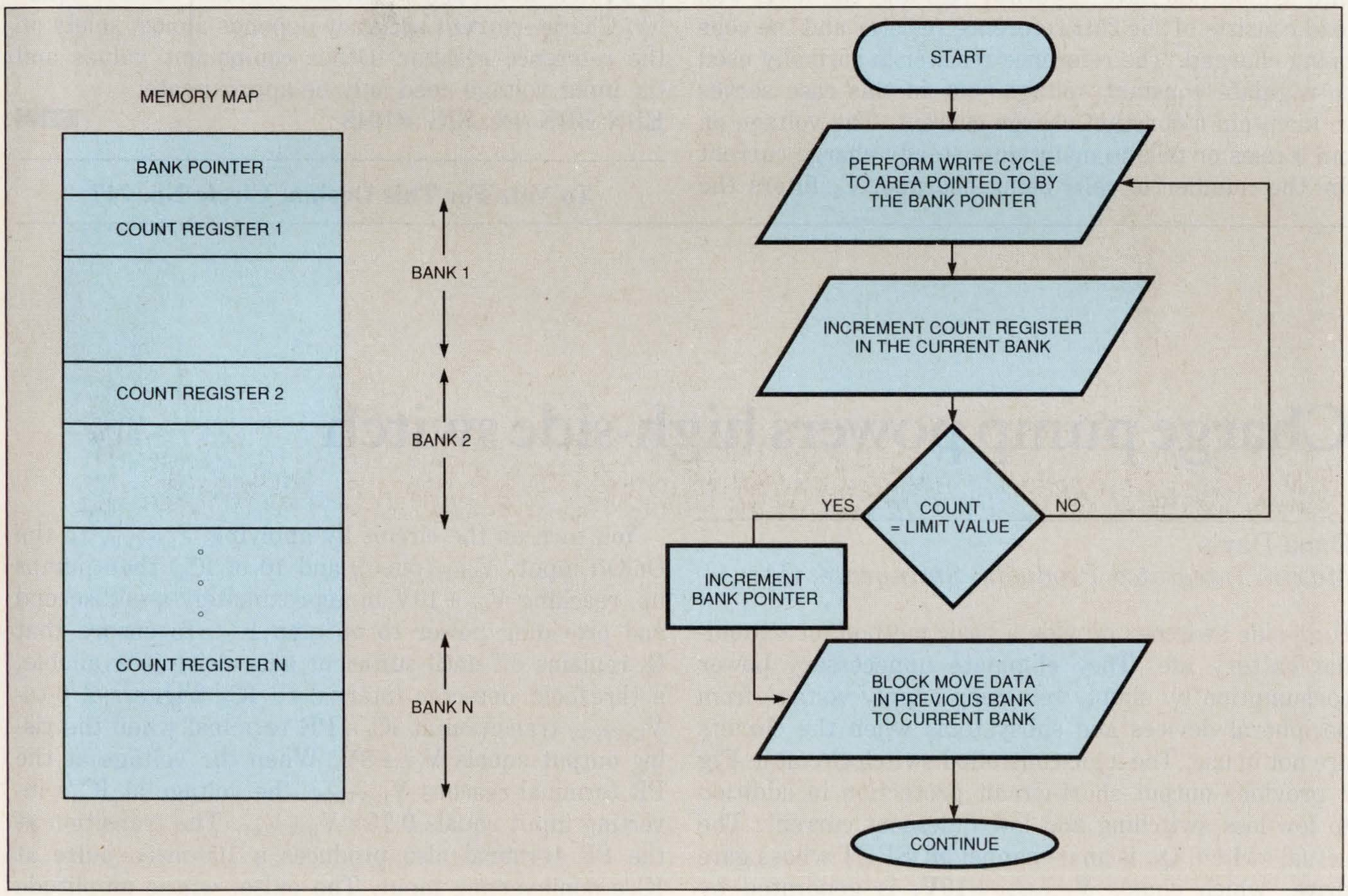

***Fig 1—Creating N banks of memory extends** an EEPROM write-cycle life by N times. The cost is the added memory.*

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 side-step 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 (C_1) and the load. The load consists of the 24Ω 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. C_2 filters the input, and C_T is the regulator timing capacitor. D_1 acts as a catch diode, and D_2 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.

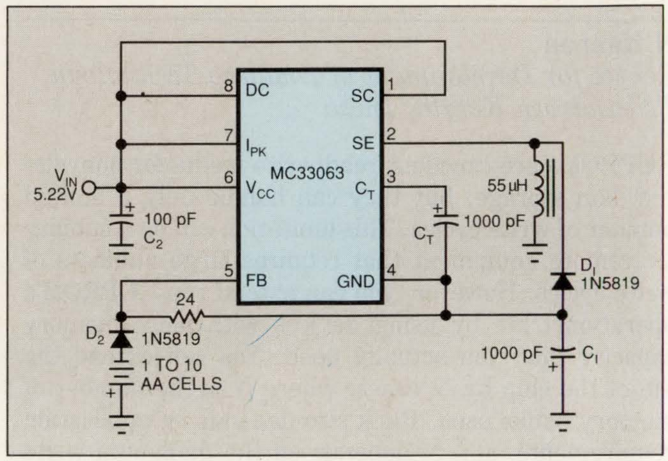

Fig 1—This switched-current regulator can charge anywhere from one to 10 1.5V NiCd cells using an input voltage of approximately 5.2V.

EDN BBS /DI_SIG #1048

To Vote For This Design, Circle No. 747

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, Q_1, is an n-channel MOSFET whose gate drive, which equals $V_{BATTERY}+10V$, is generated by IC_1, a regulated charge pump.

You turn on the circuit by applying $V_{BATTERY}$ to the On/Off input. V_{OUT} (pins 9 and 10 of IC_1) then pumps up, reaching $V_{CC}+10V$ in approximately a millisecond and providing power to op amp IC_2. To ensure that Q_1 remains off until sufficient gate drive is available, a threshold detector internal to IC_1 triggers a 0-to-$V_{BATTERY}$ transition at IC_1's PR terminal when the rising output equals $V_{CC}+8V$. When the voltage at the PR terminal reaches $V_{BATTERY}$, the voltage at IC_2's inverting input equals $0.75\times V_{BATTERY}$. The transition at the PR terminal also produces a 100-msec pulse at IC_2's noninverting input. The pulse, whose amplitude is $V_{BATTERY}$ minus one diode drop, jump-starts Q_1 into

conducting. The comparator-configured amplifier then compares Q_1's source voltage with the inverting input voltage. As long as the source voltage is more positive, Q_1 remains on.

Feedback through R_1 provides short-circuit protection. If excessive load current pulls the source voltage below the reference level at IC_2's inverting input, the gate drive goes low and turns off Q_1. Collapsing load voltage then latches the switch off. To reset, pull the On/Off input to ground for at least 100 msec.

EDN BBS /DI_SIG #1050

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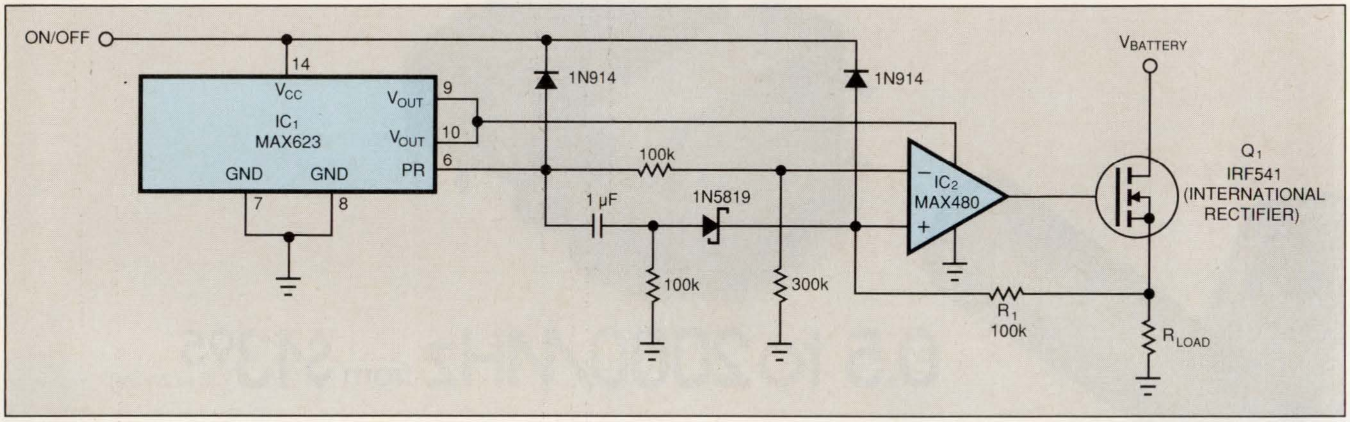

***Fig 1—A regulated charge-pump IC generates** a gate drive equal to $V_{BATTERY}+10V$ for the high-side power switch Q_1, an n-channel power MOSFET.*

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 output voltage is less than 0.01 dB. The circuit can also operate from higher positive supply voltages, depending 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 R_4. With $R_4=10\times R_1$, the bandpass filter has a Q of 10, which implies low distortion. The circuit starts reliably and shows no evidence of spurious high-frequency oscillation. For split-supply operation, remove R_7, make $R_6=R_5$, and short circuit C_3.

EDN BBS /DI_SIG #1049

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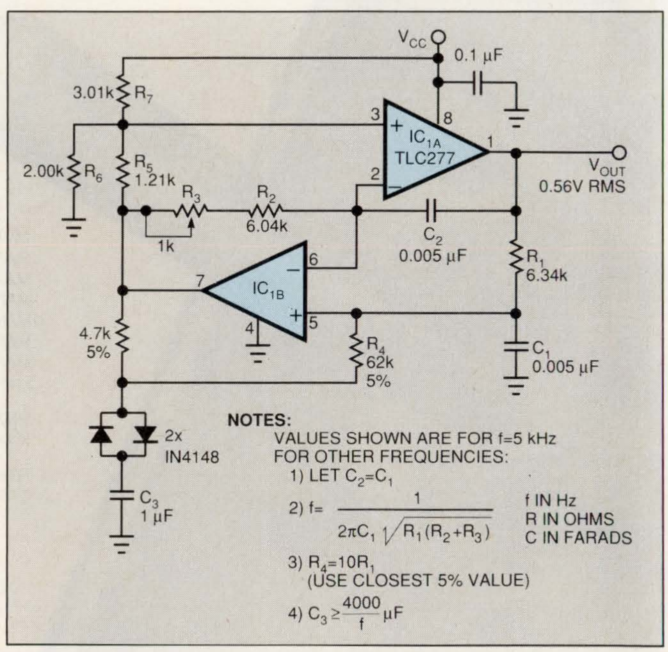

***Fig 1—Based on a modified GIC bandpass filter,** this 5-kHz sine-wave oscillator runs off 5V.*

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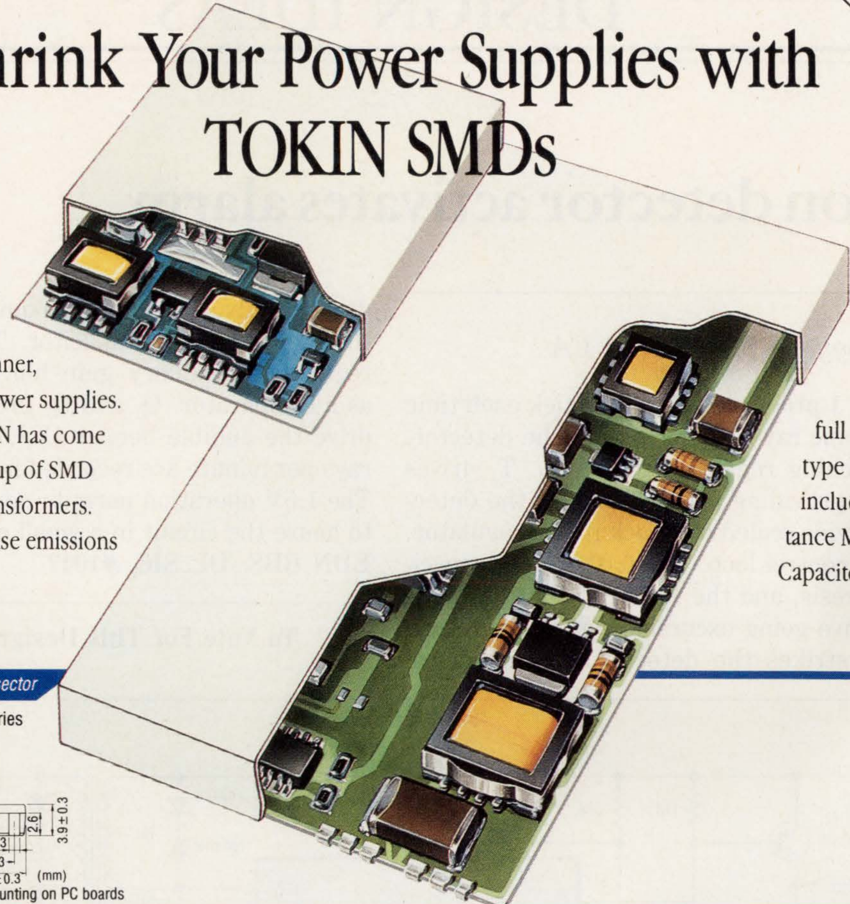

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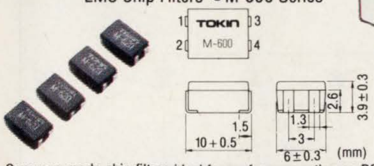

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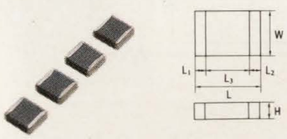

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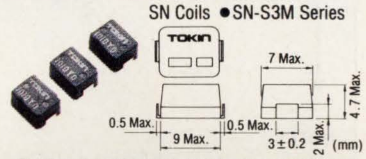

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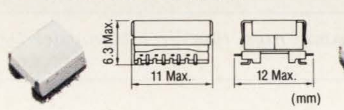
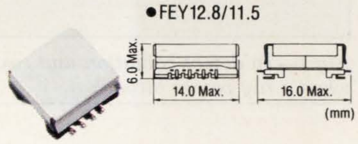
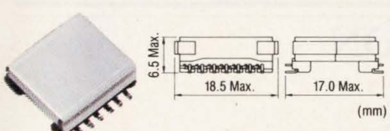


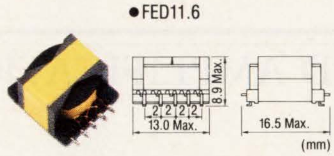
●FEY12.8/11.5



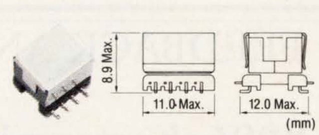
●FEY15.3/13.0



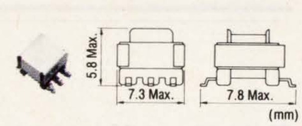
●FED11.6



●FEP7T



●FEE5



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 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 T_1. T_1 drives a voltage tripler, providing 500V of bias to the detector. R_1 and R_2 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 T_1'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. Q_1 and Q_2 provide additional gain to drive the audible beeper (X_1). 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.

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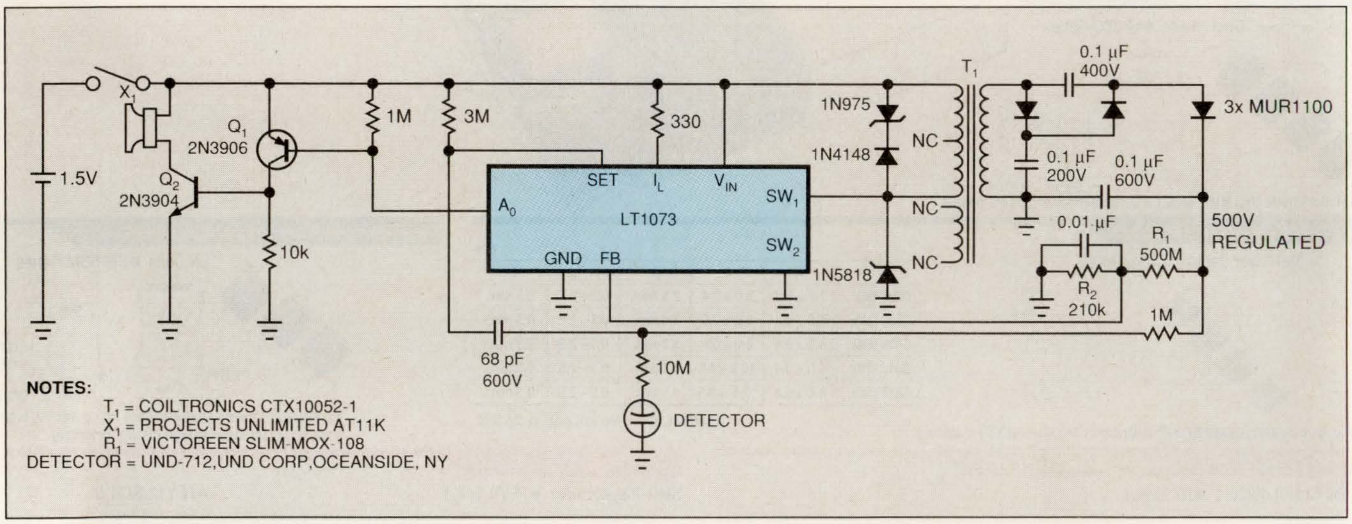

***Fig 1—To detect radiation and cosmic rays,** this circuit provides 500V of bias to the radiation detector, whose impedance drops sharply when a ray passes through it.*

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 idiosyncrasy 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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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

The winning Design Idea for the August 5, 1991, issue is entitled "Detector spots sneaky smokers," submitted by Miss J Vandana of SEMP (Kalpakkam, TN, India).

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
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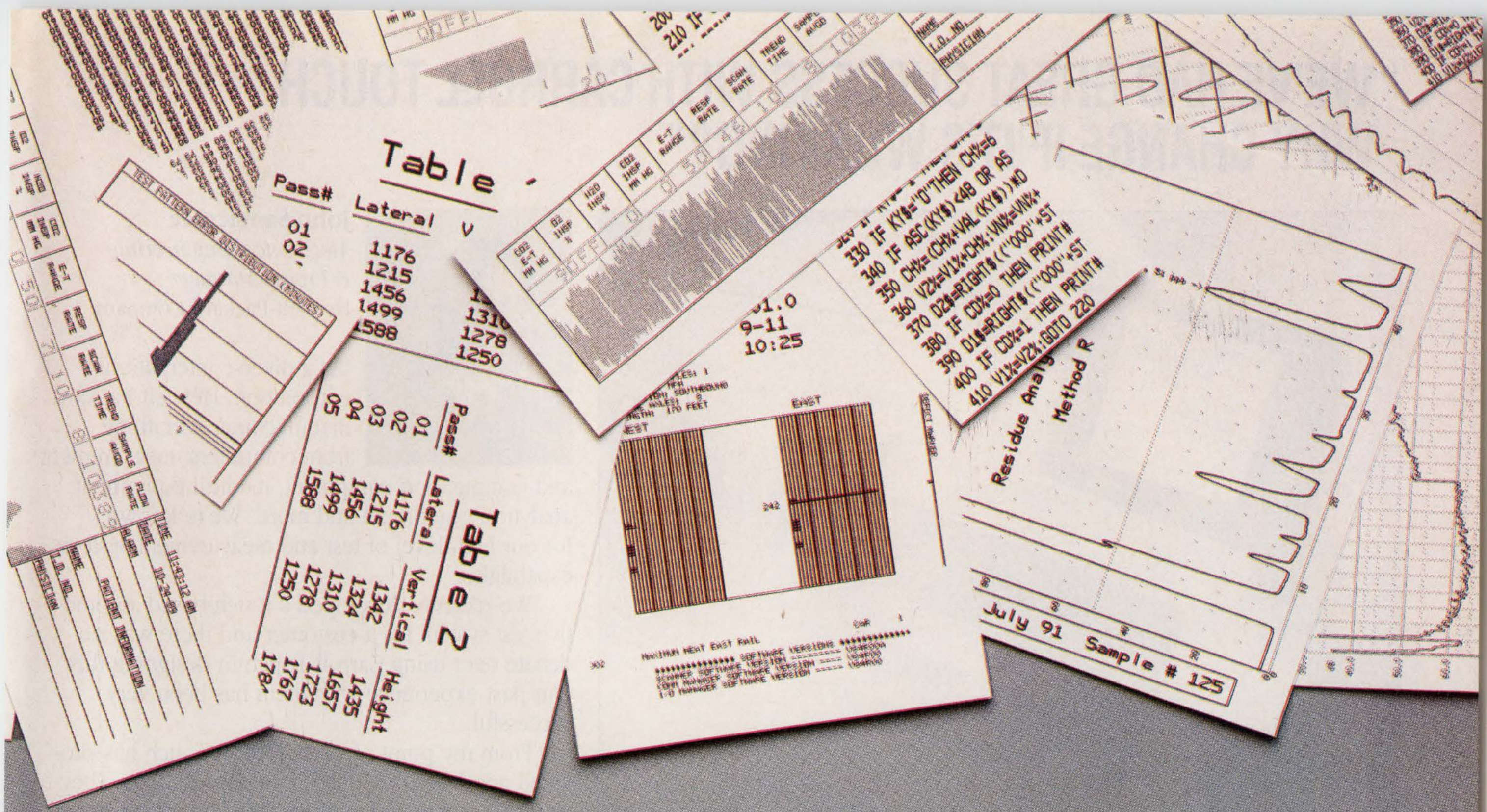
Table
Pass#
Lateral
Table 2
Vertical
Height
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Sample # 125
Residue Analy
Method R
330 IF KY$="0"THEN CH$=6
340 IF ASC(KY$)<48 OR AS
350 CH$=CH$+VAL(KY$))*D
360 V2$=V1$+CH$:VN$=VN$+
370 D2$=RIGHT$(("000"+ST
380 IF CD$=0 THEN PRINT#
390 D1$=RIGHT$(("000"+ST
400 IF CD$=1 THEN PRINT#
410 V1$=V2$:GOTO 220

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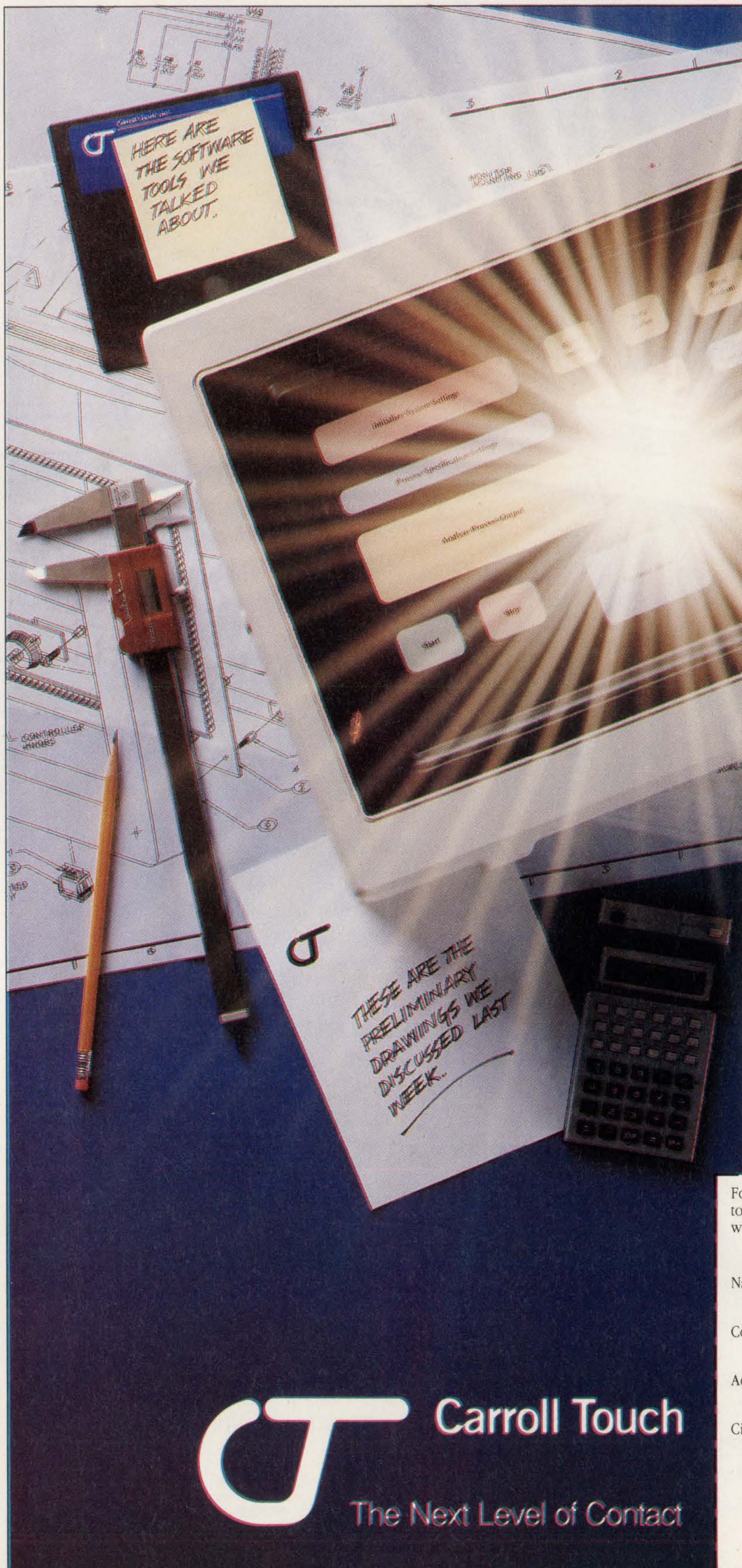

