A CAHNERS PUBLICATION

MARCH 30, 1989

EDN®

Electro/89 preview: sessions and products

Designer's guide to dynamic RAMs—Part 1

Logic-synthesis tools

RISC CPU boards

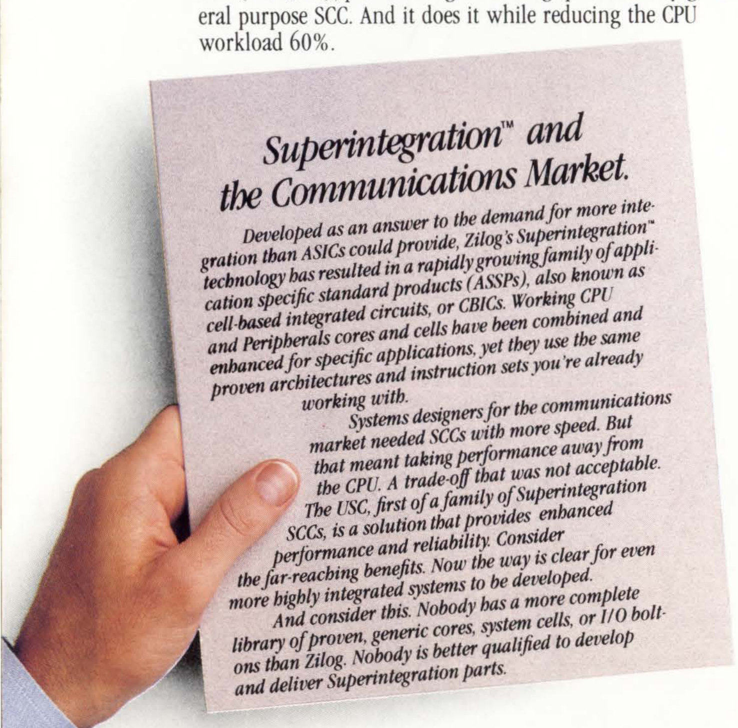
ELECTRONIC TECHNOLOGY FOR ENGINEERS AND ENGINEERING MANAGERS

Processors let PCs construct realistic 3-D graphics

Z I L O G

The next standard.
A new generation of high performance SCCs.

Zilog's universal serial communication controller, the USC (Z16C30™), provides higher throughput than any general purpose SCC. And it does it while reducing the CPU workload 60%.



More speed.

The USC is four times faster than any general purpose SCC. You get guaranteed data rates of 10 Mbits/sec. But speed is not the only USC advantage.

More CPU power.

The USC requires less attention from the system CPU. That means more power for the system. The USC's lower overhead is due to easy initialization, auto-sequencing word transfers from deep FIFOs, fly-by DMA control, and reduced latency from an efficient, chained interrupt structure.

More flexibility.

You've got two completely independent channels, as well as multi-protocol capability. Because the USC has two BRGs per channel you can transmit and receive at two different bit rates. And the USC's universal bus interface means you can cut the cost of GLU logic and expensive board real estate.

More performance.

CMOS and Superintegration™ bring more CPU power and higher data throughput. The USC carries a 12.5 MByte/sec bus bandwidth punch. Straight DMA connect and 32-byte FIFOs make the USC's systems simple, elegant and fast. Very fast.

More reliability.

With the USC you get Zilog's proven quality and reliability. Unique built-in testability features allow access to nodes and registers for testing program functionality in real time. Find out more about the USC or any of Zilog's growing family of Superintegration products. Contact your local Zilog sales office or your authorized distributor today. Zilog, Inc., 210 Hacienda Ave., Campbell, CA 95008, (408) 370-8000.

Right product. Right price. Right away. **Zilog**

ZILOG SALES OFFICES: CA (408) 370-8120, (714) 838-7800, (818) 707-2160, **CO** (303) 494-2905, **FL** (813) 585-2533, **GA** (404)923-8500, **IL** (312) 517-8080, **MA** (617) 273-4222, **MN** (612) 831-7611, **NJ** (201) 288-3737, **OH** (216) 447-1480, **PA** (215) 653-0230, **TX** (214) 987-9987, **CANADA** Toronto (416) 673-0634, **ENGLAND** Maidenhead (44) (628) 39200, **W. GERMANY** Munich (49) (89) 612-6046, **JAPAN** Tokyo (81) (3) 587-0528, **HONG KONG** Kowloon (852) (3) 723-8979. **TAIWAN** (886) (2) 741-3125, **SINGAPORE** 65-235 7155, **DISTRIBUTORS: U.S.** Anthem Electric, Bell Indus., Hall-Mark Elec., JAN Devices, Inc., Lionex Corp., Schweber Elec., Western Microtech. **CANADA** Future Elec., SEMAD, **LATIN AMERICA** Argentina—Yel.-(1) 46-2211, Brazil—Digibyte (011) 241-3611, Mexico—Semiconductores Profesionales (5) 536-1312.

CIRCLE NO 50

Dale® Can.

The phone book is full of magnetics suppliers. But one call – to Dale® Electronics – can add more than just a supplier to your next project.

We have the breadth of line, the staff and the facilities to deliver the exact part you need, exactly on time. We can document this in many ways – including a customer list full of firms who've proven it's more efficient to turn in-house magnetics production over to us.

So tell us your needs: A molded, shielded inductor, a MIL-C-15305 model, a high-volume, roll-coated choke, a custom switch model design. Off-the-shelf or one of a kind, Dale can be the partner you need to provide time-saving, cost-efficient magnetic components.

Call today or write for a copy of our expanded Magnetic Components Catalog. Dale Electronics, Inc., East Highway 50, Yankton, South Dakota 57078. Phone: 605-665-9301.

DALE®

Dale Makes Your Basics Better

CIRCLE NO. 1

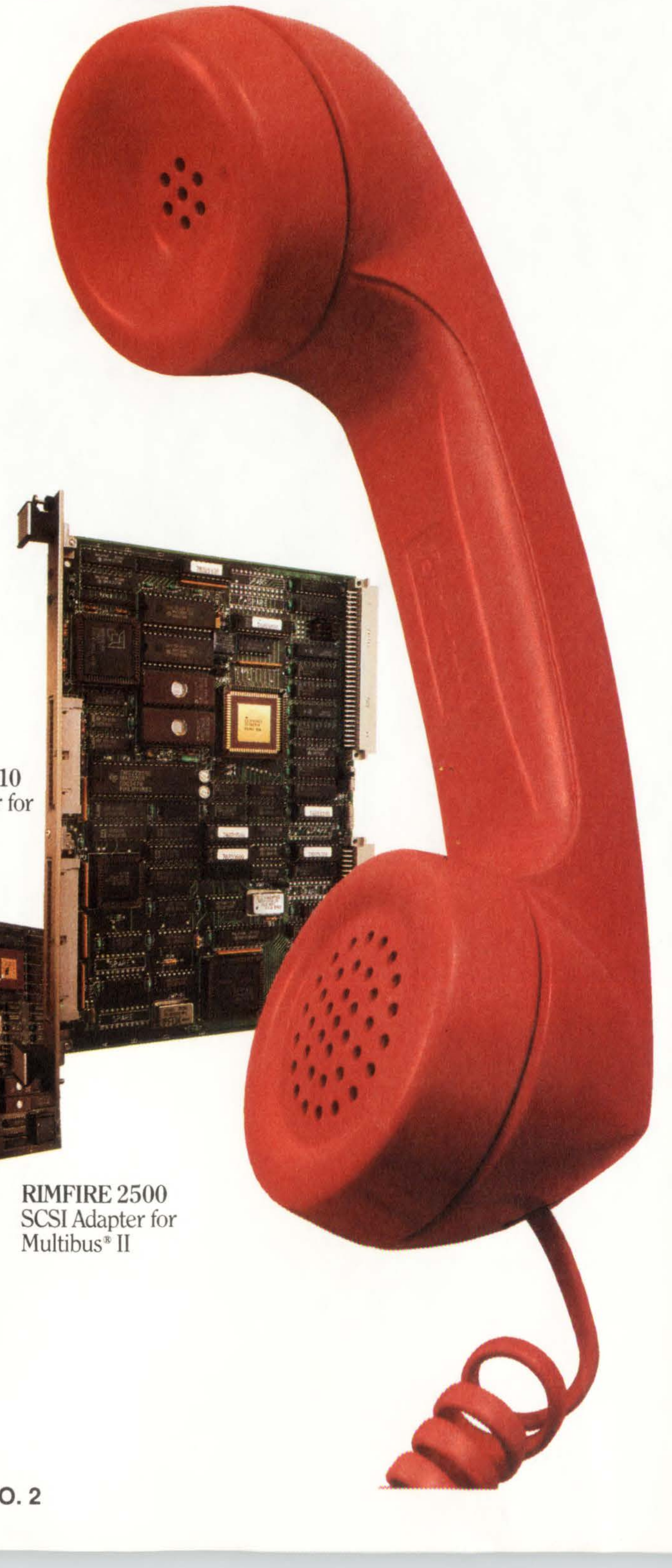
WANT TO TALK SCSI? CALL CIPRICO AT 1-800-SCSI-NOW.

Why talk SCSI with Ciprico? To start with, we're the only vendor with a complete line of high-performance SCSI host bus adapters for Multibus® I, VMEbus, and Multibus II. Each board was designed to optimize performance with its system bus. And consider our experience. Ciprico has over 50,000 boards installed worldwide. Our design expertise provides you with the highest possible performance at the lowest possible price.

But that's not all. Ciprico has *respondability*. We have the largest staff of customer support engineers in the industry to help you resolve any integration problems. Plus software drivers for all major operating systems.

Our SCSI adapters are all based on an 80186 microprocessor, providing a command queuing, pass-through SCSI command software interface. Each board supports SCSI disconnect/reconnect and asynchronous and synchronous transfer rates of 2MB/s and 5MB/s respectively. And a floppy port is optional for cost effective system design.

So if you're currently designing a system based on Multibus I, VMEbus, or Multibus II, give us a call to talk SCSI.



CIPRICO

2955 Xenium Lane
Plymouth, MN 55441

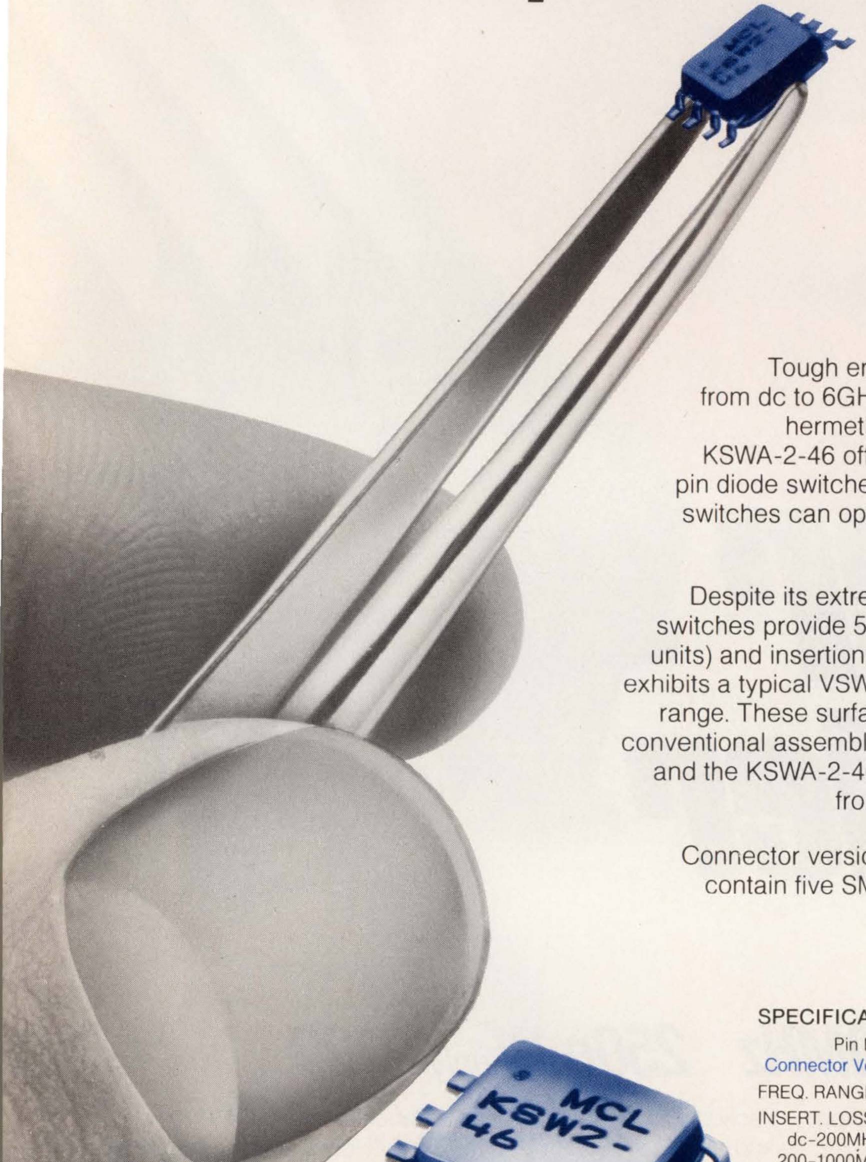
CIPRICO LISTENS. AND RESPONDS.

Multibus is a registered trademark of Intel Corporation.

CIRCLE NO. 2

tiny SPDT switches

absorptive... reflective



dc to 4.6GHz from $32.95 (10-24)

Tough enough to pass stringent MIL-STD-883 tests, useable from dc to 6GHz and smaller than most RF switches, Mini-Circuits' hermetically-sealed (reflective) KSW-2-46 and (absorptive) KSWA-2-46 offer a new, unexplored horizon of applications. Unlike pin diode switches that become ineffective below 1MHz, these GaAs switches can operate down to dc with control voltage as low as -5V, at a blinding 2ns switching speed.

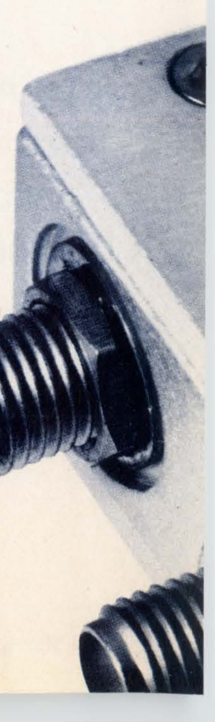
Despite its extremely tiny size, only 0.185 by 0.185 by 0.06 in., these switches provide 50dB isolation (considerably higher than many larger units) and insertion loss of only 1dB. The absorptive model KSWA-2-46 exhibits a typical VSWR of 1.5 in its "OFF" state over the entire frequency range. These surface-mount units can be soldered to pc boards using conventional assembly techniques. The KSW-2-46, priced at only $32.95, and the KSWA-2-46, at $48.95, are the latest examples of components from Mini-Circuits with unbeatable price/performance.

Connector versions, packaged in a 1.25 x 1.25 x 0.75 in. metal case, contain five SMA connectors, including one at each control port to maintain 3ns switching speed.

Switch fast... to Mini-Circuits' GaAs switches.

SPECIFICATIONS

Pin Model	KSW-2-46		KSWA-2-46	
Connector Version	ZFSW-2-46		ZFSWA-2-46	
FREQ. RANGE	dc-4.6 GHz		dc-4.6 GHz	
INSERT. LOSS (db)	typ	max	typ	max
dc-200MHz	0.9	1.1	0.8	1.1
200-1000MHz	1.0	1.3	0.9	1.3
1-4.6GHz	1.3	1.7	1.5	2.6
ISOLATION (dB)	typ	min	typ	min
dc-200MHz	60	50	60	50
200-1000MHz	45	40	50	40
1-4.6GHz	30	23	30	25
VSWR (typ) ON	1.3:1		1.3	
OFF	—		1.4	
SW. SPEED (nsec) rise or fall time	2(typ)		3(typ)	
MAX RF INPUT (bBm)				
up to 500MHz	+17		+17	
above 500MHz	+27		+27	
CONTROL VOLT.	-8V on, OV off		-8V on, OV off	
OPER/STOR TEMP.	-55° to +125°C		-55° to +125°C	
PRICE (10-24)	**$32.95**		**$48.95**	
	$69.95		**$79.95**	



finding new ways...
setting higher standards

Mini-Circuits

A Division of Scientific Components Corporation
P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500
Fax (718) 332-4661 Domestic and International Telexes: 6852844 or 620156

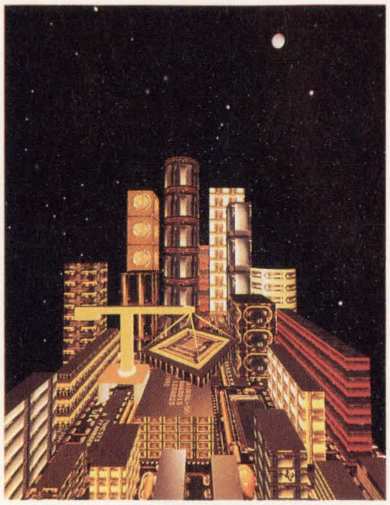
C 117 REV. E

CIRCLE NO 136

EDN Magazine Edition

Volume 34, Number 7 March 30, 1989

ELECTRONIC TECHNOLOGY FOR ENGINEERS AND ENGINEERING MANAGERS



On the cover: *With any one of three recently introduced processors, you can give your PC's graphics an added dimension. See pg 96.*

This cover art was produced by Diane Molina and Ben Deiman of Bendi Photographic Design on equipment from Austin Business Computers Inc. The image was created on an IBM PC/AT-compatible computer containing a 34010-based Truevision ATVista videographics card. The image started with 35-mm color slides of the ATVista card and the TI34020 graphics processor. It was then digitized with a Howtek slide scanner. Extrusions of the chips were made to look like buildings with TOPAS software from AT&T Graphics Software Labs. The designer used Truevision Vista TIPS to create the textures. This photograph was provided courtesy Texas Instruments.

SPECIAL REPORT

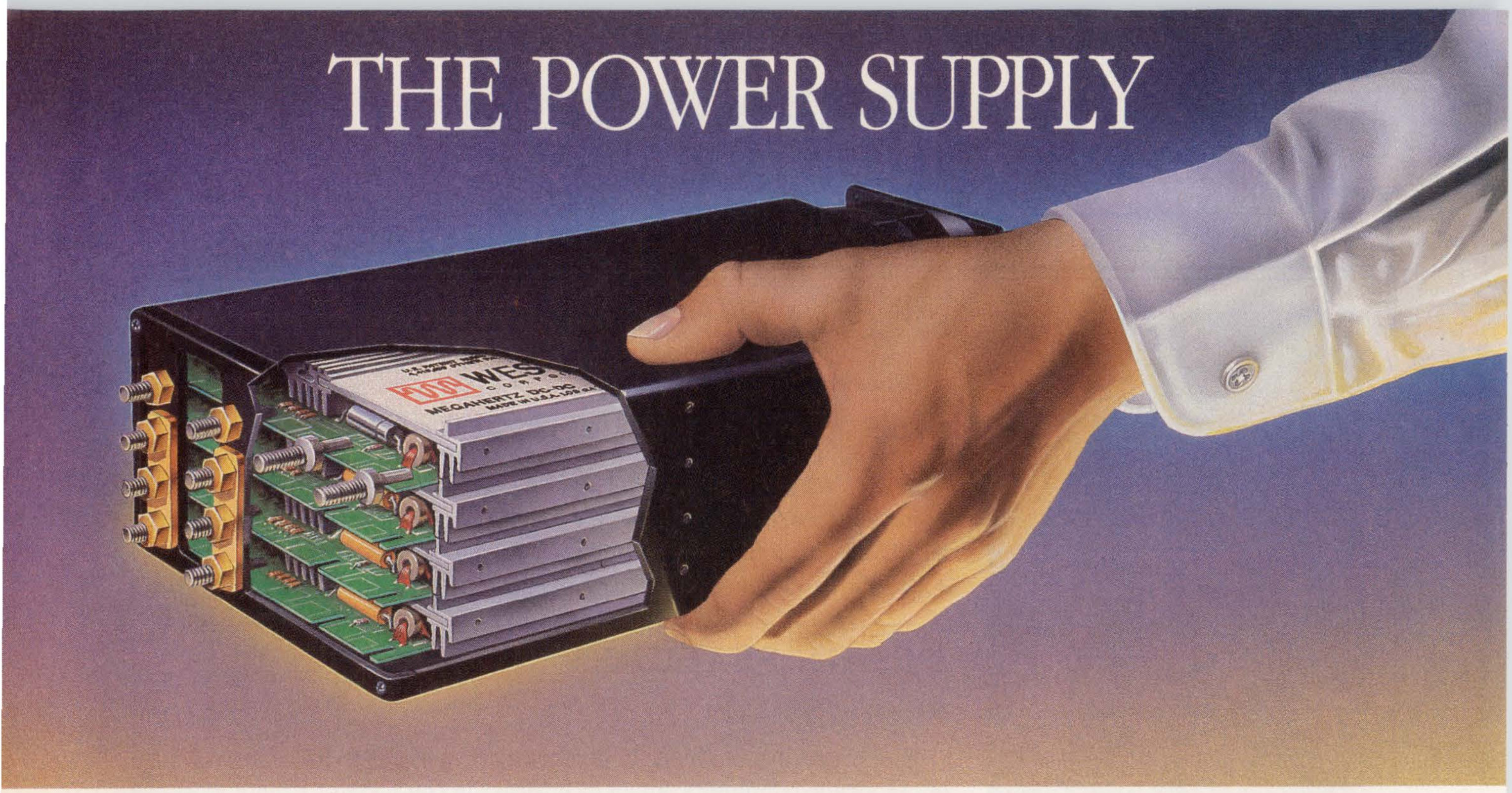
DESIGN FEATURES

Continued on page 7

EDN®(ISSN 0012-7515) is published 49 times a year (biweekly with 2 additional issues a month, except for February, which has 3 additional issues and July and December which have 1 additional issue) by Cahners Publishing Company, A Division of Reed Publishing USA, 275 Washington Street, Newton, MA 02158-1630. Terrence M McDermott, President; Frank Sibley, Senior Vice President/General Manager, Boston Division; Jerry D Neth, Vice President/Publishing Operations; J J Walsh, Financial Vice President/Magazine Division; Thomas J Dellamaria, Vice President/Production and Manufacturing. Circulation records are maintained at Cahners Publishing Company, 44 Cook Street, Denver, CO 80206-5800. Telephone: (303) 388-4511. Second-class postage paid at Denver, CO 80206-5800 and additional mailing offices. POSTMASTER: Send address corrections to EDN® at the Denver address. Saul Goldweitz, Chairman; Ronald G Segel, President and Chief Executive Officer; Robert L Krakoff, Executive Vice President; William M Platt, Senior Vice President. Annual subscription rates for nonqualified people: USA, $105/year; Canada/Mexico, $125/year; Europe air mail, $150/year; all other nations, $150/year for surface mail and $230/year for air mail. Single copies are available for $10. Please address all subscription mail to Eric Schmierer, 44 Cook Street, Denver, CO 80206-5800.

BPA ABP

THE POWER SUPPLY



REDEFINED

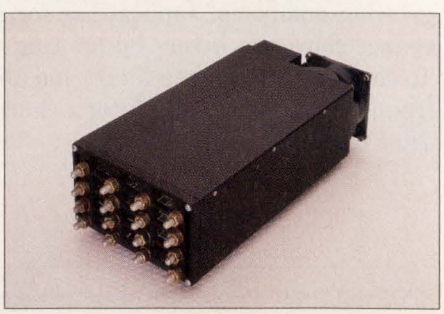
THE WESTCOR STAKPAK™. NEW GENERATION 250 TO 1200 WATT SINGLE OR MULTIPLE OUTPUT OFF-LINE SWITCHER. 3.2 X 5.5 X 11.4 INCH CASE. FAN-COOLED.

Stack the odds in your favor by designing-in Westcor's 6 watt/cubic inch high power megahertz switcher. Capitalizing on patented and proven megahertz module technology and innovative thermal management techniques, the StakPak provides up to 1200 watts of power at 50°C with 1 to 8 isolated and fully regulated outputs.

For existing designs the StakPak's small size and low profile allow system enhancement without mechanical redesign. Simply replace your open frame switcher with up to 1200 watts of StakPak power or replace your "box switcher" with 2 StakPaks and realize up to twice the power without losing additional space. StakPak power factor correction provides 850 watts of output power from a standard 115 VAC wall outlet. In new designs, more space can be devoted to functionality or the system can be downsized.

The StakPak's 8 module output section can be factory configured in virtually an infinite number of voltage, current and power combinations. Special models providing between 250 to 1200 watts and outputs from 2 to 95 VDC are available.

Other features include outstanding electrical performance; UL, CSA, VDE safety agency approval (in process); variable speed fan option for low ambient noise enviroments and 3 phase or DC input options. Indeed, with unprecedented power density, versatility and new features, the StakPak redefines power packaging. Please contact Westcor for a data sheet, pricing and additional information.



STANDARD 1200 WATT STAKPAK MODELS (110/220 VAC input)

Model	Output Voltage (VDC) and Maximum Current (amperes) per Channel				
	#1	#2	#3	#4	#5
Single Output					
SP1-1801	2 @ 240				
SP1-1802	5 @ 240				
SP1-1803	12 @ 100				
SP1-1804	15 @ 80				
SP1-1805	24 @ 50				
SP1-1806	28 @ 42				
SP1-1807	48 @ 25				
Dual Output					
SP2-1801	2 @ 120	5 @ 120			
SP2-1802	5 @ 120	5 @ 120			
SP2-1803	5 @ 120	12 @ 66			
SP2-1804	12 @ 66	12 @ 66			
SP2-1805	15 @ 53	15 @ 53			
Triple Output					
SP3-1801	5 @ 180	12 @ 16	12 @ 16		
SP3-1802	5 @ 150	12 @ 33	12 @ 16		
SP3-1803	5 @ 180	15 @ 13	15 @ 13		
SP3-1804	5 @ 150	15 @ 26	15 @ 13		
Quad Output					
SP4-1801	5 @ 150	12 @ 16	12 @ 16	5 @ 30	
SP4-1802	5 @ 150	15 @ 13	15 @ 13	5 @ 30	
SP4-1803	5 @ 150	12 @ 16	12 @ 16	24 @ 8	
SP4-1804	5 @ 150	15 @ 13	15 @ 13	24 @ 8	
Five Output					
SP5-1801	5 @ 120	12 @ 16	12 @ 16	5 @ 30	24 @ 8
SP5-1802	5 @ 120	15 @ 13	15 @ 13	5 @ 30	24 @ 8

Total output power may not exceed 1200 watts for any model, single or multiple output. Lower power StakPak models are available. Please contact the factory.

™

WESTCOR CORPORATION • 485-100 Alberto Way • Los Gatos, CA 95032 • (408) 395-7050 • FAX (408) 395-1518

Westcor is a subsidiary of VICOR CORPORATION

CIRCLE NO 137

Continued from page 5

TECHNOLOGY UPDATE

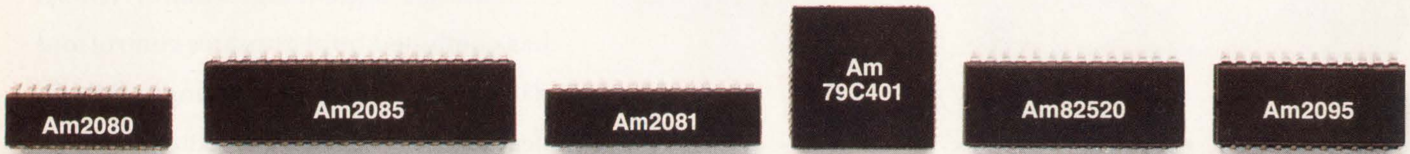
PRODUCT UPDATE

NEW PRODUCTS

DEPARTMENTS

April 1st Special Supplement

Cahners Publishing Company, A Division of Reed Publishing USA □ Specialized Business Magazines for Building & Construction □ Manufacturing □ Foodservice & Lodging □ Electronics & Computers □ Interior Design □ Printing □ Publishing □ Industrial Research & Technology □ Health Care □ and Entertainment. Specialized Consumer Magazines: □ American Baby □ and Modern Bride.