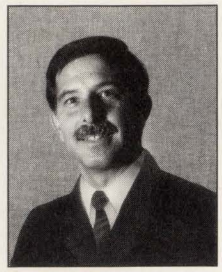

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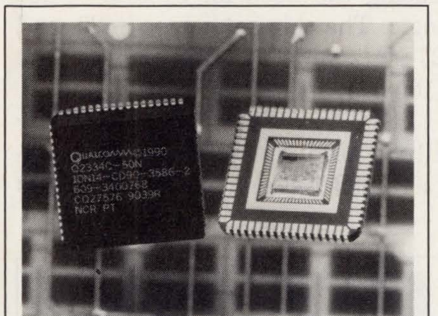

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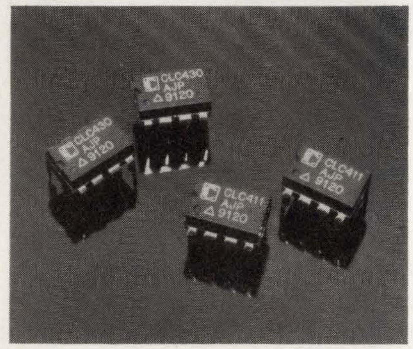

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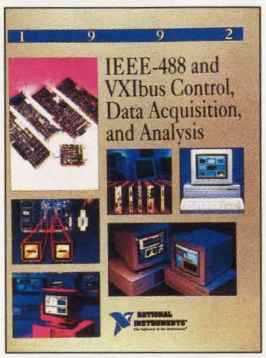

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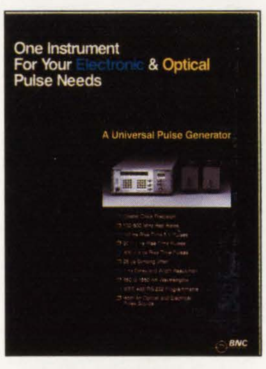

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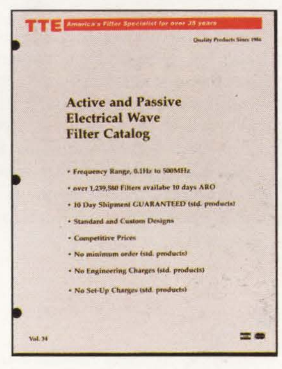

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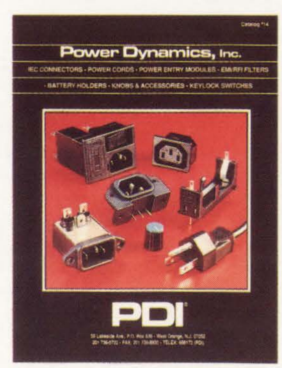

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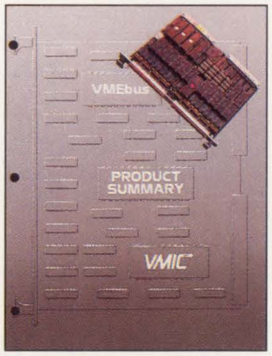

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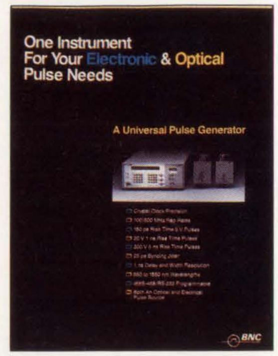

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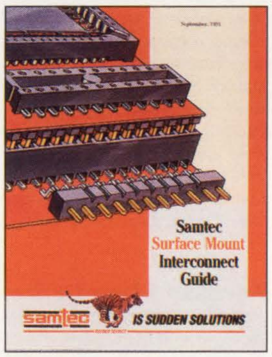

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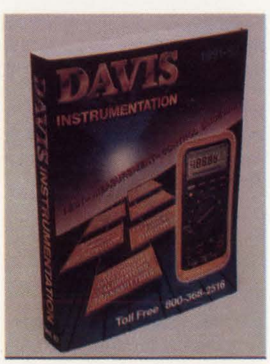

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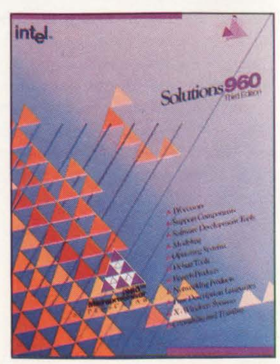
Circle # 13

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.

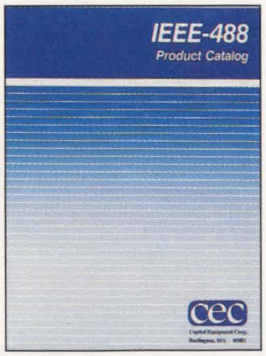


Intel Corporation
5000 W Chandler Blvd., CH3-61
Chandler, AZ 85226
800-548-4725

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.

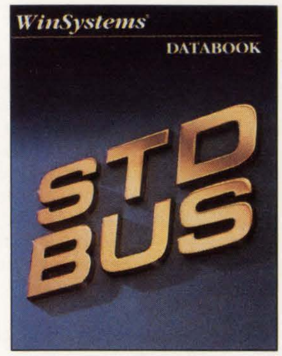


Capital Equipment Corpation
Burlington MA 01803
Literature: 800-234-4232;
Tech Support: 617-273-1818;
FAX: 617-273-9057

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

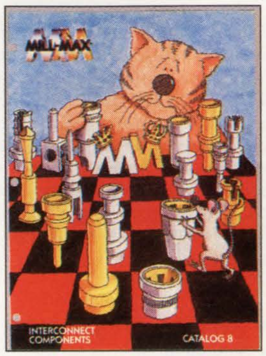


WinSystems, Inc.
715 Stadium Drive, Suite 100
Arlington, TX 76011
817-274-7553 FAX: 817-548-1358

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 .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.

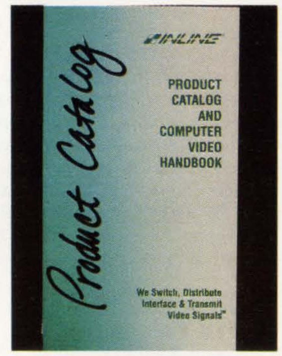


Mill-Max
190 Pine Hollow Road
Oyster Bay, NY 11771
516-922-6000 FAX: 516-922-9253

Circle # 32

COMPUTER VIDEO INTERFACING CATALOG AND HANDBOK

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.

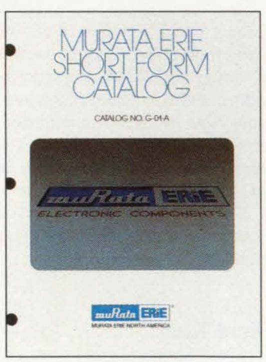


Communications Specialties, Inc.
89A Cabot Court
Hauppauge, NY 11788
516-273-0404 FAX: 516-273-1638

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

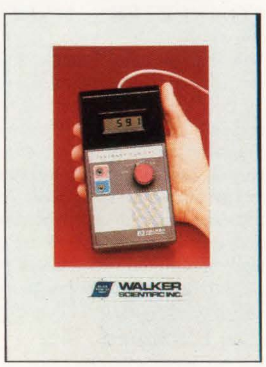
Powerful, easy-to-use electronic design with the Doulgas CAD/CAM Professional System. This fully-integrated package takes you from schematic drawing to final-routed board with the advantage of the remarkable graphics and ease of use of the Apple Macintosh. Features: unlimited multilayers, SMT support 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 (1nTes1a) 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 3½ digit LCD display provides a resolution of 0.05%.

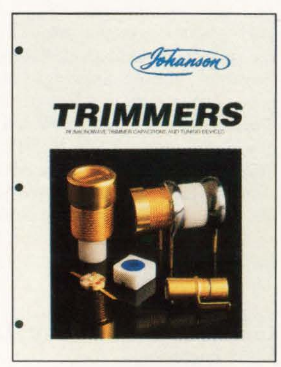


Walker Scientific Inc.
Rockdale Street
Worcester, MA 01606
508-852-3674

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.



Johanson Manufacturing Corporation
Rockaway Valley Road
Boonton, NJ 07005
201-334-2676

Circle # 22

AC/DC SWITCHING POWER SUPPLIES AND DC/DC CONVERTERS

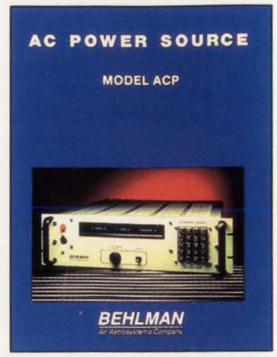
This 48-page catalog covers International Power Sources' AC/DC switching power supplies and DC/DC converters. New products include a DC/DC converter for use with flash memory, a 55W universal input tabletop switching power supply, and a 200-650W Eurorack series. Included are 1 to 150W printed circuit 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

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. Built-in computer allows preprogramming of desired events and computer interfacing. Models start as low as $4,430.

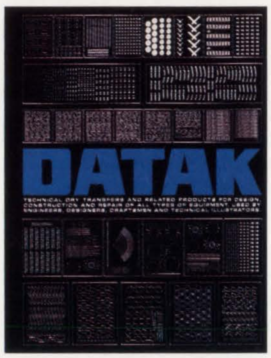


Behlman
6 Nevada Drive
Lake Success, NY 11042
800-456-2006 FAX: 805-642-0790

Circle # 24

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 of preset titles, letters, numbers, and symbols in all sizes. The printed circuit section describes Direct Etch™ and JotDraft™ patterns, PC repair kits, and fabrication supplies. 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

PUT THE FUN BACK INTO ELECTRONICS!

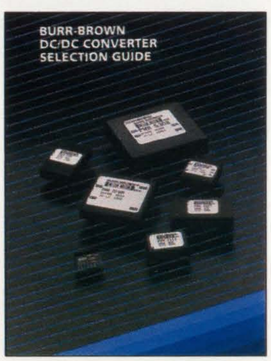
From low cost test and measurement equipment to valuable additions to your stereo, IV and computer systems, ELEKTOR ELECTRONICS runs the gamut every month! Elektro's eleven yearly issues average fourteen articles each, all world class electronic construction projects from intermediate to advanced-designed, 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

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

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 C.S.A. listed and approved. Call or FAX us your requirements for an immediate quotation.

Kord King
111 New Street
Mt. Joy, A 17552
717-753-8081 FAX: 717-653-6569

Circle # 28

POWER SEMICONDUCTORS & HV SUPPLIES

1991-92 Collmer catalog details Fuji Electric's power semiconductors. Ratings, specifications, outline drawings. Modules: power Darlington (with high-performance Z-Series); new high-gain 600V and 1200V; new 600V and 1200V IGFBT; diode bridge; intelligent power. Also MOSFETs, switching transistors, MOVs; 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 79925
214-233-1589 FAX: 214-233-0481

Circle # 29

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 torodial. 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

STANDARD LOW PRESSURE SENSORS

Monolithic Sensors Inc. offers a folder fully detailing the background and capabilities of the company. MSI engineers and manufactures 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

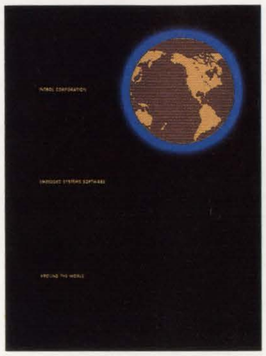
IC SOCKETS AND CONNECTORS

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

CROSS SOFTWARE, DEVELOPMENT TOOLS

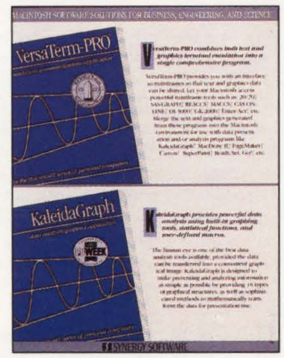


C and Modula-2 Cross Compilers, Macro Assemblers and Source Level Debuggers for Motorola and National Semiconductor families of microprocessors and microcontrollers. Introl software runs on MSDOS systems and most workstations.

Introl Corporation,
9220 W. Howard Avenue,
Milwaukee, WI 53228
414-327-7171 FAX: 414-327-7734

Circle # 33

VERSA TERM AND VERSA PRO

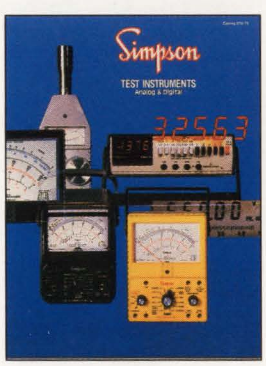


Our award winning text and graphics terminal emulation applications **VersaTerm** and **VersaTerm-PRO,** use Serial, LocalTalk or Ethernet (TCP/IP, Telnet, FTP, and LAT included) connections to access mainframes like DEC VAX, Cray, Prime and IBM. Our data analysis and graphing application, **KaleidaGraph**, 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

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

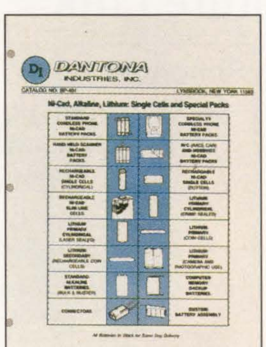
SIMPSON MICROPROCESSOR CONTROLLERS

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 5 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

BATTERIES—NI-CAD, ALKALINE AND LITHIUM

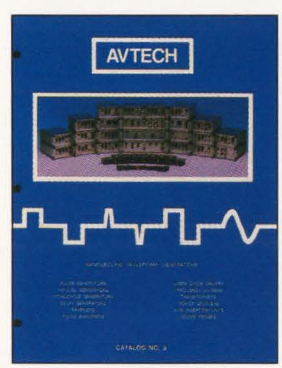


Dantona Industries now stocks thousands of batteries for Computers, Portable Phones, Medical, Military and Consumer uses. Our assembly capabilities have also been increased to include the manufacture of specialty packs for Medical, Military and OEM applications. Only the highest quality brand names like: Sanyo, Panasonic, Varta, Saft, Gates, Tadiran, Duracell 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

HIGH SPEED PULSE GENERATORS

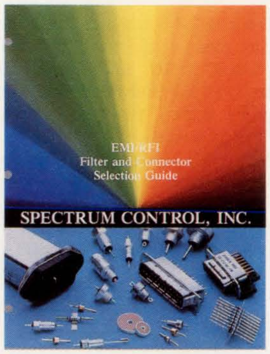


Over 300 unique models are listed in our new 113 page Catalog No. 8 with a selection of pulse and impulse generators, laser diode drivers, monocycle generators, amplifiers, samplers, delay generators, frequency dividers, pulse transformers, power splitters, scope probes, etc., for PRF to 250 MHz, rise 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.

Avtech Electrosystems 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 filter, resin sealed filters, hermetically sealed filters, multisection filters, filterplate 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

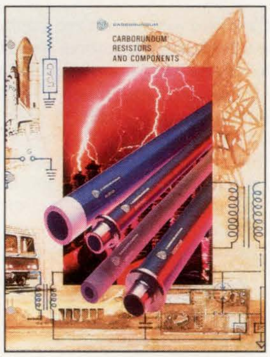
Universal Input (85-270 Vac) power supplies are featured in Integrated Power Designs' new catalog. Product families range from 45 to 115 watts, and offer one to four outputs.

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 1¼ 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

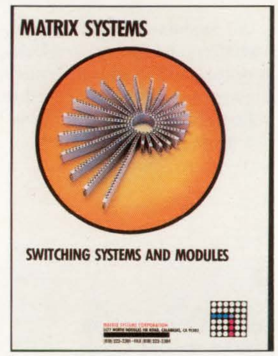


New brochure presents high-performance ceramic resistors that exceed performance of conventional film, composition and wire-wound resistors. Designed for high voltages, energies or frequencies. Resistors are available in three types: AS—high voltage/energy for capacitor crow bar circuits, pulse-forming 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

TTI's November 1991 Newsletter contains technical articles and news of training courses on Environmental Engineering, Contamination Control, Hazardous Materials Safety, ElectroStatic Dischare, more. Complete 1992 Open Training Schedule.

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**

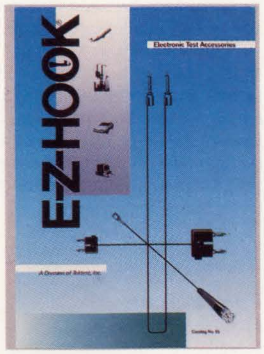
1992 Mailing Schedule

Issue Date	Closing Date
February 17, 1992	December 20, 1991
April 23, 1992	March 6, 1992
June 18, 1992	May 1, 1992
August 20, 1992	July 3, 1992
October 29, 1992	September 11, 1992
December 24, 1992	November 6, 1992

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.

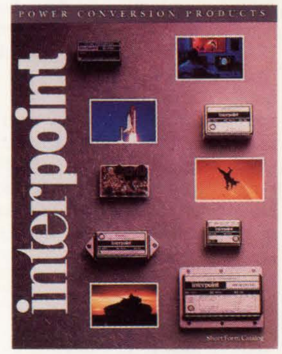


E-Z-Hook
P.O. Box 450
Arcadia, CA 91066
818-446-6175 FAX:818-446-0972

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.



800-822-8782 Ext. 241

Circle # 46

PROGRAMMABLE POSITION CONTROL

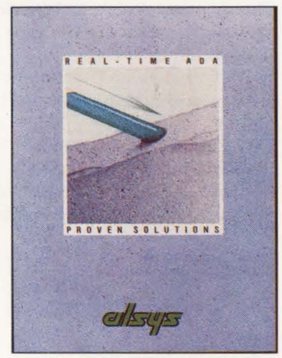
A complete 416 page engineer's guide with specifications, dimensions and performance data presents brushless servos, microstepping motor systems, indexes, linear motors and absolute encoders.

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

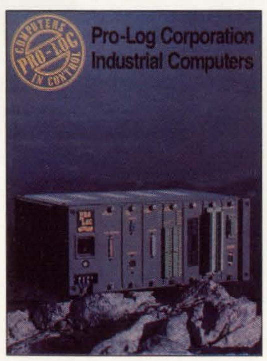


Alsys, Inc.
67 South Bedford Street
Burlington, MA 01803-5152
617-270-0030 FAX: 671-270-6882

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.



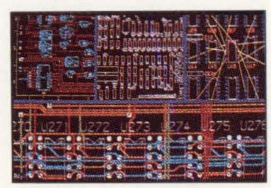
Pro-Log Corporation
2555 Garden Road
Monterey, CA 93940
800-538-9570 FAX: 408-646-3517

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
- 1-mil rip up and Retry Autorouter
- WINDOW 3.0 with VMS
- Opt Autoground plane and simulation



Design Computation, Inc.
1306 Highway 33
Farmingdale, NJ 07727
908-938-6661 FAX: 098-938-6662

Circle # 50

DAWN VME PRODUCTS FULL-LINE CATALOG

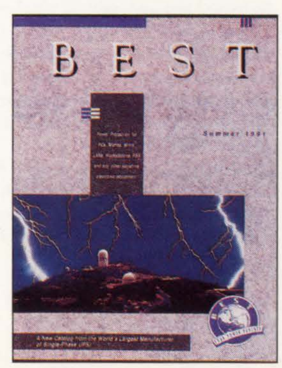
Dawn VME Products offers it's Product Catalog, filled with information on the full product line. Dawn's catalog includes both VMEbus and SUNbus backplanes, extender boards, slot bypass boards, slot load boards, card cages and enclosures, power supplies, fully assembled, packaged systems, and more. The 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

DATA CONVERSION COMPONENT DATABOOK

DATEL's new 294 page, data sheeet 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 dc or ac voltage and resistance. It's jaw-like clamp permits measurement without breaking the circuit or disturbing insulation. The unit features a 3½ digit LCD display and is accurate within 1%. The C-600 complies with IEC 348 Safety Requirements for Electronic Measuring Apparatus.

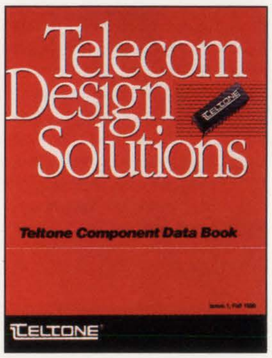
F.W. Bell, Inc.
6120 Hanging Moss Road
Orlando, FL 32807
407-678-6900

Circle # 54

TELECOM 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

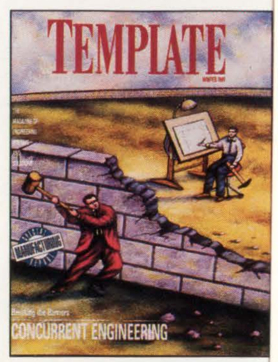


Teltone Corporation
22121-20th Avenue SE
Bothell, WA 98021-4408
800-426-3926 FAX: 206-487-2288

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

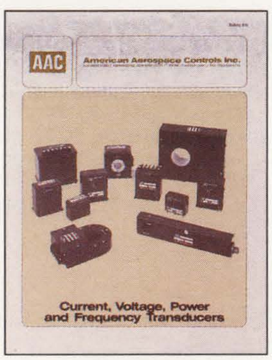


800-832-6979 ext TEMP

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 voltage sensors, watt and var transducers, bidirectional current sensors. Specifications, descriptions, photos of these units are provided as well as application and ordering information.

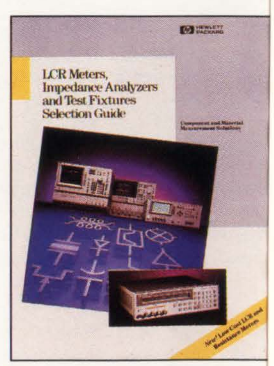


American Aerospace Controls, Inc.
570 Smith Street
Farmingdale, N.Y. 11735
516-694-5100 FAX: 516-694-6739

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 Pruneridge Ave., Bldg 49A
Cupertino, CA 95014-9795
800-452-4844

Circle # 58

E(E)PROM PROGRAMMERS

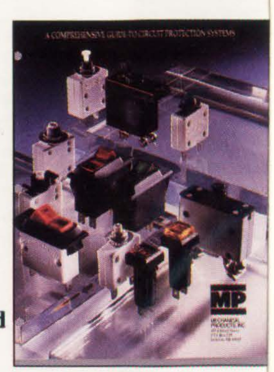
Reliable, fast and easy to use, Needham's Electronics E(E)Prom programmers are available in PC based or stand-alone models. Supporting 2716-4Megabit devices, Needham's programmers are capable of support for the latest in EPROM technology. Whether your needs are development or production, Needham's Rlectronics 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

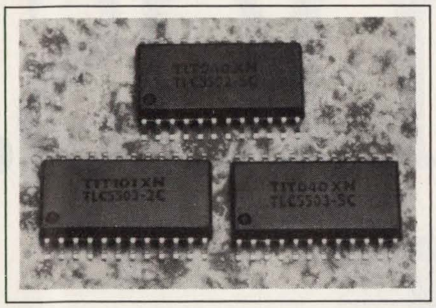
FREE CIRCUIT PROTECTION CATALOG

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
517-782-0391 FAX: 517-782-2810

Circle # 60



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.