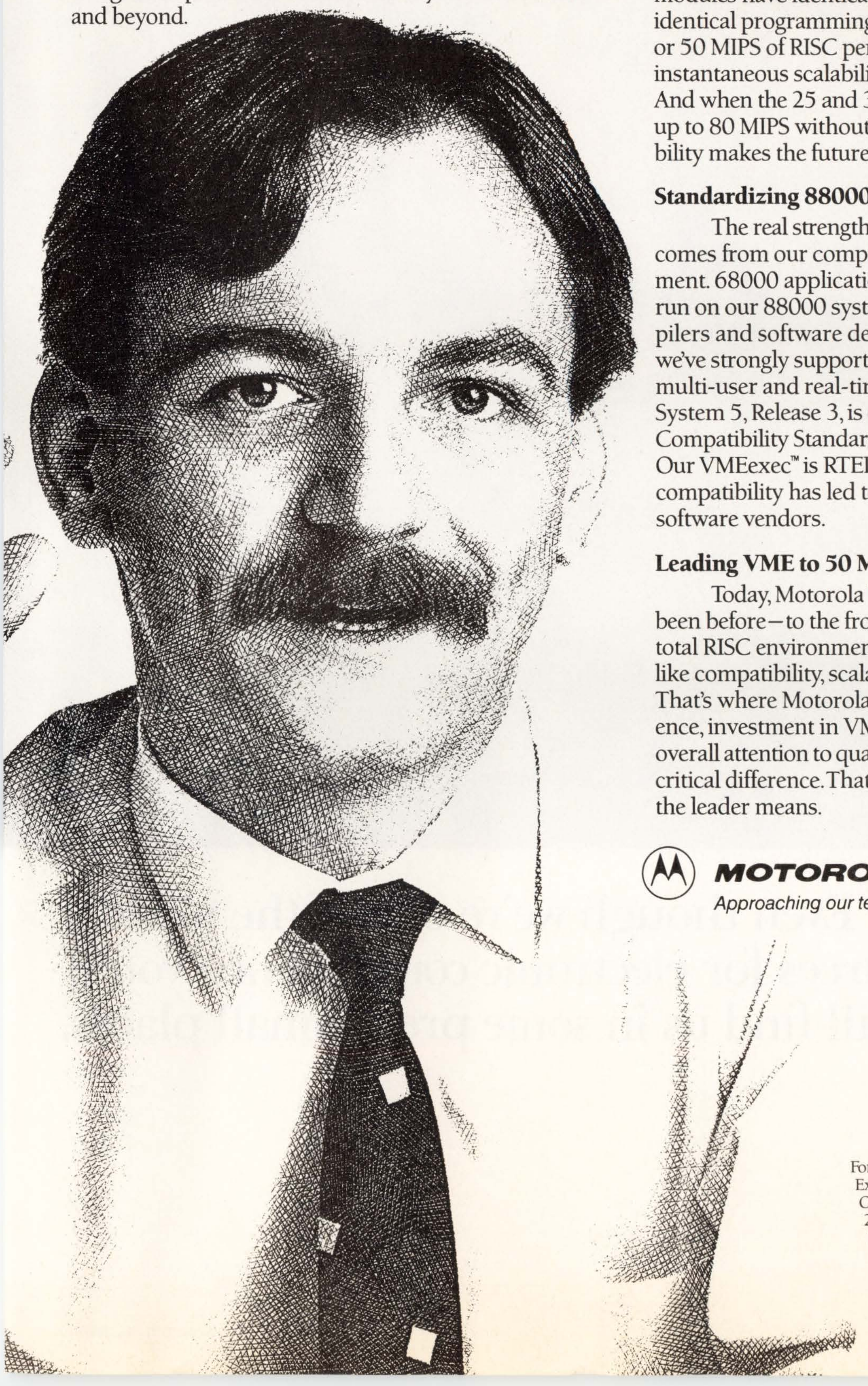
ISDN S-transceiver | ISDN S-transceiver + data link controller | ISDN S-transceiver/ extended performance | ISDN Integrated Data protocol controller | ISDN high level serial controller | ISDN Ping pong transceiver

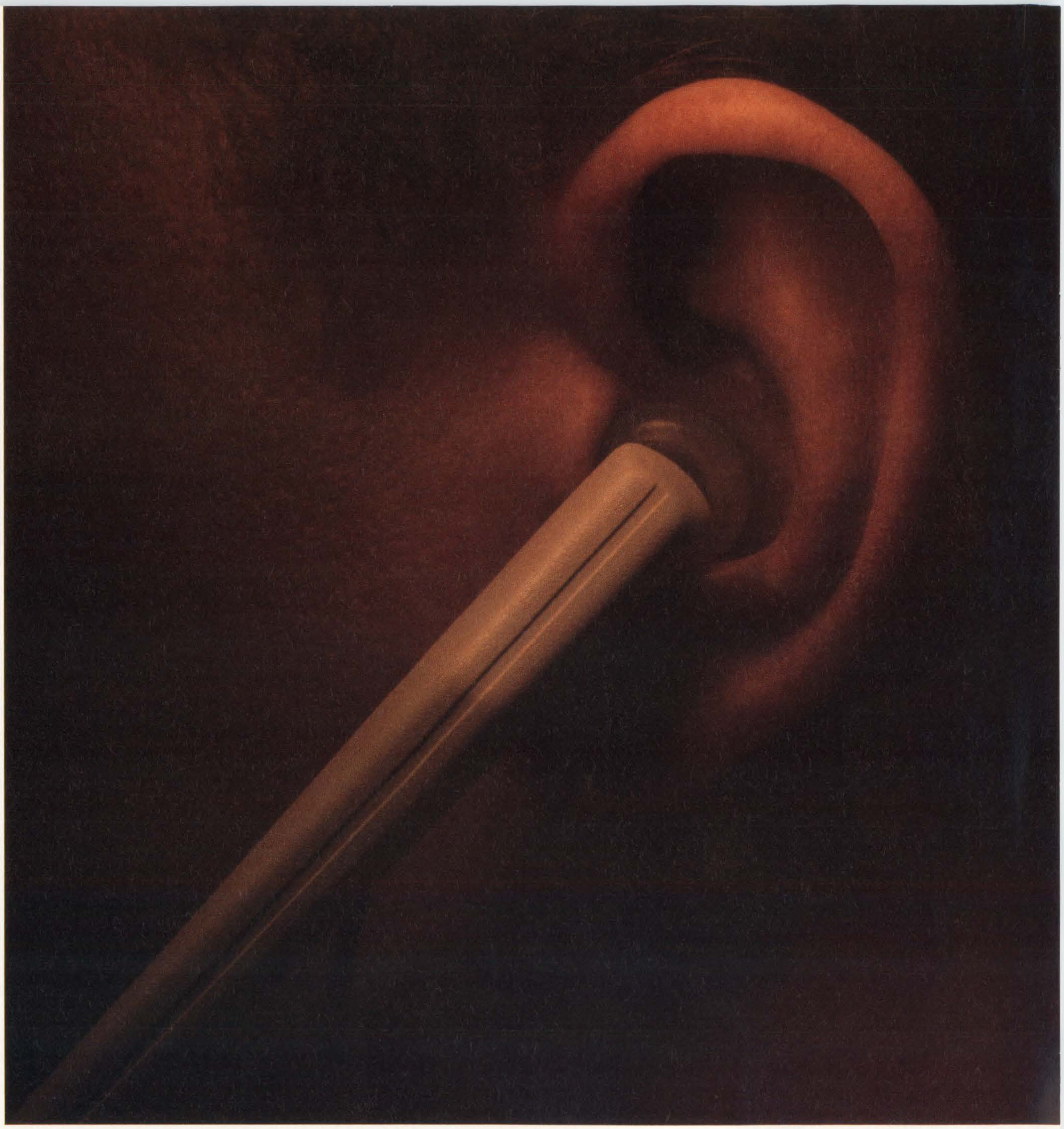
It takes to make a

"The VME world doesn't just need RISC performance.

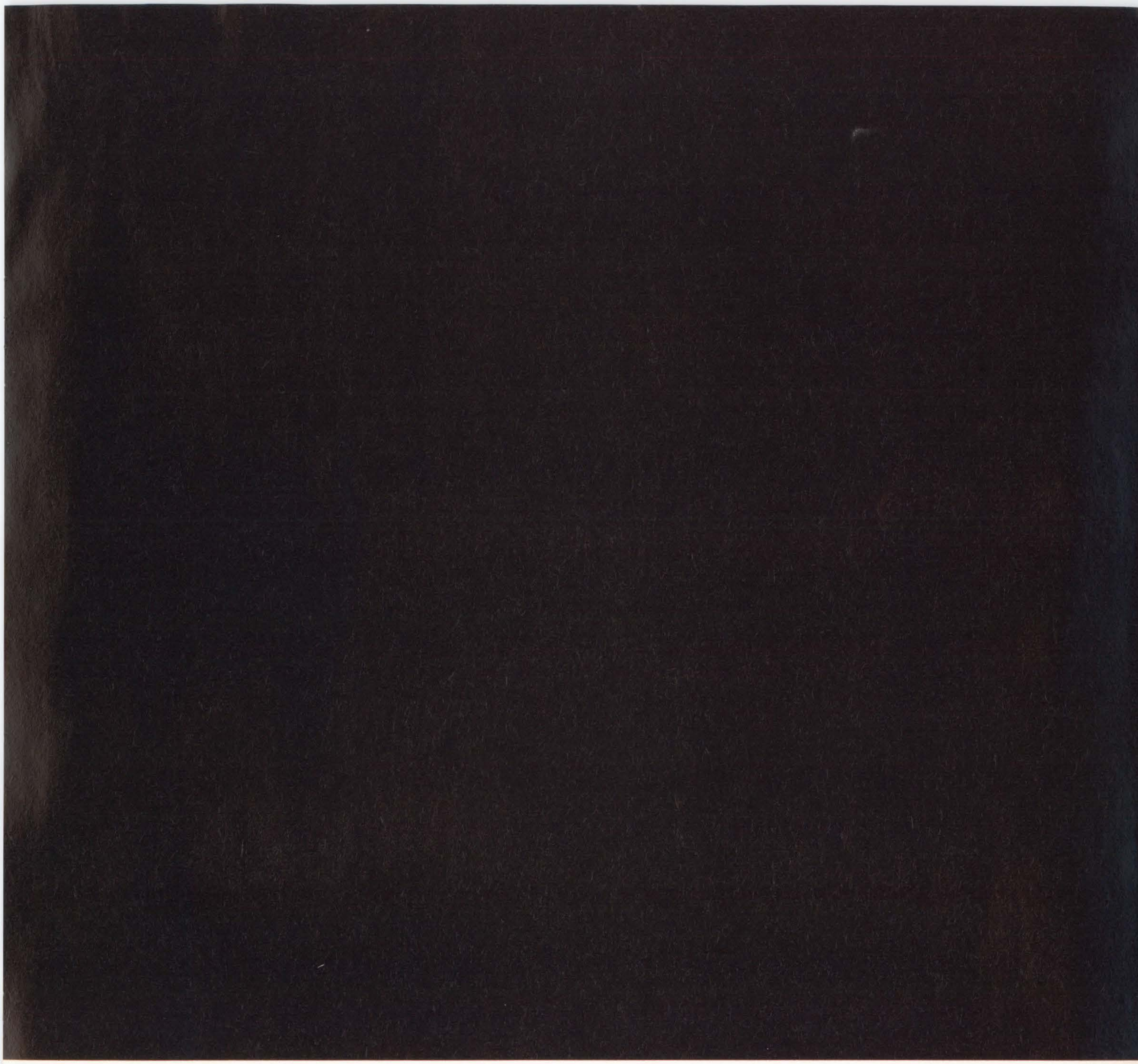
It needs a total RISC computing environment."

Andreas Schreyer,
RISC Product Marketing Manager





Even though we're one of the world's largest sources for electronic components, you'll still find us in some pretty small places.



ITT ElectroMechanical Components Worldwide. Our name not only describes what we do, but it also says we're an international company, with worldwide presence. So, it should really come as no surprise that you'll find our products in everything from the rotary dial in a telephone headset, to places like Willow Springs.

Fact is, you can find our switches, relays, connectors, cable assemblies and test accessories in virtually every part of the world. In almost every application.

Whether it's in telecommunications, instrumentation, medical electronics, automotive, military, aerospace, computers or consumer electronics, ITT EMC Worldwide has the experience and technical expertise to help you build a quality product, every time.

For seventy-five years, our engineering strength and customer support have been second to none. That's why many of the world's leading companies select us for their ship-to-stock programs.

When you do business with the companies of ITT EMC Worldwide, you can always expect quality, service and on-time delivery. And no matter where you are in the world, chances are we've got a representative nearby.

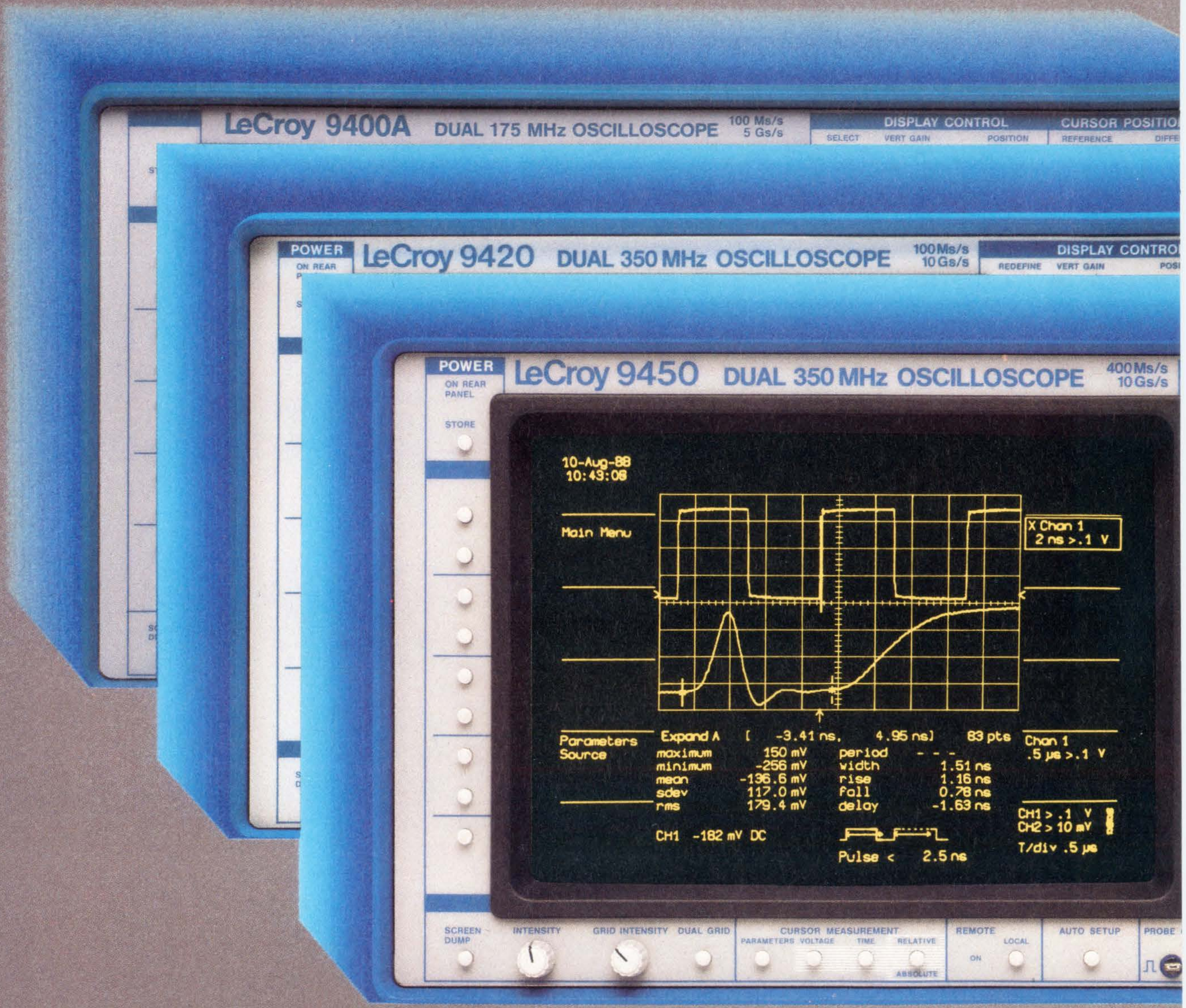
So, drop us a line today. And see how small a one billion dollar company can be.

1851 East Deere Avenue
Post Office Box 35000
Santa Ana, CA 92705-6500
Or call (714) 261-5300

ITT ElectroMechanical Components Worldwide
Discover our strengths.

CIRCLE NO 141

Who do the Best



Model	Bandwidth (MHz)	Sampling Rate S.S. (Ms/s)	RIS (Gs/s)	Memory per Channel (kwords)	Vertical Resolution (bits)	FFT Spectral Analysis
9450	350	400	10	50	$8^{\dagger}$	yes
9420	350	100	10	50	$8^{\dagger}$	yes
9400A	175	100	5	32	$8^{\dagger}$	yes

† up to 12 bits with averaging

Enter the Knowledge-based

NCR

Cross the threshold into the Knowledge-based Engineering Environment (KE²), a world created by NCR specially for ASIC designers.

Here, the normal conventions of ASIC design are superseded.

Previously unthinkable deadlines are now routine.

Increased levels of quality are matched by decreased cost per gate.

Yesterday's integration impossibilities are mere keystrokes away.

And your control is absolute.

In ASICs, knowledge is power and with KE² tools and libraries, you command the knowledge amassed by hundreds of top ASIC designers over the past decade.

For example, our Design Synthesis™ tool lets you design entire blocks without getting bogged down in implementation details. The system automatically generates correct and efficient logic specifications from your high-level language descriptions.

Design Advisor™ is an expert system that puts you in charge of a "team" of top ASIC design, test and production professionals that we "captured" in software. At your request, this "team" analyzes the design and reports back to you with comments and suggestions for your review.

ViTat™, NCR's Static Timing Analysis Tool, compresses the time needed to analyze high performance designs by up to two months over pattern-driven simulations.

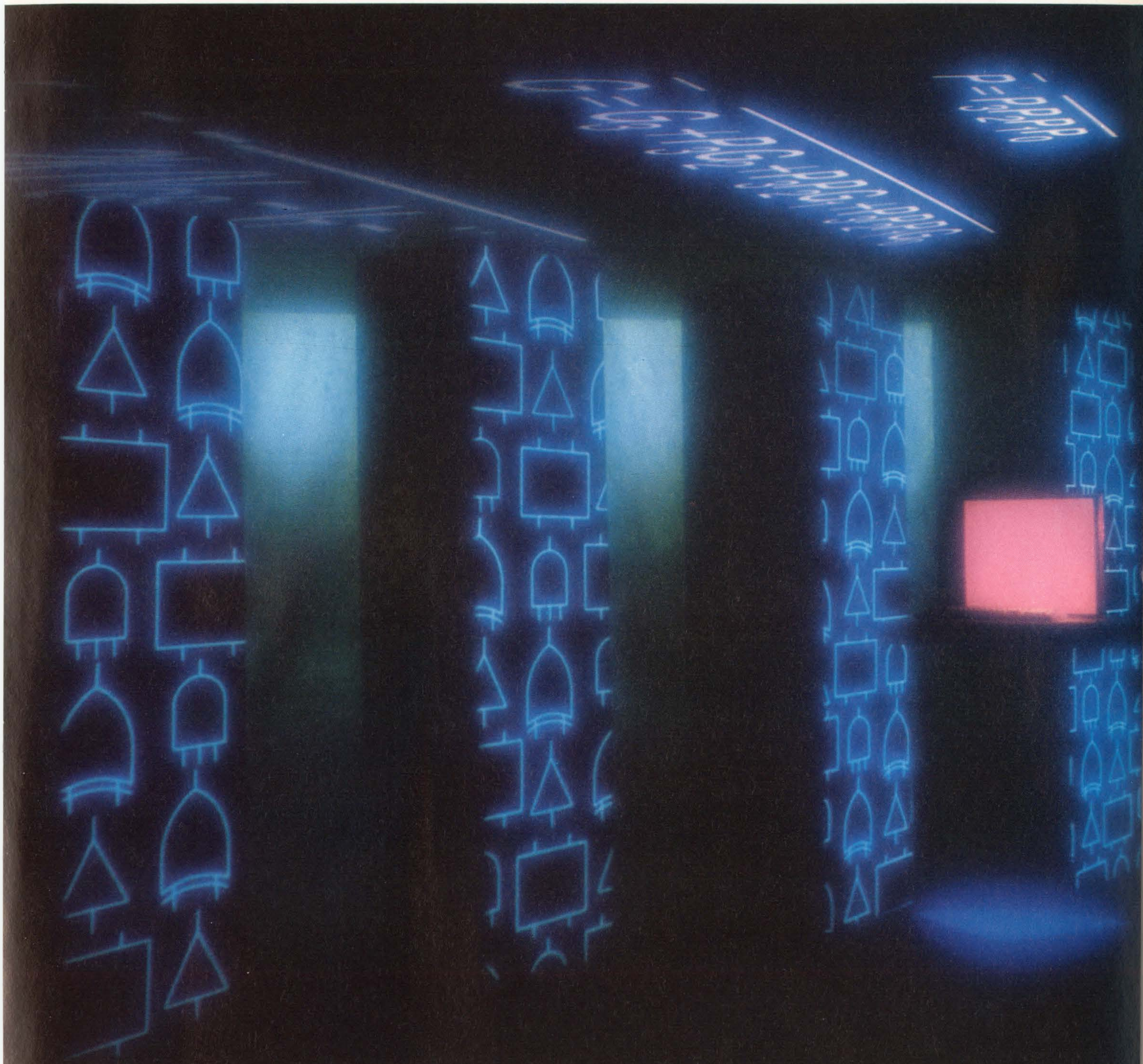
And there's much more, including function compilers, extensive libraries of digital/analog cells, MPU cores and supercells and the complete NCR ViSys™ tool set.

Leave behind the ASIC design systems that restrain your capabilities and tether your imagination. Enter a world where there is more time, more power, more options. Where all your capabilities are multiplied.

A world all the more incredible because it's not an illusion, it's real.

For additional information on the Knowledge-based Engineering Environment, call the NCR Hotline **1-800-334-5454**. Or write, NCR Microelectronics, 2001 Danfield Court, Ft. Collins, CO 80525.

Engineering Environment.™



Creating value

CIRCLE NO 143

NEWS BREAKS

EDITED BY JOANNE DE OLIVEIRA

DEVELOPMENT TOOL SIMPLIFIES CREATION OF USER INTERFACES

The Microware Systems Corp (Des Moines, IA, (515) 224-1929) Rave (Real-time Audio/Video Environment) software-development tool simplifies the design of human interfaces for real-time applications such as process-control systems. The development tool, an extension to the OS-9 real-time operating system, allows you to combine audio and video signals, computer-generated graphics, and customizable menus to create a user interface. Rave consists of three software packages. The File Manager ($300) and the Graphics Support Library ($175) handle run-time chores and include drivers that interact with system hardware. You use the Presentation Editor ($995) to create a user interface. All of the products will be available in May.—Maury Wright

INTERFACE UNIT LINKS SCSI AND IEEE-488 BUSES

If your computer or workstation provides a SCSI port, you may have thought that only peripherals such as disk and tape drives could take advantage of it. Now, however, you can use a SCSI port to control external data-acquisition systems, measuring instruments, and other devices that operate on the IEEE-488 bus. The SCSI488 interface unit from IOtech Inc (Cleveland, OH, (216) 439-4091) lets a SCSI port control as many as 14 IEEE-488 devices. Keep in mind that many computers and workstations provide only SCSI and RS-232C ports for communication with peripheral devices.

Because the interface is bidirectional, you can also use one IEEE-488 port to control as many as seven SCSI-based devices. Although the device's internal microprocessor controls the flow of information, it doesn't interfere with block-transfer operations, which can reach a speed of 800k bytes/sec. You can buy the SCSI488 for $795; it's available from stock.—Jon Titus

PROTOTYPING BOARD KITS INCLUDE A RISC-LIKE 32-BIT μP

Intel Corp (Dept 9P01, Santa Clara, CA, (800) 548-4725) now offers two kits that provide designers with a low-cost way to evaluate or prototype products based on the 20-MHz, 32-bit, 80960KB RISC-like processor from Intel. The kits include working CPU boards, schematics, programmable logic equations, and a software debug monitor. You can choose from kits with slightly different 80960KB-based boards. The EVQT960F20 kit costs $1960 and includes 128k bytes of zero-wait-state static RAM and 128k bytes of flash EPROM, which are installed on the CPU board. The board included in the $960 EVQT960E20 kit hosts 128k bytes of 2-wait-state static RAM and sockets for 128k bytes of EPROM. The CPU boards include an onboard prototyping area and a connector that you can use to add external circuits. Shipments will start by midyear.—Maury Wright

FAMILY OF 1- TO 10-MHz 12-BIT ADCs FEATURES LOW DISTORTION

Datel Inc (Mansfield, MA, (508) 339-3000) has announced a complete family of sampling A/D converters that operate at sampling rates of 1, 2, 5, and 10 MHz. The ADS-112 (1-MHz), ADS-132 (2-MHz), ADS-131 (5-MHz), and ADS-130 (10-MHz) converters offer excellent dynamic performance. At the Nyquist frequency, the total harmonic distortion is −73 dB for the 1-MHz and 2-MHz devices and −69 dB for the 5-MHz and 10-MHz devices. The number of effective bits at the Nyquist frequency is 11.0 for the two lower-frequency devices and 10.6 for the two higher-frequency devices.