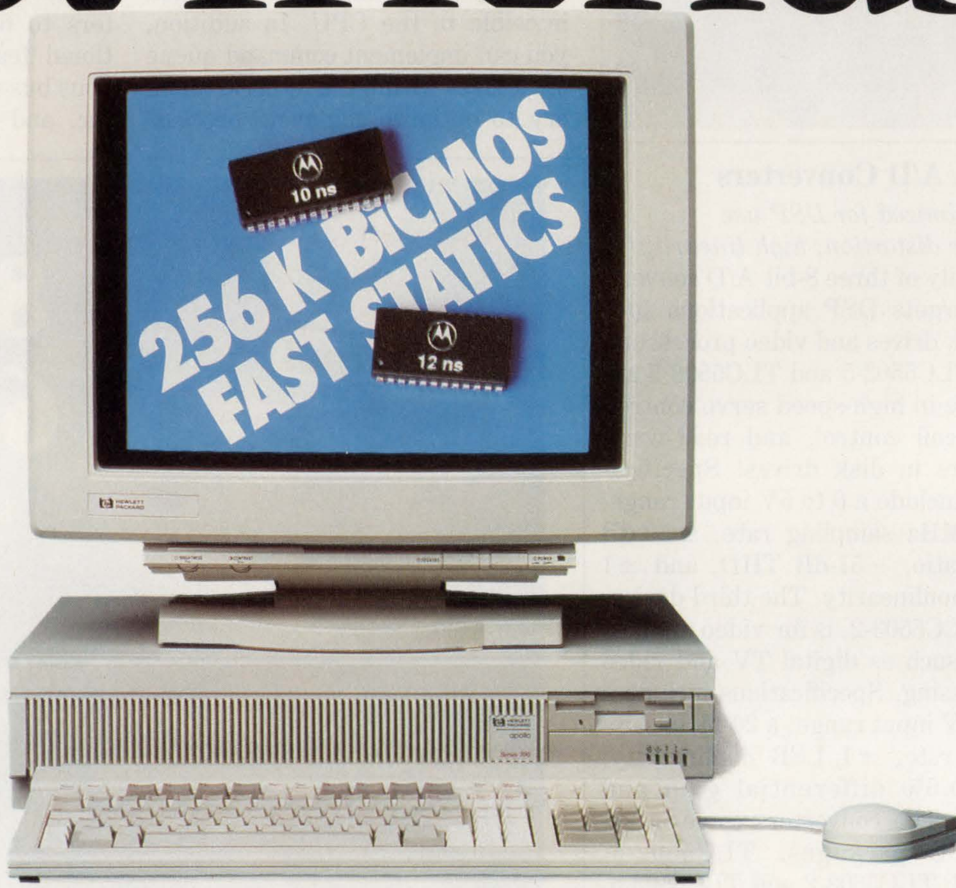
Circle No. 392

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

Fast friends.



Motorola and Hewlett-Packard.

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.

MOTOROLA

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).

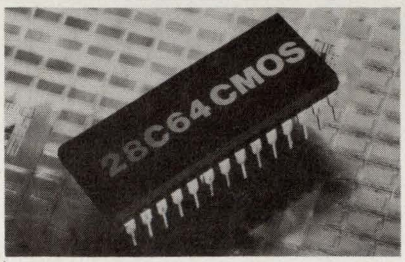
GEC Plessey Semiconductor, 1500 Green Hills Rd, Scotts Valley, CA 95066. Phone (408) 438-2900. **Circle No. 394**

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**



Serial EEPROMs With Extended Features

- *V_{CC} lockout for write protection*
- *Low power consumption*

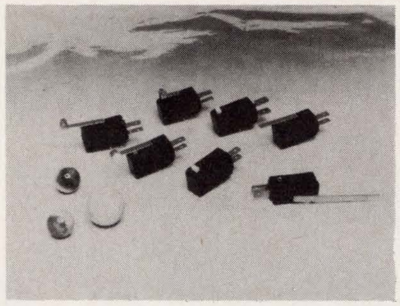
The XL93LC06 (256-bit) and XL93LC46 (1k-bit) EEPROMs include several features that enhance performance. A V_{CC} lockout function provides protection from inadvertent write commands, and an auto-increment feature allows the devices to output a continuous stream of memory content in response to a single read instruction. An operating current of 2 mA and a standby current of 2 μA ensure low power consumption. Both devices are compatible with the Microwire standard for serial data storage and transfer. Package options include 8-pin DIP and SO in a choice of standard pinouts. In an 8-pin DIP, XL93LC06, $0.68; XL93LC46, $0.73 (1000).

Exel Microelectronics, Box 49038, San Jose, CA 95161. Phone (408) 432-0500. **Circle No. 396**


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.

1GB-plus Disk Drive Comparison Criteria	Maxtor Panther P0-12S	Seagate Wren 7
Capacity (unformatted)	1.2GB	1.2GB
Seek Time	13ms	15ms
Track-to-Track	2ms	2.5ms
Internal Transfer	17.4 to 29.7Mb/s	15-23Mb/s
Maximum Seek	26ms	34ms

Novell Labs Tested & Approved
We Drive Harder.
Maxtor®
© 1991 Maxtor Corporation
® Panther is a registered trademark of Maxtor Corp.
CIRCLE NO. 176



Miniature Switches

- *Available in two styles*
- *Rated for 15.1A operation*

V7 Timesaver Series miniature on-off/off-on 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 Filatex textile 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 0.1×0.1-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 8003, Painesville, OH 44077. Phone (216) 354-3148. FAX (216) 354-0509.

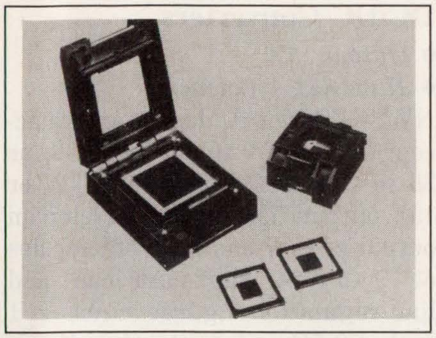
Circle No. 381

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, $10; SMD Series, $20; SMMD Series, $22 (100).

Engineered Components Co, Box 8121, San Luis Obispo, CA 93403. Phone (805) 544-3800. FAX (805) 544-8091. **Circle No. 382**

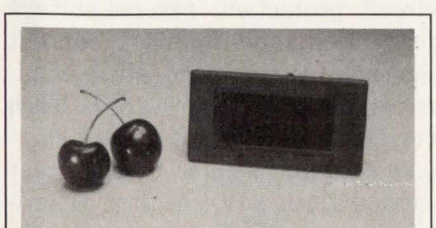


Test Sockets

- *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. Receptacles are available for all sockets in the series. A 256-lead, 46-mm version, $105.40 (250).

CTI Technologies Inc, 7855 E Evans Rd, Suite A, Scottsdale, AZ 85260. Phone (602) 998-1484. FAX (602) 483-2731. **Circle No. 383**



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 $10^9\Omega$, and supply requirements are 5V at 130 mA. Decimal-point position is user selectable. The unit measures 3.1×1.7×0.95 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**

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 2×2×0.4 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 10^6 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 1.25×0.80×0.4-in. phenolic package that carries a UL 94V-0 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

National Semiconductor

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.

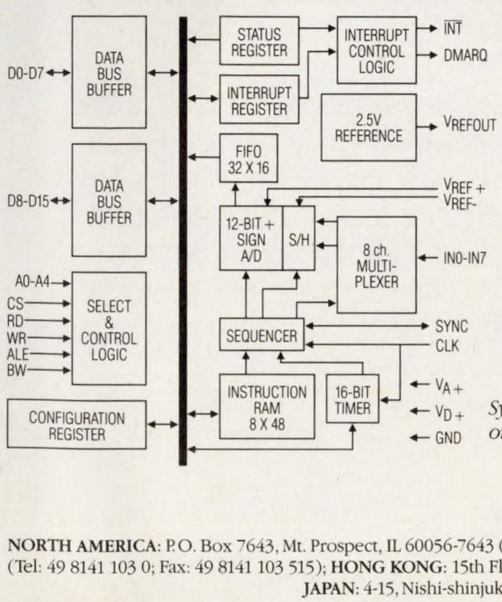
That's why we designed the industry's first +5V 12-bit plus sign Data Acquisition System, the LM12458. A highly integrated one-chip solution that not only shrinks board space but also reduces design and debug time.

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.



System-level integration on a single chip.

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.

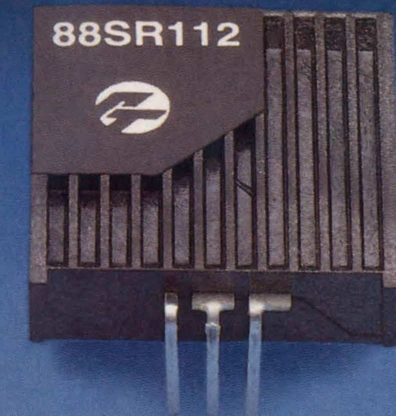
National Semiconductor

NORTH AMERICA: P.O. Box 7643, Mt. Prospect, IL 60056-7643 (Tel: 1 800 628 7364, ext. 143; Fax: 1 800 888 5113); **EUROPE:** Raiffeisenstraße 10, D-8016 Feldkirchen, Germany (Tel: 49 8141 103 0; Fax: 49 8141 103 515); **HONG KONG:** 15th Floor, Straight Block, Ocean Center, 5 Canton Rd., Tsimshatsui, Hong Kong (Tel: 852 737 1600; Fax: 852 736 9921); **JAPAN:** 4-15, Nishi-shinjuku, Shinjuku-ku, Tokyo, Japan 160 (Tel: 81 3 3299 7030; Fax: 81 3 3374 4303).

THE POWER CHIPSET™ FOR NOTEBOOK COMPUTERS

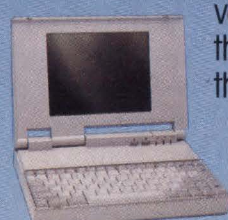
(Actual size: 1"x 1")

A fully self-contained 3 Amp, 1 MHz, step-down Integrated Switching Regulator



A fully self-contained 1 MHz step-up Boost Converter

This new *Power Chipset*™ from Power Trends provides the entire power supply for your notebook computer in less than 1 cubic inch. It features a +5 volt, 3 Amp, 1 MHz Integrated Switching Regulator (ISR) that provides state-of-the-art power density of more than 50 watts per cubic inch and a high 85% efficiency at maximum load. **This means less board space and longer battery life!**



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.

POWER TRENDS

Power Trends, Inc. 1101 North Raddant Road, Batavia, IL 60510 • (708) 406-0900 • FAX (708) 406-0901

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 $LiMnO_2$ 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).

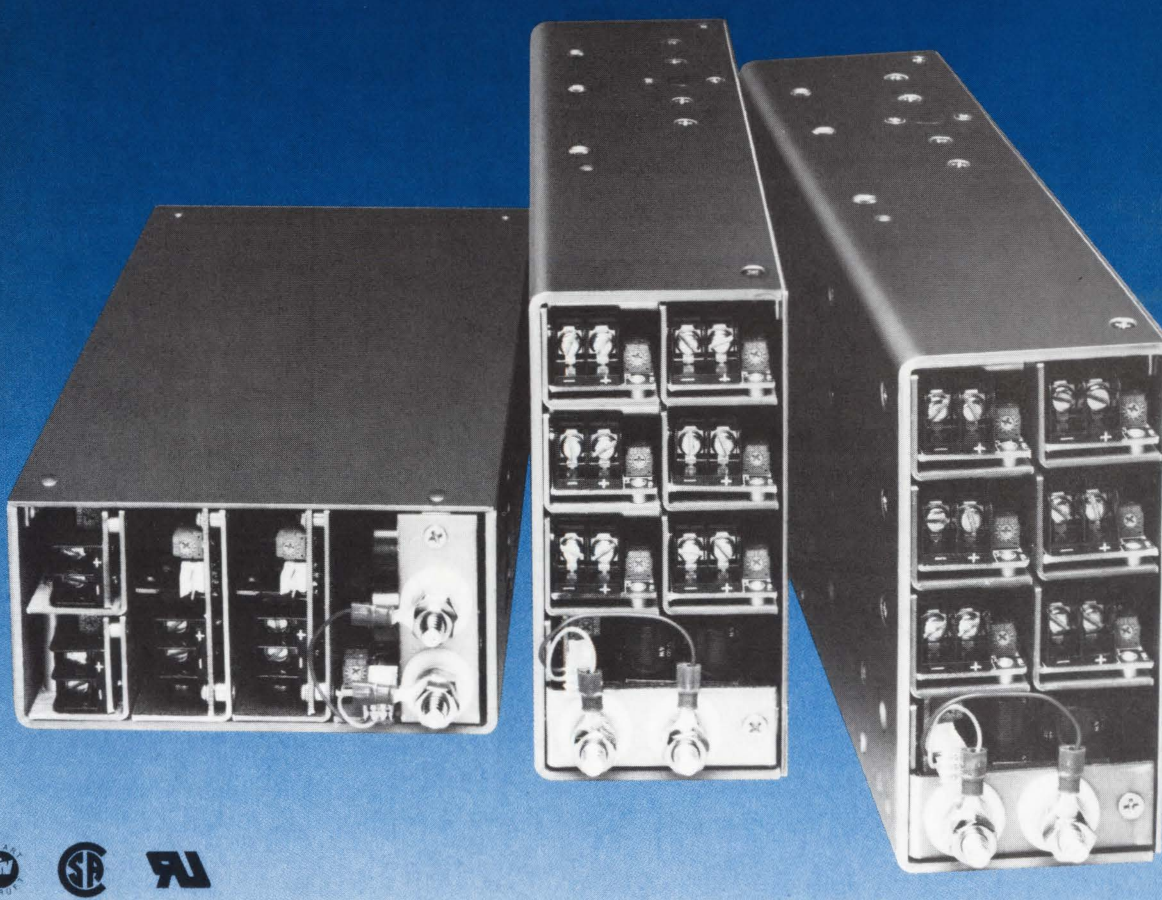
Okaya Electric America Inc, 503 Wall St, Valparaiso, IN 46383. Phone (219) 477-4488. FAX (219) 477-4856. **Circle No. 388**

VM SERIES BUS SWITCHERS– VME, VXI, FUTUREBUS

10 Watts/Cu.In. @ 50°C !

Unique Deltron MODUFLEX Design

- Modular High Density Construction
- FINTEGRA – Distributed Thermal Management with Cooling Fins Integral to Each Module



- 1 to 7 outputs
- 400 to 1500 watts
- 120 kHz. MOSFET design
- Current mode control
- All outputs regulated and floating

Call Toll Free 1-800-523-2332
In PA: 215/699-9261

Deltron inc.
POWER PRODUCTS

VM-101 3/91

SPECIFICATIONS

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.

LINE REGULATION
Less than ±0.1% or ±5mV for input changes from nominal to min. or max. rated values.

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 UNDERVOLTAGE
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

CASE	WATTS	H	x	W	x	L
1	400 W/500 W	2.5"	x	5.05"	x	9.0"
2	750 W	2.5"	x	5.20"	x	9.63"
3	1000 W	5.0"	x	5.05"	x	10.4"
4	1500 W	5.0"	x	5.20"	x	11.0"
5	860W	2.5"	x	5.0"	x	6.85"

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.

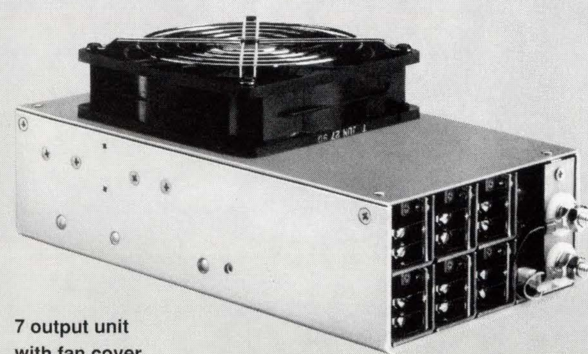
VM Series feature outstanding quality, insuring full compliance to specifications, reliable field operation and long service life. This exceptional quality is a result of three major efforts.

- 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.*



7 output unit
with fan cover

SINGLE OUTPUT MODELS

Model	VDC	Amps	
VM12D0-YY	2VDC	150A	Nominal Power 860 W Case 5
VM12D1-YY	3.3VDC	150A	
VM12D2-YY	5VDC	150A	
VM12D3-YY	12VDC	72A	
VM12D4-YY	15VDC	57A	
VM12D6-YY	24VDC	36A	
VM12D9-YY	48VDC	18A	

MULTIPLE OUTPUT MODELS

Model VM1A-YY
Total Power: 400 Watts
Case: 1
Ratings: 5VDC @ 50A, 5VDC @ 10A, 12VDC @ 12A, 12VDC @ 6A

Model VM2A-YY
Total Power: 400 Watts
Case: 1
Ratings: 5VDC @ 50A, 12VDC @ 6A, 12VDC @ 6A, 24VDC @ 6A

Model VM1B-YY
Total Power: 500 Watts
Case: 1
Ratings: 5VDC @ 80A, 5VDC @ 10A, 12VDC @ 12A, 12VDC @ 12A

Model VM2B-YY
Total Power: 500 Watts
Case: 1
Ratings: 5VDC @ 80A, 12VDC @ 12A, 12VDC @ 6A, 24VDC @ 6A

Model VM3B-YY
Total Power: 500 Watts
Case: 1
Ratings: 5VDC @ 80A, 12VDC @ 12A, 24VDC @ 6A, 5VDC @ 10A, 12VDC @ 6A

Model VM1D-YY
Total Power: 750 Watts
Case: 2
Ratings: 5VDC @ 120A, 12VDC @ 12A, 24VDC @ 6A, 5VDC @ 10A, 12VDC @ 6A

Model VX1B-YY
Total Power: 500 Watts
Case: 1
Ratings: 5VDC @ 30A, 2VDC @ 10A, 5VDC @ 10A, 12VDC @ 6A, 12VDC @ 6A, 24VDC @ 3A, 24VDC @ 3A

Model VX1D-YY
Total Power: 750 Watts
Case: 2
Ratings: 5VDC @ 60A, 2VDC @ 12A, 5VDC @ 12A, 12VDC @ 8A, 12VDC @ 8A, 24VDC @ 4A, 24VDC @ 4A

Model VX1E-YY
Total Power: 1000 Watts
Case: 3
Ratings: 5VDC @ 80A, 2VDC @ 20A, 5VDC @ 20A, 12VDC @ 10A, 12VDC @ 10A, 24VDC @ 5A, 24VDC @ 5A

Model VX1F-YY
Total Power: 1500 Watts
Case: 4
Ratings: 5VDC @ 120A, 2VDC @ 30A, 5VDC @ 30A, 12VDC @ 15A, 12VDC @ 15A, 24VDC @ 8A, 24VDC @ 8A

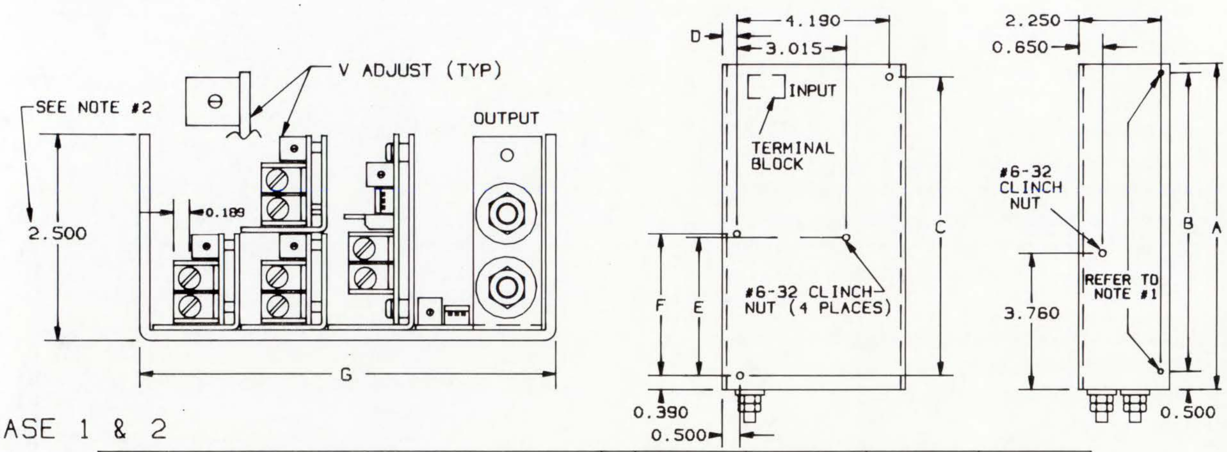
OPTIONS

Code	Function	Code	Function
00	None	04	EMI Filter
01	Power Fail	32	Cover
02	Auto Ranger	64	Fan Cover

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:

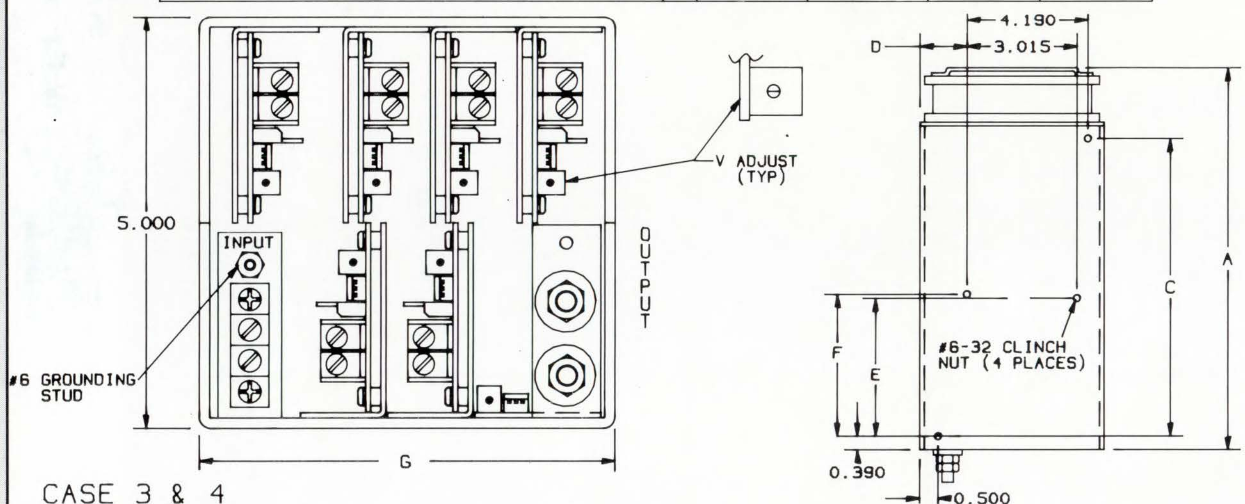
(1) WITH COVER (#6-32), W/O COVER (.150 DIA.)

(2) W/FAN COVER UNIT HEIGHT (4.100)

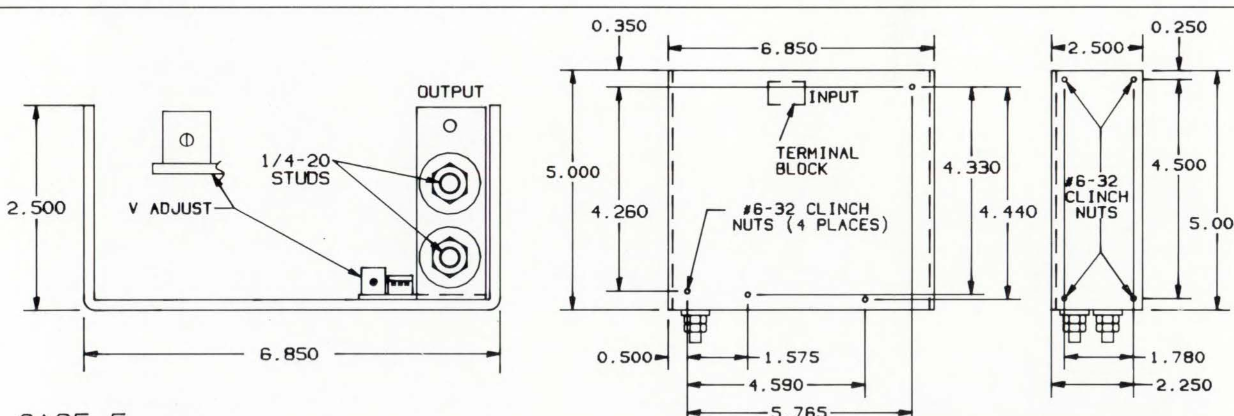
(3) TERMINAL BLOCKS (#6-32)

(4) STUDS (1/4-20)

	CASE 1	CASE 2	CASE 3	CASE 4
	400/500 W	600/750 W	1000W	1500W
A	9.000	9.630	10.400	11.000
B	8.250	8.880	-----	-----
C	8.260	8.890	8.260	8.890
D	.410	.425	.410	.425
E	3.820	4.450	3.820	4.450
F	3.930	4.560	3.930	4.560
G	5.050	5.200	5.050	5.200



CASE 3 & 4



CASE 5

Deltron inc.

290 WISSAHICKON AVENUE, P.O. BOX 1369, NORTH WALES, PA 19454
PHONE: 215/699-9261 • FAX: 215/699-2310

Int'l. Units: Delaire • Sallynoggin Road, Dun Laoghaire, Co. Dublin, Ireland. Tel: (01) 851411 Prefixes – from U.K. – (0001)–Int'l. + 353–(1) Telex: 30442DEL EI
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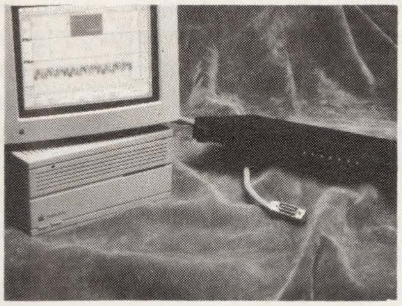
TEST & MEASUREMENT INSTRUMENTS



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.

IOtech Inc, 25971 Cannon Rd, Cleveland, OH 44146. Phone (216) 439-4091. FAX (216) 439-4093. TWX 650-282-0864.

Circle No. 410

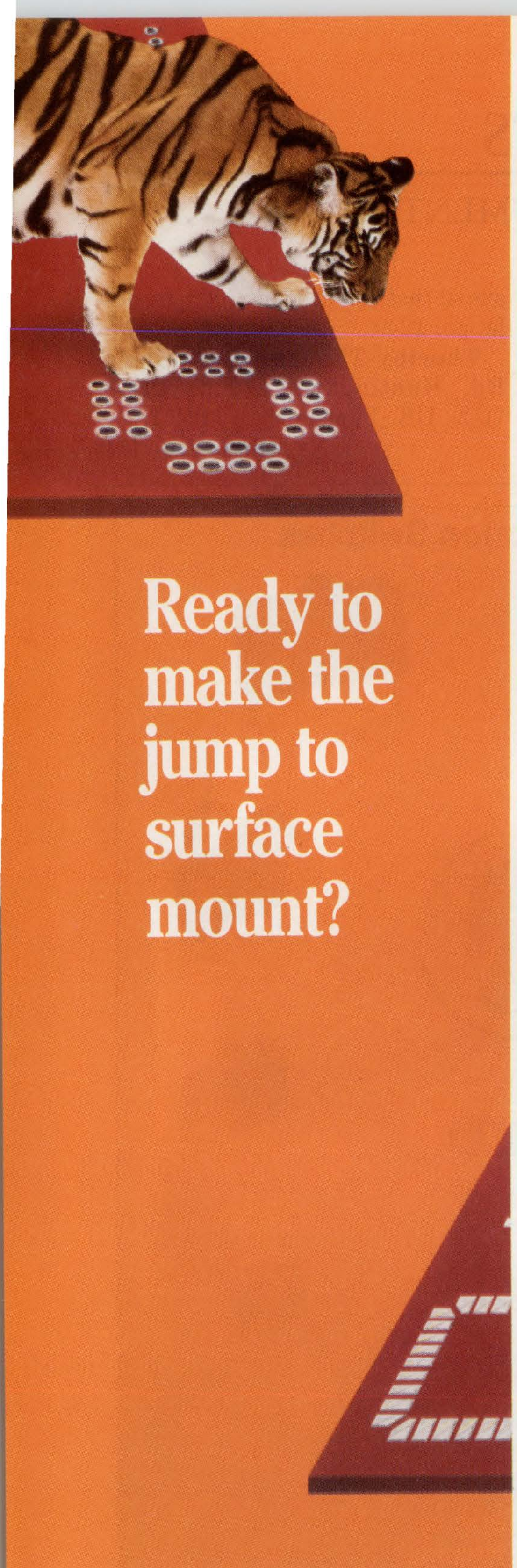
Function Generator

- *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



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.

Contec Microelectronics USA Inc, 2188 Bering Ave, San Jose, CA 95131. Phone (800) 888-8884; (408) 434-6767. FAX (408) 434-6884.
Circle No. 412

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.

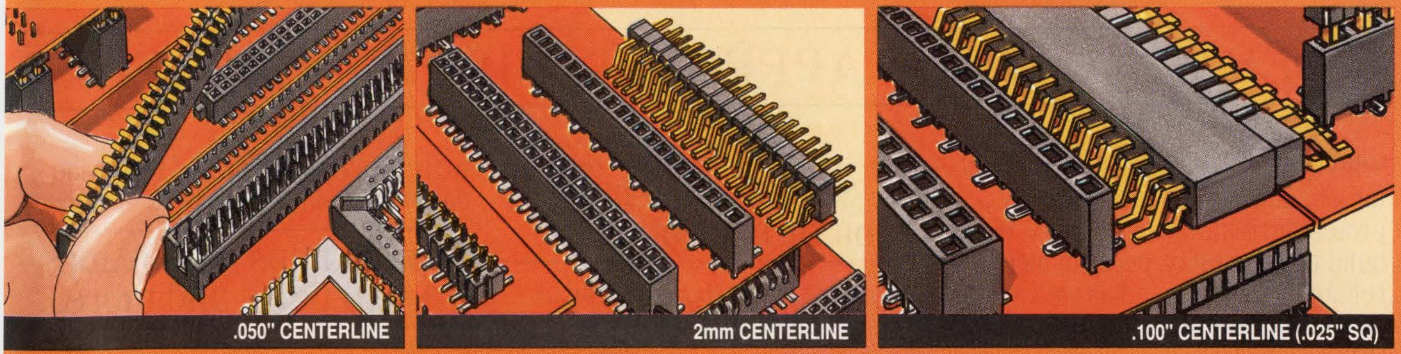
Pragmatic Instruments Inc, 7313 Carroll Rd, San Diego, CA 92121. Phone (619) 271-6770. FAX (619) 271-9567. **Circle No. 413**

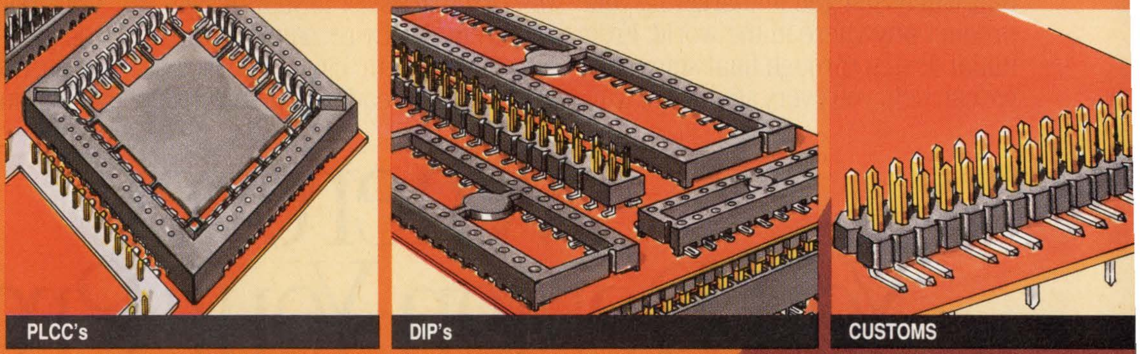
Coprocessor For Micro Channel Architecture Bus

- *Consists of two boards*
- *Switches between Basic and DOS with simple commands*

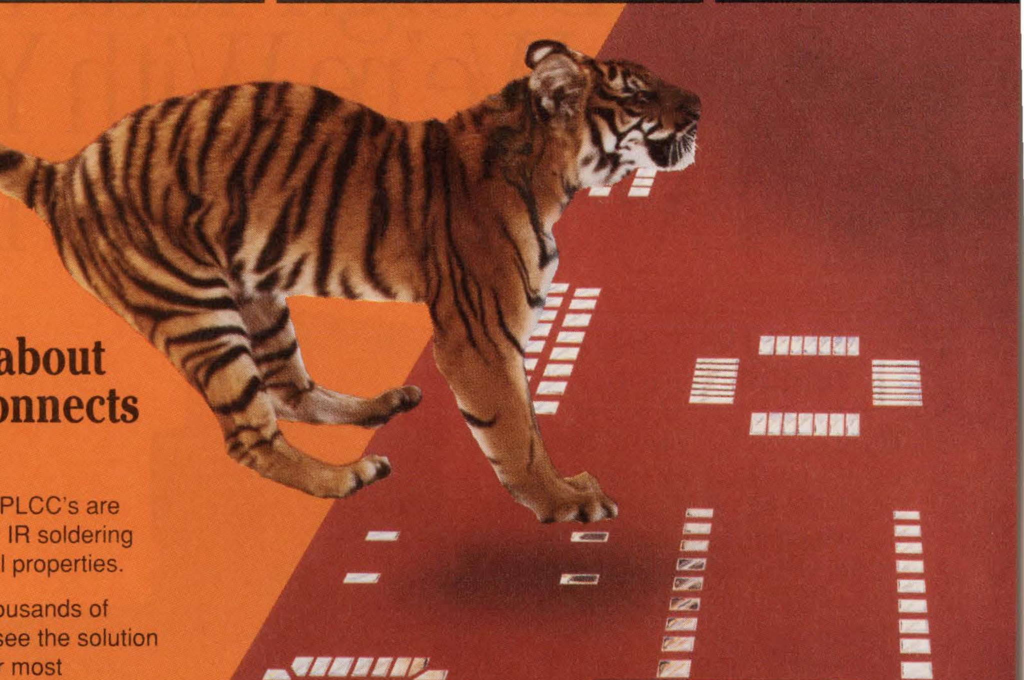
A set of two boards for the Micro Channel Architecture bus of the IBM PS/2 family lets these PCs run Hewlett-Packard Basic and Basic Plus—dialects of the popular programming language tailored to instrument control. The Microcat board set lets you invoke simple commands to switch rapidly between the MS 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**





Samtec SMT solutions assure a safe landing!



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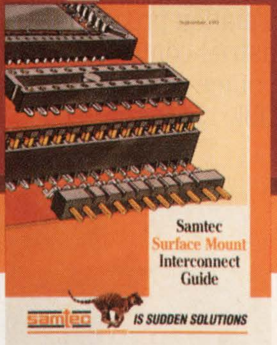

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CIRCLE NO. 193

INTERNATIONALLY APPROVED CIRCUIT BREAKERS

When you're designing your product for global markets, take steps to protect it right. Choose Airpax. We build in the quality, performance and reliability you demand as well as the required international certification that will assist you in marketing your product anywhere in the world. From initial design through final shipment we can help you every step of the way.

Step-by-step help on three continents.

Engineers at our design/manufacturing centers in Belgium, Japan and the U.S. will assist in your design requirements by recommending the correct magnetic circuit breaker. When you're ready to manufacture, we're strategically located to provide on-time/just-in-time delivery anywhere.

50 milliamps to 100 Amps, 1 to 6 poles and more.

Consider your choices: SNAPAK® in rocker, toggle, paddle, baton, push-pull or push-to-reset styles; IEL, DIN rail mount in single or multi-handle; IEG in a toggle and snap-in mount; and E-Frame branch circuit protectors. Designed to withstand shock, vibration and temperature variances.

Wherever You Design Your Product, We're With You Every Step Of The Way.

UL, VDE, CSA, TUV and SEV approvals.

For any international marketer, it can be a maze of acronyms out there. Not for Airpax, because ours is the broadest line of magnetic circuit breakers fully accepted for international applications in marine, instrumentation, medical systems, appliances, power supplies, information processing systems, industrial controls, HVAC equipment and other devices that demand reliable circuit protection.

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CIRCLE NO. 195

AIRPAX®

A North American Philips Company.

2.4-GHz Frequency Counter

- *Has 8-digit readout and 2-digit price*
- *Has 10-mV sensitivity*

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 3090 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 autoset 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, 5600MD 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

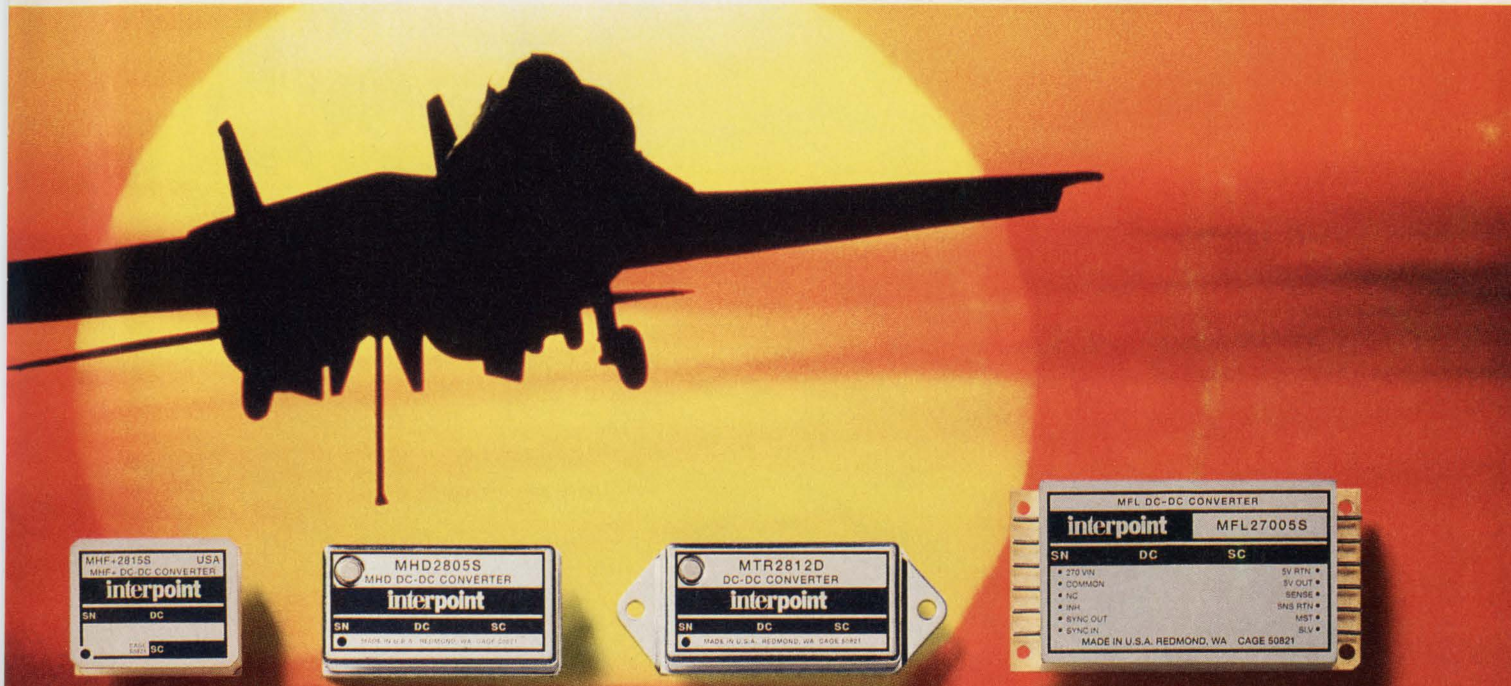
- *Uses 7-in. space in equipment rack*
- *Houses eight 150W modules*

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 dc-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

Our newest line of defense against heat.



MHF+ Series: 15 W, 125° C. MHD Series: 20 W, 125° C. MTR Series: 30 W, 125° C. MFL Series: 65–200 W, 125° C.

Insist on Interpoint.

A full line of high-temperature DC-DC converters from the industry leader.

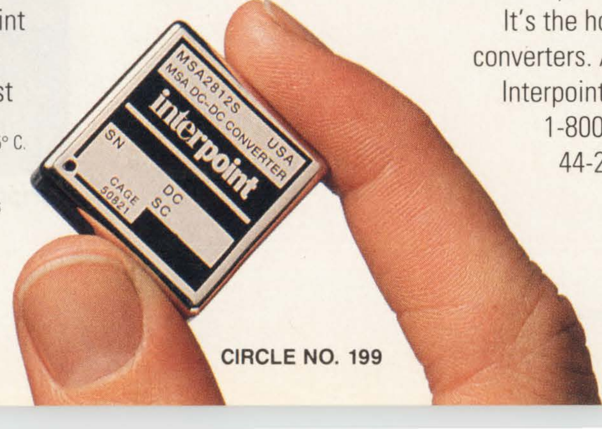
Get the hottest technology in board-mounted power supplies. Full military temperature range. Unsurpassed reliability. The lowest profiles. You can get it all with Interpoint's new line of DC-DC converters.

From arctic blasts to desert storms, Interpoint's new generation DC-DC converters stand up to the toughest military environments. They deliver full power over the entire -55° to +125° C. temperature range. And over an unprecedented power range, too. Interpoint can now offer you an off-the-shelf hybrid power supply for any power level from 2 to 200 watts.

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.



MSA Series: 5 W, 125° C.

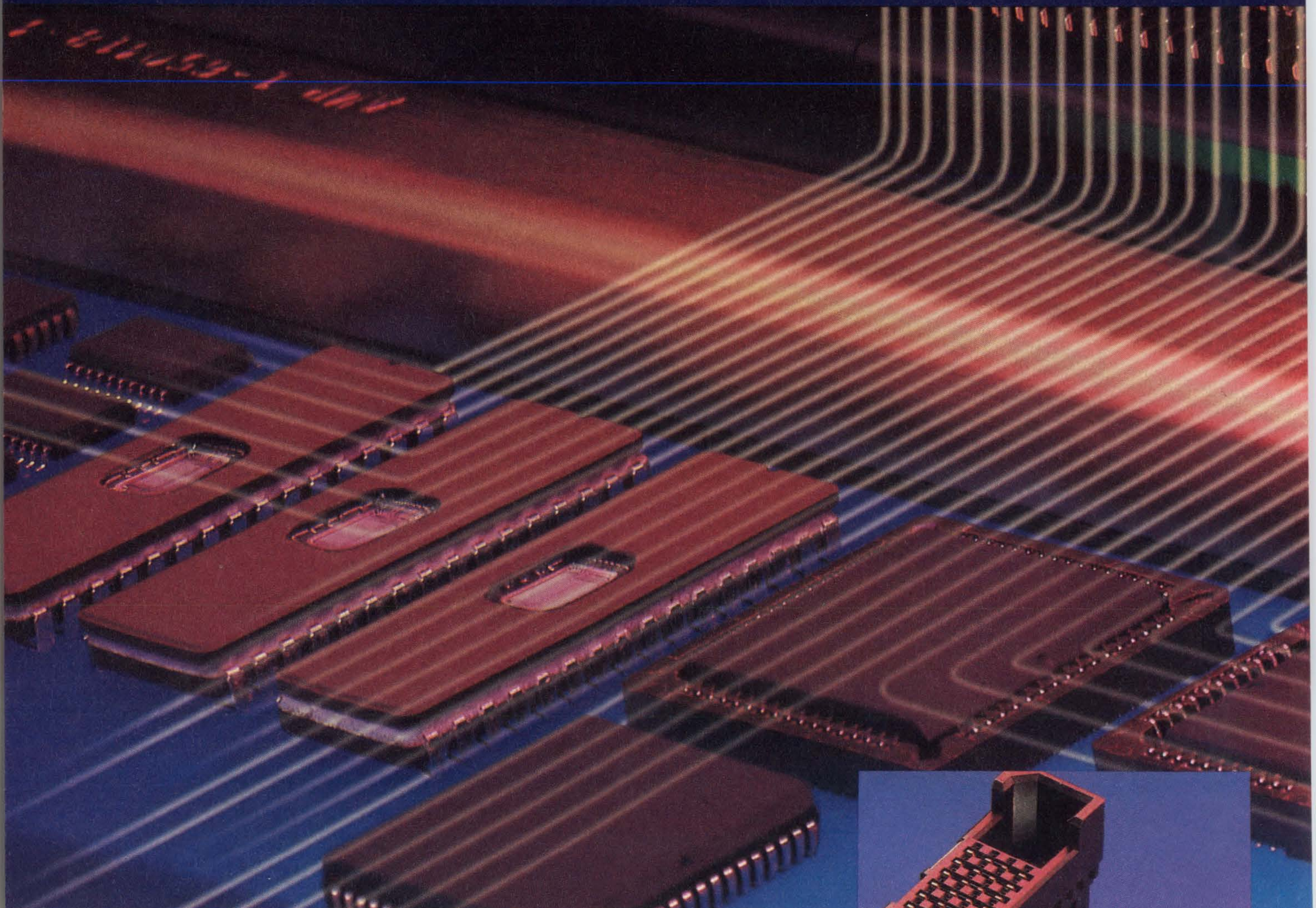
Interpoint's new line of DC-DC converters features constant PWM switching frequencies from 500 to 700kHz. Built-in sync. Parallel operation. Up to 50 dB audio rejection. Line and load regulation as low as 0.1%. And full MIL-STD-704 input for 28- and 270-volt systems.

interpoint

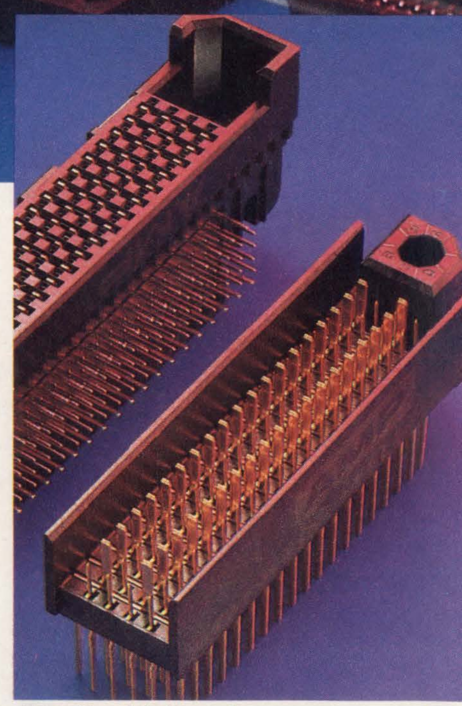
10301 Willows Road P.O. Box 97005
Redmond, WA 98073-9705

CIRCLE NO. 199

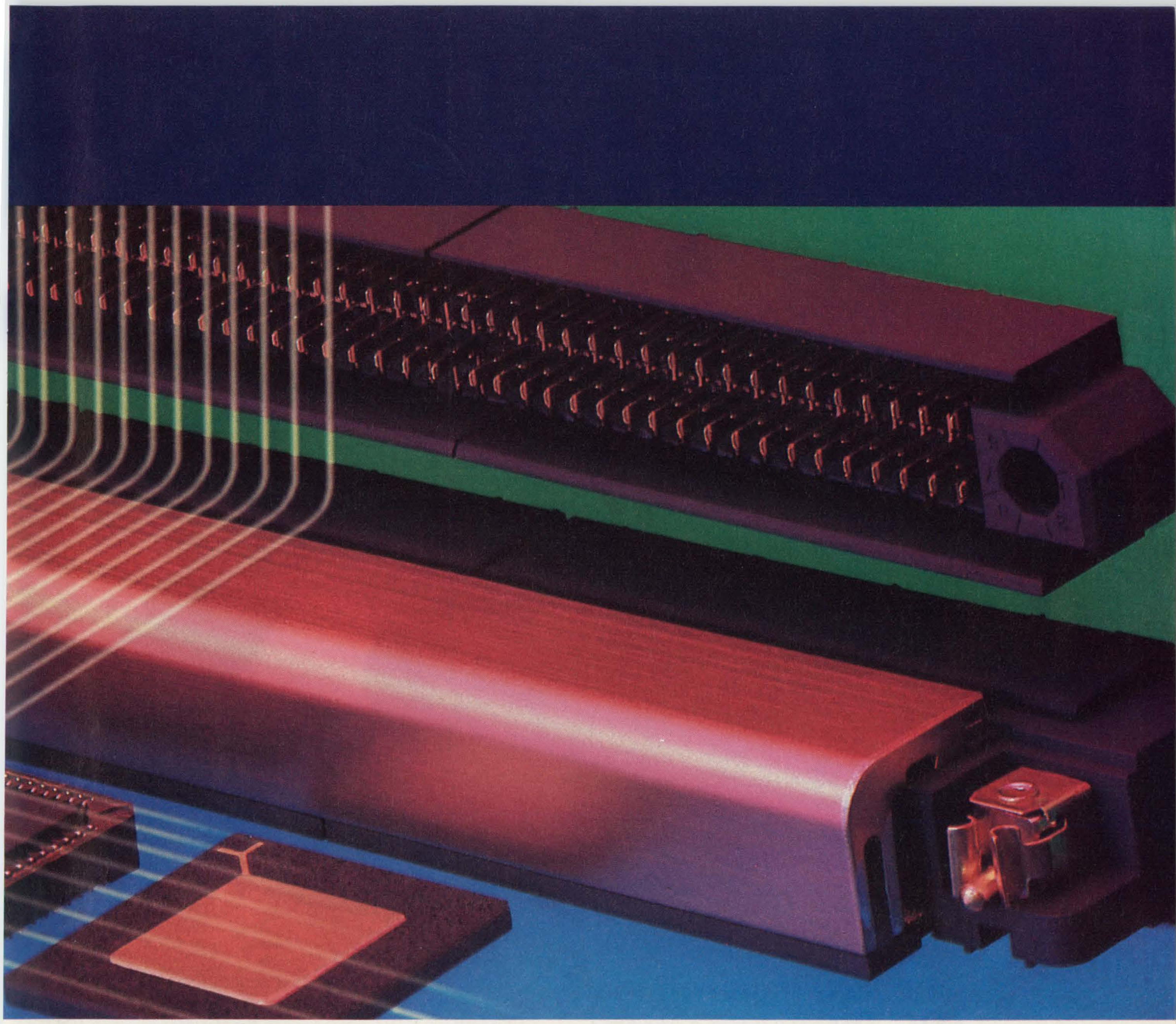
Making the interface transparent to sub-nanosecond rise times.



THIS IS AMP TODAY.



Stripline high-performance connectors.