The ADCs, which also feature low noise and low nonlinearity specs, use a digitally corrected subranging architecture to achieve 12-bit resolution. The design of these converters includes an internal sample/hold circuit, on-chip references, a clock, 3-state outputs, and user-selectable output coding. Power dissipation ranges from 1.3W for the 1-MHz part to 4.9W for the 10-MHz device. Pricing for commercial units is $259 (24-pin ADS-112), $346 (32-pin ADS-132), $465 (40-pin ADS-131), and $549 (40-pin ADS-130). Delivery, from stock to four weeks.—Dave Pryce

FULL-HEIGHT 5¼-IN. WINCHESTER STORES 764M BYTES

The MK-358 Winchester disk drive from Toshiba (Irvine, CA, (714) 380-3000) offers an unformatted capacity of 764M bytes. The 8-platter drive dedicates one surface to servo control, but also relies on servo information embedded in each sector to ensure accurate tracking. The SCSI version of the drive costs $2645 (1000); the ESDI version is $2495 (1000). The SCSI version includes support for SCSI-2 features. Furthermore, the SCSI drive features an extensive command set that is stored on the drive and downloaded to RAM on power up. You can update the command set by downloading from a floppy disk. The company can easily implement custom command sets.—Maury Wright

EVALUATION BOARDS AID IN RISC-μP DEVELOPMENT

Two boards from Step Engineering (Sunnyvale, CA, (408) 733-7837) can assist you in developing systems based on the AMD (Sunnyvale, CA) 29000 RISC (reduced-instruction-set computer) processor. The $3445 Step PCEV (personal-computer evaluation vehicle) incorporates the μP along with 512k bytes of dual-ported video RAM, and plugs into the IBM PC/AT bus. The $1750 Step STEB (stand-alone target evaluation board) includes a 29000 μP, 512k bytes of RAM, two serial ports, and sockets for as much as 512k bytes of ROM. The company ships the board with a ROM-based debugging monitor called MON29K. Step also offers a line of software-development products for the 29000 μP; the PCEV and STEB boards give you a ready target for code developed with those tools.—Steven H Leibson

RETARGETABLE CROSS-MACROASSEMBLER REDUCES TOOL PURCHASES

If you're tired of buying yet another assembler every time you incorporate a new μP in one of your designs, or if you've been avoiding using a new μP because you don't have the software tools necessary to program it, the CASM retargetable cross-assembler from AnyWare Engineering (Boulder, CO, (303) 442-0556) can solve your problem. The $195 software package includes the cross-macroassembler, a linker, and a definition-file compiler. Definition files describe a particular μP's instruction set and assembly-language syntax by using a proprietary, procedural programming language. The language eases the task of molding the assembler to complex, pipelined architectures, such as those in RISC processors, and to wide instruction words, such as those used in digital signal processors. CASM also includes definition files for the 8085, Z80, 8041, 8048, 8051, 8096, 6805, 68HC11, 6502, and R2000 μPs and the NEC 7720 digital signal processor.—Steven H Leibson

DECODER FACILITATES 2-CHIP TELETEXT SYSTEMS

The MV1815 single-chip CMOS teletext decoder and one dynamic RAM are all that you need to put together a complete teletext system. Adding extra memory allows you to store as many as 254 teletext pages. Manufactured by Plessey Semiconductors (Swindon, UK, TLX 449637; in the US: Scotts Valley, CA, (408) 438-2900), the decoder includes all level 1 teletext functions and many level 2 functions. In addition, it has an on-chip data slicer, two separate page-acquisition circuits, and RGB color-display logic. Its character sets support 13 languages, including most European and Scandinavian languages. Engineering samples of the MV1815 are available now. Production parts, which are expected to sell for around £5 (100,000), will be available during the third quarter of 1989.—Peter Harold

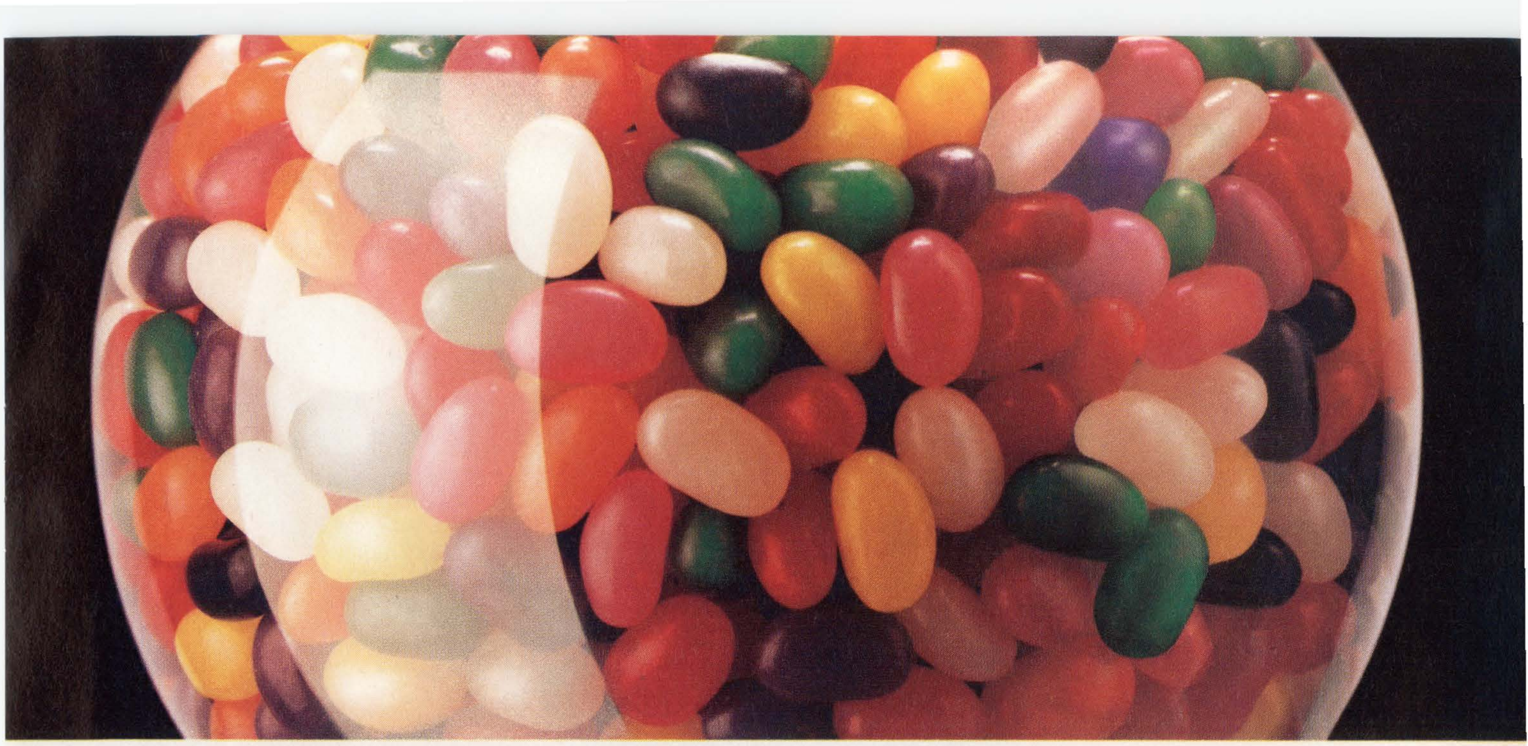
OPERATING SYSTEM ADDS FAULT TOLERANCE TO UNIX

Under an agreement between Integrated Micro Products (Consett, UK, TLX 537747; in the US: Santa Cruz, CA, (408) 429-1338) and Unisoft Corp (Emeryville, CA, (415) 420-6400), both companies will internationally market Integrated Micro Products' new FT-Unix fault-tolerant operating system. Because the operating system's fault tolerance is completely transparent, the system provides a standard Unix V.3 software environment in which you can run unmodified application programs. Together with suitable hardware, FT-Unix supports the synchronization of two CPUs, mirroring of data on separate disks, redundant I/O and communications operations, and isolation and reintegration of hardware modules to support diagnostic and servicing operations. It also supports the use of uninterruptible power supplies. FT-Unix licenses will be less than twice the price of standard Unix V.3, and both companies will promote its adoption as an open standard.—Peter Harold

SYSTEM TRANSLATES SPOKEN JAPANESE TO SPOKEN ENGLISH

Matsushita has reportedly developed a translation system that can convert spoken Japanese sentences to the corresponding English sentences in approximately 5 to 10 sec. Unlike conventional voice-translation systems, which recognize only registered voices and require the speakers to divide sentences into clauses, this machine accepts natural speech from arbitrary speakers. Conventional machines are also fairly large; this system is the size of a typical workstation. It comprises a sound-recognition device, a general-purpose (Sun-3) workstation, and a sound-composition device.

The system performs its translation by converting spoken Japanese to a series of alphabetical phoneme symbols and transmitting them to the workstation, where a translating program analyzes and comprehends the sentence, translates it into English, and formulates the English verbalization. To do so, the system uses the translation program developed by Professor Masaru Tomita of Carnegie-Mellon University. The system can translate about 3000 short Japanese sentences (of two to four clauses) after 50 words have been entered in the dictionary. In testing the system, the firm has achieved an 80% recognition figure; the company plans to improve the accuracy of recognition to the 85% to 90% level. It also expects to offer high-speed performance and eventually to offer translation from English to Japanese. In addition, Matsushita reportedly aims to produce the world's first portable translation machine.—Joanne De Oliveira



If this is how you see LEDs, the ad is over.

The popular myth goes something like this: "An LED, is an LED, is an LED." Or: "If you've seen one, you've seen them all." And of course: "LEDs? They're commodity products."

Notions we at Dialight, steadfastly reject. And once you're familiar with our products, you'll know why.

Take our Circuit Board Indicators. Single or multiple discretes aligned in a sturdy plastic housing, complete with their own current limiting resistor. The entire assembly polarity-keyed to guarantee correct insertion.

Each unit is 100% tested—ready to insert for wave soldering. No leads to bend, trim, or break. No time wasted fumbling with discretes.

Dialight pioneered the concept more than fifteen years ago to satisfy the OEM need for fast and reliable circuit board installation of LEDs. And we've been perfecting it ever since. Developing hundreds of standard and custom designs. A heritage of technological advance you can see in our new super-bright gallium aluminum arsenide units.

All meticulously engineered with the understanding that the failure of a "jelly bean product" can cost thousands in end-user downtime, and who-knows-what in customer loyalty.

The same understanding might bring you to call 201-223-9400, or write Dialight Corporation, 1913 Atlantic Ave., Manasquan, NJ 08736, and ask for our catalog or a product sample. At the very least, it's brought you to the real end of our ad.

DIALIGHT CORPORATION
A Cambridge Electronic Industries Company

Engineering is the only commodity we sell.

CIRCLE NO 145

value-packed
filters from $11.45

dc to 3GHz

- less than 1dB insertion loss over entire passband
- greater than 40dB stopband rejection
- 5 section, 30dB per octave roll-off
- VSWR less than 1.7 (typ)
- over 100 models, immediate delivery
- meets MIL-STD-202
- rugged hermetically sealed package (0.4 x 0.8 x 0.4 in.)
- BNC, Type N, SMA available

finding new ways...
setting higher standards

Mini-Circuits

A Division of Scientific Components Corporation
P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500
Fax (718) 332-4661 Domestic and International Telexes: 6852844 or 620156

LOW PASS **Model**	***LP–**	**10.7**	**21.4**	**30**	**50**	**70**	**100**	**150**	**200**	**300**	**450**	**550**	**600**	**750**	**850**	**1000**
Min. Pass Band (MHz) DC to		10.7	22	32	48	60	98	140	190	270	400	520	580	700	780	900
Max, 20dB Stop Frequency (MHz)		19	32	47	70	90	147	210	290	410	580	750	840	1000	1100	1340

Prices (ea.): Qty. (1-9) P $11.45, B $32.95, N $35.95, S $34.95

HIGH PASS **Model**	***HP–**	**50**	**100**	**150**	**200**	**250**	**300**	**400**	**500**	**600**	**700**	**800**	**900**	**1000**
Pass Band (MHz)	start, max.	41	90	133	185	225	290	395	500	600	700	780	910	1000
	end, min.	200	400	600	800	1200	1200	1600	1600	1600	1800	2000	2100	2200
Min. 20dB Stop Frequency (MHz)		26	55	95	116	150	190	290	365	460	520	570	660	720

Prices (ea.): Qty. (1-9) P $14.95, B $36.95, N $39.95, S $38.95

*Prefix P for pins, B for BNC, N for Type N, S for SMA   *example:* **PLP-10.7**

C105 REV. E

CIRCLE NO 146

tough attenuators

one-piece design defies rough handling from $16.95 (1-9)

- Each unit undergoes high-impact shock test
- Unexcelled temperature stability, .002 dB/°C
- 2W max. input power (SMA is 0.5W)
- BNC, SMA and N models (TNC, consult factory)
- Immediate delivery, one-year guarantee
- **50 ohms, dB values,**
  1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 15, 20, 30, and 40
- **75 ohms dB values,** 3, 6, 10, 15, 20 BNC only
- **Price** (1-9 qty.)
  CAT (BNC) $16.95 SAT (SMA) $20.95
  NAT (N) $23.95

*Freq. (MHz)	Atten. Tol. (Typ.)	Atten. Change, (Typ.) over Freq. Range		VSWR (Max.)	
		DC-1000	1000-1500	DC-1000 MHz	1000-1500 MHz
DC-1500 MHz	±0.3	0.6	0.8	1.3	1.5

*DC-1000 MHz (all 75 ohm or 30 dB models) DC-500 MHz (all 40 dB models)

Model Availability

SAT (SMA) CAT (BNC) NAT (N)

Model no. = a series suffix and dash number of attenuation.
Example: CAT-3 is CAT series, 3 dB attenuation.

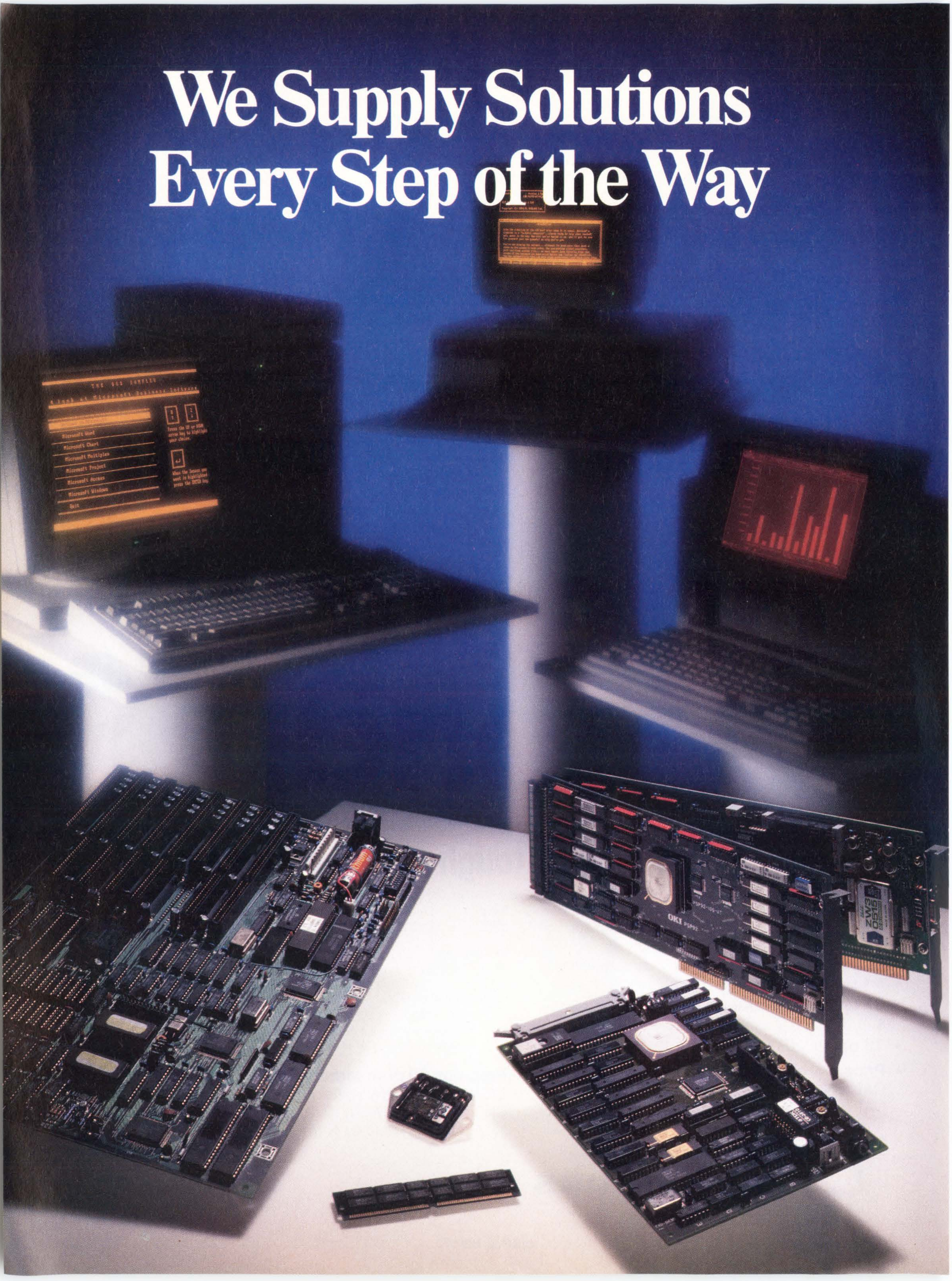
Precision 50 ohm terminations $8.25 (1-9)
DC to 2 GHz, 0.25W power rating, VSWR less than 1.1
BNC (model BTRM-50), TNC (consult factory)
SMA (model STRM-50), N (model NTRM-50)

finding new ways ...
setting higher standards

Mini-Circuits

A Division of Scientific Components Corporation
P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500
Fax (718) 332-4661 Domestic and International Telexes: 6852844 or 620156

C 92 REV. E


We Supply Solutions
Every Step of the Way

PHILIPS

Hertz.

The 1.05 GHz Fluke 6060B.

The 6060B also offers a number of amenities that make it easy to use. Uncluttered front panel layout. Bright digit editing. Stored front panel set-ups. Increment stepping. And relative amplitude and frequency. To name a few.

The 6060B is just one member of a family of general purpose RF signal generators from Fluke, each designed to deliver more performance than you thought you paid for.

Test the true performance of the 6060B for yourself. Because what you don't know might hurt you. Call Fluke toll-free at **1-800-44-FLUKE** and arrange for a demonstration.

Fluke 6060B
10 kHz — 1.05 GHz
+13 dBm maximum output level
±1 dB level accuracy
-60 dBc spurious

John Fluke Mfg. Co., Inc., P.O. Box C9090, M/S 250C, Everett, WA 98206. U.S. (206) 356-5400. Canada (416) 890-7600. Other countries: (206) 356-5500. Specifications subject to change without notice. Ad no. 0881-F6060.

FLUKE

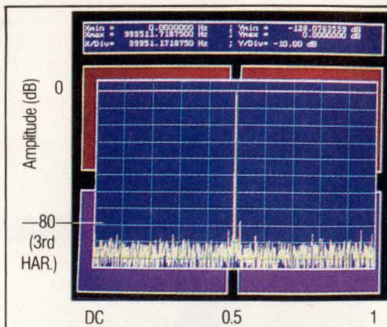
One company offers 1,2,5, & 10MHz 12-bit sampling A/D converters. DATEL.

Superior dynamic performance brings both harmonic distortion and signal-to-noise ratios to new lows.

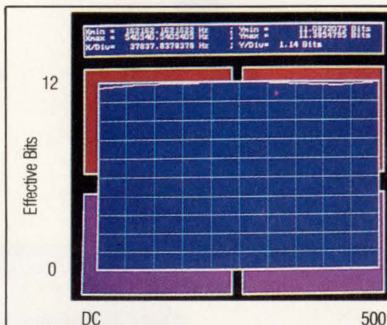
We're working hard at DATEL to bring you new lows - to create new highs in performance. The *lowest* harmonic distortion. The *lowest* non-linearity. The *lowest* absolute accuracy errors. The *lowest* power consumption. The *lowest* physical size. And the *lowest* price. All to produce the highest dynamic and static performance in sampling A/D converters available anywhere.

Features unavailable anywhere else in all models include an internal sample hold with full power input bandwidth higher than Nyquist frequency, together with a functionally complete architecture. DATEL has truly produced the First complete Family of 12-bit ADCs.

With DATEL, you now have four new reasons guaranteed to shorten your ADC selection cycle. Bottom-line, compare these converters with our competition and you'll see that there is no reason to look anywhere else. Call us at (508) 339-3000.



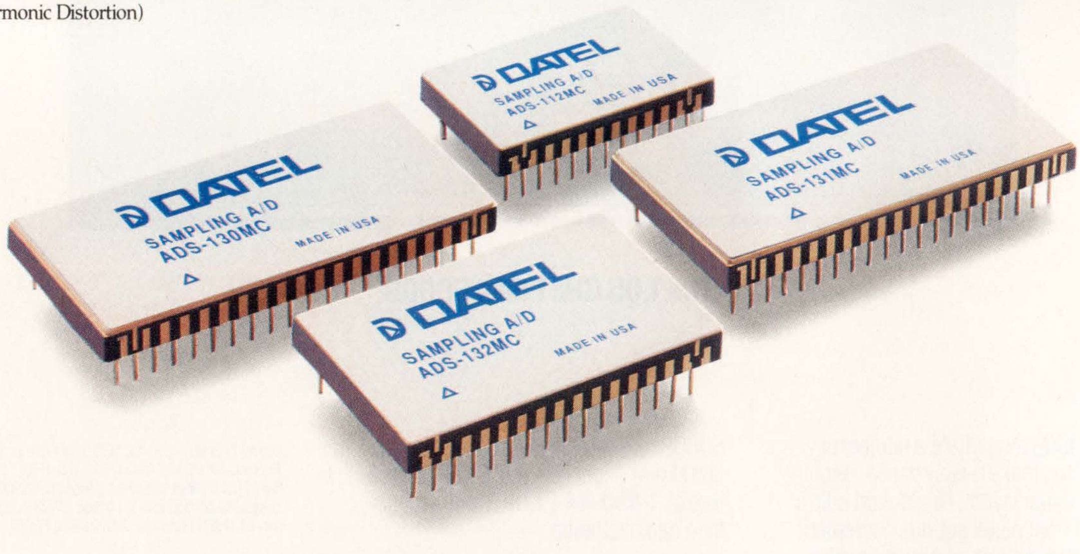
FFT Magnitude Spectrum



Effective Bits Curve

Model	Sampling Rate	Effective Bits at Nyquist Frequency	THD* at Nyquist Frequency	Power Dissipation	Package	Price (1-9)
ADS-112	1MHz	11.0	-73 dB	1.3 watts	24-pin DDIP	$259
ADS-132	2MHz	11.0	-73 dB	2.9 watts	32-pin TDIP	$346
ADS-131	5MHz	10.6	-69 dB	4.2 watts	40-pin TDIP	$549
ADS-130	10MHz	10.6	-69 dB	4.5 watts	40-pin TDIP	$775

* THD (Total Harmonic Distortion)



DATEL

INNOVATION AND EXCELLENCE IN PRECISION DATA ACQUISITION.

Datel, Inc., 11 Cabot Boulevard, Mansfield, MA 02048 (508) 339-3000

MIL-STD-1772 DATEL CERTIFIED

See us at ELECTRO/89 Booth 1704

CIRCLE NO 152

SIGNALS & NOISE

Don't confuse the DFT with the FFT

I found Tom Springer's article "Sliding FFT computes frequency spectra in real time" (September 29, 1988, pg 161) to be interesting and informative. The concept of a recursive algorithm for calculating a discrete Fourier transform (DFT) became particularly important to our research group about a year ago, and I published an internal technical note whose results were identical (and whose title was nearly identical) to Tom Springer's. There were, however, a few inaccuracies in Tom's article that may tend to confuse any reader working through the algorithm derivations.

In particular, the term "FFT" was used throughout the article as a generic label for the discrete Fourier transform. Although the FFT label could be used to describe *any* fast Fourier transform (that is, any transform algorithm using fewer calculations than the canonical DFT implementation), it has generally been associated with *the* fast algorithm produced by eliminating redundant calculations through a binary factoring principle. The recursive algorithm described in the article is nowhere derived or related to the FFT, but is a direct derivation from the definition of the DFT.

The derivation in the colored box at the bottom of pg 164 begins with the definition of the DFT, and not the FFT, as it states. In addition, the derivation makes no distinction between the time-series function x(n) and the frequency-domain function X(m). This problem is particularly confusing in the last and most important expression, where the frequency- and time-domain functions are mixed in the right-hand side of the equation.

Also, **Fig 3** on pg 164 illustrates the $X^{k+1}(m)$ frequency spectrum as being computed from an $N+1$ point time series beginning at k and ending with $k+N$. The sequence should, of course, begin with $k+1$.

In addition to the caveats Tom mentioned, there are two others worth mentioning. First, because the computation is recursive, errors due to floating-point approximations will accumulate, the severity increasing with the size of the transform. Also, as with all DFT calculations, there is an implicitly applied windowing function. In the case of the sliding DFT, the windowing function is rectangular, with unity magnitude. The sliding DFT, as presented, will not accommodate other windowing functions.

Randall Johnson,
Research and Technology Development
De La Rue Printrak
Anaheim, CA

Some thoughts on American education

Richard Simonelli and Jorgen Vinding raise valid points [about engineering education] in their letters (Signals & Noise, EDN, September 29, 1988, pg 31). In his references to Hirsch and Ravitch and Finn, Jorgen Vinding shows more deep thought on the subject than the average engineer. The reference to Bloom will be appreciated by a large sample of educated Americans, who have read (at least in excerpts or interviews) about what the educational system has done to miseducate or de-educate students. Jorgen's recommendation that only 10 to 12% of a student's credits be in the humanities seems to me a bit low.

Ronald Khol makes the point (in *Machine Design*, October 20, 1988) that in Europe and Japan a degree from an American university is considered to be almost meaningless. He recommends that all students, regardless of their eventual fields of specialization, should have two years of intensive science and math. Such a requirement would be very good for journalism majors. It might reduce such ridiculous things as the wire-service science article that stated repeatedly that fluorocarbons release chlorine. Or the *Time* magazine article about Sprague, which stated that Sprague makes "capacitators," or the one about Gillette that claimed the company applies "silicon" (instead of *silicone*) to razor blades. Freshman chemistry these reporters obviously have not had.

Richard Simonelli is quite right that a formal, conventional liberal arts curriculum is not the only answer. In a large number of faculties, that is merely multiple exposure to socialist propaganda. My late wife had, in essence, a fine liberal education, though she had never had a college course. She read deeply of biography, history, and constitutional law, as well as news and business magazines, and she could discourse intelligently in these fields.

Walter B Jones
Clear Lake City, TX

PC-resident analog-I/O cards

This is a short note to compliment your publication for including the excellent article "PC-resident analog-I/O cards," by contributing editor Bill Travis, in the September 15, 1988, issue of EDN (pg 150).

In addition to being very well written, the article was the most complete examination of the present status of this technology that I've seen anywhere in the past couple of years.

Bill should, in my opinion, receive some special recognition for doing such an exceptional job on this complex and timely subject. Thanks to all, and keep up the good work.

James Bischof
Advertising, Marketing, and Public Relations
Newport Beach, CA

THE ANALOG IC SEARCH STARTS...

AND STOPS HERE

PMI's free **Precision Decisions selector guide disk** eliminates the search of your entire library for the analog or data conversion IC essential to your design.

All you need is the disk, an IBM©-compatible PC, and DOS. With PMI's unique program, input your IC design specs or current part number and the disk does the searching. **Once the optimum device has been identified for you,** (operational amplifier, data converter, matched transistor, voltage reference, voltage comparator, sample-and-hold amplifier, analog switch, or multiplexer) refer directly to the appropriate data sheet in PMI's 1300 page full line catalog for complete design curves and specifications on the part.

Precision Decisions also features pricing, Mil/Aero and SSM Audio product listings, new product guide, sales office listing, and part numbering system. **Free quarterly updates** ensure you have current information available.

PMI offers the latest design tools to make your job easier. Call us and find out the other ways we can help you.

To receive your free copy of Precision Decisions, call **800-843-1515** or complete and mail the coupon below. **Your next search for an analog IC will start and stop with PMI.**

PMI®
Precision Monolithics, Inc.
A Bourns Company

1500 Space Park Drive
P.O. Box 58020
Santa Clara, California 95052-8020

Please send me a free copy of Precision Decisions

Name: ______________________

Title: ______________________

Company: ______________________

Address: ______________________

____

Phone Number: ______________________

Check boxes that apply:

☐ I would like to recieve free quarterly updates of Precision Decisions

☐ Also send me PMI's full line catalog

EDN 033089

ALTAMONTE SPRINGS: (407) 260-9780, **ATLANTA**: (404) 263-7995, **BOSTON**: (508) 794-0026, **CHICAGO**: (312) 250-0808, **DALLAS**: (214) 690-3495, **DENVER**: (303) 792-9595, **DETROIT**: (313) 227-2190, **LOS ANGELES**: (818) 886-6881, **MILPITAS**: (408) 942-8060, **ORANGE COUNTY**: (714) 637-9602, **PHILADELPHIA**: (215) 953-1070

CIRCLE NO 118

SIGNALS & NOISE

Oops

The Special Report on power MOSFETs and IGBTs appearing in EDN's January 5, 1989, issue (pg 128) incorrectly listed Powertec Inc (Chatsworth, CA) as a supplier of those products. The company does not make MOSFETs or IGBTs; it manufactures power supplies only.

Address update

"EDN's 15th Annual μP/μC Chip Directory," which appeared in the October 27, 1988, issue (pg 164) included an incorrect address for Fujitsu Microelectronics Inc. The correct address, phone number, and FAX number are:

Fujitsu Microelectronics Inc
Advanced Products Div
50 Rio Robles, Bldg 3
San Jose, CA 95134
Phone (408) 922-9000
FAX 408-432-9070

YOUR TURN

EDN's Signals and Noise column provides a forum for readers to express their opinions on issues raised in the magazine's articles or on any topic that affects the engineering industry. Send your letters to the Signals and Noise Editor, 275 Washington St, Newton, MA 02158. We welcome all comments, pro or con. All letters must be signed, but we will withhold your name upon request. We reserve the right to edit letters for space and clarity.

21st Century CMOS Technology, NOW

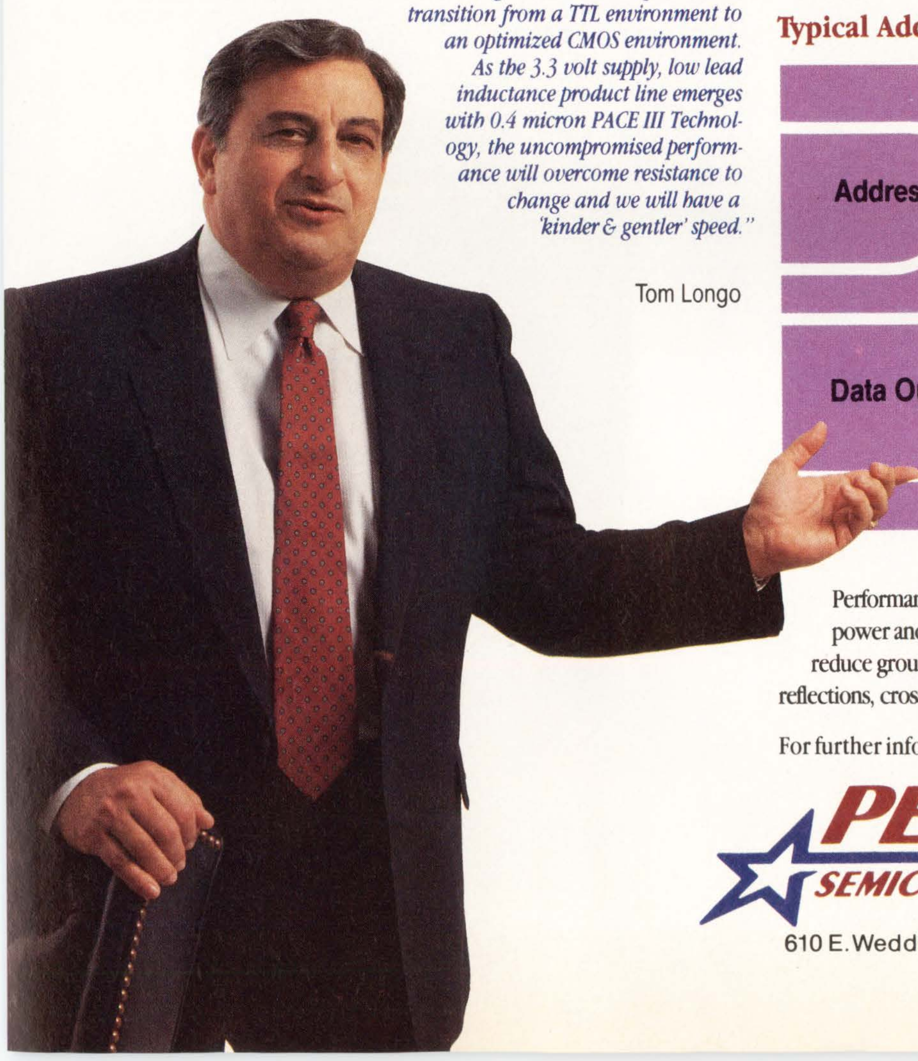
0.4 micron/6ns SCRAMs

First of a New Generation of 3.3V Center-Pin Power and Ground Products.