'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.

AMP

CIRCLE NO. 273

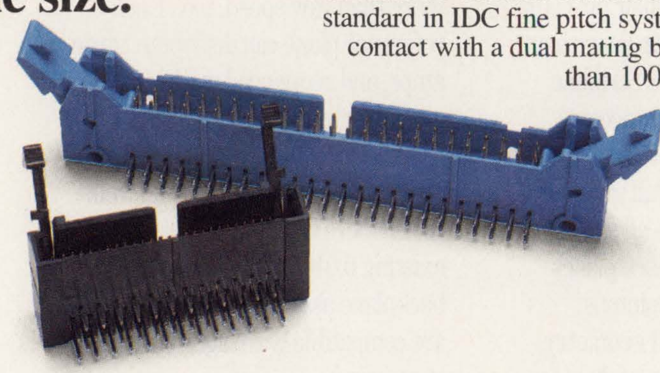
The next generation of IDC Interconnection:

Same performance, one-half the size.

System 311 is the next generation of reliable high performance IDC mass termination systems from Thomas & Betts, a pioneer in the development of IDC.

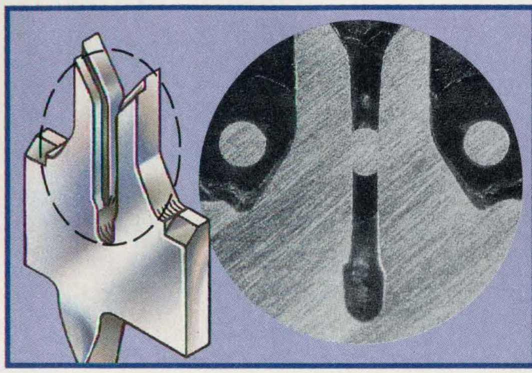
A natural evolution, the new System 311 combines the finest capabilities of our proven Ansley® IDC System, downsized and precision engineered to terminate .025 pitch cable.

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,

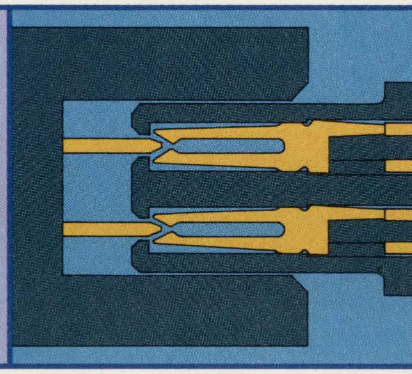


• *NORTH AMERICA* – **Canada:** 708-357-0404; **Mexico:** Naucalpan, 905-393-85-10 • *PACIFIC* – **Australia:** Wyong North, NSW, 61-43-53-2300; **Hong Kong:** Kowloon, 852-739-1286; **Japan:** Tokyo, 81-3-3791-6411; **Singapore:** 65-747-0244; **Taiwan:** Taipei, 886-2-713-0509

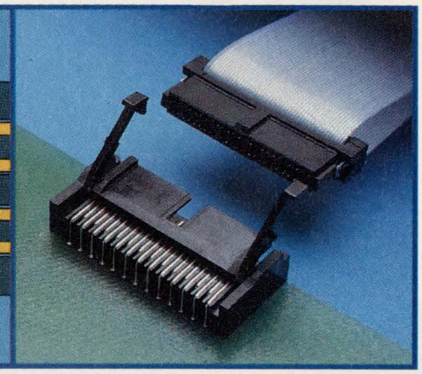
TION



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.

Thomas&Betts

• ***EUROPE*** **– England:** Marlow, 44-6284-6055; **France:** Rungis Cedex, 33-1-4687-2385; **Germany:** Egelsbach, 49-6103-4040; **Italy:** Milano, 39-2-6120451; **Luxembourg:** Foetz, 35-255-0002; **Spain:** Barcelona, 34-3-3002252; **Sweden:** Upplands Vasby, 46-760-88110

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These PLD devices range from standard PAL®-type devices like our 10ns CMOS 22V10 and 4.5ns ECL 20EV8 to application specific devices including 7.5ns 32-bit address decoders, 55MHz programmable state machines, 32-bit programmable bus interfaces, up to 5000-gate CMOS EPLDs and more.

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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- 10ns CMOS PL22V10
- 4.5ns ECL 100/10H20EV8-4
- 5ns programmable high-speed decoder (PHD16N8)
- 7.5ns PLUS16L8/R4/R6/R8 and PLUS20L8/R4/R6/R8
- 25ns zero standby power PLC18V8Z

Application specific PLDs

- 55MHz programmable state machines (PLUS105/405-55)
- 7.5ns 32-bit address decoder (PHD48N22-7)
- 32-bit programmable bus interface (PML2552-35)
- 10ns memory decoder (PLUS153-10, PLUS173-10)
- 5000-gate CMOS EPLD (PLV5000)

Signetics

EXTENDING THE DIMENSIONS OF PERFORMANCE

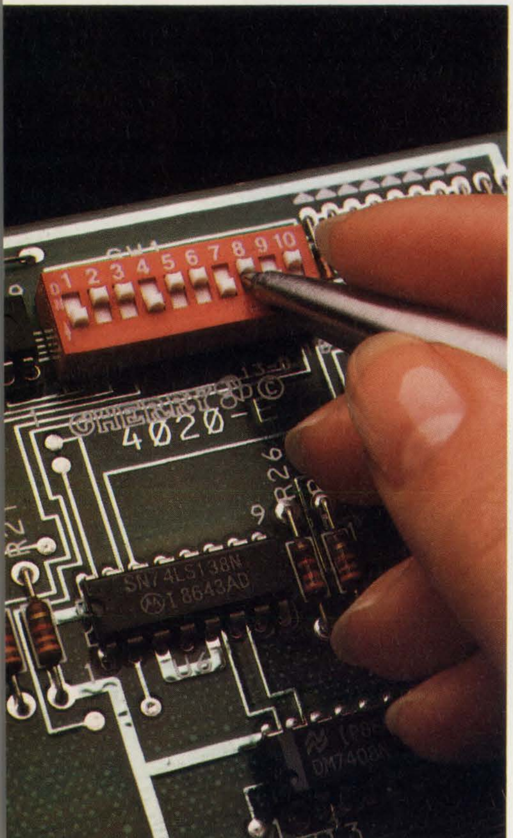
PHILIPS

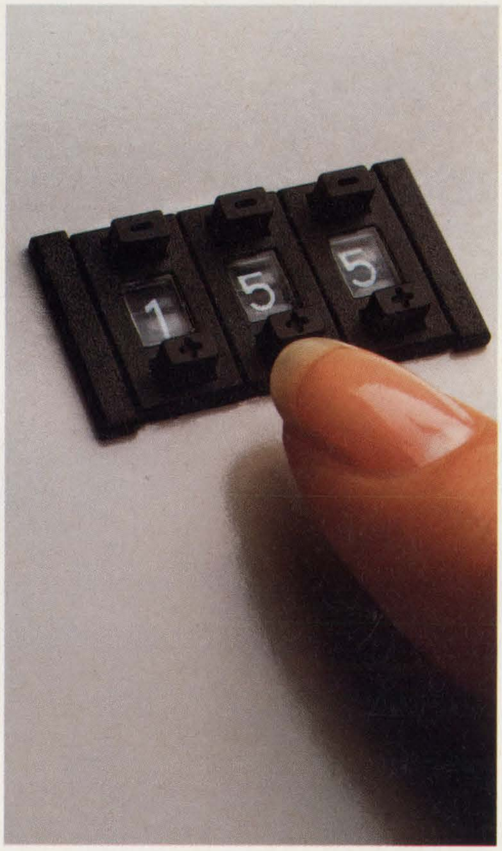
PHILIPS

CIRCLE NO. 202

Why make users do this?

When they can do this!





Changing DIP switches is a five stage process: disconnect the device, remove outer housing, reset the DIP switches, reassemble unit, and reconnect the device. Minimum downtime: 20 minutes.

Changing an *Address Switch* takes only one step: punch in the "address" on the back of the computer. Maximum downtime: 20 seconds.

Introducing the *Address Switch*™
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.*

Wouldn't the *Address Switch* make your product much more user-friendly?

Make "Switch-Addressable" One of Your Selling Features.

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. The *Address Switch* puts your device in the "preferred" category.

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.

Give Us Your Address, and We'll Give You Ours.

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.

"Switch Addresses with the *Address Switch*."

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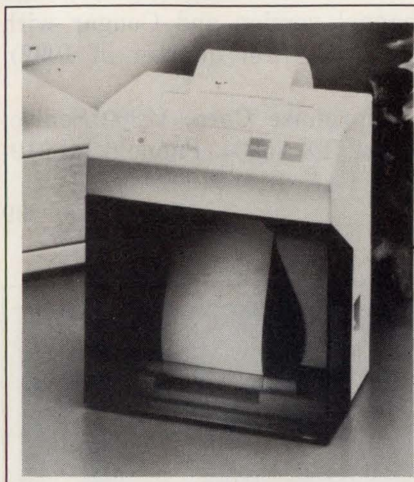
Circle #34 For Immediate Need

Circle #35 For Future Need

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 24×12 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 190×140×223.5 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 680302 processor and 256 kbytes of SRAM*

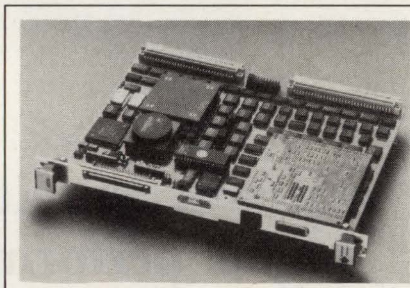
The SB302 device is a wide-area-network (WAN) controller for the SBus. It provides two full-duplex serial ports on a single-width expansion card. The board lets an SBus system communicate over E1 (2.048 Mbps) or T1 (1.544 Mbps) lines. You can independently program the two serial ports. For example, one port can operate at E1 rates while the other operates at 64 kbps. Motorola's 68302 integrated multiprotocol processor implements asynchronous, high-level 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

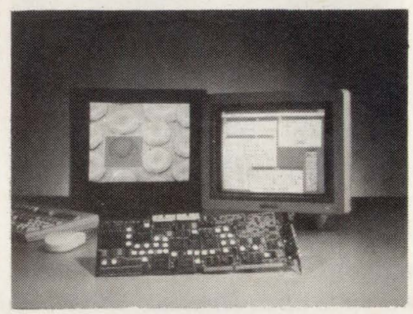
- *Operate in VMEbus or VME64 systems*
- *Support 10-Mbyte/sec rates and extended command set*

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 communicates with 10Base-2, 10Base-5, and 10Base-T networks. Single-channel V/SCSI-2 4220 Cougar, $2195; dual-channel version and Cougar with Ethernet (first quarter of 1992), $2790.

Interphase Corp, 13800 Senlac, Dallas, TX 75234. Phone (214) 919-9000. FAX (214) 919-9200.
Circle No. 399



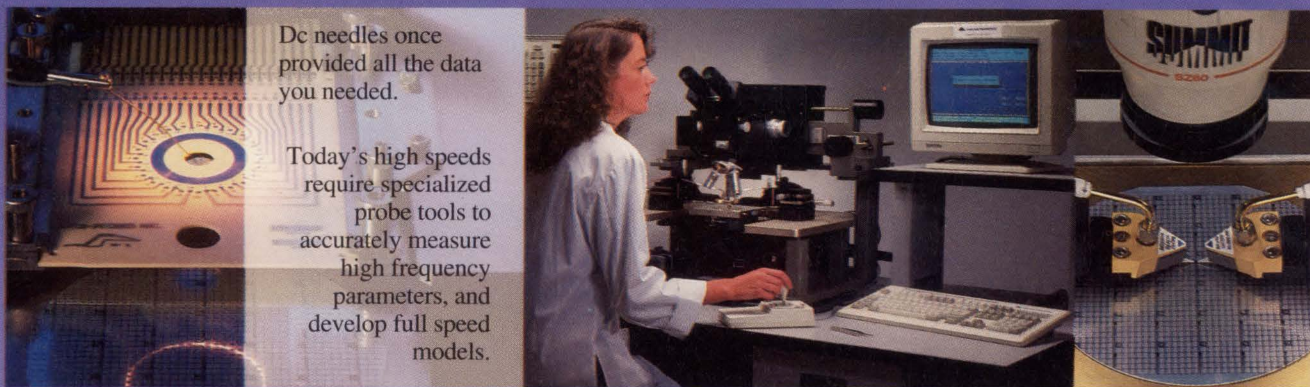
Frame Grabber

- *Has programmable gain for 16,000 selectable ranges*
- *Captures real-time images having 640 × 480 square pixels*

The DT2867-LC frame-grabber board for the 16-bit ISA bus captures real-time images from video cameras, VCRs, and still-video projectors. It provides 640 × 480 pixels with 256 gray levels. You can continuously adjust the offset and reference voltage on the input A/D converter. A programmable-gain input amplifier can select more than 16,000 ranges, allowing the input range to vary from 0-0.06 to 0-1.92V. A phase-locked loop eliminates image jitter by tracking sync-pulse variations common to VCRs. You can also image-capture to an external event using an external trigger pulse. The board stores images in one or two 512-kbyte frame buffers or displays the images directly. You can also overlay 15-color graphics on live images. $2495.

Data Translation, 100 Locke Dr, Marlboro, MA 01752. Phone (508) 481-3700. FAX (508) 481-8620. TLX 951646. **Circle No. 400**

REMEMBER WHEN DC MEASUREMENTS FIT HIGH-SPEED MODELS?



THAT WAS THEN. THIS IS NOW.

Today's high-speed devices are simply too fast for yesterday's measurement methods. To develop accurate models you need modern tools that test "at-speed", on the wafer. You need tools that provide better data, and more data, to characterize and refine your process with fewer design turns. You need probes that won't contaminate your measurements with crosstalk and parasitic impedance.

You need the all-new Summit 10000 Semi-Automatic Probe Station from Cascade Microtech.

Summit 10000 is specifically designed for high-speed measurements using gigahertz microprobes, and offers superior rigidity, planarity and precision for probe placement with picosecond resolution.

The Summit 10000 automatically performs the large numbers of measurements required for meaningful statistical modeling and process control. While the industry's only square chuck holds your wafer and calibration substrate at the same time, speeding calibration and system verification.

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The Summit 10000 Probe Station is just the latest in a full line of cutting-edge solutions from the leader in high frequency measurement. Cascade Microtech offers a wide range of microprobes and stations for digital and microwave applications. Plus comprehensive applications support to help you step up to today's high-speed measurement technology.

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.**

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Beaverton, Oregon 97005
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Circle No. 28 For Information Only

Circle No. 29 To have a Sales Engineer contact me now.

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**

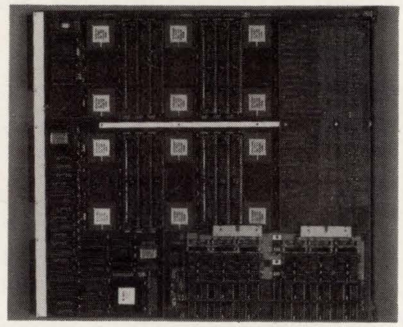
Vector Processor

- *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-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**



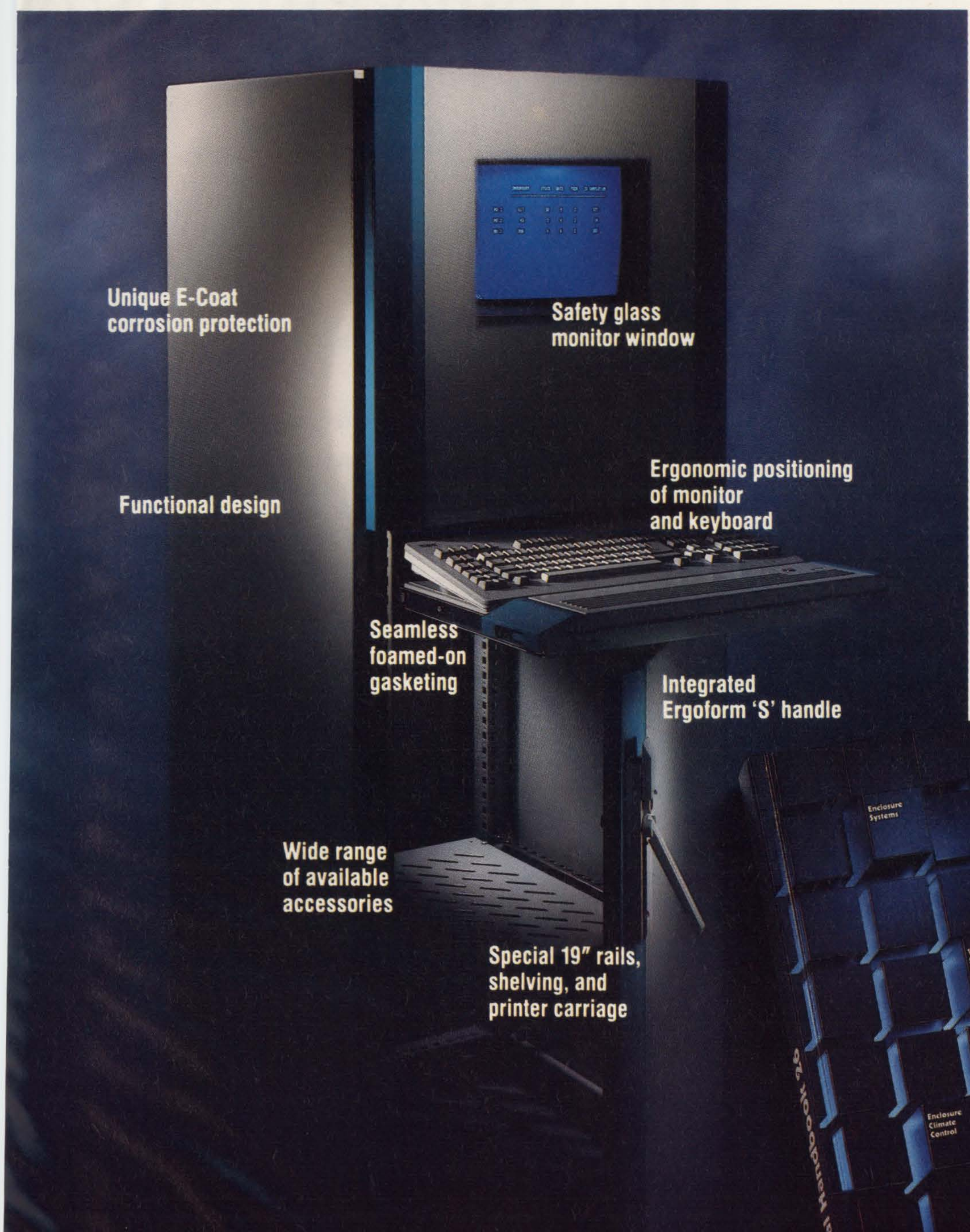
VMEbus DSP Board

- *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**

What You Don't Know About RITTAL Can Hurt Your Design.



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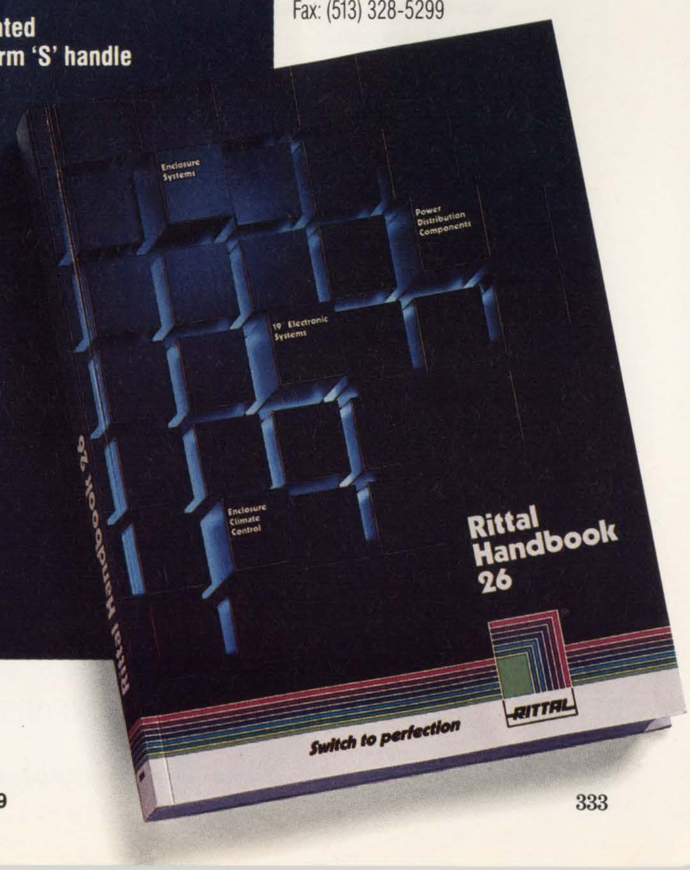
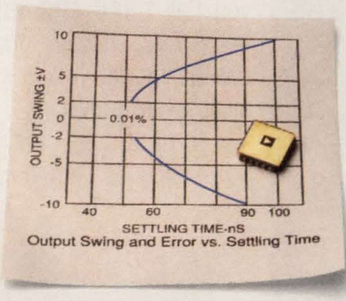


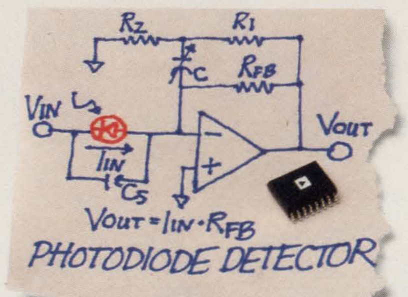
CIRCLE NO. 209

Whether you fax it, fire it, send it
measure it, wire it, compute it
The Analog family of



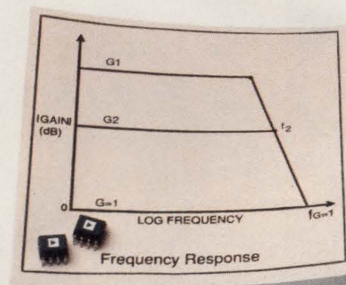
Precision

With the AD840, AD841 and AD842, there's no need to trade speed for accuracy. All three settle to 0.01% within 100 ns (840/842) and 110 ns (841) – critical in data acquisition and instrumentation applications – and offer low offset voltages and drifts, and fast slew rates.



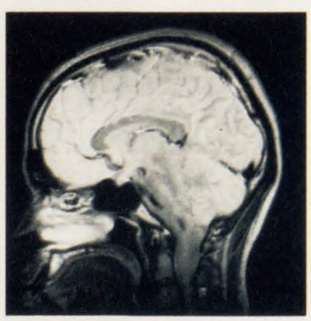
FET Input

For op amps requiring low input current, the OP-42, OP-44, AD845 and AD843 are all remarkably fast – slew rates are 58, 120, 100 and 250 V/μs, respectively. In addition, they offer offset voltages of less than 1 mV and extremely low current noise.



Transimpedance Amplifiers

The OP-160, OP-260, AD844, AD846, AD9617 and AD9618 all utilize a current feedback architecture to achieve slew rates from 450 to 2000 V/μs without compromising stability – even in hostile environments. Other benefits include low power dissipation and high unity-gain bandwidth.



If whatever it is you're trying to do involves high-speed op amps, Analog Devices is the company to call. With our current products and new introductions, we have the broadest line of high-speed op amps available. A line that gives you the right combination of speed, precision, noise and price. So chances are, we've got exactly what you need for

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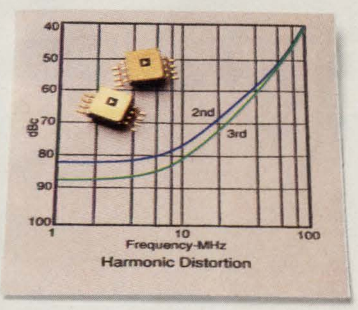
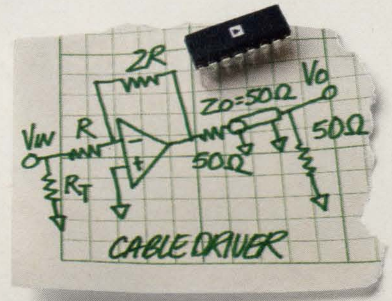
high-speed op amps.



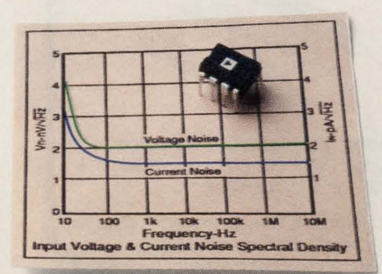
Buffers

If you're looking for extremely low distortion buffers, look at the specs of the AD9620 and AD9630 – distortion at 20 MHz: – 73 dBc and – 66 dBc, respectively; fast settling time: less than 8ns to 0.02%; and extremely low noise: 2.2 nV/$\sqrt{\text{Hz}}$.



General Purpose

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.



Low Noise

It used to be you had to choose between speed or low noise. But with the AD829, you get both. It features voltage noise of 2 nV/$\sqrt{\text{Hz}}$ and current noise of 1.5 pA/$\sqrt{\text{Hz}}$ with a 50 MHz unity-gain bandwidth. Those specs, combined with the low price of $2.95/100s, make it ideal for both audio and video applications.

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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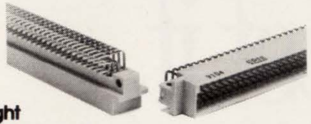


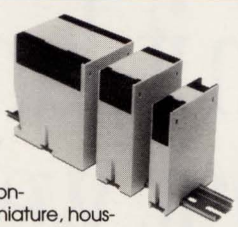
Right Angle Pressfit

Cost-efficient ERNIPress 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
- Gas tight connection withstands corrosion and vibration

ERNI

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)
- DIN-rail mountable

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Application Specific DIN Connectors

PCB process compatibility and application specific options from ERNI:

- SMT DIN Connectors
- PCB hold-down clips
- Variable pin lengths for early-make-late-break connections for "Zap-proofing"

ERNI

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

ERNI

CIRCLE NO. 253

PCB Edgecard Connectors

ERNI Edgecard connectors featuring the latest configurations and options:

- Connectors for every bus type like STD, Multi(+ S-100), Q, Apple II, XT & AT, Microchannel, and more
- Complete range of high-density .050" types
- Extensive options in contact style, type of termination, mounting, and plating

ERNI

CIRCLE NO. 254

.050" SMC

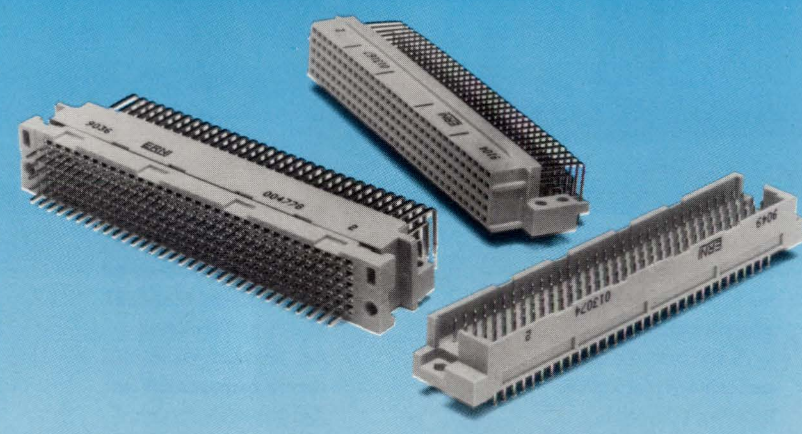
Introducing ERNI's .050" SMC two-piece high-density connector system:

- Perpendicular (daughter to mother board), stacking (parallel or mezzanine), and side-to-side (edge-to-edge) mating configurations
- Anti-twist contact design assures longer life and reliability
- Built-in keying plug cavity for easy plug installation

ERNI

CIRCLE NO. 255

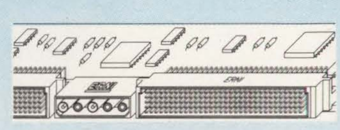
IN THE SPACE OF THIS 7"x10" AD YOU COULD MAKE 4,640 CONNECTIONS.



Introducing The New High-Density 160 Connector From ERNI.

An interesting addition to DIN 41612, the new Type E and TE 160 pin connectors meet today's design needs for high-density connectors. So pack it in: 160 connections in an array of 5 rows of 32 contacts in 3.740" x .618" — Type E160 external dimensions (Yes, 29 connectors could physically fit in this ad space!).

Spec it where miniaturization requires more contacts in less space. Take advantage of its flexibility through either standard (E) or inverse (TE) styles. Choose your connections: dip solder, wire wrap, or compliant pressfit. More choices: 3 quality grades with either gold- or tin-plated termination areas — providing design options to withstand up to 500 mating cycles. Add in ERNI's Eurocard Center connector and you have a multifunctional signal + coax + power + fiber optic system or 362 signal connections all possible on a double Eurocard. The selections list seems endless when you include backplane shrouds, coding strips, pressfit tooling, and more.



160 pins + Eurocard Center connectors = Increased I/O with power, coax, &/or fiberoptics

And with ERNI you get a world-class supplier manufacturing in 5 countries with offices in 20 others. With ERNI you get more than just a DIN supplier, you get a multi-product company.

So get with ERNI and get to know more about us and about all the possibilities and advantages of the 160 series. Phone or write to: ERNI Components; 520 Southlake Blvd.; Richmond, VA 23236; Phone (804) 794-6367; FAX (804) 379-2109.

ERNI

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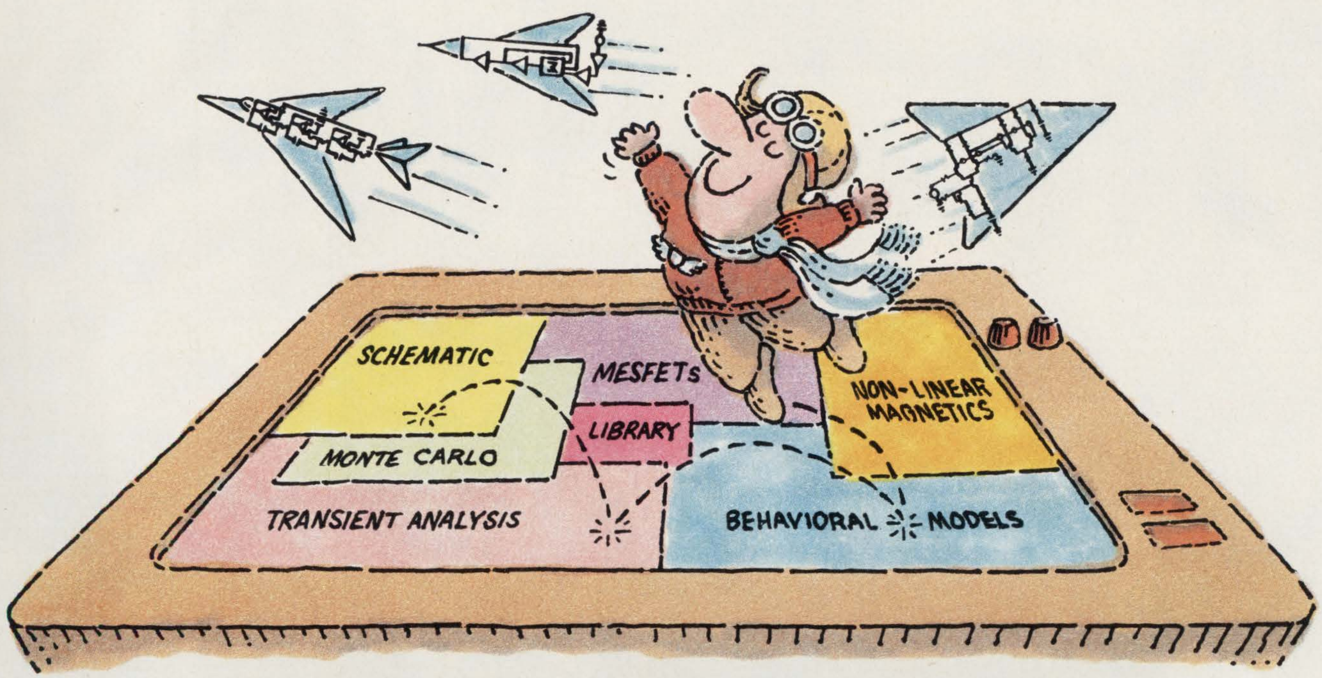
CIRCLE NO. 297



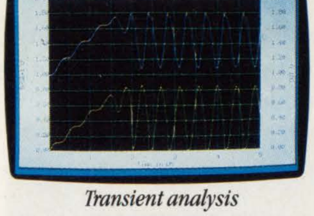
THE NEW MICRO-CAP III.™ SO YOU CAN TEST-FLY EVEN MORE MODELS.

It wasn't easy. But we did it. Made the long-time best-selling IBM® PC-based interactive CAE tool even better.

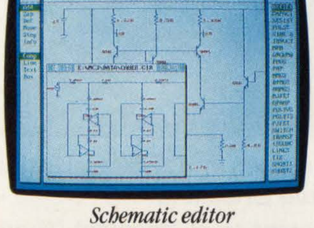
Take modeling power. We've significantly expanded math expression capabilities to permit comprehensive analog behavioral modeling. And, beyond Gummel Poon BJT and Level 3 MOS, you're now ready for nonlinear magnetics modeling. Even MESFET modeling.

Analysis and simulation is faster, too. Because the program's now in "C" and assembly language. That also means more capacity—for simulating even larger circuits.

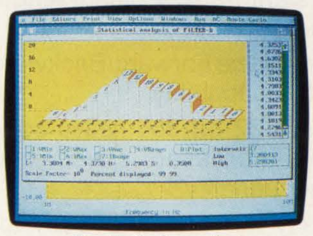
As always, count on fast circuit creation, thanks to window-based operation and a schematic editor. Rapid, right-from-schematics analysis—AC, DC, fourier and transient—via SPICE-like routines. The ability to combine digital/analog circuit simulations using integrated switch models and parameterized macros. And stepped component values that streamline multiple-plot generation.



Transient analysis



Schematic editor



Monte Carlo analysis

And don't forget MICRO-CAP III's extended routine list—from impedance, Nyquist diagrams and BH plots to Monte Carlo for statistical analysis of production yield. The algebraic formula parsers for plotting virtually any function. The support for Hercules, CGA, MCGA, EGA and VGA displays. Output for plotters and laser printers.

Cost? Still only $1495. Evaluation versions still only $150. Brochure and demo disk still free for the asking. Call or write for yours today. And see how easily you can get ideas up and flying.

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CAE & SOFTWARE DEVELOPMENT TOOLS

Mixed-Signal ASIC Tool

- *User-generated analog performance parameters*
- *Prelayout simulation models for analysis*

The AMI Mixed-Signal Design Solution (MSDS) tool set lets you build mixed-signal designs from your desktop. You can define analog functions that are transformed into prelayout models for simulation and test. The system includes an automated design-analysis tool, the Design Critiquer, to catch early design errors. It analyzes circuits based on expert analog-IC design techniques and knowledge. The company provides an A/D simulator, Saber/Cadat, for mixed-signal circuit analysis. The MSDS Analog Model Builder verifies the testability of circuits for specific testers. Test multiplexer circuits are available to help make circuit test points visible for test. The package includes Mentor Graphics' schematic-capture software and the AMI 1.5-μm CMOS design library and utilities. MSDS system, from $75,000.

Gould AMI, 2300 Buckskin Rd, Pocatello, ID 83201. Phone (208) 233-4690. **Circle No. 420**

C Programs For Windows

- *C compiler runs under Windows*
- *Combines GUI builder, compiler, and Windows tools*

Quickwindows for C combines a graphical-user-interface builder (a subset of QuickCASE:W) with a Windows-hosted C compiler and debugger. You can interactively build your application interfaces and then link them to QuickC code without having to define control constants and variables by hand—a common source of program errors. Unlike most Windows development tools that run under DOS, QuickC for Windows runs in Windows, allowing you to edit, compile, and debug Windows programs in one system. The compiler comes with a special library, Quickwin, which when compiled with a DOS*C program, enables it to run directly under Windows in its own window. Using Quickwin, programmers can build Windows applications without the Windows system development kit; all necessary documentation and tools come with this package. $199.

Microsoft Corp, 1 Microsoft Way, Redmond, WA 98052. Phone (206) 882-8080. FAX (206) 883-8101. **Circle No. 421**

Simulation Tool For IGBTs

- *Simulates steady-state switching characteristics*
- *Predicts current, voltage, and charge*

This IGBT (insulated-gate-bipolar-transistor) simulation model combines many of the characteristics of CMOS and bipolar power transistors. The model is physics-based for accuracy, and you can use it to model switching losses and transient circuit conditions for IGBT transistors. Running with the company's Saber analog simulator, the model is supplied at no extra charge to Saber users.

Analogy Inc, 9205 SW Gemini Dr, Beaverton, OR 97005. Phone (503) 626-9700. **Circle No. 422**

GNU C For 56001 And 96002 DSPs

- *C compiler for DSP chips*
- *20% speed improvement over Motorola 56001 C*

The company ports the GNU C compiler from the Free Software Foundation (Cambridge, MA) to its DSP processors, allowing you to use the same compiler for DSP applications and host coding. The development tool kit provides an optimizing C compiler, the GNU source-level debugger, and technical documentation. The tool set also offers a host-software floating-point emulation feature, enabling you to debug the DSP code on the host platform before downloading to the target. Also available from the Free Software Foundation is the GNU Emacs editor with a windowed interface to the debugger. The compiler is hosted on a 386 PC and compatibles and Sun SPARCstations. Compiler, $709. Source code is available for a nominal duplication fee.

Motorola Inc, Microprocessor Products Group, 6501 William Cannon Dr W, Austin, TX 78735. Phone (512) 891-2030. **Circle No. 423**

Floating-Point DSP Datapath Compiler/Library

- *ASIC library compiles math processing structures*
- *Has DSP, floating point complex functions*

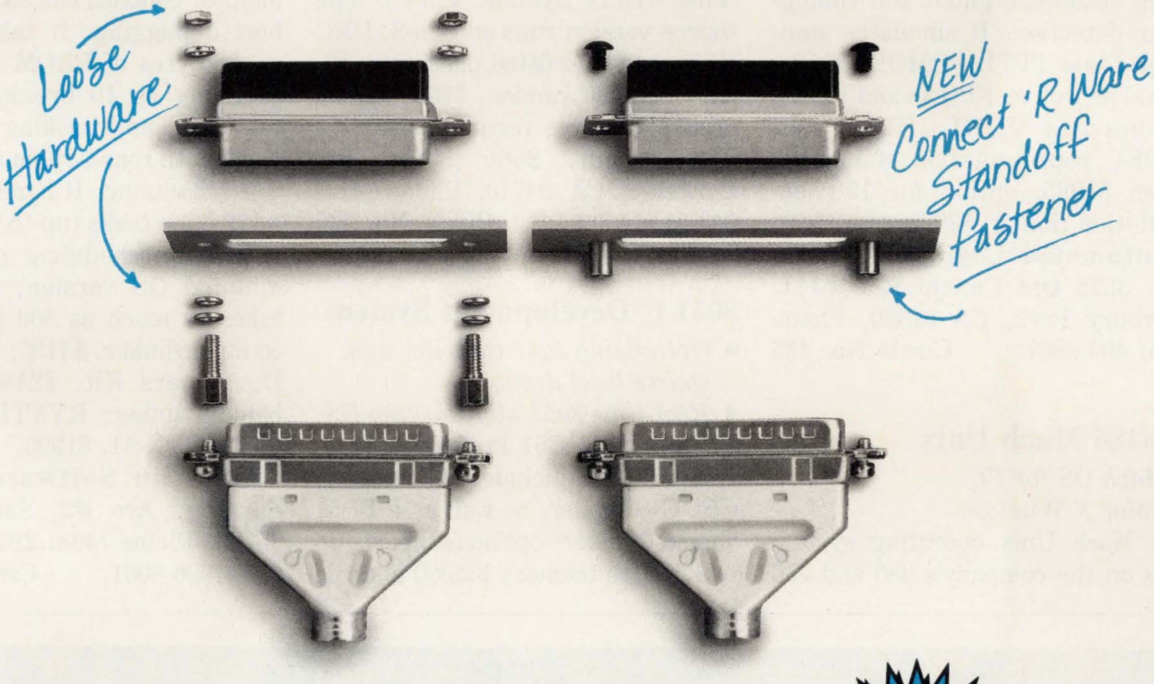
The VDP370 compiler and cell library generates high-density, high-performance datapath circuits for advanced processing. It supports both fixed-point and floating-point DSP processing. The compiler also generates an optimized layout for either gate-array or standard-cell implementation. It uses cells 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**

Concerned about DFA?

To assemble the I/O panel on the left requires six more parts and costs about five times more in time and labor than the panel on the right.

Which one are you going to recommend?



Connect 'R Ware™ standoffs provide consistent and exact spacing for optimal pin contact in panels from .037" to .250", and allow significant labor savings.

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CIRCLE NO. 227

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Interactive PC Logic Simulator

- *Aids design cycle with fast, flexible interaction*
- *Allows you to patch in logic solutions*

The Susie 6.0 logic simulator provides interactive design-oriented simulation. It runs on a PC, allowing you to model all or part of a circuit. It allows you to stop simulation and modify a design by patching in a logic solution or even changing logic families to eliminate race or timing problems. A set of special test vector generators minimizes simulation setup. The simulator features automatic glitch and timing-error detection. It simulates standard logic (TTL, CMOS, ECL, GaAs) as well as FPGAs and PLDs. It supports VHDL, EDIF, and JEDEC representation standards. From $1995; option for 10-psec-resolution timing, $3995.

Automated Logic Design Co Inc, 3525 Old Conejo Rd, #111, Newbury Park, CA 91320. Phone (805) 499-6867. **Circle No. 425**

386/486 Mach Unix

- *Mach OS for PC*
- *Color X Windows*

The Mach Unix operating system runs on the company's 386 and 486 PCs. It also supports SCSI peripherals and color VGA, driven by the X-Windows graphical user interface. Mach was developed by Carnegie Mellon University: It combines the "Berkeley Unix" with a microkernel approach. The system includes the 4.3 Berkeley interface, TCP/IP internet networking from Berkeley's Tahoe release, NFS file system, X-Window version 11.4, and GNU utilities from the Free Software Foundation. This package is a binary version. A source version requires compilation on the target system and an AT&T source license (Unix System V.3+). The source version runs on Sun-3, DEC VAX, and 80386/486 platforms. Binary 386/486 version, $1595 ($1395 prepaid); source version, $4500.

Mt Xinu, 2560 Ninth St, Berkeley, CA 94710. Phone (415) 644-0146. **Circle No. 426**

8051 C Development System

- *Optimizing 8051 compiler and source-level debugger*
- *Real-time 8051 multitasking OS*

The Franklin C51 Professional Developers Kit includes an updated C51 C compiler, as well as a BL51 "banked linker" option (supports up to 1-Mbyte memory banks) and the RTX51 real-time kernel. Also supplied is an enhanced dScope51 source-level debugger and simulator. The C compiler now supports multitasking and memory-bank switching. An option enables the C compiler to produce assembly-language source code for hand optimization of critical loops. The linker analyzes the program and automatically inserts intrabank operations for movement between memory banks. The debugger has been upgraded to a mouse-based interface; it supports simulation of power-down and idle power modes. A monitor controls the 8051 target for host debugging. It takes as much as 4 kbytes of PROM and handles as many as 10 breakpoints. The real-time, multitasking kernel supports both round-robin and preemptive scheduling. It handles as many as 19 open tasks (up to 256 defined) with four scheduling priorities. A minimal OS version, RTXTINY, takes as much as 400 bytes. Basic compiler/linker, $1195; Professional Developers Kit, $2195 with the banked linker; RTXTINY version of the RTX-51, $1995.

Franklin Software Inc, 888 Saratoga Ave #2, San Jose, CA 95129. Phone (408) 296-8051. FAX (408) 296-8061. **Circle No. 427**

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Discover why more engineers are designing Scotchdamp™ brand Vibration Control Materials into electronic equipment. From disk drives and circuit boards, to video cameras, sensitive measuring devices and even jet engines, thin, lightweight 3M damping materials efficiently dissipate vibrational energy. Mechanical fatigue, performance loss and unwanted noise are virtually eliminated.

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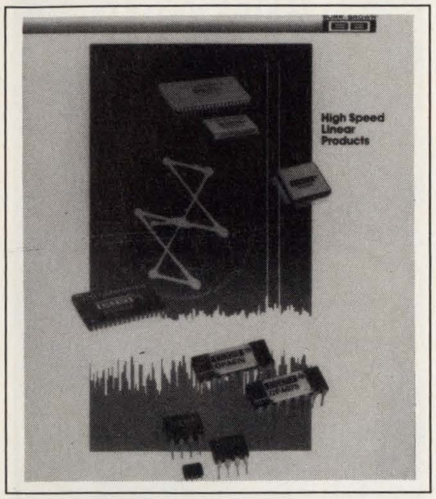


Publication Describes High-Speed Linear Products

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 power-supply 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 booklet'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.

Prem Magnetics Inc, 3521 N Chapel Hill Rd, McHenry, IL 60050. **Circle No. 405**

Catalog-On-Disk For Crystal Clock Oscillators

This disk contains a "complete" catalog, according to the vendor. It provides diagrams and waveforms for all of MF's clock oscillators, including TTL, HCMOS, ECL, VCXO, and PLLs. You can access an unknown model number by entering the attributes, such as logic family, frequency, stability, and 3-

 CIRCLE NO. 228

state or multiple outputs. The next display then briefly shows suitable oscillators including through hole and surface mount. You can select specifications for any model along with the outline, waveforms, and test fixtures. The disk runs on any PC with MS-DOS.

MF Electronics Corp, 10 Commerce Dr, New Rochelle, NY 10801. **Circle No. 406**

Guide To Bipolar Power Transistors

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**

Data-Acquisition And Signal-Processing Products

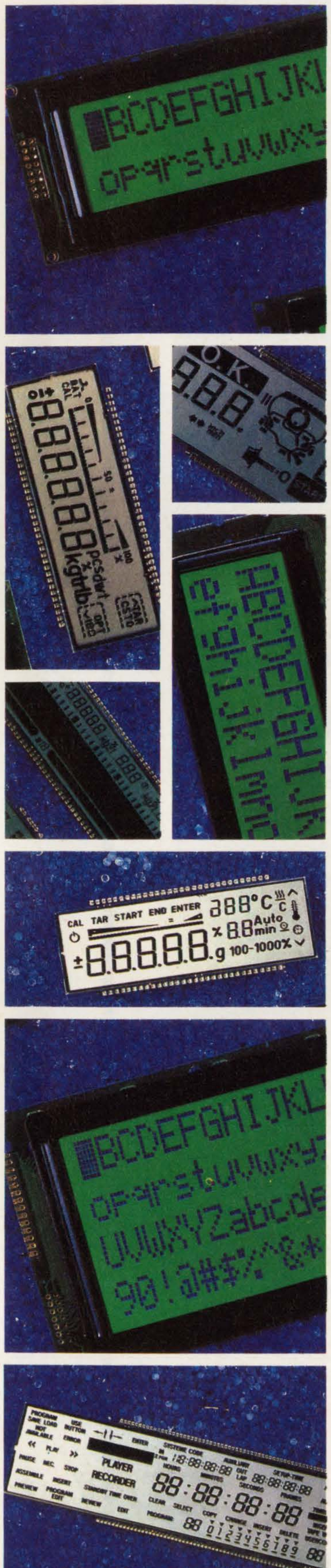
This 6-pg brochure highlights data-acquisition hardware and software products. It features plug-in boards for IBM PCs, PS/2, EISA, and Apple Macintosh computers. The publication explains how these boards perform various combinations of analog, digital, and timing I/O functions. It also includes driver and application-software options for programming data-acquisition hardware. Also mentioned are the Labwindows 2.0, Labview 2, and Measure application-software packages that integrate instrument-control, data-acquisition, analysis, and display capabilities for accelerating system development.

National Instruments Corp, 6504 Bridge Point Pkwy, Austin, TX 78730. **Circle No. 408**

Brochure Deals With Industrial STD-32 Bus

This brochure presents an overview of this 8-, 16-, or 32-bit industrial-computer standard that's compatible with the 8-bit STD Bus. It includes excerpts from the STD-32 Bus specification, diagrams of the STD-32 connector and card edges, and answers to questions about the specification. The brochure also incorporates technical data sheets of STD-32 products.