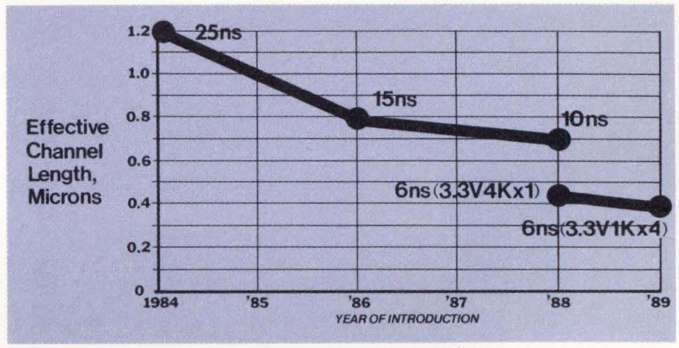
Performance now offers two 6ns SCRAMs: P3C3148 1Kx4 and P3C3147 4Kx1. These SCRAMs are superfast Static CMOS Random Access Memories. Future superfast products, using center-pin power and ground with a 3.3 volt power supply, will include SCRAMs with 4Kbit to 256K bit densities and popular logic parts such as buffers, transceivers, latches, flip-flops, comparators, registers and gate arrays.

"It has been clear for some time that the primary consideration which could limit the use of future generations of CMOS technology in the highest speed applications were issues associated with constraints that have been hangovers from bipolar TTL circuit implementations. If those constraints are not removed, then either performance will be compromised or serious application problems will result. It is easy to see the value of the changes that are needed to take maximum advantage of the attributes of the fine line CMOS technology in the sub half-micron regime (PACE III). Therefore, we have decided to invest a significant part of our Company's technical and marketing resources to help make the transition from a TTL environment to an optimized CMOS environment. As the 3.3 volt supply, low lead inductance product line emerges with 0.4 micron PACE III Technology, the uncompromised performance will overcome resistance to change and we will have a 'kinder & gentler' speed."

Tom Longo

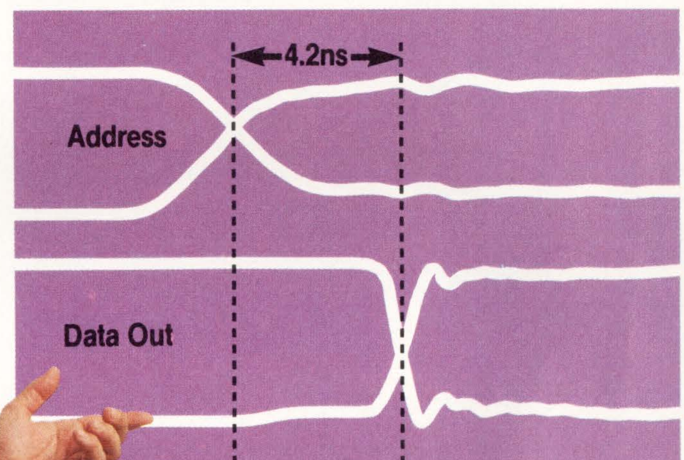


4K Bit Density Static RAM Speeds



Performance's PACE III Technology, which features 0.4 micron effective gate length, 0.75 micron line widths and 250ps gate delay, offers a 40 percent speed improvement even with a 35 percent voltage reduction. Superfast 6ns SCRAM performance is available now with significantly lower power dissipation.

Typical Address to Dataout Delay: 4Kx1 SCRAM



Performance's superfast 3.3 volt products incorporate multiple center power and ground pins as well as reduced signal swings to dramatically reduce ground bounce and simplify signal interconnection issues such as reflections, cross talk and ringing.

For further information or to order SCRAMs call or write:

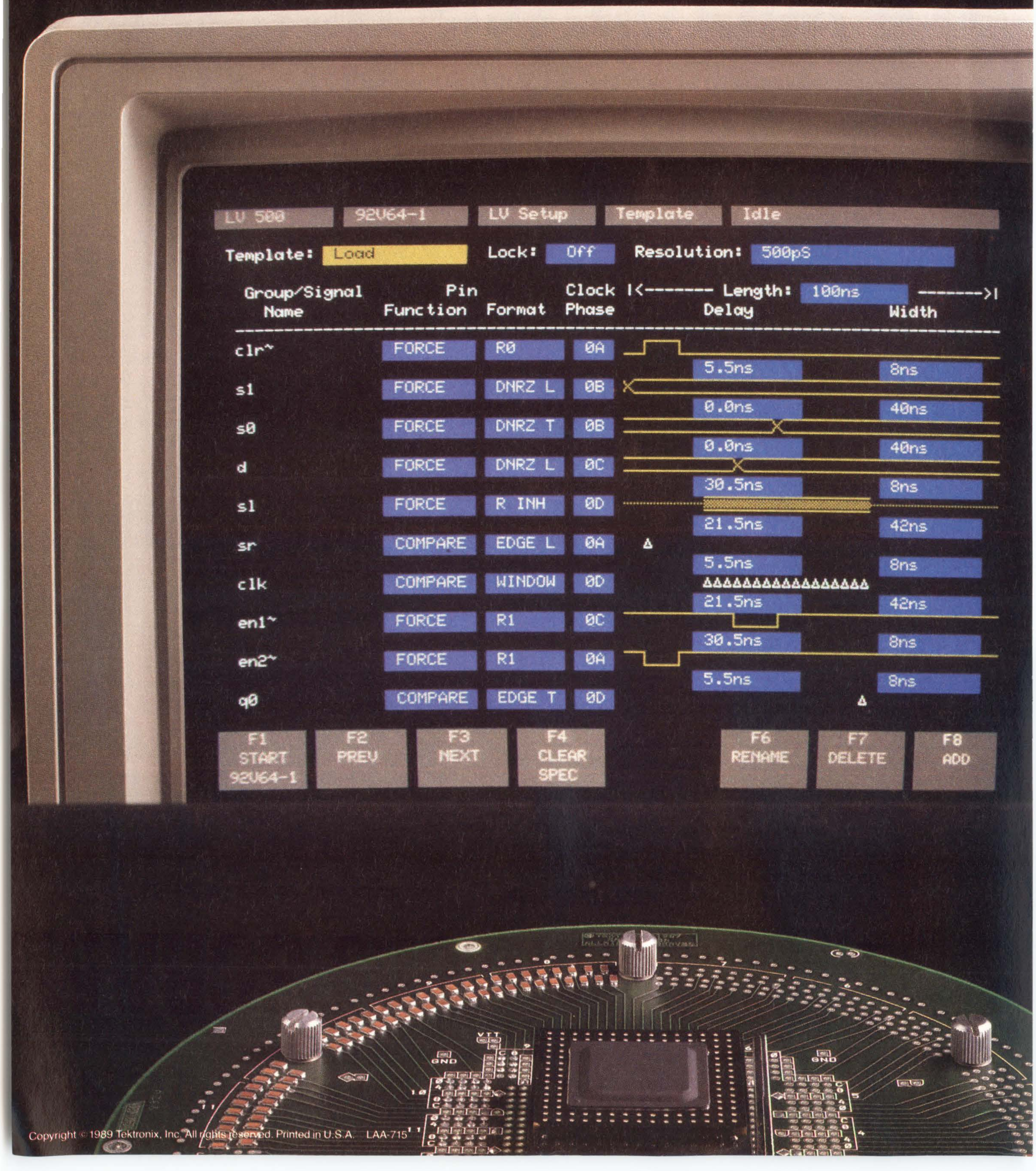
PERFORMANCE SEMICONDUCTOR CORPORATION

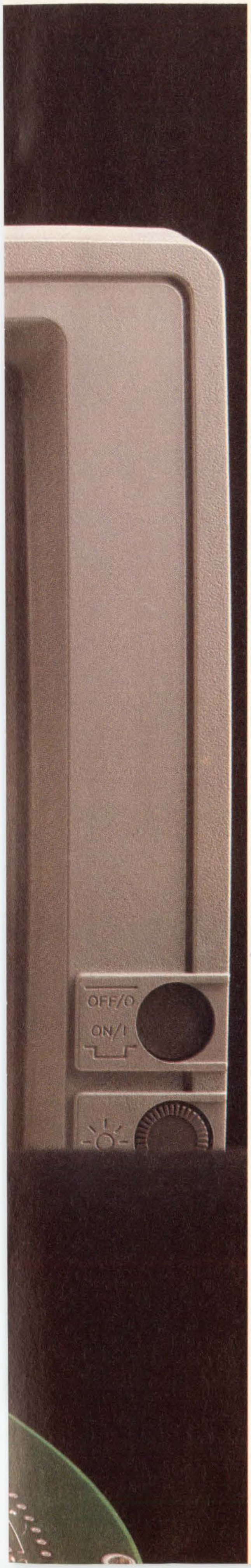
610 E. Weddell Drive, Sunnyvale, CA 94089 (408)734-9000

CIRCLE NO 75

PERF0001/S

Tek's New ASIC Verification System.





Big Tester Performance At A Benchtop Price.

For a fraction of the price of large production testers, designers can now easily perform timing verification and margin analysis on their own ASICs, using a turnkey system with the critical timing of the million-dollar machines.

Tek's new LV 500 ASIC Verification System is a true *designer's* solution, integrated into a 50 MHz, 256-channel, 64K deep benchtop system with a test head just 17 inches square.

Using a simple menu structure and concepts familiar to the designer, the LV 500 combines elementary operation with astonishing performance, made possible by integrating all 256 bidirectional channels onto a single PCB. Results include:

More accurate simulation, even for complex synchronous devices. The LV 500 lets you vary cycle length and timing for each of 16 clock generators on a cycle-by-cycle basis.

Familiar operation for example, template-based test cycles replicate the everyday timing diagrams of your IC book.

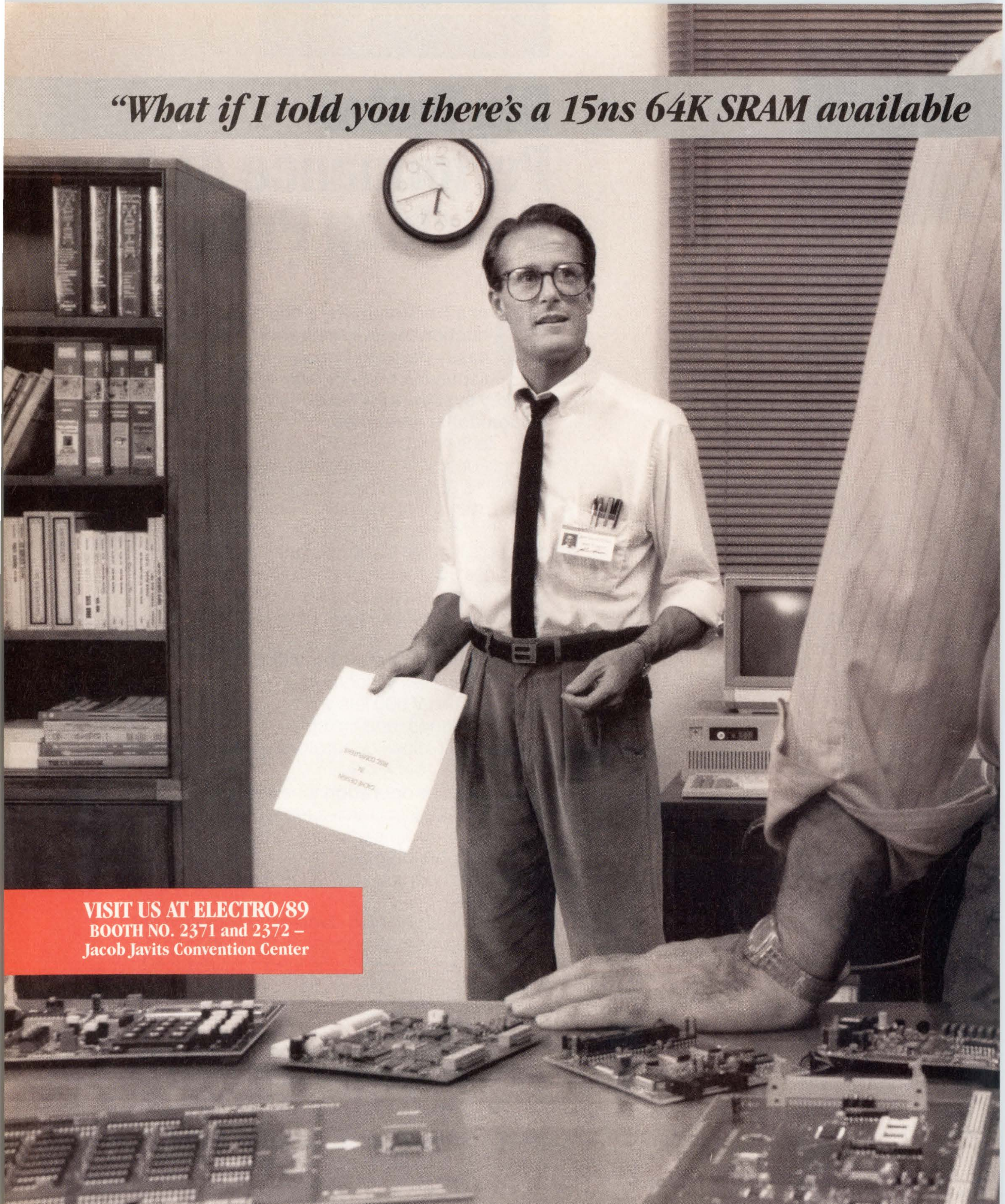
Graphic displays. See clearly when devices are operating too close to parametric boundaries.

Thanks to its high degree of integration, the LV 500 rarely needs calibration. DUT fixturing is simplified. And capacitance loading is reduced to about 25 pF, further contributing to the system's accurate results. And it is compatible with virtually all logic simulators.

Don't wait for chips to fail in production —or worse, for products to fail in the field. Start putting ASIC verification where it does the most good: in the hands of the designers themselves. For more information or a demonstration, contact your Tek sales representative. Or call 1-800-245-2036.

Tektronix®
COMMITTED TO EXCELLENCE

Circle 7 for Literature **Circle 8 for Sales Contact**


"What if I told you there's a 15ns 64K SRAM available
VISIT US AT ELECTRO/89
BOOTH NO. 2371 and 2372 –
Jacob Javits Convention Center

now?"

"I'd say you've been reading too many supermarket tabloids."

"Seriously! You get high speed and quantity delivery, plus the ability to drastically cut your qual costs!"

"OK, I'll bite. Who's got 'em?"

"Toshiba."

"Why didn't you just say that in the first place?"

While others continue to talk speed, Toshiba now delivers 15ns Static RAMs.

The exceptional access speed of the new 15ns 64K SRAM family is the result of a little technological wizardry and lots of 1.0μ CMOS know-how. The bottom line is a 15ns 64K SRAM that dissipates less power and requires a smaller-sized die than more costly BiCMOS devices.

And, if you've been looking for ways to cut qualification costs on your 64K SRAMs, look no further than Toshiba's 64K SRAM family. By using an aluminum master slice common to all configurations within the 64K family, the cost of qualifying individual parts is reduced by as much as 75%!

Toshiba builds a full line of SRAMs that offer high speed and fully static operation. A line whose depth and breadth provides higher system performance and lower system costs when designing high-speed cache memories, high-speed main memories, high-speed buffers and writeable control stores for minis, superminis, workstations, RISC-based systems, real-time processors, high-speed storage and high-end graphics applications.

When it comes to SRAMs, Toshiba's got all the speeds, configurations and densities you need. Including 256K, coming soon.

Toshiba High-Speed SRAMs

Configuration	Density	Speed (ns)				Availability
64K x 1	64K	35	45	55		Now
16K x 4	64K	15	20	25	35	Now
16K x 4 (OE)	64K	15	20	25	35	Now
8K x 8	64K	15	20	25		Now
8K x 9	72K	15	20	25		Now
64K x 4	256K	20	25	35		Early '89
64K x 4 (OE)	256K	20	25	35		Early '89
32K x 8	256K	20	25	35		Early '89
32K x 9	288K	20	25	35		Early '89
16K x 12	192K module	25	35			Now
16K x 16	256K module	25	35			Now

And plenty of packaging options, too. From JEDEC standard Skinny DIPs and SOJs to ZIP Modules.

Not to mention the kind of service and deliverability others can only talk about.

Call today for complete data sheets and applications notes at 1-800-888-0848 ext. 517.

TOSHIBA

TOSHIBA AMERICA, INC.

ELECTRONIC COMPONENTS BUSINESS SECTOR

Service is our key component.

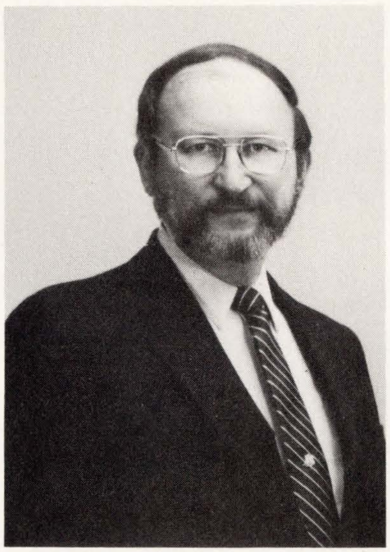
CIRCLE NO 122

MST-88-012

(913) 236 – 8800, Sterling Electronics-Kansas, (913) 236 – 5589; **NEVADA,** Marshall Electronics Group, (916) 635 – 9700, (602) 496 – 0290, Sterling Electronics, (602) 268 – 2121, Western Microtechnology, (408) 725 – 1660; **NEW HAMPSHIRE,** Cronin Electronics, Inc., (617) 449 – 5000, Marshall Electronics Group, (617) 658 – 0810, Sterling Electronics-Boston, (617) 938 – 6200, Western Microtechnology, (617) 273 – 2800; **NEW JERSEY,** General Components, Inc., (609) 768 – 6767, Marshall Electronics Group, (201) 882 – 0320, (609) 234 – 9100, Milgray Electronics, Inc., (516) 420 – 9800, (609) 983 – 5010, (800) 257 – 7808, (800) 257 – 7111, Sterling Electronics-So. Plainfield, (201) 769 – 7000; **NEW MEXICO,** Marshall Electronics Group, (602) 496 – 0290, Sterling Electronics-Albuquerque, (505) 884 – 1900; **NEW YORK,** Marshall Electronics Group, (516) 273 – 2424, (607) 798 – 1611, (716) 235 – 7620, Milgray Electronics, Inc., (516) 420 – 9800, (716) 235 – 0830, Rome Electronics, (315) 337 – 5400; **NORTH/SOUTH CAROLINA,** Marshall Electronics Group, (919) 878 – 9882, Milgray Electronics, Inc., (404) 393 – 9666, Resco Raleigh, (919) 781 – 5700, (704) 588 – 1530; **NORTH/SOUTH DAKOTA,** Marshall Electronics Group, (612) 559 – 2211, Reptron Electronics, (612) 938 – 0000; **OHIO,** Marshall Electronics Group, (513) 898 – 4480, (216) 248 – 1788, (614) 891 – 7580, Milgray/Cleveland, Inc., (216) 447 – 1520, (800) 321 – 0006, Reptron Electronics, (614) 436 – 6675, (216) 349 – 1415; **OKLAHOMA,** Marshall Electronics Group, (214) 233 – 5200, Milgray Electronics, Inc., (214) 248 – 1603, Sterling Electronics-Tulsa, (918) 663 – 2410; **OREGON,** Marshall Electronics Group, (503) 644 – 5050, Western Microtechnology, (503) 629 – 2082; **PENNSLYVANIA,** General Components, Inc., (609) 768 – 6767, Marshall Electronics Group, (609) 234 – 9100, (412) 963 – 0441, Milgray/Cleveland, Inc., (216) 447 – 1520, (800) 321 – 0006, Milgray/Delaware Valley, Inc., (609) 983 – 5010, (800) 257 – 7808, (800) 257 – 7111; **RHODE ISLAND,** Cronin Electronics, Inc., (617) 449 – 5000, Marshall Electronics Group, (617) 658 – 0810, Sterling Electronics-Boston, (617) 938 – 6200, Western Microtechnology, (617) 273 – 2800; **TENNESSEE,** Marshall Electronics Group, (205) 881 – 9235, Milgray Electronics, Inc., (404) 393 – 9666, Resco Raleigh, (919) 781 – 5700; **TEXAS,** Marshall Electronics Group, (214) 233 – 5200, (915) 593 – 0706, (713) 895 – 9200, (512) 837 – 1991, Milgray Electronics, Inc., (214) 248 – 1603, Sterling Electronics, (713) 623 – 6600, (512) 836 – 1341, (214) 243 – 1600; **UTAH,** Marshall Electronics Group, (801) 485 – 1551, Sterling Electronics-Denver, (303) 792 – 3939, Milgray Electronics, (801) 272 – 4999; **VERMONT,** Cronin Electronics, Inc., (617) 449 – 5000, Marshall Electronics Group, (617) 658 – 0810, Sterling Electronics-Boston, (617) 938 – 6200, Western Microtechnology, (617) 273 – 2800; **VIRGINIA,** Marshall Electronics Group, (301) 840 – 9450, Milgray/Washington, Inc., (301) 621 – 8169, (800) 638 – 6656, Resco Raleigh, (919) 781 – 5700, Sterling Electronics, (703) 742 – 8400, (804) 226 – 2190; **WASHINGTON,** Marshall Electronics Group, (206) 486 – 5747, Western Microtechnology, (206) 881 – 6737; **WISCONSIN,** Goold Electronics, (312) 593 – 3220, Marshall Electronics Group, (414) 797 – 8400, Milgray/Chicago, Inc., (312) 350 – 0490, Reptron Electronics, (612) 938 – 0000; **CANADA,** Marshall Electronics Group, (416) 674 – 2161, ITT Multicomponents, (604) 291 – 8866, (403) 451 – 4001, (403) 253 – 8575, (306) 933 – 2888, (204) 786 – 8401, (416) 736 – 1144, (613) 226 – 7406, (514) 335 – 7697, (506) 857 – 8011, Space Electronics Sales Corp., (514) 697 – 8676, (416) 636 – 8814, (613) 596 – 5340, (604) 294 – 1166.

EDITORIAL

Farewell...



It never once occurred to me in the last 20 years that I would someday write a farewell letter to you, the good and loyal readers of EDN. I never considered working for another publication because I always thought EDN was the best, even in earlier years, when it wasn't. Now, it truly is the best publication in the electronics industry. It has the most professional and the most knowledgeable editorial staff, serves the most exciting industry in the world, and has the most loyal readers of all.

But there comes a time when we must move on to new opportunities and challenges, which is what I'm doing. Though I feel bittersweet at the thought of leaving EDN, I'm pleased to become publisher of Test & Measurement World—a magazine that serves the same exciting industry. I'm also pleased to continue my affiliation with Cahners Publishing. And making the transition that much easier is the fact that many of you are readers of Test & Measurement World. I am most fortunate indeed.

Together we've faced many changes these past 20 years, the most significant being the microprocessor. That single development revolutionized not only every aspect of the electronics industry (and your job), but also every industry worldwide.

We positioned EDN to help you understand how to use and exploit the benefits of that and every other significant technical development. I believe that we've served you well—and you tell me I'm right in readership survey after readership survey.

EDN will continue to serve you well under the leadership of both Peter Coley, a good friend and supportive publisher, and my successor, Jon Titus, who is an outstanding editor.

I thank my entire editorial staff for their loyalty, support, and professionalism. And I thank you for all the same reasons. I wish for all of you, staff and reader alike, the sentiments of an old Navy saying, "May you have fair winds and a following sea."

Roy W. Forsberg

Roy Forsberg
Vice President/Editorial Director

Jesse H Neal
Editorial Achievement Awards
1987, 1981 (2), 1978 (2),
1977, 1976, 1975

American Society of
Business Press Editors Award
1988, 1983, 1981


If you believe EPLDs are
constrained by their architecture,
this should open your mind.

Introducing MAX. A totally new architecture that will change your thinking about EPLDs.

You can choose from a family of devices with a full range of densities from 16 to 128 macrocells in a variety of packaging options.

Still think that EPLDs can't be fast and dense?

Then prepare to erase and reprogram your thinking.

The new MAX family from Altera has a radically different EPLD architecture that can make your fastest, densest designs fly out the door in no time.

With twice the speed and three times the density of conventional EPLDs.

At the heart of the MAX architecture are Logic Array Blocks incorporating three major innovations:

First, streamlined, totally programmable macrocells with multiple control product terms.

Secondly, Logic Expanders that let you assign additional product terms to any macrocell.

Finally, decoupled I/O that lets you use all your pins and flip-flops independently.

Tying it all together, a Programmable Interconnect Array (PIA) links MAX's multiple LABs efficiently.

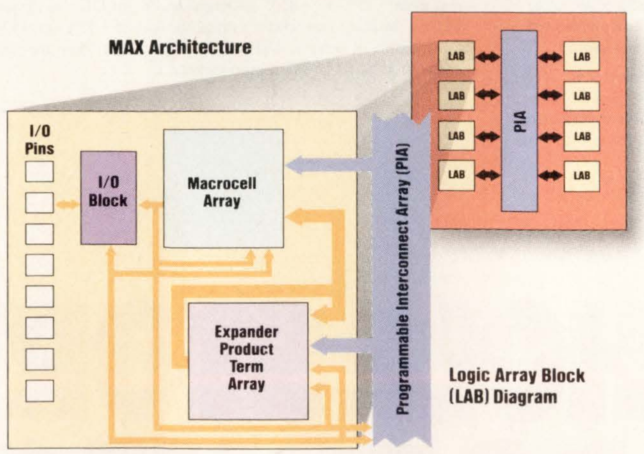
When you combine the MAX architecture with a high speed, 0.8 micron CMOS process, you get high density devices with extraordinary performance.

And to get those devices to market faster, there's MAX+PLUS.™ Logic synthesis makes it the most powerful, easy to use software ever developed for EPLDs.

That's why the MAX family is destined to become the new standard for logic design.

For more information, call Altera today: 1-800-545-3377.

And see how easy it is to change your thinking about EPLDs.



At the highest densities, MAX incorporates a Programmable Interconnect Array that gives you the high performance of small arrays with large array density.

ALTERA

3525 Monroe Street, P.O. Box 58163
Santa Clara, CA 95052-8163 (408) 984-2800

Whether it's a question of speed, bandwidth, power consumption or cost, our family of 8-bit A/D flash converters has the answer.

For example, if you need a monolithic high speed, ECL-compatible converter, there's our AD770 or AD9002.

The AD770 is our fastest ECL-compatible 8-bit converter, with a guaranteed sample rate of 200MSPS. And its 250MHz full power bandwidth and SNR performance with high frequency input signals can't be beaten. The AD770 is available in commercial and extended temperature range versions.

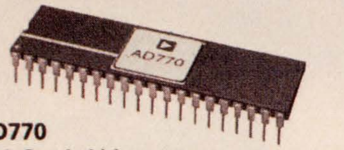
The AD9002 has a guaranteed sample rate of 125MSPS – yet its nominal power dissipation is a mere 750mW – and it operates from a single −5.2V power supply. The AD9002 is also available with MIL-STD-883 processing, making it ideal for a wide range of applications.

On the other hand, if it's a TTL-compatible 8-bit flash converter you need, there's our AD9012 or AD9048.