Ziatech Corp, 3433 Roberto Ct, San Luis Obispo, CA 93401. **Circle No. 409**



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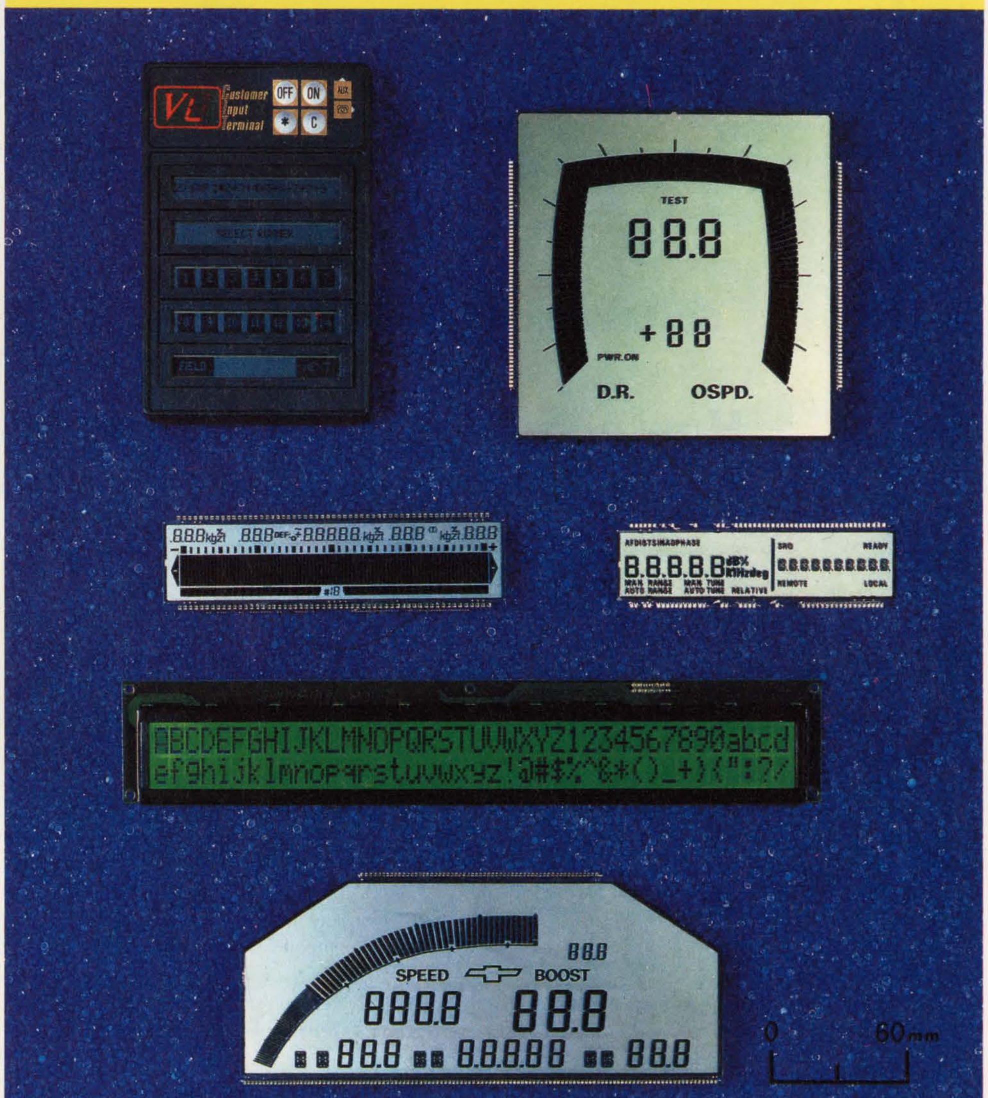

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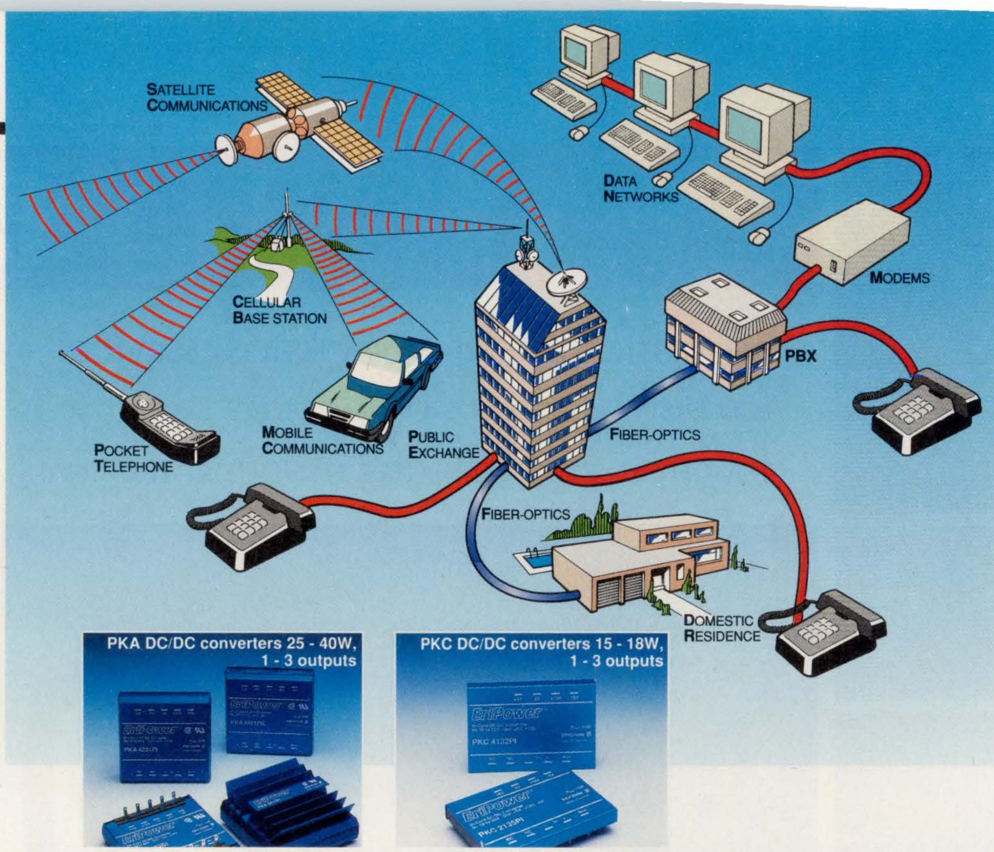

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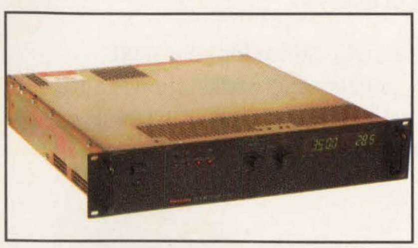
Enforcement of IEC 555-2 regulations regarding new power requirements is scheduled to take effect in Europe beginning this coming year. This means design engineers must add power factor correction to their power supplies if they expect their products to be sold or distributed into the European marketplace.

To help you in this process Sorensen, a world leader in the design and manufacture of high quality power supplies, is currently offering three models that have applications in computer, computer peripherals, telecommunications, ATE and other industrial areas.



DCS Series

The DSC 3Kw series power supply features 5 models - 8, 12, 40, 60 and 80 volts with additional models scheduled for availability in 1992.

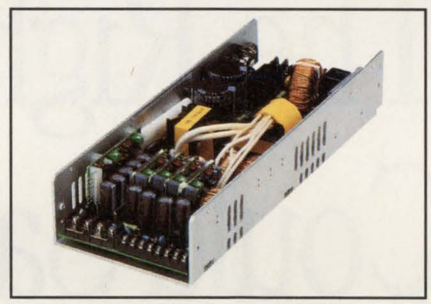
The current power supplies are zero up and have two basic operating modes, constant voltage and constant current.

- 3½ digit volt and ammeter.
- Optional power factor correction.
- Optional IEEE 488 plug-in programming card.

2Kw "S" Series

Sorensen's 2Kw single output power supply meets all approvals, - UL1950, EN60950, CSA C22.2 No. 234-M90.

- Power factor correction, per IEC 555-2. (Available 1st Qtr. 1992)
- FCC Part 15, Class B.
- Seven different output voltages available.



KSA400 PFC Series

The new KSA400 PFC, has power factor correction, per IEC 555-2. Four outputs as standard;

- V1 = 5vdc @ 40 amps.
  V2 = 5vdc - 15vdc @ 0-6 amps.
  V3 = 5vdc - 15vdc @ 0-6 amps.
  V4 = 12-24vdc @ 0-6 amps.
- Size: 2.5 in. x 5.0 in. x 14.0 in.
- Universal Input
- UL1950, EN60950, CSA C22.2 No. 234-M90

For more information and complete specifications call us **TOLL FREE: 1-800-525-2024 or Fax us at (312) 775-7432.**

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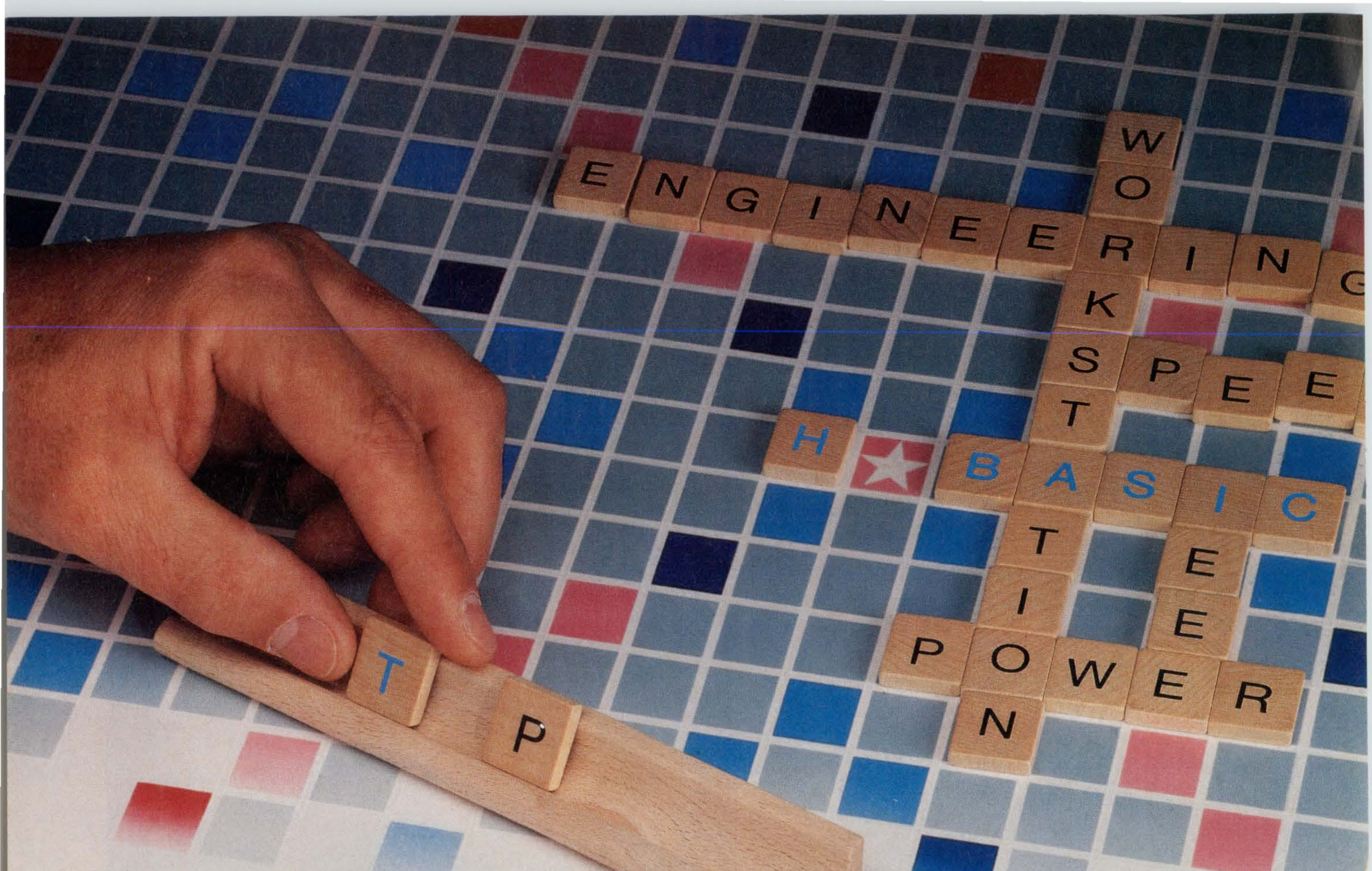
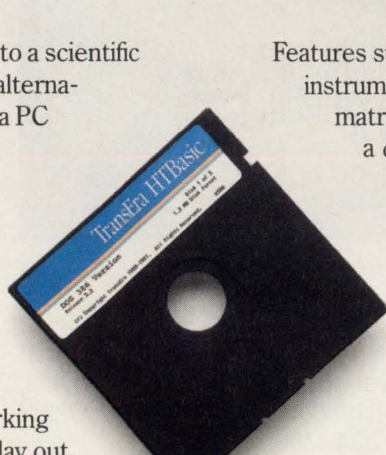


The Right Choice Could Save You $25,000.

HTBasic from TransEra will turn your PC into a scientific workstation at a fraction of the cost. A *real* alternative to a high-priced dedicated workstation, a PC with HTBasic gives you the capabilities you need for complex scientific/engineering applications, while retaining compatibility to run and share data with standard PC software.

The savings don't end with the workstation itself. With an HTBasic system, you can use industry-standard printers, graphic output devices, and networking systems. You get the flexibility you need to lay out the system you want without being tied to limited offerings from one supplier.

HTBasic is a state-of-the-art language which gives you a number of advanced scientific/engineering features not found in other BASIC packages.



Features such as data acquisition and IEEE-488/RS-232 instrument control syntax, COMPLEX arithmetic, matrix mathematics, complete HP-style graphics, a comprehensive on-line help facility, and many more, add up to increased productivity for all levels of users.

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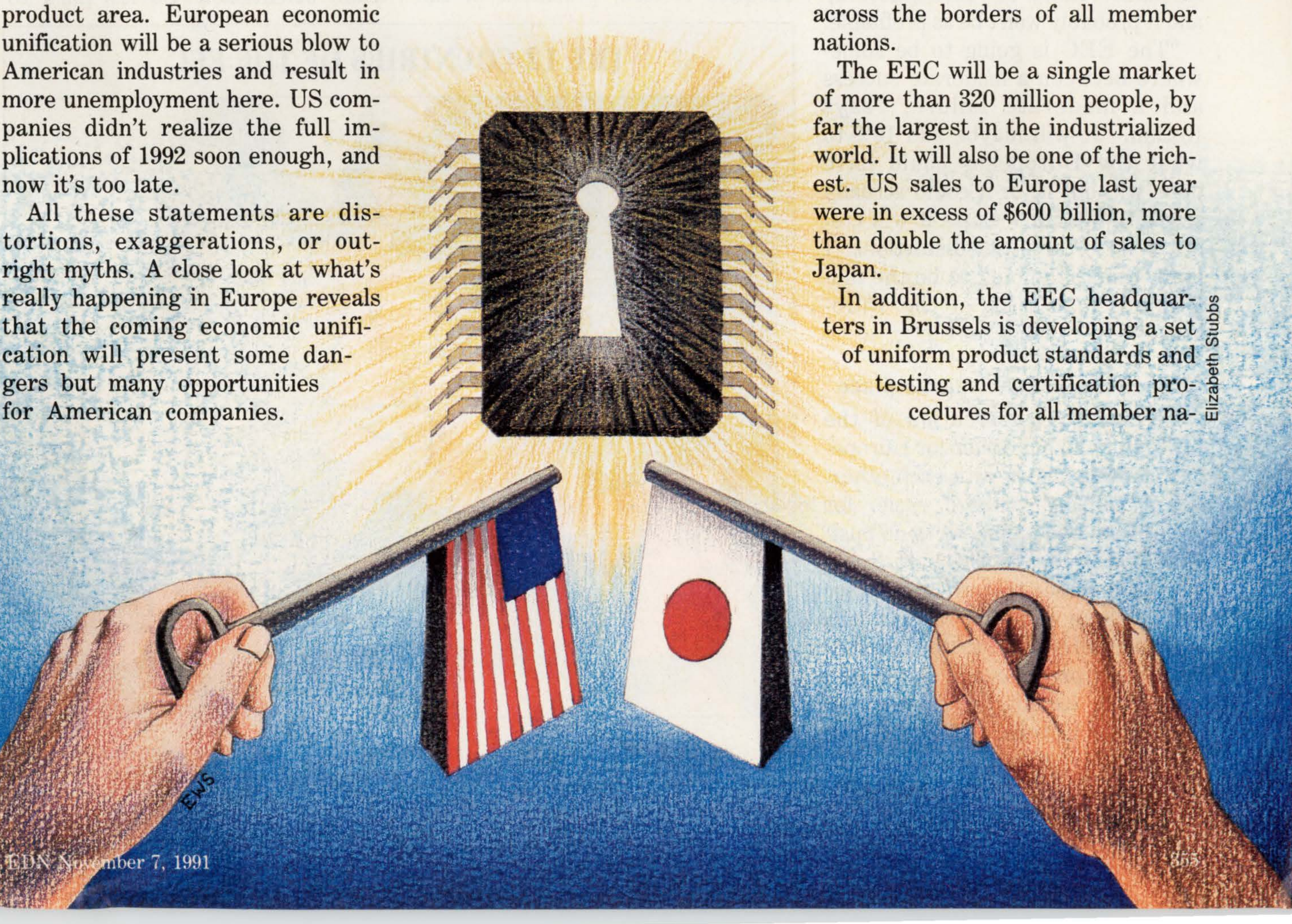
The economic challenge of a united Europe

Jay Fraser, Associate Editor

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?

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.



Elizabeth Stubbs

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 nations. When these standards are finally in place, they will be a boon for many industries, especially telecommunications and consumer electronics. After 1992, you'll 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 Euro-hustlers 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.

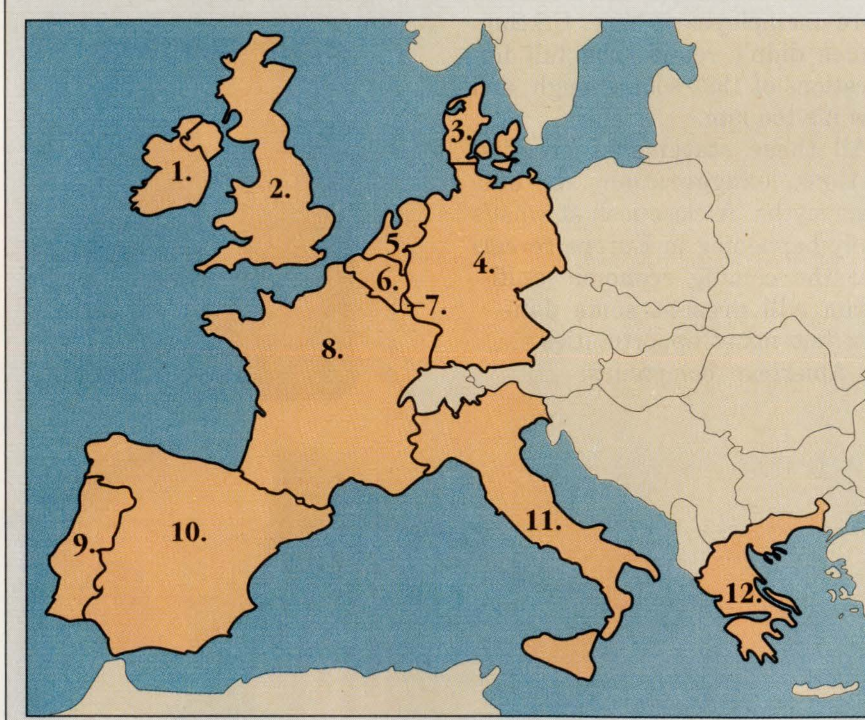
Norman Weizer, senior consultant at Arthur D Little Inc (Cambridge, MA), believes the greatest economic danger for American engineers actually comes from their own companies. "[Engineers] have something to fear if the company they work for isn't treating the EEC seriously and making an attempt to really 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

THE 12 COUNTRIES OF THE EEC



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12.GREECE

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 work force 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.

"Nineteen ninety-two is the best PR drive since 'Terminator 2.' But it may have about as much reality as 'Terminator 2' and it probably won't be as profitable."

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 work force 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.

A few years ago a 4-nation consortium of Nixdorf (Germany), Olivetti (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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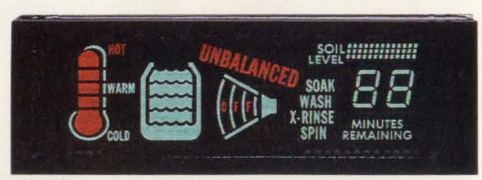

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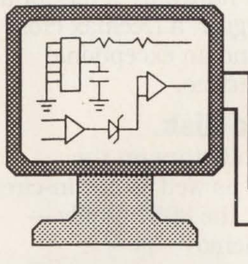

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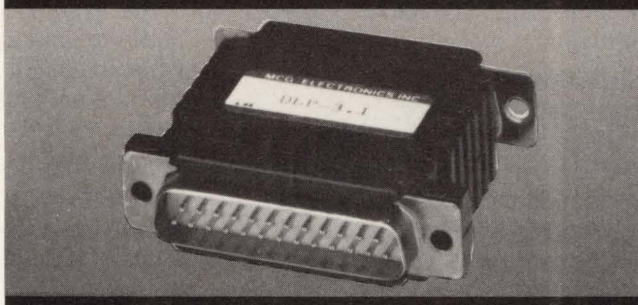

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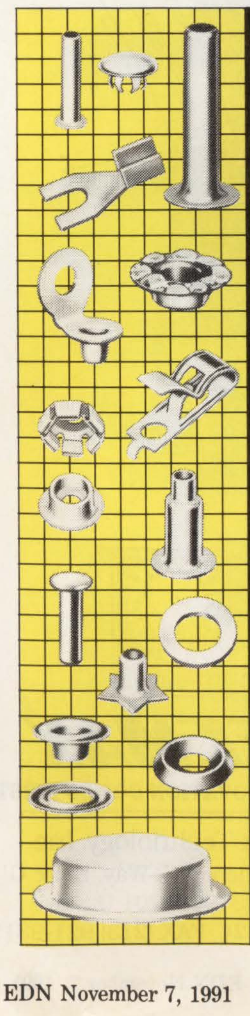

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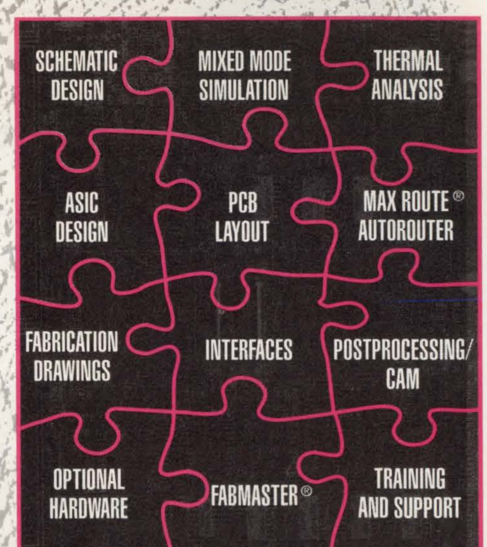

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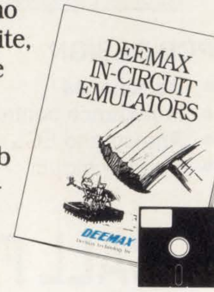

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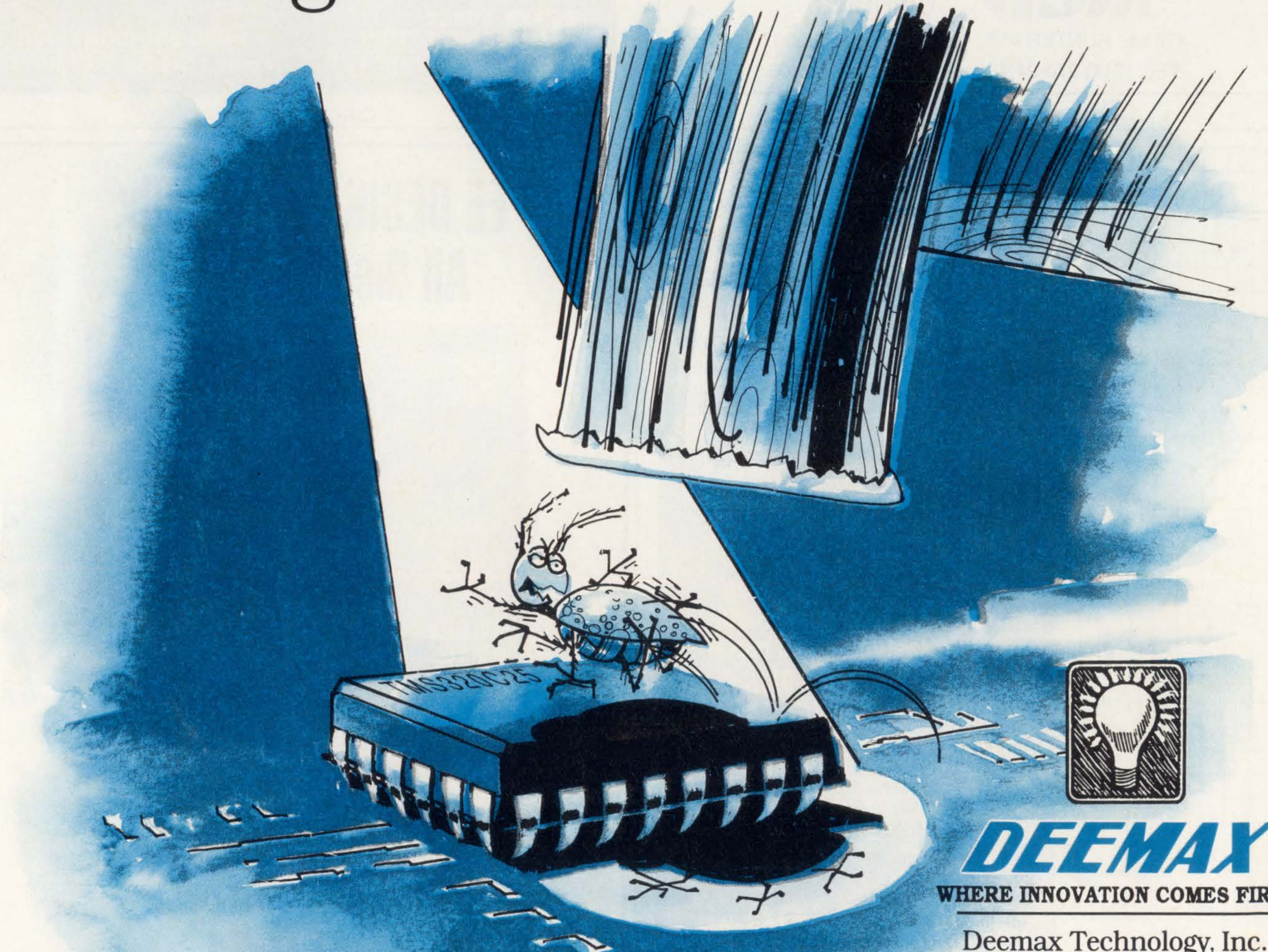