The AD9012 is the industry's fastest TTL-compatible converter, with a guaranteed sampling rate nearly twice that of its

ANALOG DEVICES

ECL COMPATIBLE



AD770
High Bandwidth,
ECL Compatible, 200MSPS
- **400MHz Small-Signal Bandwidth**
- **19pF Input Capacitance**
- **Bipolar or Unipolar Input**
- **+5V/−5.2V Power Supplies**

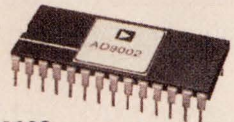
The AD770 200MSPS A/D Converter uses an advanced VLSI bipolar process and a proprietary design to achieve new levels of performance in sampling rates and signal bandwidths for flash converters. Full power bandwidth is 250MHz.

The AD770 is ideal for high performance digital oscilloscope, radar, communications and electronic warfare systems. High input bandwidth permits undersampling of high frequency band-limited signals.

Multistage comparator design reduces the probability of errors due to metastable states or insufficient gain; decoding logic further reduces errors with a two-stage error-correcting architecture.

All inputs and outputs are ECL compatible, and analog inputs can be either bipolar or unipolar signals with up to 4V range. High accuracy and minimum temperature drift are preserved with end point reference Force and Sense connections.

There are three grades available. JD and KD grades are specified over a 0 to +70°C range; the SD grade is specified for temperatures from −55°C to +125°C. All standard grades are packaged in 40-pin ceramic DIPs; contact the factory for other package options.



AD9002
Low Power,
ECL Compatible, 125MSPS
- **160MHz Analog Input Bandwidth**
- **17pF Input Capacitance**
- **750mW Power Dissipation**
- **Single −5.2V Power Supply**

Designs for radar, digital oscilloscopes, ATE systems, electronic warfare, communications/signal intelligence systems and a wide variety of other applications can be made easier with the AD9002 High Speed Monolithic A/D Converter.

An overflow bit indicating overrange signals can also be used to "stack" two AD9002 units to get 9-bit resolution of the digitized signal.

Input capacitance is typically 17pF and only 22pF maximum, simplifying the choice of a driving amplifier. Cooling requirements and power supply problems are also eased because of the low 750mW dissipation of the AD9002.

Two grades are available; one has 0.5LSB linearity, and the other has 0.75LSB linearity. Both versions are offered for operation from −25°C to +85°C packaged as 28-pin DIPs or 28-pin PLCCs. Military temperature range devices of −55°C to +125°C are available as ceramic DIP and LCC packages; they are compliant to MIL-STD-883 requirements.

FOR THE WHOLE STORY DO SOME SP

CIRCLE NO 126

nearest competitor. Plus the AD9012 offers excellent ac performance, low power operation and low input capacitance.

The AD9048 is an improved version of an industry-standard 8-bit TTL-compatible A/D converter, with the highest sampling rate, widest bandwidth, lowest input capacitance and lowest power. And the AD9048, as well as the AD9012, is available to MIL-STD-883.

There's no question about it – high performance characteristics are traits in our family of 8-bit A/D flash converters. So no matter what your requirement is for 8-bit analog-to-digital conversion, we have the solution.

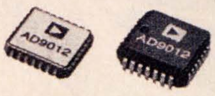
If you want more information in a flash on our 8-bit flash converters, call your nearest Analog Devices sales office or our applications engineers. Answers for the AD770 are at (617) 935-5565. For the AD9002, AD9012 and AD9048, call (919) 668-9511.

ANALOG DEVICES

Analog Devices, Inc., One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106; Headquarters: (617) 329-4700; California: (714) 641-9391, (619) 268-4621, (408) 559-2037; Colorado: (719) 590-9952; Maryland: (301) 992-1994; Ohio: (614) 764-8795; Pennsylvania: (215) 643-7790; Texas: (214) 231-5094; Washington: (206) 575-6344; Austria: (222) 885504; Belgium: (3) 237 1672; Denmark: (2) 845800; France (1) 4687-34-11; Holland: (1620) 81500; Israel: (052) 911415; Italy: (2) 6883831; Japan: (3) 263-6826; Sweden: (8) 282740; Switzerland: (22) 31 57 60; United Kingdom: (932) 232222; West Germany: (89) 570050.

8-Bit Flash Converters

TTL COMPATIBLE



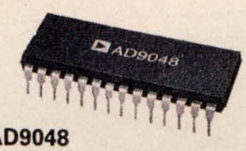
AD9012
Low Power, Wide Bandwidth, TTL Compatible, 75MSPS
- **160MHz Input Bandwidth**
- **16pF Typical Input Capacitance**
- **Power Dissipation<1W**
- **Minimum 46dB SNR**

The AD9012 is a TTL compatible A/D converter fabricated in an advanced bipolar process which makes it possible to operate at typical conversion speeds up to 100MSPS.

For commercial and industrial applications, the AD9012 is an excellent choice for professional video, instrumentation, digital radio and PC-based video digitizing equipment.

In military applications, the requirement for mil-qualified devices can be met with MIL-STD-883 units in electronic countermeasures, missile guidance, radar, radar warning and other military systems equipment.

The AD9012 is available in two grades: one has 0.5LSB linearity, and the other has 0.75LSB linearity. Both operate from −25°C to +85°C and are packaged as 28-pin DIPs or 28-pin PLCCs. Military temperature range devices of −55°C to +125°C are available as ceramic DIP and LCC packages.



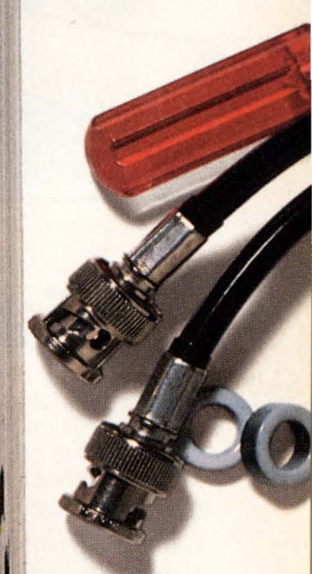
AD9048
Low Power, Low Cost, TTL Compatible, 35MSPS
- **15MHz Typical Bandwidth**
- **Input Capacitance Typically 16pF**
- **550mW Power Dissipation**
- **Industry-Standard Pinouts**

As its name implies, the monolithic AD9048 Video A/D Converter is an ideal choice for real-time conversion of video signals.

Its full power bandwidth is typically 15MHz, with no missing codes, and is a guaranteed minimum of 10MHz.

Low power dissipation of 550mW typical makes the AD9048 adaptable and attractive for a broad range of applications. In addition to professional video systems and video imaging, it is an excellent choice for electro-optics, digital radio and electronic warfare systems, among others.

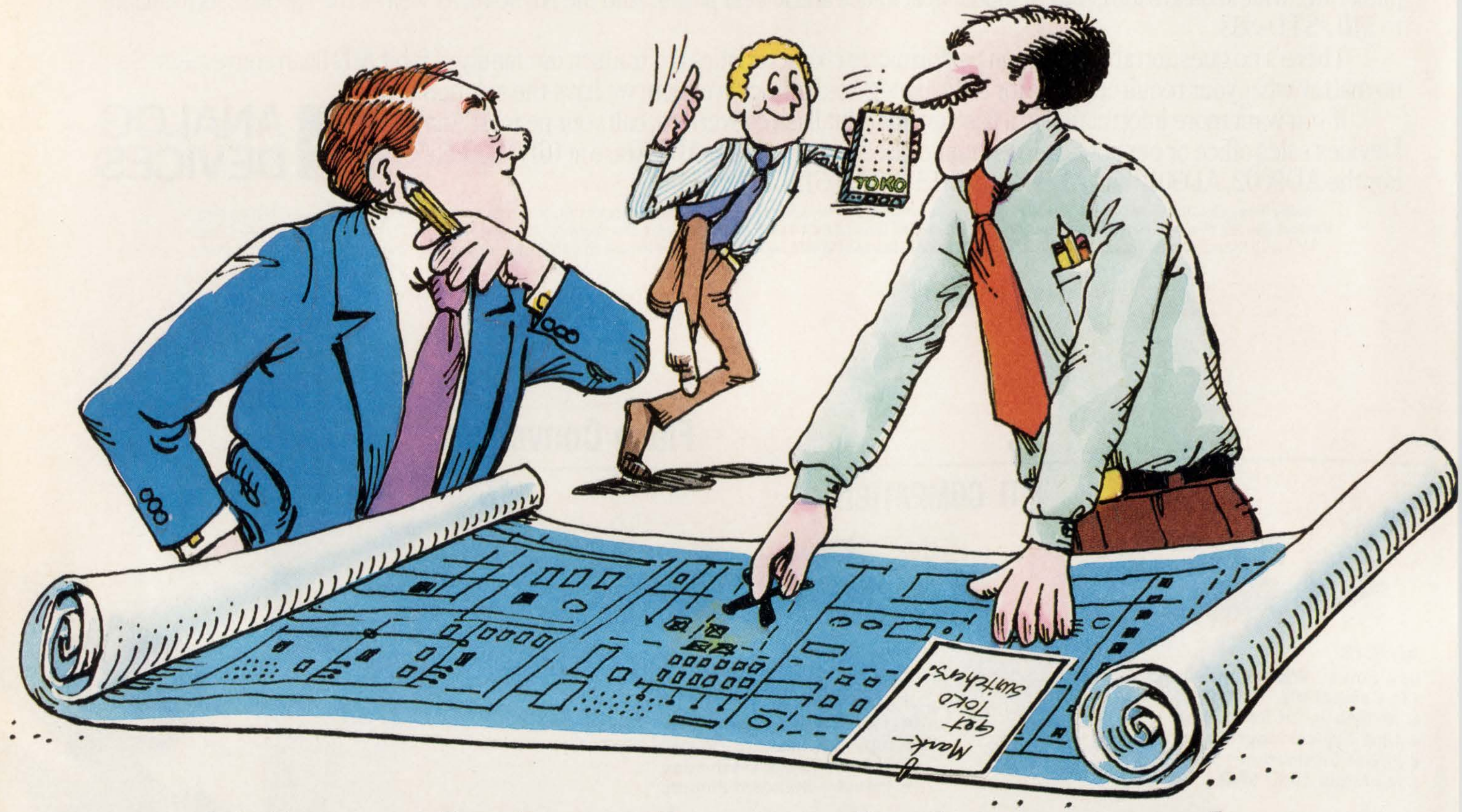
The AD9048 has industry-standard pinouts and is available over two temperature ranges, with two grades of linearity. Linearities of either 0.5LSB or 0.75LSB can be ordered for 0 to +70°C commercial ranges, or −55°C to +125°C military temperatures. Commercial versions are in 28-pin DIPs and PLCCs; military versions are in ceramic DIP and LCC packages. Both commercial units and MIL-STD-883-compliant devices are standard products.



ON FLASH CONVERTERS
EED READING.

CIRCLE NO 127

Need 50 watts of power or less?



Toko switchers have what you need.

There's no need to overbuy or add extra bulk and heat when you're specifying a low-wattage power supply. Toko has the output power you need in leading-edge switchers.

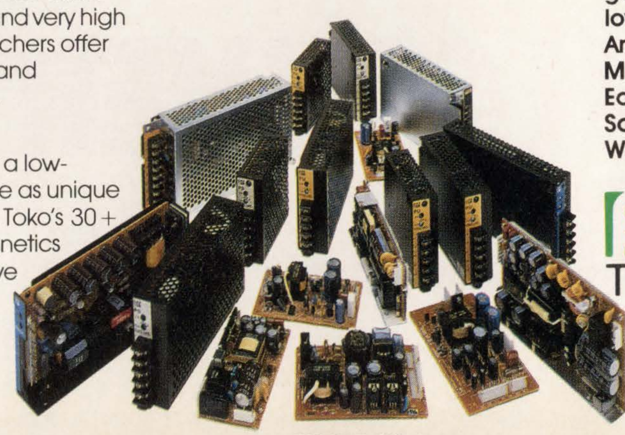
With over 250 models in the under 50-watt category, Toko offers you the right switcher at a price that will also make the controller happy. Whether you're powering computer peripherals, portable devices or other systems where space is at a premium, Toko is the name to know.

More high-tech features.
Because Toko is a low-power specialist, we're at the forefront of technology. For example, our new MW series offers 85-264VAC universal input and very high power densities. All Toko switchers offer high-switching frequencies and excellent EMI/RFI protection.

Low power is different.
The design requirements for a low-power compact switcher are as unique as your own product needs. Toko's 30+ years of experience in magnetics and filtering technology have led to development of switchers that pack the most clean reliable power into your available space.

SERIES	VAC INPUT VOLTAGE	RATED POWER	NO. OF OUTPUTS	NO. OF STANDARD MODELS
ET	85-132	10W	3	6
		15W		
EM	170-264	10W	3	6
		15W		
PU & PS	85-132/	10W	1	192
	110-175/	15W		
	170-264	30W		
		50W		
PE&PT	85-132/	15W	3 (PT)	60
	170-264	30W	1 (PE)	
		50W		
MW	85-264*	15W	3	7
		30W		
		50W		

*Automatic (no jumpers required)



Toko stays on the job.
With MTBF over 200,000 hours, 105°C electrolytic capacitors, 100% 8-hour burn-in, and 20% derating of all components, you may never need our 2-year guarantee. Toko dependability and commitment to servicing your needs give you the lowest cost of ownership in the long run. Our prices and no-charge options save you money now.

Ask about our Free Sample Evaluation Program. For a free power supply guide and to discuss your own low-power needs, contact Toko America, Headquarters and Midwest Branch (312) 297-0070; East Coast Branch (203) 748-6871; Southeast Branch (205) 830-0952; West Coast Branch (408) 432-8281.

TOKO
TOKO AMERICA, INC.

Your strategic partner... for all the right reasons.

CIRCLE NO 128

Logic synthesis prepares for VHDL

Although logic-synthesis tools offer greater efficiency to system designers, the current generation still suffers from a lack of compatibility with other CAE packages.

Michael C Markowitz, *Associate Editor*

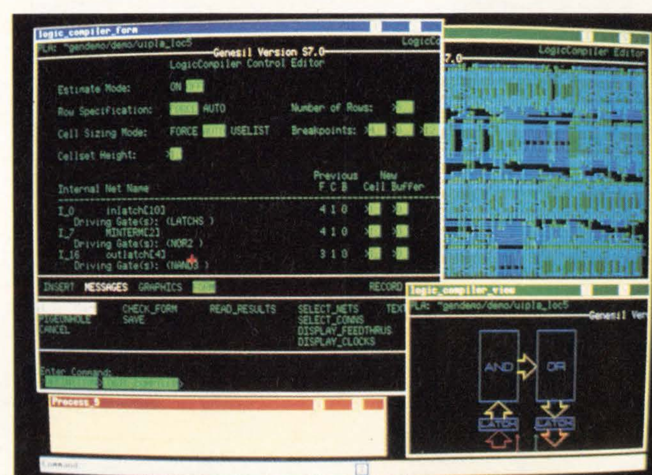
Logic synthesis tools are the latest in a long line of CAE tools that are destined to shrink the product development cycle for ICs and ultimately convert gate-level designers to systems engineers. These tools have the ability to increase your design productivity while minimizing the risks of introducing design faults. But despite the efficiency gains, danger still lurks: Logic-synthesis software is still new, and the CAE industry is undergoing a radical transformation—thanks to the Very-high-speed-integrated-circuit (VHSIC) Hardware Description Language (VHDL).

The increasing complexity of the current generation of PLD and IC designs has stretched the capabilities of the engineers who create them. The difficulty of effectively trading-off such considerations as performance and packaging while still trying to meet delivery deadlines prompted the development of logic-synthesis software. The software translates and optimizes a design far faster than you could manually.

One way you can utilize this time savings is to simulate and test the design more extensively. If you had more time you could run system simulations that would let you improve on the oft-quoted statistic that 50% of ASICs fail to perform in their target system. You might also play "what if . . . " games to evaluate performance-area tradeoffs; most of the synthesis packages have options that let you limit parameters like gate count and critical-path speed.

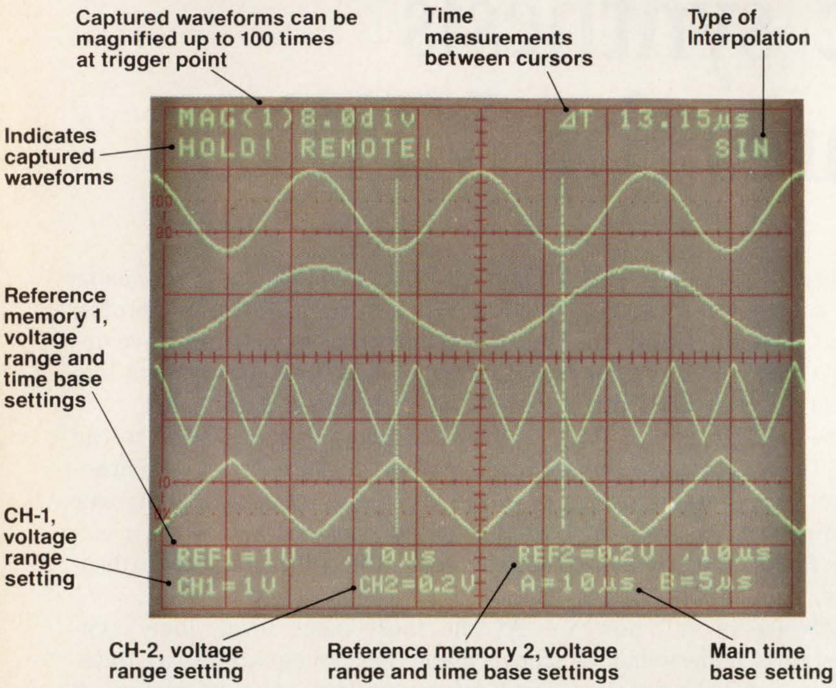
There are two major obstacles to the widespread acceptance of logic synthesis. One hurdle is the confusion over what logic synthesis is and what it can do; the second is a lack of standardization.

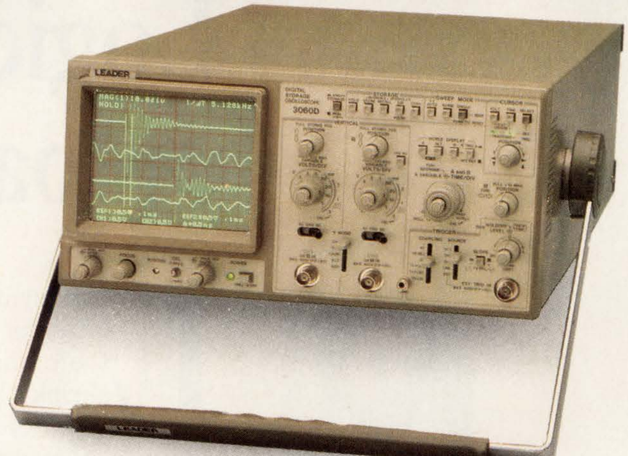
At the most basic level, logic synthesis maps Boolean equations to a gate-level representation of your design. A broader definition stretches the input medium to include high-level circuit descriptions, like register-transfer-level (RTL) descriptions and hardware-description language (HDL) implementations. Further, the broader definition of synthesis encompasses two separate operations—translation of the behavioral circuit description to a structural implementation and, subsequently, optimi-



You can specify a PLA with state equations, *logically optimize it, and then implement it in compiled standard cells with the Genesil Logic Compiler.*

LEADER





New full-time digital storage oscilloscope grabs fast events!

Perfect for freezing fast and slow events, the Model 3060D performs as a 40MS/s digital storage oscilloscope and 60-MHz real-time scope.

With high-speed digitizing and CRT readout with cursors, you can capture and easily analyze single-shot events, fast transients and slowly occurring phenomena.

Expand captured waveforms up to 100 times and interpolate them; store four waveforms in the 2k word/2-channel memory for immediate or later evaluation, and send fully documented waveforms to a plotter.

Plus, calibrated delay sweep, pre-trigger functions, p-p auto triggering, sine and pulse interpolation, autoranging time base . . . etc. And for computer control, GPIB is standard.

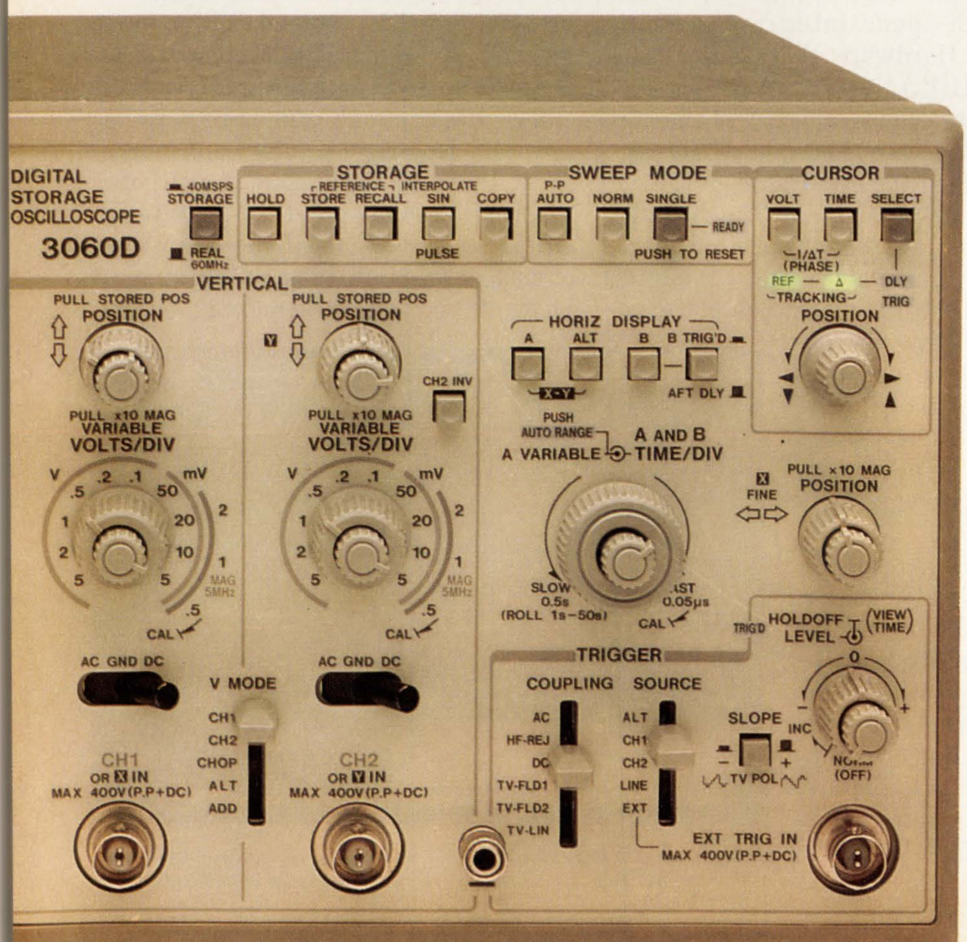
The 3060D is backed by a TWO-YEAR WARRANTY, and factory service depots on both coasts.

Look at Leader and see the difference. Phone now for our catalog, an evaluation unit, and the name of your nearest "Select" Leader Distributor.

Call toll-free
1 800 645-5104
In NY State
516 231-6900

Leader Instruments Corporation
380 Oser Avenue, Hauppauge, New York 11788
Regional Offices:
Chicago, Dallas, Los Angeles, Boston, Atlanta
In Canada call Omnitronix Ltd. 416 828-6221

LEADER
FOR PROFESSIONALS WHO KNOW THE DIFFERENCE



CIRCLE NO 129

zation of the structure to eliminate redundancy and inefficiency. Optimization is where you can design for high speed, low real-estate utilization, or some combination of the two. Trading off these considerations is the part of logic synthesis where engineers can obtain their highest level of productivity enhancement today.

To help visualize the design process and where logic synthesis fits into it, refer to the "Y" chart model **(Fig 1)** adapted from the original suggested by Gajski and Kuhn **(Ref 1).** This model proposes three ways to represent a design. More complex designs can use all three representations at various times in their development. But you might design exclusively at the gate level for smaller integrated circuits or at the polygon level for discrete transistors.

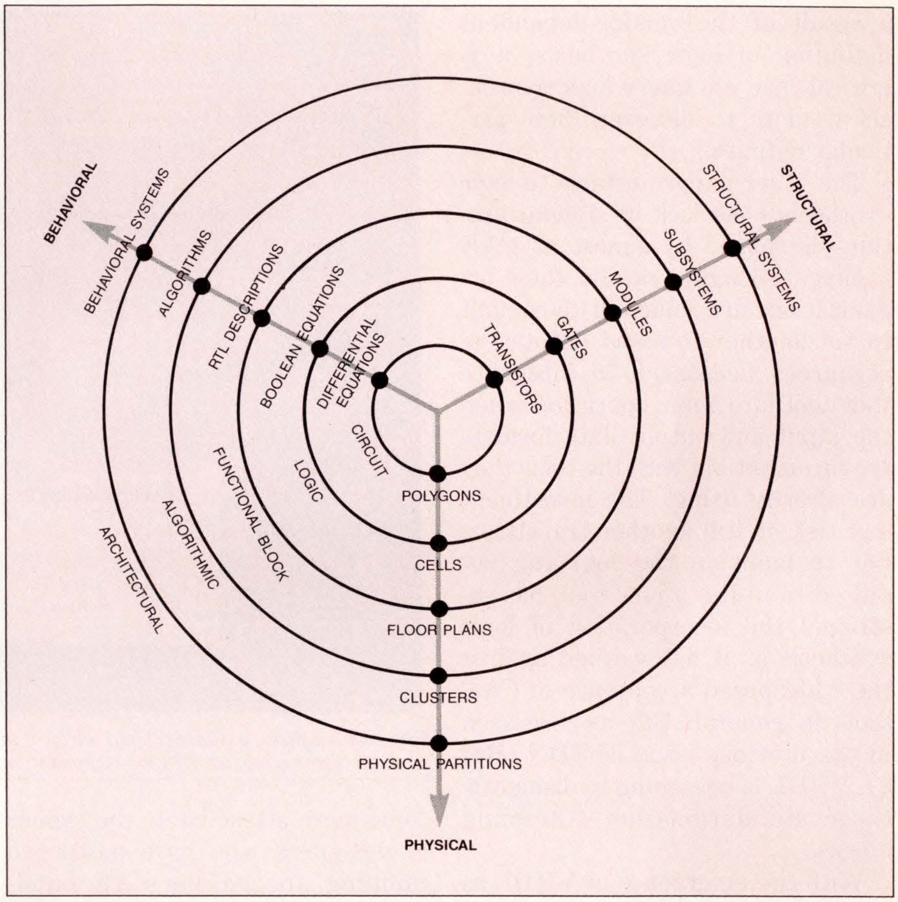


***Fig 1—The Y chart is a three-part representation** of a design that can help you understand the design process and how you can use CAE tools to achieve your design goals.*

The behavioral domain is the highest and most theoretical level at which you can represent a design. At this level, you are solely concerned with the function of the circuit from input to output. At the most abstract level, you can specify a design as a behavioral system. Refinement makes this specification more detailed as an algorithm; an RTL description; a set of Boolean equations; and, ultimately, as a set of differential equations. All of these representations define outputs as some function of the inputs and, possibly, time.

The structural domain specifies what elements you use to convert inputs into outputs and how you connect these elements to work toward their goal. Paralleling the refinement of the behavioral domain, the structural domain can be as abstract as a structural system. Providing more detail lets you define your circuit as a group of subsystems, which can include CPUs and memories. You could then refine your subsystems as modules, such as ALUs and registers. The modules can be further specified as gates and flip-flops; the gates and flip-flops can then be specified as transistors.

Finally, the physical domain describes the actual geometric implementation of the circuit. You can, at the most general level, represent a design as a collection of physical partitions. By refining the description and providing more detail, you can describe the physical circuit as a cluster; a floor plan; a group of cells; and, most basically, as an assortment of polygons.

A series of concentric circles connect each of the levels of detail. The circles represent, at the most philosophical level, an architectural description of the design. Refining the design produces the algorithmic, functional-block, logic, and circuit descriptions.

In the jargon of the industry, logic synthesis at its simplest is strictly the translation from one level of detail in the behavioral domain to the same level of detail in the structural domain. Broadening the view a little, some vendors of synthesis tools include optimization in their definition of logic synthesis. These routines eliminate redundancies and inefficiencies that the synthesis software creates. At the most extreme end, some vendors insist that true logic synthesis encompasses translation, optimization, and refinement. Thus—independent of what you put in—you ultimately finish logic synthesis with either a transistor- or gate-level representation of your circuit. As

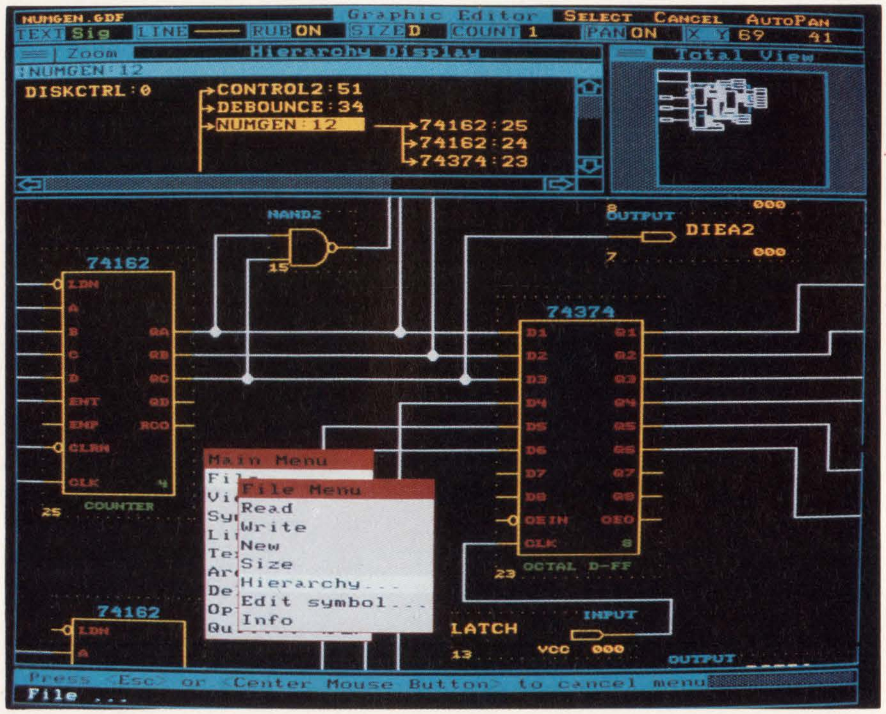
Logic synthesis

a result of the vendor-dependent definition of logic synthesis, it is critical that you query logic-synthesis vendors to discover their particular definition.

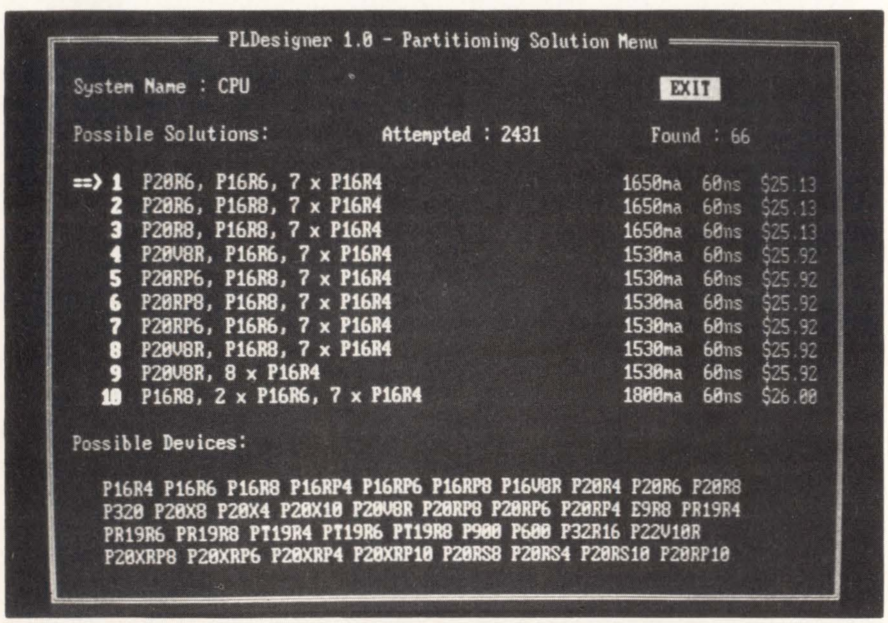
The other major obstacle to logic synthesis—the lack of standardization—is shared by almost all CAE packages. Engineers and their organizations are reluctant to commit to yet another tool and devote the resources necessary to integrate that tool into their operation when the input and output data formats are incompatible with the tools they are already using. The investment and risk of still another translator, not to mention the learning required to utilize a new tool, has restricted the incorporation of logic synthesis as it has worked against the widespread acceptence of CAE tools in general. But as discussed in the previous issue of EDN (**Ref 2**), VHDL is beginning to dismantle these standardization stumbling blocks.

With the emergence of VHDL as a standard for the documentation and design of integrated circuits and systems, CAE tools will become more attractive to the legions of designers who have postponed jumping aboard the CAE bandwagon for fear of either being left with a dinosaur or committing to the wrong standard. Most logic synthesis vendors and, indeed, most CAE vendors are coming to the realization that VHDL is the biggest game in town and are making major efforts to enable their software to accept VHDL input and generate VHDL output.

Initially, VHDL will be primarily a documentation and transfer language, hence the necessity for front-end design tools that can create and output VHDL code from some other input format. The reluctance of designers to embrace new techniques over their well-worn, time-proven methods will impede VHDL's rate of acceptance. Additionally, if you are immersed in a design project, you have little time to spend learning a new way to design—essentially by writing code—and if you are between designs and have more time, you might not have the motivation to learn a new design technique. Call it a Catch-22. But once the benefits become clearer and the reluctance to write code rather than draw or capture



You can capture a hierarchical circuit using TTL logic *from which the PLDS-MAX package synthesizes an EPLD programmimg file.*



The PLDesigner software partitions the circuit *and chooses the most cost-effective solutions within the performance constraints that you set.*

a design dissipates, VHDL will gather steam as a design language.

In the meantime, the decision to use logic-synthesis tools depends largely on your circumstances. If you design a large number of complex circuits, then the productivity enhancements offered by the current generation of logic-synthesis packages would probably outweigh the instability of the CAE marketplace and future enhancements to logic-synthesis tools. If you don't design circuits that could ultimately make their way into Department of Defense (DoD) systems, many of these logic-synthesis tools would probably serve your purposes quite well. On the other hand, if you only do a few designs, or are under DoD mandate to use VHDL either for design or documentation, then you might want to wait for the VHDL dust to settle before jumping into logic synthesis.

If you decide that you must have logic-synthesis capability or just want to know what's available, you should know that some vendors target their logic-synthesis software to either PLDs or ASICs because of the different requirements of each technology. Some of the PLD-specific synthesis vendors have made a committment to VHDL; others are still waiting to see how the dust settles. Minc's PLDesigner will have a provision for VHDL input in the third quarter of this year.

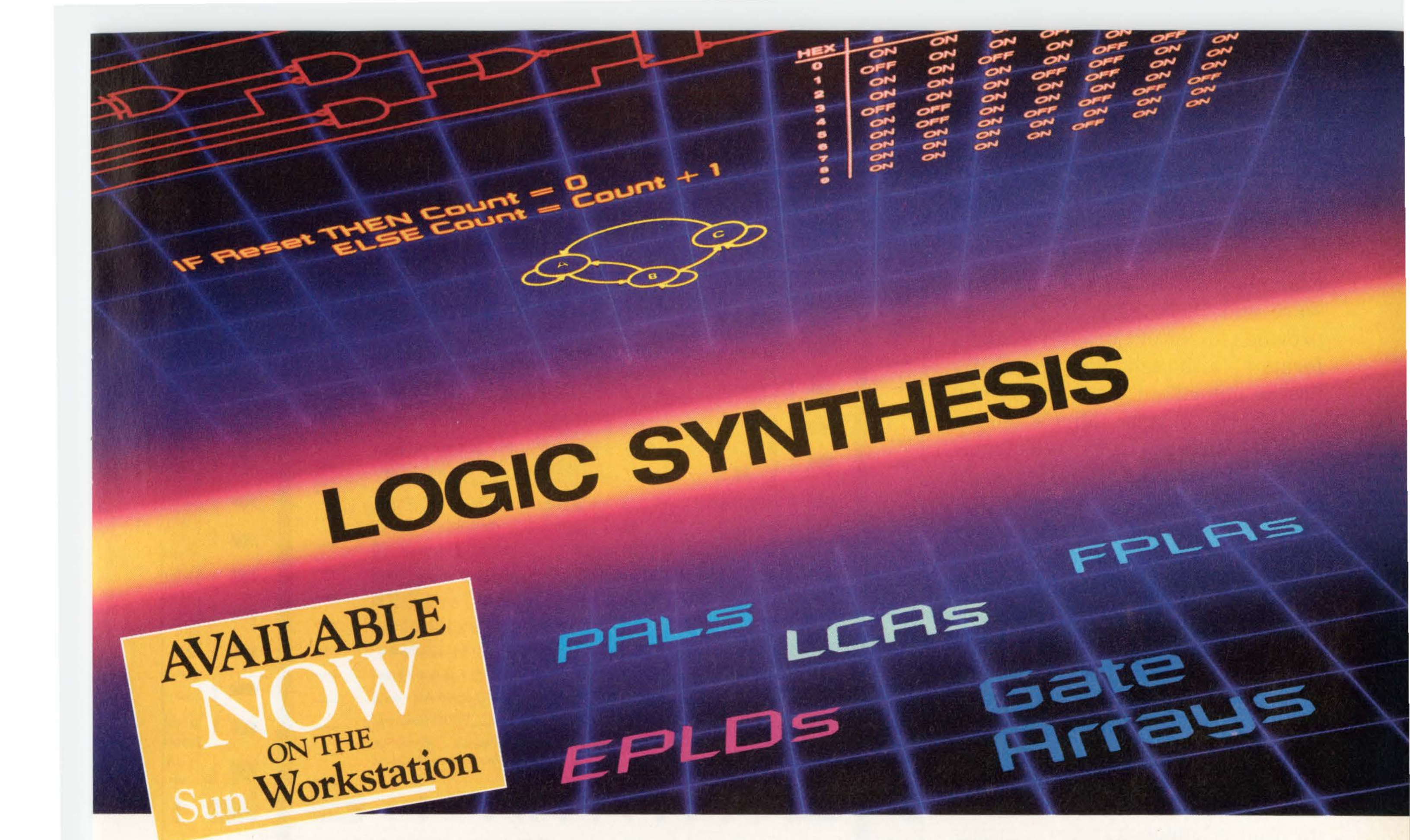
Altera is targeting a fourth-quarter introduction of VHDL capability for its PLDS-MAX software. The company is planning to add some extensions that its software will accept to the VHDL-language inputs to give you greater flexibility in creating your design. PLDS-MAX will output your circuit in standard VHDL format without the extensions, so you can exchange data with other VHDL-compatible tools. OrCAD is developing a VHDL compiler for its OrCAD/PLD that will let you program PLDs from a VHDL behavioral circuit description.

PLDesigner, PLDS-MAX, and OrCAD/PLD create JEDEC (Joint Electron Devices Engineering Committee) standard file outputs for programming PLDs. PLDS-MAX generates Altera's ADF format netlist as well as a PLD pro-

TABLE 1—LOGIC-SYNTHESIS PACKAGES

COMPANY	PRODUCT	VHDL	PLDs/ASICs	CAPABILITY	OPTIMIZATION	WORKSTATIONS	PRICE
ALGORITHMIC SYSTEMS	ASCYN LOGIC SYNTHESIZER	IN DEVELOPMENT	P, A	1, 2, 3, 4	LOCAL/GLOBAL	PC/XT, PC/AT, VAX, APOLLO, MAC	$3000 TO START
ALTERA	PLDS-MAX	Q4 '89	P	1, 2, 3, 4	GLOBAL	PC/AT, PS/2	$4995 INCLUDING PROGRAMMING HARDWARE
DATA I/O	GATES	—	P, A	1, 2, 3, 4	LOCAL/GLOBAL	PC/XT, PC/AT, PS/2, /386, SUN-3	$4440
MENTOR	PLDSYNTHESIS	Q3 '89	P	1, 2, 3, 4	LOCAL/GLOBAL	APOLLO	$14,900
MINC	PLDESIGNER	Q3 '89 INPUT	P	1, 2, 3, 4	LOCAL/GLOBAL	PC/XT, PC/AT	$4500
NCR	DESIGN SYNTHESIS	H2 '89	A	1, 2, 3, 4	LOCAL/GLOBAL	APOLLO (MENTOR GRAPHICS)	$51,500 INCLUDING NCR LIBRARIES
ORCAD	ORCAD/PLD	INPUT IN DEVELOPMENT	P	1, 2, 3, 4	GLOBAL	PC	$495
SEATTLE SILICON	FINESSE	IN DEVELOPMENT	A	1, 2, 3	GLOBAL	APOLLO (MENTOR GRAPHICS	$59,000 WITH CHIPCRAFTER
SILC	SILCSYN	OUTPUT NOW INPUT SEPT '89	A	1, 2, 3, 4	LOCAL/GLOBAL	SUN, APOLLO, DEC	$50,000 TEST OPTION $28,000
SILICON COMPILER SYSTEMS	LOGIC COMPILER	IN DEVELOPMENT	A	1, 2, 3	LOCAL	SUN, APOLLO, DEC (MENTOR/ DAISY)	$24,500
SYNOPSYS	DESIGN COMPILER	IN DEVELOPMENT	P, A	1, 2, 3, 4	LOCAL/GLOBAL	SUN, APOLLO, DEC (MENTOR)	$35,000
TRIMETER	DESIGN CONSULTANT	JUNE '89	A	1, 2, 3, 4	LOCAL/GLOBAL	SUN, APOLLO, DEC (MENTOR/ DAISY)	$49,500
VLSI TECH	LOGIC SYNTHESIZER	INPUT Q3 '89 OUTPUT IN DEVELOPMENT	P, A	1, 2, 3	LOCAL/GLOBAL	SUN, APOLLO, DEC, HP, ELIXI, RIDGE	$30,000
XILINX	DS-23	N/A	P	1, 2, 3	LOCAL/GLOBAL	PC/AT, SUN, APOLLO	$1500 $3000

NOTES:
1=COMBINATORIAL LOGIC
2=SEQUENTIAL LOGIC
3=SYNCHRONOUS CIRCUITS
4=ASYNCHRONOUS CIRCUITS



LOGIC SYNTHESIS GIVES YOU MORE DESIGN CHOICES.

FutureNet® FutureDesigner™ gives you more choices than any other design entry software—choices in how you enter your design, in target technologies, and in design output. And only FutureDesigner uses logic synthesis to automatically turn your input choices into your output choices, optimizing and streamlining your design for the technology you select.

CHOOSE THE DESIGN ENTRY METHOD. Only FutureDesigner lets you describe your design in the easiest, fastest, most natural way. You can enter some functions structurally, using DASH schematics. Others can be described behaviorally with any combination of truth tables, state diagrams, or high-level logic equations. Interactive verification and design rule checking help you catch errors up front, as you design.

CHOOSE THE TARGET TECHNOLOGY. FutureDesigner is technology independent. After you've described your design, you can choose any mix of TTLs, PLDs, LCAs, gate arrays, or other ASIC devices for implementation. It's also easy to migrate designs from one technology to another—for example, from TTL to PLD, PLD to LCA, or PLD to gate array.

Choose the platform: FutureDesigner runs on 80386 and 80286 machines, IBM® personal computers, and the Sun-3 Series.

CHOOSE THE OUTPUT FORMAT. With more than 100 DASH-Partners providing a broad range of complementary products and services, FutureDesigner's industry-standard format is accepted virtually everywhere. When you design with FutureDesigner, you'll have more choices in technologies, CAE systems, foundries, and service bureaus.

CHOOSE FUTUREDESIGNER WITH LOGIC SYNTHESIS. With its unique logic synthesis capabilities, FutureDesigner reduces and factors your design, eliminating redundancy and improving efficiency. It optimizes for the particular technology you've selected, making the necessary speed/size trade-offs. Then it generates the schematics, net lists, or JEDEC files for programming PLDs. Automatically.

Call us today for more information. Find out why FutureDesigner is the design entry software of choice.

1-800-247-5700
Ext. 153

Data I/O Corporation 10525 Willows Road N.E., P.O. Box 97046, Redmond, WA 98073-9746, U.S.A. (206) 867-6899/Telex 15-2167
Data I/O Canada 6725 Airport Road, Suite 302, Mississauga, Ontario L4V 1V2 (416) 678-0761
Data I/O Europe World Trade Center, Strawinskylaan 633, 1077 XX Amsterdam, The Netherlands +31 (0)20-6622866/Telex 16616 DATIO NL
Data I/O Japan Sumitomoseimei Higashishinbashi Bldg., 8F, 2-1-7, Higashi-Shinbashi, Minato-ku, Tokyo 105, Japan (03) 432-6991/Telex 2522685 DATAIO J

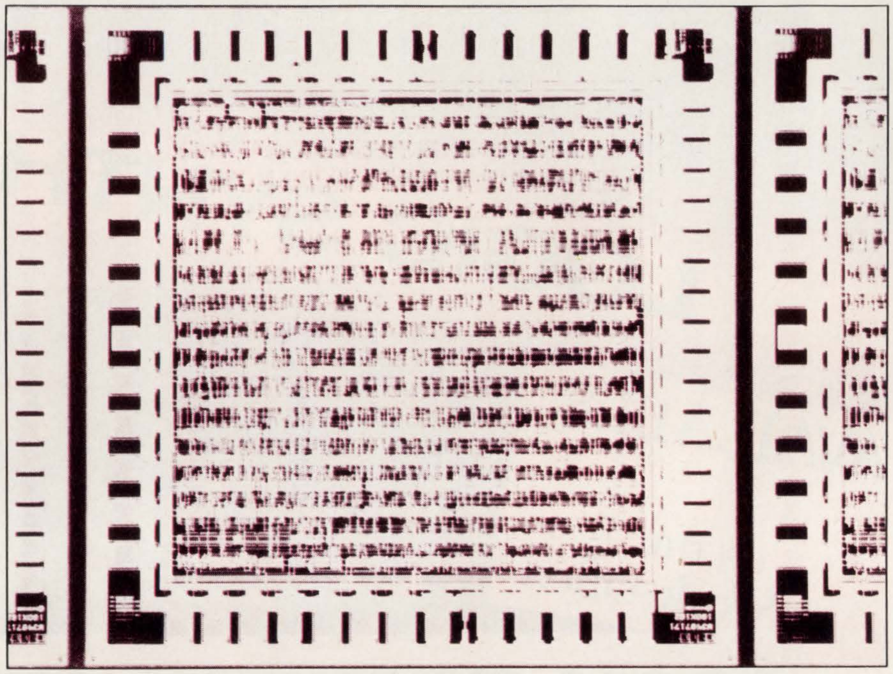
CIRCLE NO 131

DATA I/O
Corporation

gramming file for use with its hardware and PLDs. The PLDesigner provides its output in several useful formats, although Minc currently has no immediate plans for providing VHDL output. Minc's output formats include EDIF (electronic design interchange format) standard netlists, and schematics that are compatible with Mentor Graphics, Daisy/Cadnetix, OrCAD, PCAD, Futurenet-Data I/O, Teradyne, and Intergraph CAE systems. As with other front-end tools, until PLDesigner provides its own facility for generating VHDL descriptions, you'll need to use an indirect approach to generate a VHDL description. An example of such an approach would be importing your schematics to a schematics package that does have VHDL generation capability.

PLD-specific tools can begin the logic-synthesis process with Boolean equations, truth tables, or state-machine descriptions. Additionally, the PLDesigner can utilize RTL descriptions as well as synchronous-waveform entry, a method that lets you enter as many as 64 input and output waveforms. A waveform compiler then builds state-machine equations; and, if the waveforms do not provide sufficient information, the software provides you with the location of the problem and suggests solutions. Finally, if your design is too large, the PLDesigner can automatically partition your design among multiple PLDs, which it selects from its own library of more than 2500 devices, based on constraints like cost, pin count, and which devices your company stocks.

Logic cell arrays (LCA) are a cross between PLDs and ASICs. Xilinx's DS-23 Automated Design Implementation Program is an adaptation of Exemplar Logic's synthesis tools optimized for LCAs. It accepts either schematics that you've created with your favorite schematic-capture tool or Boolean equations. The DS-23 requires another front-end tool to create the circuit description from which the Xilinx software synthesizes and optimizes an LCA-compatible circuit. Thus, the company is relying on the capabilities of other front-end tools for VHDL compatibility.



Logic synthesis tools *have the capability to synthesize chips more complex then those they could generate even a year ago. This SCSI core is functionally equivalent to the NCR 53C80 SCSI chip but is fully synchronous. It has roughly 1000 gates, took six weeks to design rather than six months, and is 9% smaller than the core of its asynchronous cousin.*

Other vendors of logic-synthesis tools target the ASIC market. Most of these vendors recognize the importance of VHDL to their customers and are making progress toward providing their tools with the capability to both accept and generate VHDL descriptions. Logic-synthesis tools that accept circuit descriptions in other HDLs have an easier conversion path to VHDL than others. These HDLs include Gateway Design Automation's Verilog; Praxis' Ella, which was developed by the British Royal Signals and Radar Establishment (RSRE), adopted by the British Standards Institution (BSI), and licensed to Praxis; and other proprietary languages,

Silc Technologies SilcSyn ASIC Design System already provides VHDL output, and the company is committed to releasing a revision with VHDL-input support in September. The company wrote the original logic-synthesis software to accept their SilcSyn HDL and is modifying the tool for VHDL compatibility. As is common with all of the ASIC logic-synthesis tools, you can create your specification using either Boolean equations or truth tables.

SilcSyn has an optional $28,000 test-synthesis package that incorporates partial scan test into the design to implement testable ASICs. The software synthesizes the partial scan function after the circuit translation process but before the optimization routine is run, so that the software minimizes the scan logic with the rest of the design. The cost of the increased testability is four I/O pins and about 10% addi-

Demanding Designers Need the Best

OrCAD/SDT III

Schematic Design Tools for the PC

Ease-of-use + Power = Productivity

In today's tough design environment, good engineering tools aren't good enough. You need the best to get the job done.

OrCAD/SDT III offers the power

SDT III comes with the options you'd expect to pay extra for.

- **Completeness:** A library of over 6100 unique parts that you can browse through in a breeze. Utilities to generate Bill of Materials, Electrical rules check, create custom library parts
- **Compatibility:** Over thirty netlist formats, over 50 supported display adapters, over 50 printer drivers, a dozen plotter drivers. We conform to your system better than anyone.
- **Complexity:** 4000+ sheet design capacity for single designs. 200 levels of hierarchy. Great support for small, simple designs to large, complex hierarchical systems.
- **Control:** SDT III gives you the ability to customize your work environment to make you more productive. This includes user definable macros, text/object sizes, sheet sizes, graphical object editor, even the colors on the screen.

OrCAD/SDT III makes it easy

The lightning fast operation saves time. The intuitive, pop-up menu displays your most likely next action. This means a short learning curve and immediate productivity.

Only $495

Get our No-risk, Demo Disk

Try before you buy. Get our free demonstration disk and see for yourself the solid performance SDT III has to offer.

Once you've given our demo disk a spin, you'll know one of the reasons why OrCAD is the world's leading supplier of PC based CAE tools.

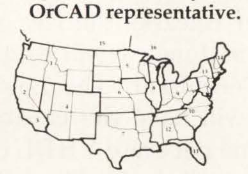
All OrCAD products come complete with one full year of technical telephone support, free product updates and access to our 24 hour BBS.

OrCAD®
Systems Corporation

1049 S.W. Baseline Street Suite 500
Hillsboro, Oregon 97123
(503) 640-9488

Call or write today for our FREE DEMO DISK

If you would like more information about this or any other OrCAD product, contact your local OrCAD representative.



1. WA, OR, MT, ID, AK
   Seltech, Inc.
   (206) 746-7970
2. N. CA, Reno NV
   Elcor Associates Inc.
   (408) 980-8868
3. So. CA
   A D G
   (714) 897-0319
4. Las Vegas, UT, AZ, NM, CO
   Tusar Corporation
   (602) 998-3688
5. ND, SD, MN, W. WI
   Comstrand, Inc.
   (612)788-9234
6. NE, KS, IA, MO
   Walker Engineering
   (913)888-0089
7. TX, OK, AR, LA
   Abcor, Inc.
   (713)486-9251
8. MI, E. WI, IL
   MacKellar Associates
   (313) 335-4440
9. IN, OH, KY, WV, W. PA
   Frank J. Campisano
   (513) 574-7111
10. VA, TN, NC, SC
    Tingen Technical Sales
    (919) 870-6670
11. FL
    High Tech Support
    (813) 920-7564
12. MS, AL, GA
    Electro-Cadd
    (404) 446-7523
13. DE, MD, DC, E. PA, NJ, NY
    Beta Lambda, Inc.
    (201) 446-1100
14. CT, RI, MA, VT, NH, ME
    DGA Associates
    (617) 935-3001
15. BC, AB, SK, MB
    Interworld Electronics, Ltd.
    (604) 984-4171
16. ON, PQ & Maritimes
    Electralert, LTD.
    (416) 475-6730

CIRCLE NO 132

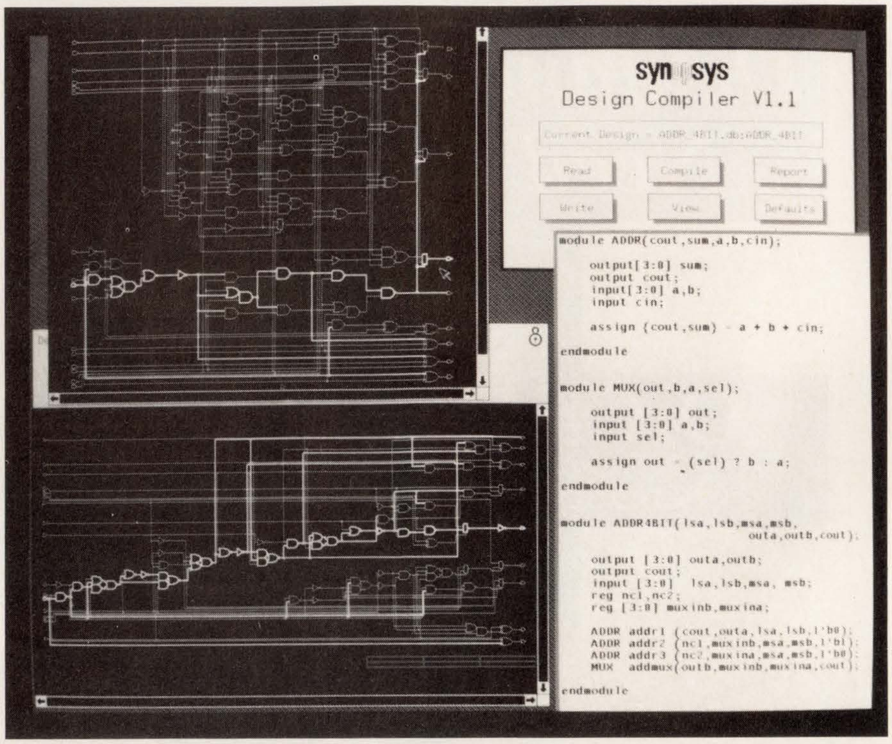
Logic synthesis

tional real estate—a savings of between one-half and two-thirds that of full scan-path designs. After implementing the logic, the software creates Mentor's logfile-format test patterns.

NCR Microelectronics has integrated SilcSyn into their KE^2 (Knowledge-based Engineering Environment) package. The company expects to offer both VHDL support and the test synthesis feature in the second half of this year. If NCR is your ASIC supplier, its Design Synthesis package maps your circuit description directly to NCR library elements. Silc Technologies has additional cell libraries from Toshiba, LSI Logic, Fujitsu, and Standard Microsystems, and has a proprietary library from GTE.

You can drive the Logic Consultant from Trimeter Technologies (which has reached an agreement to be acquired by Mentor Graphics) with Boolean equations, truth tables, schematics, or netlists. When Trimeter releases the Design Consultant in June, it will contain the Logic Consultant. The Logic Consultant will have the capability to utilize and generate VHDL descriptions as well as Verilog HDL descriptions. The software lets you exchange netlists and schematics with either Daisy or Mentor workstations or with other CAE toolsets utilizing EDIF. Another enhancement to the Design Consultant will be a graphic state-machine-diagram editor that lets you draw a state machine to use as the input to the logic-synthesis software.

Seattle Silicon and Silicon Compiler Systems have leveraged their experience in silicon compilers to present an approach that could ultimately fulfill the original promise of silicon compilation. That promise was to enable you to plug a high-level circuit specification into a black box and receive a fully fabricated, tested, and ready-to-use piece of silicon.