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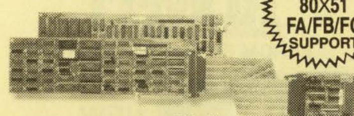

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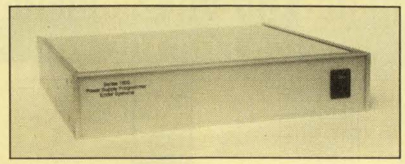

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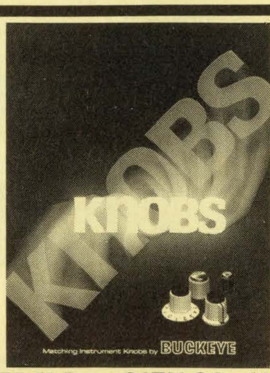

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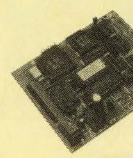

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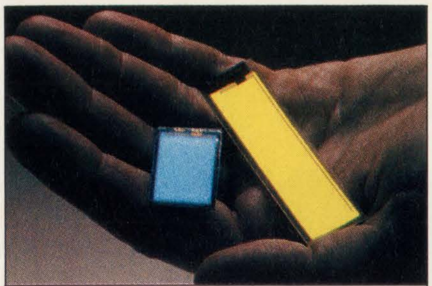

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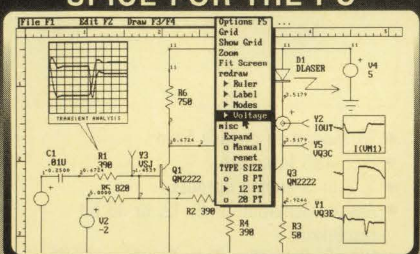

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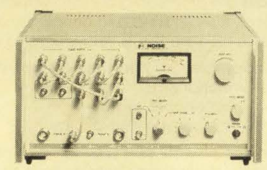

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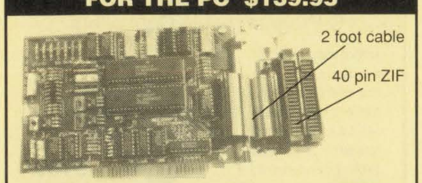

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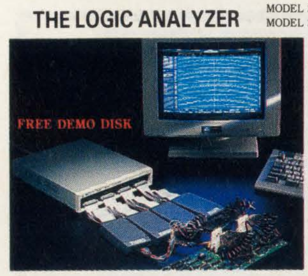
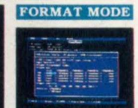


FORMAT MODE



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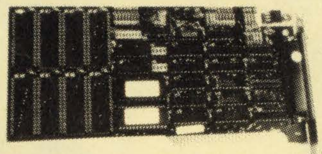

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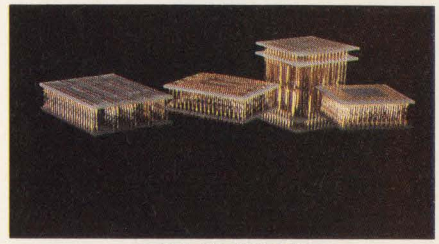

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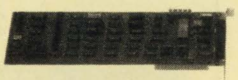

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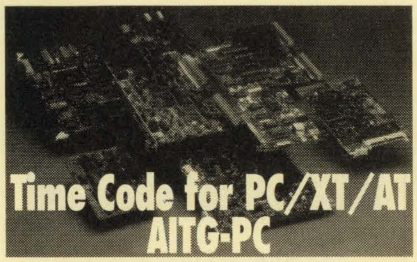

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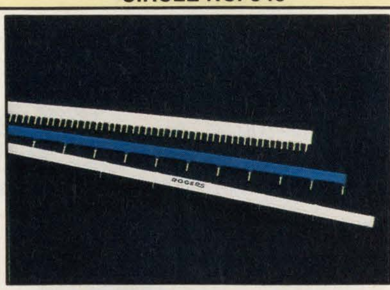

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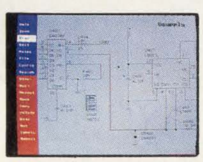

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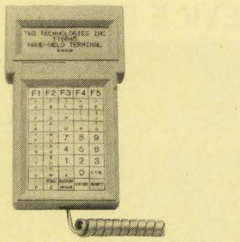

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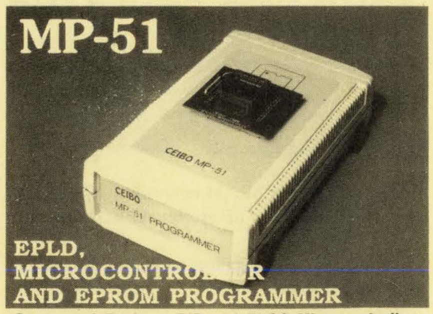

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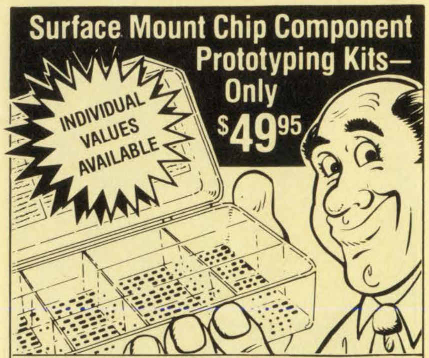

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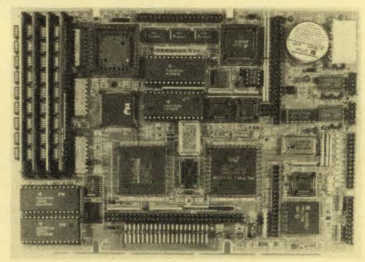

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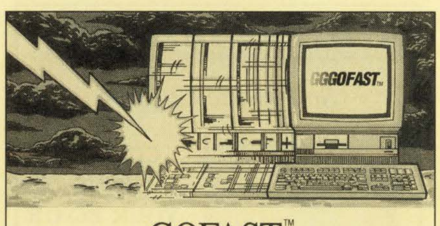

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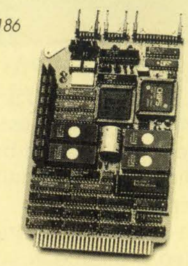

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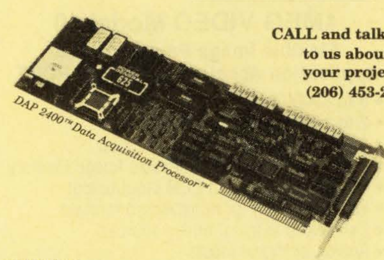

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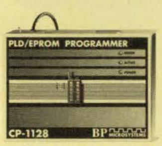

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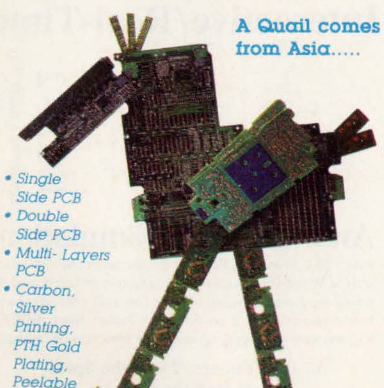

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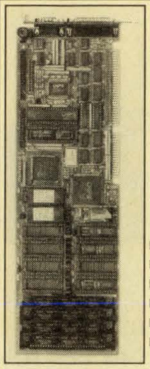

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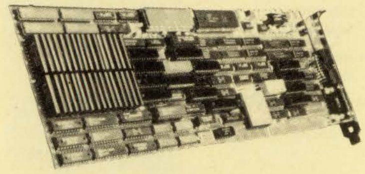

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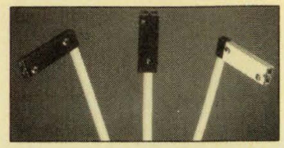

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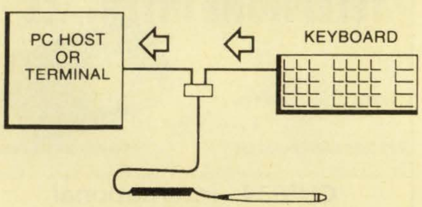

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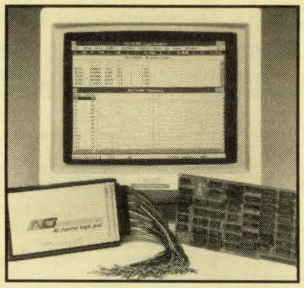

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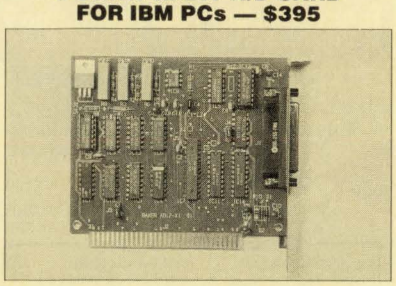

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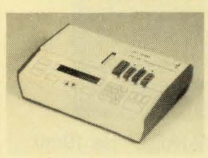

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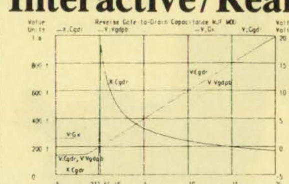

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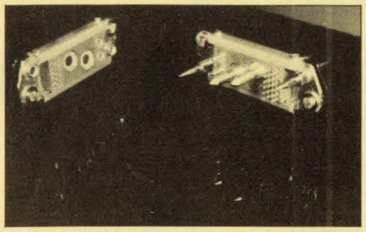

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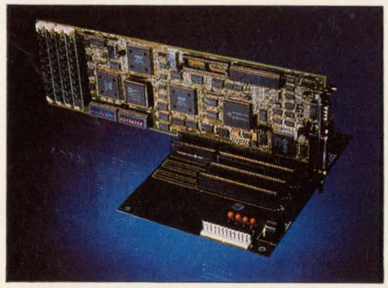

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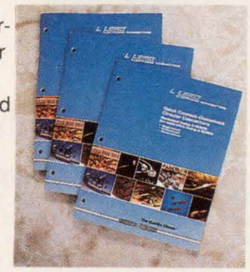

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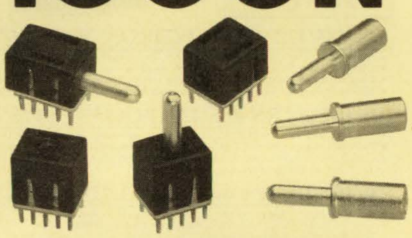

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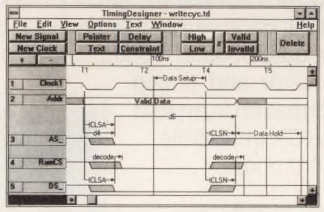

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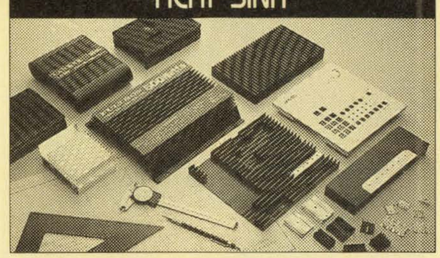

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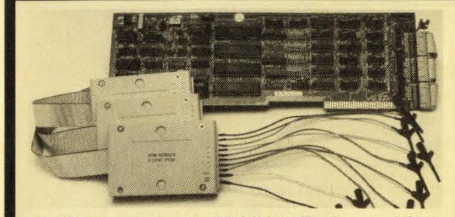

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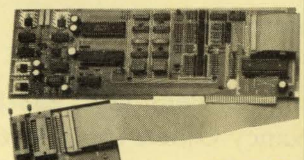

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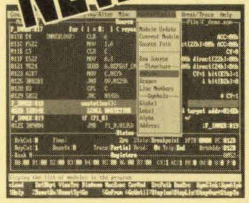

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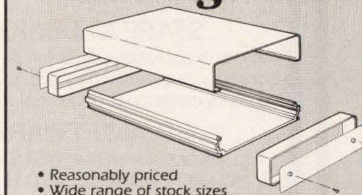

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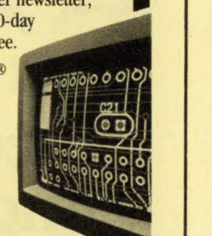

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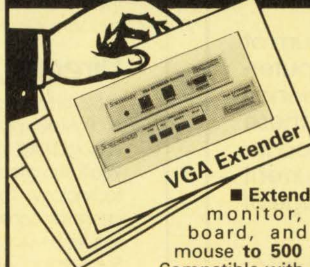

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Magazine Edition	Dec. 5	Nov. 14	Product Showcase—Volume I • ICs & Semiconductors, Microprocessors, Power Sources, Hardware & Interconnect, Software
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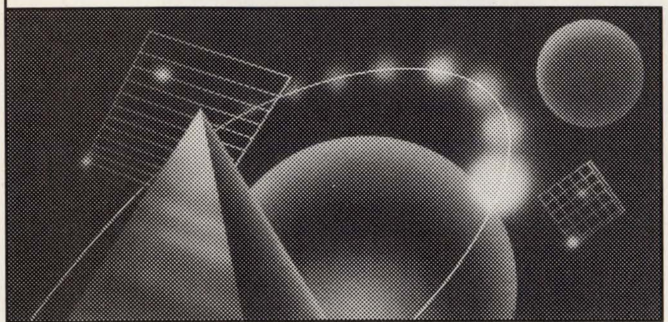

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Manage a team in the development of signal processing and communications hardware including technical, cost and schedule objectives. In doing so, you'll plan, organize and monitor all hardware development tasks. A BS/MSEE plus a minimum of 5 years' 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, i860 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; EBI 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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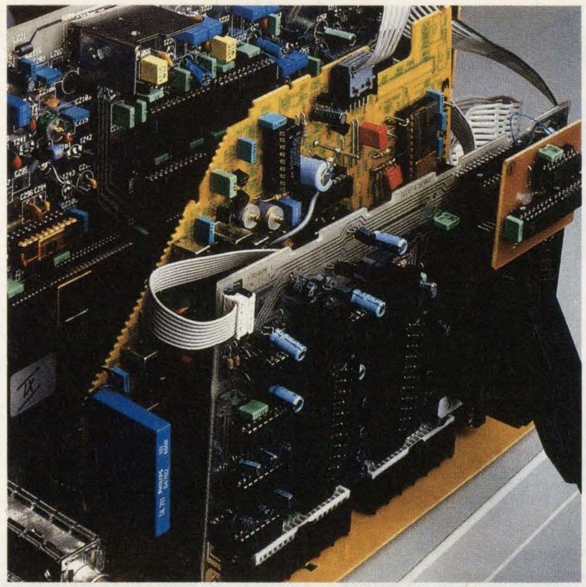

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Reprints of EDN articles are available on a custom printing basis at reasonable prices in quantities of 500 or more. For an exact quote, contact Andrea Marwitz, Cahners Reprint Service, Cahners Plaza, 1350 E Touhy Ave, Box 5080, Des Plaines, IL 60017. Phone (708) 390-2240.

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1. Names and complete addresses of the Publisher, Editor and Managing Editor are: VP/Publisher, Peter D. Coley, 275 Washington Street, Newton, MA 02158. Editor, Jonathan Titus, 275 Washington Street, Newton, MA 02158. Managing Editor, Joan Morrow Lynch, 275 Washington Street, Boston, MA 02158.
2. The owner is Cahners Publishing Co., A Division of Reed Publishing USA, 275 Washington Street, Newton, MA 02158.
3. The known bondholders, mortgages, and other security holders owning or holding 1 percent or more of total amount of bonds, mortgages, or other security are: None.

Extent and Nature of Circulation

	Average No. Copies Each Issue During Preceding 12 Months	Actual No. Copies of Single Issue Published Nearest to Filing Date
A. Total No. Copies (Net Press Run)	145,340	160,372
B. Paid and/or Requested Circulation		
1. Sales through dealers & carriers, street vendors and counter sales	None	None
2. Mail Subscriptions (Paid and/or Requested)	141,926	157,152
C. Total Paid and/or Requested Circulation	141,926	157,152
D. Free distribution by mail, carrier, or other means samples, complimentary, and other free copies	1,912	1,788
E. Total Distribution (Sum of C & D)	143,838	158,940
F. Copies not distributed		
1. Office use, left over, unaccounted, spoiled after printing	1,502	1,432
2. Returns from news agents	None	None
G. Total	145,340	160,372

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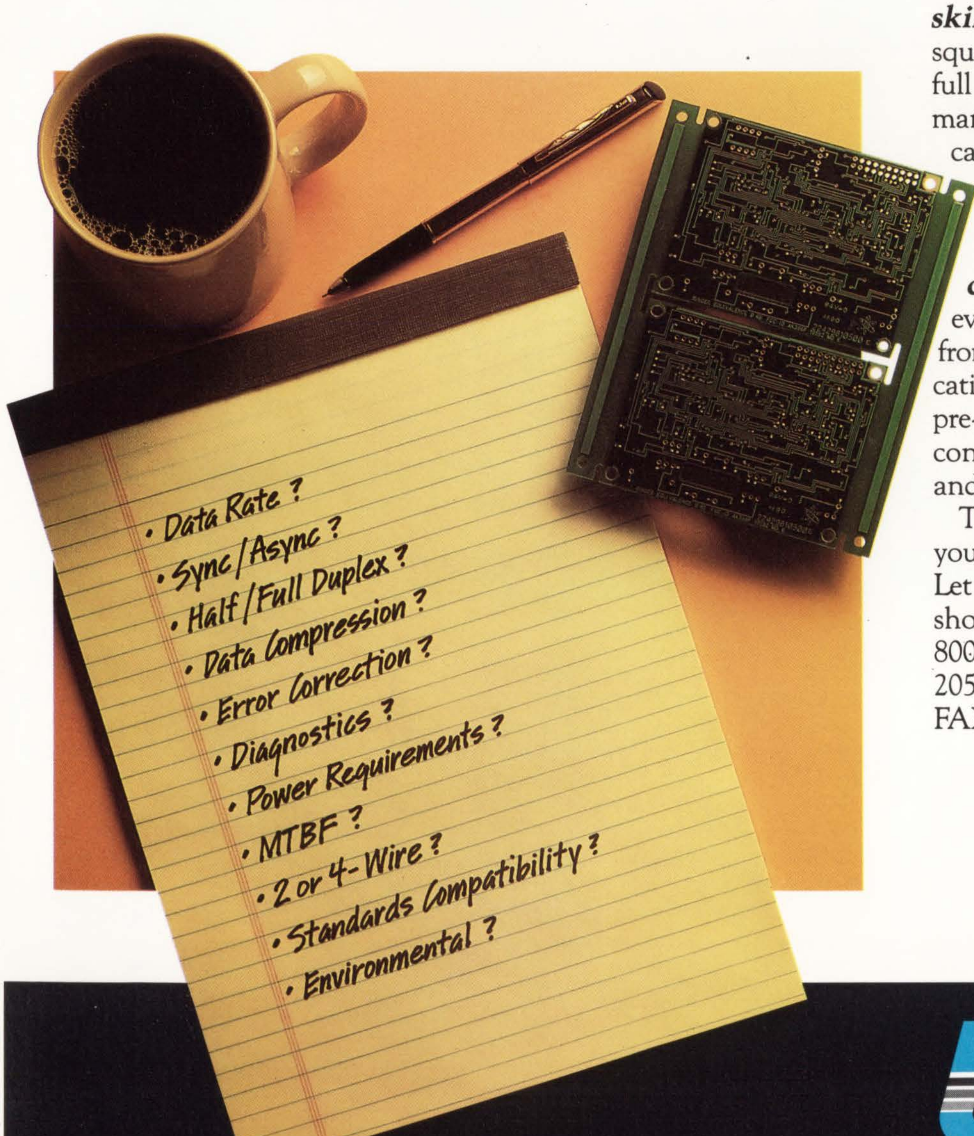

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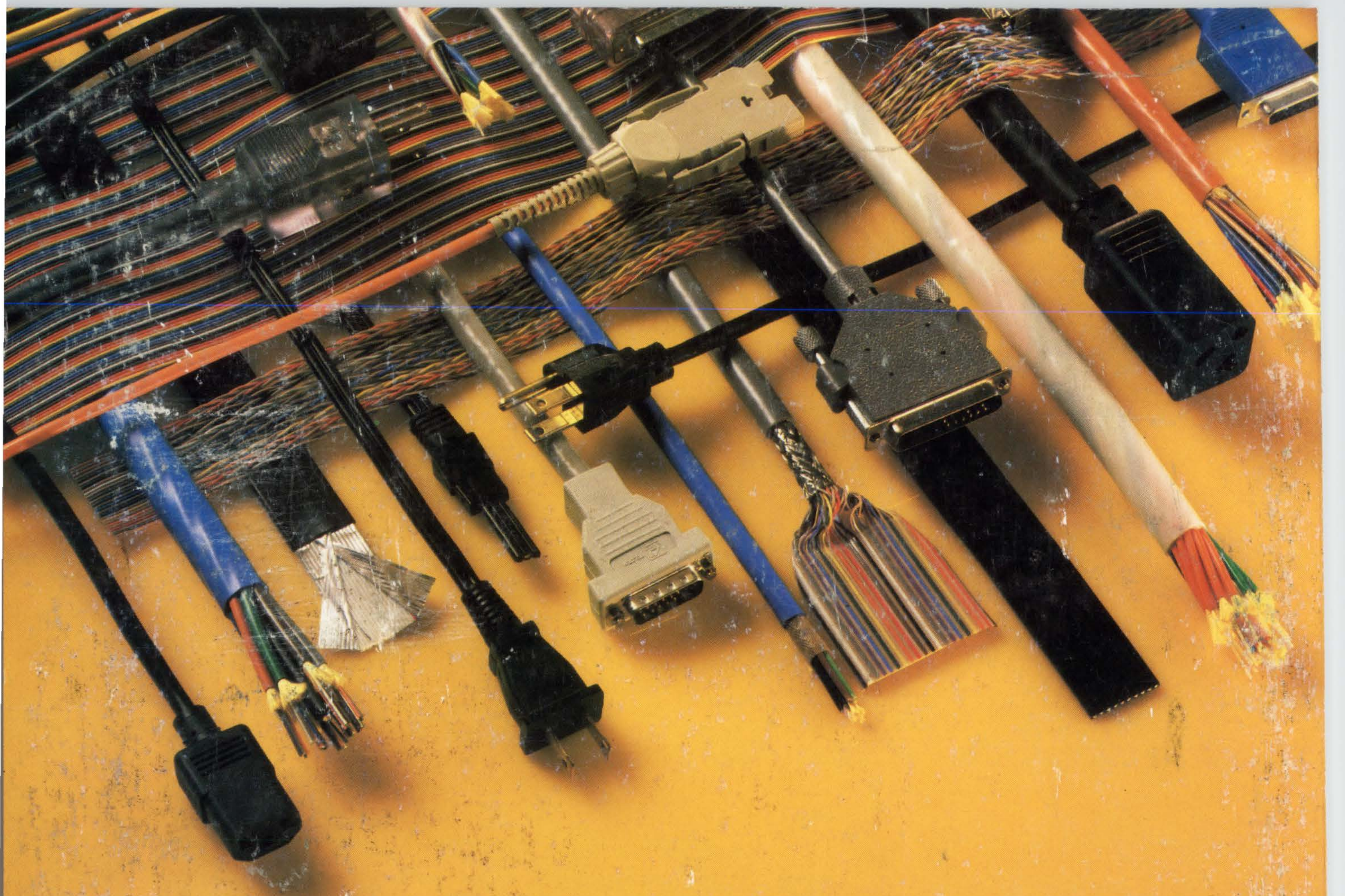

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