The advantage to logic synthesis is that you can optimize a design *for either high performance (top) or area efficiency (bottom). Synopsys' Design Compiler highlights the critical path, so you can visualize possible problem areas in the circuit.*

Neither Seattle Silicon's Finesse nor Silicon Compiler Systems' Logic Compiler currently support VHDL. However, both companies are committed to supporting the langauge and are developing enhancements that will bring VHDL capabilities to their tools. Finesse offers the ability to incorporate scan as a test strategy at the description level—currently you can use Boolean equations, truth tables, and state-machine descriptions to drive both Finesse and the Logic Compiler. The ability of these silicon compilers to size drive transistors automatically according to loading is a feature that provides more flexibility, better matching between circuit stages, and more efficient real-estate utilization than the typical standard-cell or gate-array alternatives.

Other vendors target their logic-synthesis tools to work with both PLDs and ASICs. Synopsys' Design Compiler and HDL Compiler accept descriptions in many formats. In addition to Boolean equations and truth tables, you can use netlists in EDIF, LSI Logic's NDL, Mentor's MIF, Tegas format, or Cadence format as well as EDIF schematics or Verilog HDL to drive the Synopsys tools. The only HDL Synopsys currently supports is Verilog, but the company is committed to VHDL and plans to include VHDL support in a future release.

VLSI Technology's Logic Synthesizer accepts input from Boolean equations and a state-machine high-level language. VLSI Technology is working to enable you to use truth tables, state diagrams, and PLA code files to drive its synthesis tools. The next release of the Logic Synthesizer will support the Ella HDL; the company's goal is to offer VHDL-input support in the synthesizer's third-quarter 1989 release. VLSI is planning VHDL output support, although it is unsure when that support will be available. The

New Precision Pulse Generator

Four Channels, 5 ps Resolution, and GPIB Interface...Price: $3350

TIMING IS EVERYTHING

Your critical timing problems are over. No more worries about drift, jitter, or control. The DG535 Precision Pulse Generator has four delay channels (two pulse outputs), each with a 1000 second range and 5 ps resolution. The four independent delays specify two variable-width pulse outputs. With only 50 ps jitter and accuracy down to 1 ppm (option 03), the instrument can handle the most demanding applications. The internal trigger may be programmed from 0.001 Hz to 1.000 MHz, or operated in single-shot or burst modes. Output levels are continuously adjustable or may be set to TTL, NIM, or ECL levels. High impedance or 50 Ohm loads can be driven with a slew rate of 1 V/ns. Optional rear panel outputs generate pulses to 35 volts.

EASY TO USE

The delay and output levels for each channel may be entered numerically or modified by cursor keys on the backlit LCD display. Delays may be linked together so that as one moves, the other follows. Up to nine instrument settings may be stored in nonvolatile RAM for later recall, and, of course, all of the instrument's functions may be controlled via the GPIB interface.

A GENERATION AHEAD

The DG535's precision, accuracy, range, and versatility make it the solution to all your timing needs, at a price that will meet your budget. Call us today for more information.

FEATURES AND PERFORMANCE

- **Four Delay Outputs**
- **Two Variable-Width Outputs**
- **Times from 0 to 1000 sec.**
- **5 ps Resolution**
- **50 ps rms Jitter**
- **1 ppm Accuracy (Option 03)**
- **Internal or External Timebase**
- **Internal, External, Single-Shot, or Burst Mode Triggers**
- **Frequency Synthesized Rate Generator**
- **Variable, TTL, NIM, and ECL Outputs**
- Optional ±35 Volt Outputs
- **GPIB Computer Interface**

FRANCE
Optilas
c.e. 1422
91019 Evry Cedex
60.77.40.63, TLX 600019

GERMANY
Spectroscopy Instruments
Carl Benz Strasse 11
D-8031 Gilching
0 8105/5011, TLX 523862

JAPAN
Tokyo Instruments
Koizumi Building
6-8-10 Nishikasai
Edogawa-ku, Tokyo 134
03 (686) 4711,TLX 6860831

Seki and Company
1-2-6, Nihonbashi Ningyocho
Chuo-ku, Tokyo 103
03 (669) 4121, TLX J24419

UNITED KINGDOM
Lambda Photometrics
Lambda House, Batford Mill
Harpenden, Herts AL5 5BZ
05827/64334, TLX 825889

Speirs Robertson
Moliver House,
Oakley Road
Bromham, Bedford
02302/3410, TLX 825633

Stanford Research Systems

1290 D Reamwood Avenue, Sunnyvale, CA 94089 FAX 4087449049, TEL (408) 744-9040

Logic synthesis

Logic Synthesizer is part of VLSI's multichip ASIC system-design package, which helps you partition your circuit according to size, power, and packaging requirements.

The Ascyn logic synthesizer, from Algorithmic Systems, has VHDL compatibility in development. The program supports Xilinx LCAs, gate arrays, and standard cells. Ascyn and Gates are the only two packages targeted for ASICs that run on the IBM PC/AT and compatibles, and Ascyn is the only package that runs on Apple's Macintosh family of personal computers.

Ikos Systems uses a simple logic-synthesis capability in its hardware-based Simulation System. Typically, if you find an error while you are simulating, you must exit the simulator, correct the circuit, recompile, re-enter the simulator, and resimulate. Because you must repeat this procedure every time you find a design error, simulation is often the bottleneck in design. With the Simulation System, you can enter Boolean equations, or netlist corrections interactively within the simulator shell. The Simulation System can perform local optimization; but, because it is strictly a simulator, it does not back annotate your logic changes to the original netlist. The simulator creates a file that documents your changes so you can update your netlist or schematic after you've finished simulating.

There is little question that logic synthesis is a powerful addition to the repertoire of system-design engineers. It can save you from entering schematics or netlists on a gate-by-gate basis. Many tools let you design using techniques that you're familiar with, like Boolean equations, truth tables, and state diagrams. Although you may not be comfortable working at the behavioral level, that's where the technology seems to be ultimately headed. Logic-synthesis tools are leading the way.

Standing in the way, however, are all the classic arguments against CAE tools: the lack of compatibility among hardware, software, and user interface. The cavalry, VHDL, is about to ride over the hill. EDN

References

1. Gajski, Daniel D, and Robert H Kuhn, "Guest Editors' Introduction: New VLSI Tools," *IEEE Computer*, December 1983, pgs 11-14.
2. Leibson, Steven H, "VHDL," *EDN*, March 16, 1989, pgs 110-124.
3. Trevillyan, Louise, "An Overview of Logic Synthesis Systems," Twenty-fourth Design Automation Conference, 1987, pgs 166-172.
4. Smith, David, "What is Logic Synthesis?" *VLSI Systems Design*, October 1988, pgs 18-26.
5. "An Introduction to Logic Synthesis," October 1988, Data I/O Corp.

Article Interest Quotient
(Circle One)
High 518 Medium 519 Low 520

For more information . . .

For more information on the logic-synthesis products discussed in this article, contact the following manufacturers directly, circle the appropriate numbers on the Information Retrieval Service card, or use EDN's Express Request service.

Algorithmic Systems
399 Pond St
Number C5
Braintree, MA 02184
(617) 849-0580
Circle No 700

Altera Corp
3525 Monroe St
Box 58163
Santa Clara, CA 95052-8163
(408) 984-2800
Circle No 701

Exemplar Logic Inc
2550 Ninth St
Suite 102 Berkeley, CA 94710
(415) 849-0937
Circle No 702

FutureNet-Data I/O Corp
10525 Willows Rd NE
Box 97046
Redmond, WA 98073
(206) 881-6444
Circle No 703

Ikos Systems Inc
145 N Wolfe Rd
Sunnyvale, CA 94086
(408) 245-1900
Circle No 704

Mentor Graphics
8500 SW Creekside Pl
Beaverton, OR 97005
(503) 626-7000
Circle No 705

Minc Inc
1575 York Rd
Colorado Springs, CO 80918
(719) 590-1155
Circle No 706

NCR Corp Microelectronics Div
2001 Danfield Ct
Fort Collins, CO 80525
(303) 226-9530
Circle No 707

OrCAD Systems Corp
1049 SW Baseline St
Suite 500
Hillsboro, OR 97123
(503) 640-9488
Circle No 708

Seattle Silicon
3075 112th Ave NE
Bellevue, WA 98004
(206) 828-4422
Circle No 709

Silc Technologies Inc
34 3rd Ave
Burlington, MA 01803
(617) 273-1144
Circle No 710

Silicon Compiler Systems
2045 Hamilton Ave
San Jose, CA 95125-6199
(408) 371-2900
Circle No 711

Synopsys Inc
1500 Salado Dr
Mountain View, CA 94043
(415) 962-5000
Circle No 712

Trimeter Technologies Inc
200 Hightower Blvd
Suite 100
Pittsburgh, PA 15205
(412) 787-8630
Circle No 713

VLSI Technology Inc
1109 McKay Dr
San Jose, CA 95131
(408) 434-3000
Circle No 714

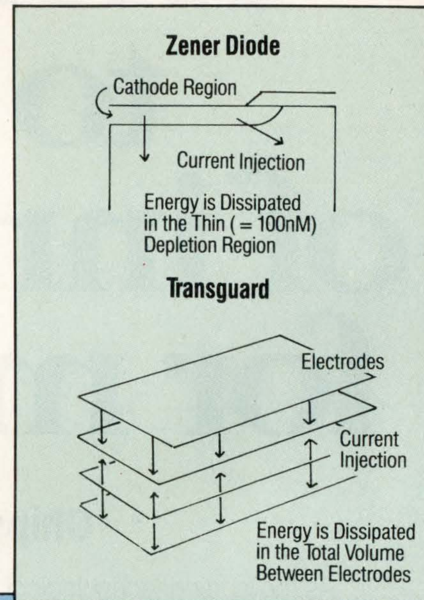
Xilinx Inc
2069 Hamilton Ave
San Jose, CA 95125
(408) 559-7778
Circle No 715

TechFile Series

SMT Solutions

Technical Information On Surface Mountable Voltage Suppressors.

Figure 1 • Energy Dissipation for Zener Diodes and Transguards



Suppressor Type		5.6V DC TransGuard	5.6V DC Zener	14V DC TransGuard	14V DC Zener
Dimensions	L x W	.126″ x .063″	.250″ x .140″	.126″ x .063″	.250″ x .140″
Clamping Voltage	V_C				
8 x 20μS, 10 Amp Peak		15.5V		30V	
10 x 1000μS, 62.5 Amp Peak			9.6V		
10 x 1000μS, 23.3 Amp Peak					25.8V
Peak Current @ 85°C 8 x 20μS Pulse	I_{PEAK}	150A	200A	150A	90A
Transient Energy 10 x 1000μS Pulse	E_{TRAN}	.4J	.5J	.4J	.5J

Table I. Comparison of Surface Mount Transient Suppressors

A Multilayer Approach to Transient Voltage Suppression

Electrical overstress, especially due to electrostatic discharge (ESD), has been a growing concern to designers and the trend toward surface mount technology (SMT) has placed severe size constraints on the components that provide this protection.

Low voltage transient suppressor applications have been dominated by specially designed zener diodes because of their clamping characteristics and smaller size. However, continuing advances in ceramic technology have made the AVX TransGuard possible—a high performance, low voltage surface mountable varistor that, unlike single plane devices, uses a multilayer structure. This structure offers significant improvement in electrical performance as well as in size and usability in SMT assemblies. (Table I)

Clamping Characteristics

Multilayer construction and improved grain structure of TransGuards result in excellent transient clamping characteristics (in excess of 150 amps peak current) while maintaining very low leakage currents under DC operating conditions.

Energy Dissipation

Varistors or semiconducting ceramics are in reality series/parallel combinations of Schottky diodes that support most energy dissipation in thin depletion regions at each Schottky barrier. Zener diodes have only a single thin depletion region at the surface, while varistors have many in series/parallel combination distributed throughout the whole ceramic volume (as seen in Figure 1). This results in superior energy dissipation per unit volume.

CIRCLE NO 134

____ Please send me the AVX Technical paper "A Multilayer Approach to Transient Voltage Suppressors."

____ Please send me more information describing AVX MLC's.

Name ____________________

Title ____________________

Company ____________________

Address ____________________

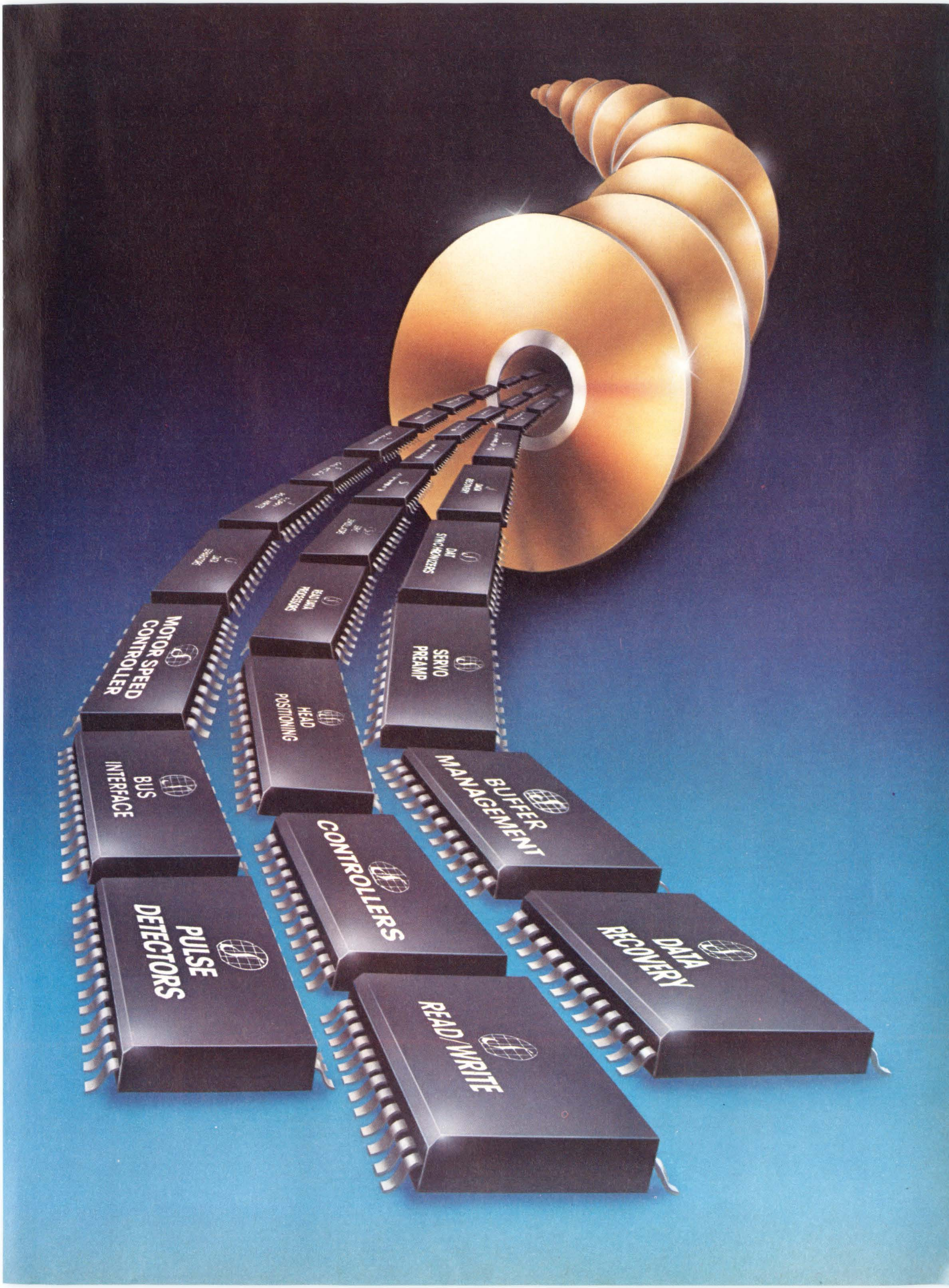
City ____________________

State ____________ Zip ________

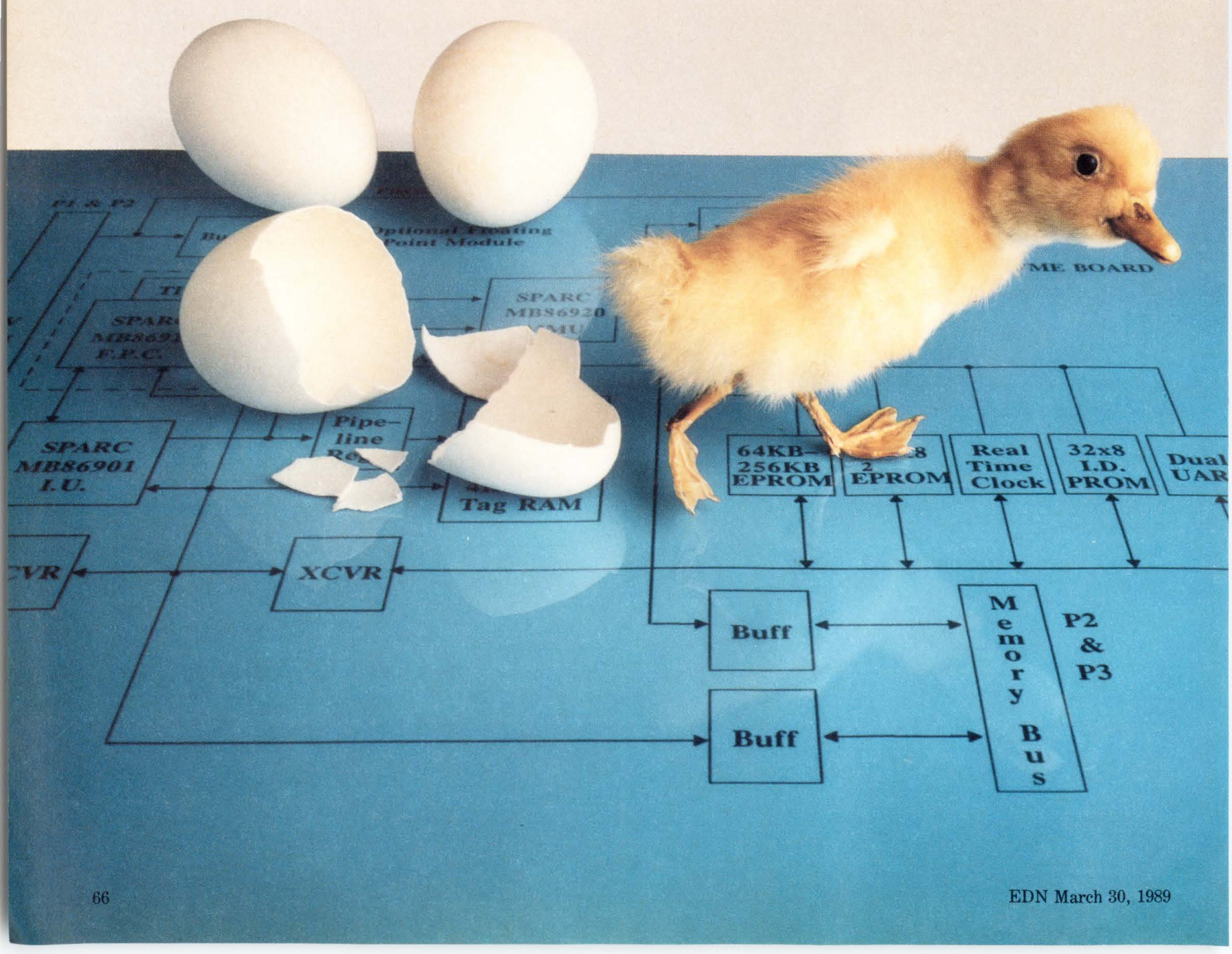
Phone ____________________

AVX Corporation, P.O. Box 867
Myrtle Beach, SC 29577
Tel: (803) 448-9411, FAX: (803) 448-1373

EDN 033089


MOTOR SPEED CONTROLLER
SERVO PREAMP
HEAD POSITIONING
BUS INTERFACE
BUFFER MANAGEMENT
CONTROLLERS
DATA RECOVERY
PULSE DETECTORS
READ/WRITE

Fujitsu's new RISC chip-computer development.



set speeds up your

Break out!

Get your computer to market before your competitors.
When you need to be first, nothing helps more than getting a head start. And nothing will get you started faster than these new SPARC™ devices from Fujitsu.

Not just a speedy microprocessor—but a complete high performance RISC chip-set. One that accelerates the development cycle of powerful minis, PCs and workstations. And eliminates many components plus the time it takes to integrate them. Yet, offers a high degree of design flexibility.

A complete chip-set to speed up your product development.
Fujitsu's new S-25™ chip-set includes a 25 MHz, 32-bit Integer Unit (IU) for high-speed processing. A Memory Management Unit (MMU) ideal for the UNIX® environment and tailored for SPARC processors. And a Floating Point Controller (FPC) that allows interface to the IU and supports IEEE single and double precision arithmetic.

In addition, these devices are fully supported by a wide range of hardware and software development tools.

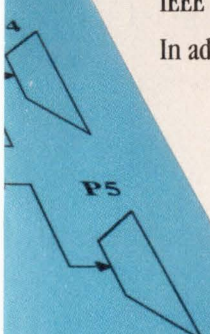
MB86901 (IU)	MB86911 (FPC)	MB86920 (MMU)
■ 25 MHz ■ 40 ns / cycle ■ 15 MIPS	■ Single & double precision floating point arith. ■ ANSI / IEEE 754-1985 std. ■ 64-bit int. data paths	■ 64-entry TLB ■ Fully associative ■ 64-Gbyte physical address

A proven architecture from a proven supplier.
SPARC is multi-sourced and proven over time. We first implemented it for the Sun 4/200 workstation over two years ago and have been producing it in volume ever since. Using the same Fujitsu manufacturing know-how that has made us a world leader in gate array and memory production.

The S-25 chip-set is a third-generation product designed at our Advanced Products Division in Silicon Valley. Where our engineering teams continue to advance the state-of-the-RISC-art—supported by the resources of a multi-billion dollar worldwide organization.

Break outs—without breakdowns!
Enjoy the competitive advantage of getting to market first! Rely on an architecture and supplier who can get you there. On time. On spec. On budget.

When you want to be first, we're the first ones to call.
(800) 523-0034



FUJITSU

FUJITSU MICROELECTRONICS, INC.

Advanced Products Division

50 Rio Robles, Bldg. 3, San Jose, CA 95134-1804

CIRCLE NO 99

MICE®

FORETELLS YOUR DEVELOPMENT NEEDS...

MICROTEK offers a complete line of MICE (Micro-In-Circuit-Emulator) for most popular 8, 16 and 32-bit microprocessors. These series of MICE are capable of debugging high speed targets without accumulating wait state, e.g. 25 MHz for 68020, 16 MHz for 68000/80C186. Protected Mode in 80386, coprocessor emulation in 16/32 bit series and bus/execution breakpoints in all series, are few examples of MICE powerful emulation features designed to meet advanced development needs.

All MICE series could work well with IBM PC/XT/AT*, IBM PS/2*, VAX*, µVAX*, Apollo*, Sun* and NEC* 98 series. Cross assembler/compiler, symbolic debugger and high level language debugger are also available to offer optimized software tool supports to an advanced development environment.

MICE SERIES AVAILABLE MODELS

µC	8048 Family, 8052 Family, Z8, Z88, 68HC11, 80515/535, V25
8-BIT	8085, 6809/E, Z80, NSC800, 6502F, 64180
16-BIT	80C86/88, 80C186/188, 80286, 68000/010, 68008, V20/30
32-BIT	80386, 68020 (25 MHZ)

MICROTEK

MICROTEK INTERNATIONAL INC.

HEADQUARTERS
Tel: 886-35-772155 Fax: 886-35-772598
Telex: 32169 MICROTEK

U.S.A. OFFICE
Tel: (213)321-2121 Fax: (213)538-1193
Telex: 797880 MICRO

EUROPE OFFICE
Tel: 49(211)556181 Fax: 49-211-572362
Telex: 8584020

See us at Electro '89, New York. Booth No. #475.

• **AUSTRIA** ALLMOS ELECTRONIC (222)6271954 • **BELGIUM** SIMAC ELECTRONICS B.V. (2)2523690 • **DENMARK** SC METRIC A/S (2)804200 • **ENGLAND** ARS MICROSYSTEMS (276)685005 • **FINLAND** OY COMDAX AB (0)670277 • **FRANCE** M.T.E. (1)39618228 • **ITALY** PRATICA SRL (11)503427 • **NETHERLANDS** SIMAC ELECTRONICS B.V. (40)582911 • **NORWAY** MORGENSTIERNE & CO A/S (2)358110 • **SPAIN** NOVATRONIC, S.A. (4)4520811 • **SWEDEN** NORDISK ARRAYTEKNIK AB (8)7349935 • **SWITZERLAND** TRACO ELECTRONIC AG (1)2010711 • **W. GERMANY** ALLMOS ELECTRONIC (89)8570000 • **AUSTRALIA** MACRO DYNAMICS (3)7202399 • **HONG KONG** IDEALAND ELEC. (3)7443516 • **INDONESIA** PT. ASCII (21)6002305 • **ISRAEL** ARITMOR (3)5447475 • **JAPAN** CORE DIGITAL CORP. (3)7955171 • **KOREA** DAESANG INC. (2)7196438 • **NEW ZEALAND** NORTHROP INSTRUMENTS (4)856658 • **PAKISTAN** EAST WEST SYSTEMS (21)529827 • **SINGAPORE** EPE COMPUTRONICS 7468182 • **THAILAND** ANA-DIGIT COMPANY (2)2217040 • **THAILAND** SANYA PHANICH (2)2225223 • **U.S.A.** MicroCASE INC. (503)6901252 • **ARGENTINA** MICROTEC INGENIERIA S.R.L. (1)469518 • **BRAZIL** DIGIBYTE SISTEMAS DIGITAIS (11)2413611 • **CHILE** EQUIPOS INDUSTRIALES S.A.C.I. (2)716882 • **SOUTH AFRICA** PROTEA TEST & MEASUREMENT (011)7883710

* Registered Trademarks: PC/XT/AT, PS/2: International Business Machines; VAX, µVAX: Digital Equipment Corporation; Apollo: Apollo Computer Inc; Sun: Sun Microsystems, Inc; NEC: NEC Corporation.

CIRCLE NO 100

RISC boards target real-time applications

A RISC board can turbocharge your real-time system design, but it may also drain your budget.

Maury Wright, Regional Editor

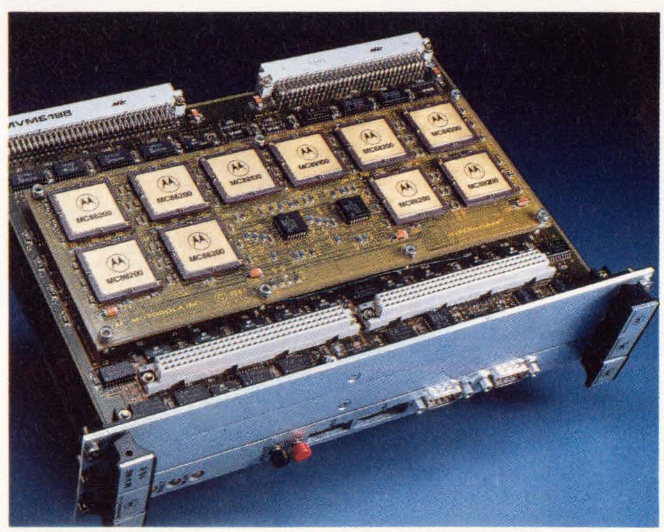
Several manufacturers of CPU boards for real-time applications now offer powerful models based on RISC (reduced-instruction-set computer) μPs. You'll have to make the usual price/performance judgment before choosing a RISC-based board for a real-time application. But you also need to consider the relative performance merits of RISC technology and the effect that a RISC architecture will have on your software-development tasks and the auxiliary hardware that surrounds the CPU. Furthermore, all of the available RISC processors are relatively new and expensive, and you currently have few choices of real-time operating systems and software-development tools for these processors.

The RISC boards available for real-time applications are primarily based on the VME Bus. RISC-board manufacturers claim that their products offer a way to build more-powerful real-time systems than you can build with CISC (complex-instruction-set computer) boards. For one thing, the board vendors suggest that you can use a single-processor RISC board in a real-time application that might previously have required a tightly coupled multiprocessor design. Furthermore, the manufacturers assert that the real-time RISC offerings can also be used in multiprocessor configurations.

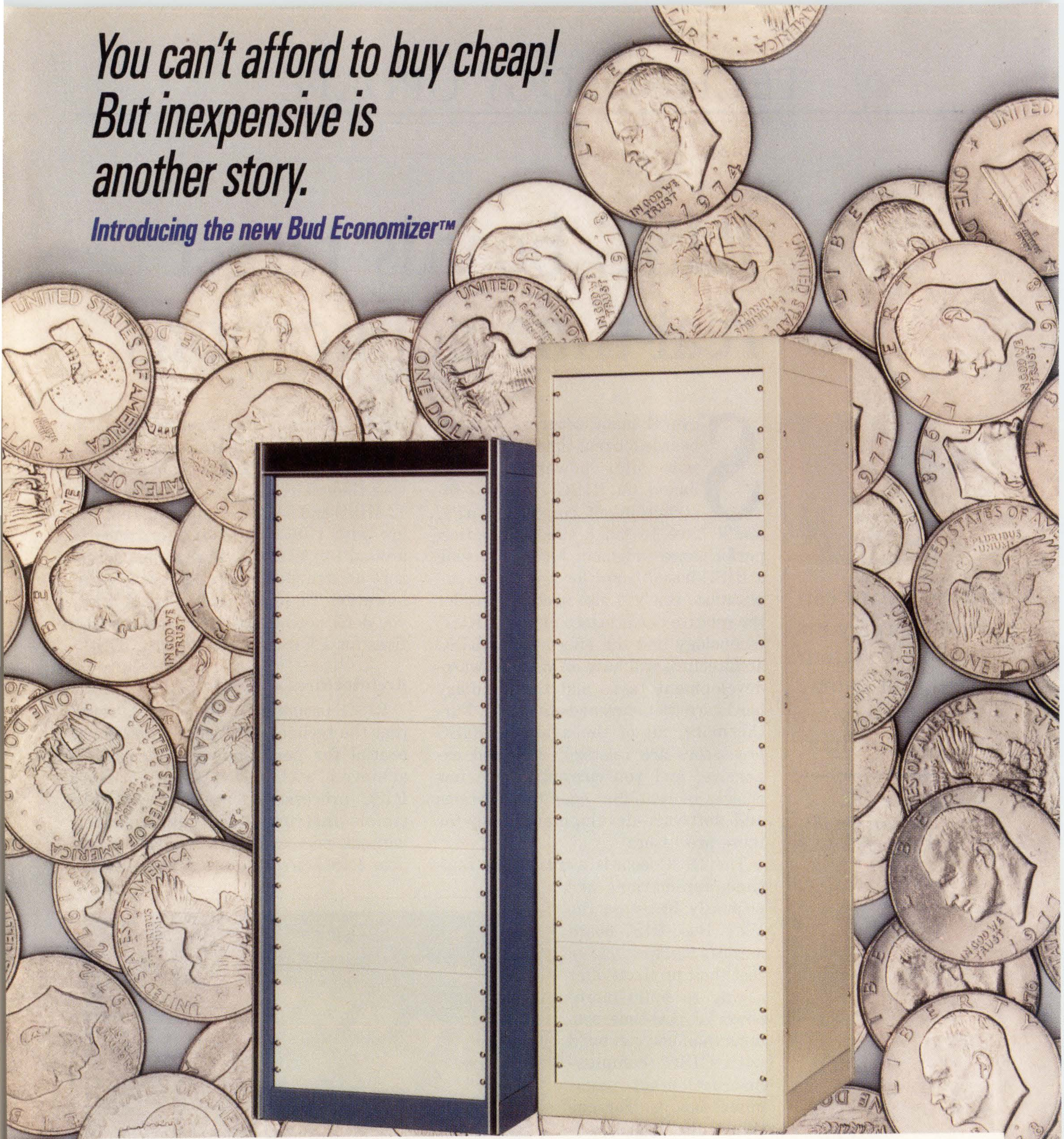
And finally, the board manufacturers spec their RISC boards' performance at 12 MIPS and higher, comparing that figure with CISC boards' performance of around 1 to 12 MIPS. Such a comparison isn't as straightforward as it may look, however: To implement a given task, you don't need to write as many instructions for a CISC as you do for a RISC.

Architectures seek an AIT of 1

RISC proponents, in general, claim that the technology offers a greater potential for performance than can be achieved with CISC architectures. RISC processors employ a relatively simple instruction set implemented without microcode. On average, available RISC processors can execute one



The 3-board VME Bus module from Motorola, *Model MVME188, hosts eight 88200 cache/MMU ICs and as many as four 25-MHz 88100 processors. One board hosts the 88000-family chips, one is the system controller, and one carries 16M bytes of RAM.*



Check these features, then count your savings when you buy the new Economizer.™

- The stiffest welded frame in the Bud line at an incredible low price.
- Removable sides for easy access.
- Fully adjustable, top of the line mounting rails for fast accessory installation.
- 19″ equipment can also be mounted from rear.
- Optional Trim Kit as shown above on blue unit.
- Accepts the complete line of Bud standard accessory items.
- Stocked in all 5 heights and 3 depths.
- Available today from your local Bud Authorized Distributor.

CIRCLE NO 101

BUD

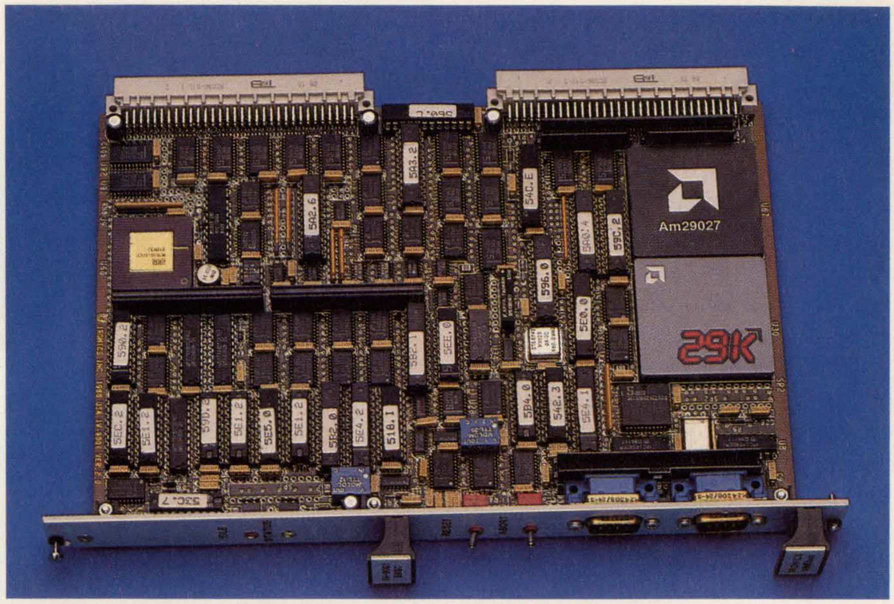
Bud Industries, Inc.

BUD EAST, INC.
4605 East 355th Street
P.O. Box 431
Willoughby, Ohio 44094
(216) 946-3200
FAX 216-951-4015

BUD WEST, INC.
7733 West Olive Avenue
P.O. Box 1029
Peoria, Arizona 85345-0350
(602) 979-0300
FAX 602-878-5371

instruction per clock cycle—an AIT (average instruction time) of 1. System-dependent latencies, however, typically make it impossible to realize an AIT of 1 in a system. (For more information on RISC technology, see **Ref 1**).

When they compare RISC and CISC processors implemented at the same clock speed and in the same silicon technology, CISC advocates concede that CISC processors can't match the AIT performance of RISCs. But CISC proponents argue that a RISC processor must execute more instructions than a CISC processor must to accomplish the same task. The RISC side counters that compilers primarily use simple instructions and therefore closely match RISC-processor instruction sets.



Burst-mode memory-read operations *allow the 29000-based Ironics IV-9001 board to operate at 17 MIPS with a cost-effective dynamic-RAM array.*

In fact, a comparison of RISC and CISC performance is significant only in relation to a specific application. Despite all the industry chatter about RISC technology, it's not automatically your best choice. The right choice for your application will be based on your analysis of the available hardware and software products for both technologies, and not on marketing hype.

The RISC-vs-CISC debate will probably continue into the next decade. But one fact stands clear: The available RISC chips and boards are members of today's highest-performance class of 32-bit μPs and μP-based boards (some CISC chips and boards are also members of that class). The available RISC boards are also members of the highest-cost class—their prices range from $7000 to more than $35,000.

RISC requires fast memory

To use a RISC μP or board for a real-time application and to exploit the performance potential that RISC technology offers, you must accept and work with two characteristics of RISC technology. First, to develop software for RISC processors, you must employ high-level languages. Second, RISC processors require fast access to fairly large memory arrays.

The requirement to program in a high-level language derives from the nature of RISC architectures. Because of the instruction set and large register file, it's not feasible for you to write your own assembly-language code (as you could for CISC processors), even for small routines for which execution speed is critical.

Furthermore, RISC architectures enhance performance by implementing such features as delayed branch execution. By delaying the execution of branch instructions, a processor can avoid waiting for the next instruction to be loaded into the execution pipeline. Compilers take advantage of such architectural features by changing the sequence in which instructions execute.

Using a high-level language isn't always a drawback, as you might be tempted to think. Languages such as C and Ada have become increasingly popular for any (RISC or CISC) 32-bit real-time application. High-level languages simplify the software-development task and make it easier to manage the large amounts of code generated in 32-bit real-time applications.

Optimizers complicate debugging

High-level languages do complicate the debugging process, however. Today's RISC and CISC compilers can optionally generate code that's optimized for run-time efficiency. In optimizing the code, the compilers often shuffle the machine-code instructions, changing their sequence. Optimization is necessary to make any code run efficiently, whether on a RISC or a CISC processor, but it's more important for RISCs, because only optimized code will take full advantage of the unique architectural features of RISCs, such as delayed branch execution.

The source-code-level debugging packages available from most compiler vendors, however, operate only on unoptimized code. Therefore, you can't debug your code when it's running at full speed (optimized) at the source-code level.

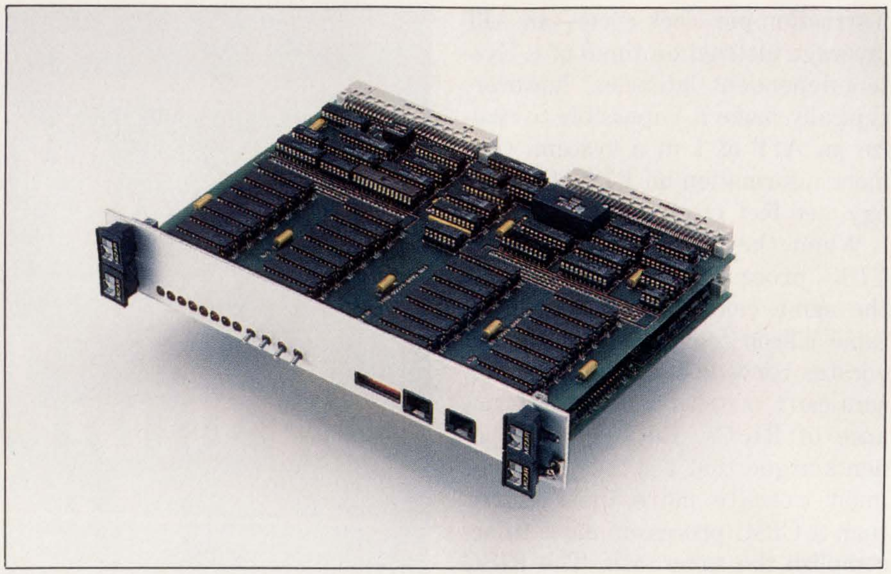
Unix-type programmers (programmers who create software for non-real-time applications) probably don't need to debug software after optimization. But in real-time applications, the code interacts directly with the real world via robots, instrumentation, motors, and other asynchronous I/O devices. If you used a source-level debugger on the unoptimized code, and then optimized the code, you might run into a problem. For example, a robot might perform actions in the wrong sequence because the compiler had shuffled the instructions. In such a situation, you may need to debug the actual optimized code.

You can debug optimized code for CISC processors at the assembly-language level. However, because of the architectural features of RISC processors (such as delayed branching and large register sets) and the level of optimization that RISC compilers perform, it's virtually impossible to debug assembly code for RISC processors. You simply can't correlate the assembly code with the source code. (For more information on RISC compilers, see **Ref 2**.)

Source tools should improve

It's a good bet that vendors of compilers and real-time operating systems will soon offer improved debugging tools. For now, however, if you must fix software glitches in real-time RISC applications, you may have to resort to the trial-and-error method.

Memory architecture holds the other key to exploiting the performance potential that RISC chips offer. The clock speeds of available RISC μPs currently range from 20 to 25 MHz, but in the next couple of years you can expect to see RISC μPs with clock rates approaching 50 MHz. To attain an AIT approaching 1, a RISC μP needs to fetch a new instruction, and perhaps even new data, every clock cycle. Architectural features such as delayed branch execution serve no purpose unless the memory can supply instructions and data to the processor without latency.



***A 1M-byte static-RAM array** provides the SPARC-based Mizar MZ7170 with the deterministic response capability required in strict real-time applications.*

A dynamic-RAM (DRAM) system can't accommodate a 20-MHz RISC μP with the required memory-access speed (at 1 instruction per clock cycle, that speed would be 50 nsec). Even schemes—such as interleaved memory—that satisfy pipelined CISC architectures fall short of the every-cycle-access needs of RISC processors. Fast CISC μPs also need faster access than DRAMs can provide, but memory latency has more of an impact on RISC performance than on CISC performance.

Cache latency varies

In general-purpose computer systems, designers implement static-RAM (SRAM) caches to provide the processors with fast memory access much of the time; the percentage of time is called the "hit rate." However, when cache misses (instances when the required instruction or data is not present in the cache) occur, the processor suffers a latency period while a new line of data is added to the cache. The latency varies according to the μP and cache architecture, but it typically ranges from 5 to 20 clock cycles.

Real-time systems require what's termed a "deterministic" response to asynchronous real-world events. Typically, a system responds to an event by generating an interrupt to a μP. The processor then invokes a routine to service the interrupt. Part of the system designer's task is to ensure that the processor can respond to and service such an interrupt in a certain maximum amount of time: the worst-case response time. Historically, designers of real-time systems have avoided cache-based architectures because of the latency caused by cache misses. The latency would raise the worst-case response time significantly.

Before choosing a RISC architecture for a real-time application, you must consider the RISC board's memory-system design. The available RISC processors each include

ALUMINUM CITY.

4SE-8101

SPRAGUE...A FULL LINE OF ALUMINUM CAPS FROM A U.S. SOURCE.

You can get any type of aluminum electrolytic capacitor that you need for *all* your applications from Sprague, the only U.S. based manufacturer of a complete line of high-performance aluminums. Whether it's axial-lead or single-ended miniature tubulars or large cans packed with capacitance, Sprague has the aluminum cap that'll meet your requirements. If you need radial or axial-lead miniatures for general purpose, power supply, special applications, or high-reliability military applications, we've got the capacitor you need. We offer all types of large cans for high-voltage SMPS input applications and low-voltage SMPS output use. And the best news of all...we can deliver fast because our aluminum cap line is available from Sprague plants in Lansing, NC and Hillsville, VA. For technical information, write for our new "Quick Guide To Aluminum Electrolytic Capacitors", ASP-502E, to Technical Literature Service, Sprague Electric Company, P.O. Box 9102, Mansfield, MA 02048-9102.

SPRAGUE®

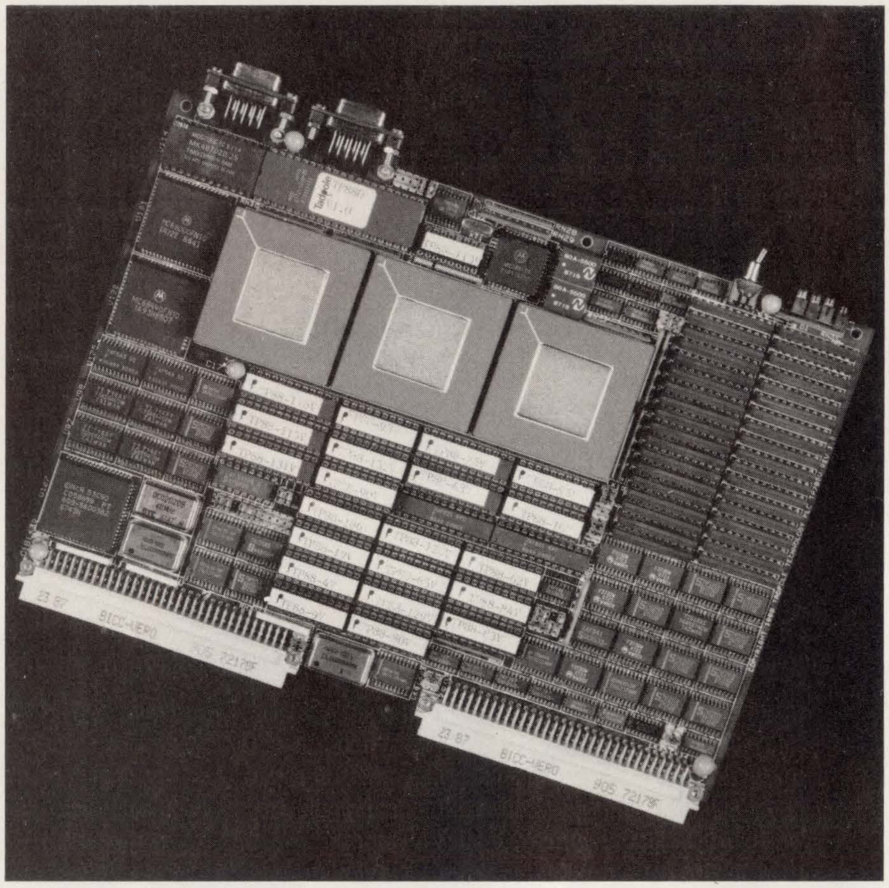
CIRCLE NO 102

architectural features that may fit one memory scheme better than another. Each of the available boards uses a specific memory implementation, so when you buy a board, you're choosing a memory system. The board's memory architecture will play a large part in determining your system's worst-case response time.

Static RAM minimizes latency

For example, Mizar chose to employ static RAM for the entire RAM array on its SPARC-based MZ7170 board set. The 2-board VME Bus product includes 1M byte of static RAM and 4M bytes of EPROM. A 20-MHz version of the board costs $6995, and a 25-MHz version adds $500. You can also add a 20-MHz Texas Instruments 8847 FPU (floating-point unit) for $995.

Mizar currently offers the Wind River Systems (Emeryville, CA) VxWorks real-time operating system and software-development tools for the MZ7170, and plans to have other real-time packages available late this summer. The MZ7170 has no memory-management unit (MMU). Jerry Fiddler, president of Wind River Systems, believes that real-time systems can't afford the latency that a MMU can add during address translation. In fact, when porting its operating system to a board that includes an MMU, Wind River bypasses the MMU.



The VME Bus-based RISC board *from Tadpole Technology, Model TP880V, includes an 88100 processor and two 88200 CMMUs. The company makes a similar product, the TP880M, that's based on the Multibus II.*

Software bypasses MMU

Harvey Goldman, vice president of marketing at Integrated Solutions, agrees with the no-MMU, no-cache philosophy for real-time applications. According to Goldman, the company has ported its UniWorks real-time operating system to boards that have caches or MMUs, but has bypassed the cache or MMU features.

Integrated Solutions currently offers the Advantedge 2000 Series. These products include a single-board computer based on a 16.67-MHz MIPS Computer Systems R2000 chip set. The board, which costs $10,000, does not support a bus such as the VME Bus. It's truly suited for applications such as workstations. The company does plan to make the UniWorks real-time operating system available for the board during the first half of the year, however. You can also expect the firm to introduce a follow-up VME Bus-based product that's more suitable for real-time applications.

In general, real-time systems employ multitasking operating systems and application software. A CPU board that doesn't contain an MMU requires you to develop each task of a set of software tasks for a single physical-address space. Therefore, the programmer must prevent different tasks from manipulating the same memory locations improperly. An MMU simplifies the programming tasks, but it may add latency in the form of address-translation time.

Burst mode speeds memory read

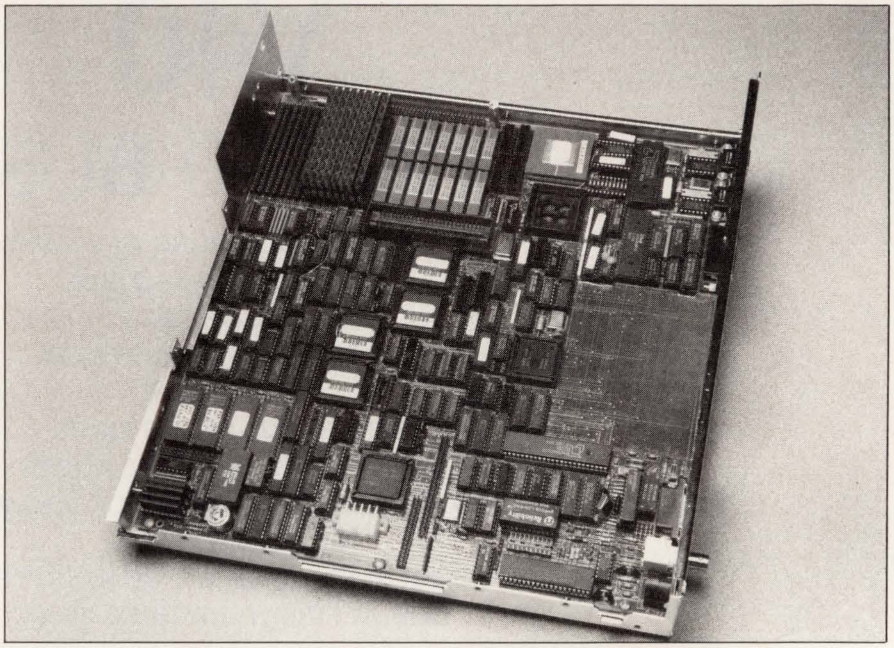
The Ironics IV-9001 board employs the AMD 29000 RISC processor, and the 29000 includes an on-chip MMU. The MMU performs translations in the instruction pipeline and eliminates latency concerns. Ironics also implemented a hybrid-cache-based memory architecture on the board. The 29000 μP employs a Harvard architecture

RISC boards for real time

with separate operand and instruction buses. The chip also includes circuitry to improve the performance of DRAM arrays. The μP can fetch operands and instructions in burst mode without issuing an address for each word fetched.

On the IV-9001, Ironics employs the burst-mode fetch feature and an interleaved array of static-column DRAMs to feed both the instruction and the operand buses of the 29000, each at speeds as high as 100M bytes/sec. In fact, the DRAM array can supply instructions to the CPU at a rate of one instruction per cycle; memory latencies are caused only by memory-refresh operations and dual-port conflicts with operand accesses.

The board also includes a 16k-byte direct-mapped operand cache that minimizes accesses to the dynamic RAM for fetching operands. A cache miss to the operand cache causes a worst-case latency of seven cycles. Ed Schulman, Ironics' vice president of marketing, points out that because of the fast clock speed of the 29000 μP, the actual worst-case latency caused by the cache is acceptable for most applications.



Based on the 16.67-MHz R2000 chip set *from MIPS Computer Systems, the Integrated Solutions Advantedge 2000 single-board computer serves real-time and Unix applications.*

Daughter card hosts RAM

Ironics implemented the DRAM array on a daughter card for the VME Bus processor board; the company offers RAM cards with 2M to 16M bytes of memory. The IV-9001 costs $7995, and a 2M-byte RAM card adds $1995. Ironics may also offer an SRAM daughter card in the future. The company offers the VRTX32 real-time kernel from Ready Systems (Palo Alto, CA) and the pSOS real-time kernel from Software Components Group (San Jose, CA) for the RISC board.

If you consider using a board based on the Motorola 88000 RISC processor, you may have to deal with an even more complex memory architecture. This RISC chip set includes the 88100 CPU IC and the 88200 CMMU (cache and MMU) IC. The 88100 employs a Harvard architecture, and it's typically accompanied by one to four 88200 CMMUs for both instruction and operand buses. According to Motorola, the 88100 can be used without any 88200 CMMUs, but no vendors currently offer such a board-level product.

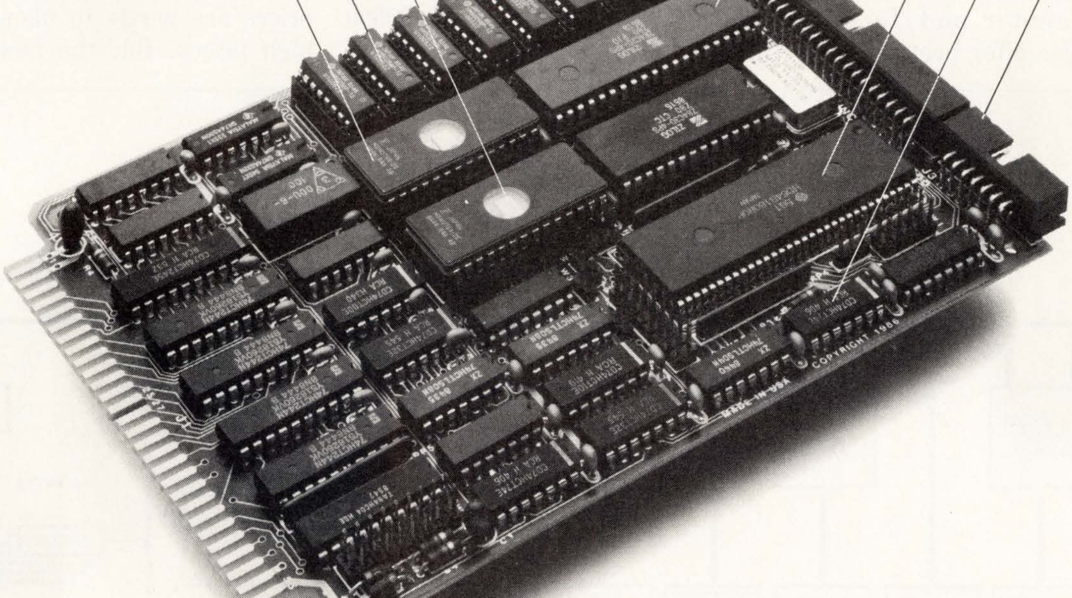
Cache IC emulates static RAM

Motorola did, however, make some provisions in the CMMU IC for real-time applications. The 88200 includes a 4-way, set-associative, 16k-byte physical-address cache. You can program any or all of the four 4k-byte segments in an 88200 to act as fast static RAM rather than as cache memory. Therefore, you can permanently load speed-critical sections of code into the memory segments that are set up as static RAM. The MMU portion of the IC performs address translations and adds no latency during accesses to the on-chip memory locations.

An 88100 CPU chip supports as many as eight 88200 CMMU ICs (four for instructions and four for operands). Therefore, the architecture potentially supports a total of 128k bytes of fast memory for cache and SRAM use. Cache-read misses add a latency of seven cycles, and misses on writes add a 4-cycle latency. Misses, however, cause the transfer of four consecutive words of data (16 bytes), not just the single word that caused the cache miss.

Motorola currently offers two 88000-based VME Bus products. The MVME181 includes an 88100 CPU and two 88200 CMMUs. A 20M-Hz version of the board costs $8995, and a 25-MHz version costs $9995. The board includes 8M bytes of DRAM to feed the CMMUs.

Motorola also offers the MVME188 3-board set, which comes in three versions. You can specify the board set with one, two, or four 88100 processors, and each of the versions includes eight 88200 CMMUs. The versions cost $22,950, $27,200, and $33,500 (100), respec-



tively. One board of the set hosts the 88000-family chips, a second board serves as a system controller, and the third board carries 16M bytes of DRAM. A proprietary memory bus connects the boards.

ICs support multiprocessing

The 88000 architecture inherently supports multiprocessing. In fact, the CMMU IC includes a bus-watching feature, and the ICs maintain cache integrity in a multiprocessor configuration. Motorola offers its VMEexec real-time operating system with the boards. The operating system supports multiprocessing. Software Components Group also plans to offer pSOS for the 88000; the product will probably be available early in the second quarter of this year.

Force Computer and Tadpole Technology also offer boards based on the 88000 family. Tadpole's VME Bus-based TP880V costs $10,995, and its Multibus-II-based TP880M costs $11,495. The Tadpole boards feature similar architectures, and they each include an 88100 processor and two 88200 CMMUs. The boards come with 4M bytes of DRAM and a 64k-byte SRAM array that the 88100 can access without latency. In addition, pSOS will be available for both boards in the second quarter.

The Force offering, the CPU-81, also includes a single 88100 and two 88200 CMMUs **(Fig 1)**. The board costs $8900, has 4M bytes of DRAM, and includes sockets for as much as 4M bytes of ROM. Furthermore, Force offers a second board, the CPU-82, that mates to the CPU-81 via a 100M-byte/sec bus **(Fig 2)**. The CPU-82 costs $9900 and carries an 88100, three 88200s, and 12M bytes of dynamic RAM.

Force labels the board set a "dyadic processor" and claims that the architecture eliminates all latency in computation-intensive applications. One of the three 88200 CMMUs on the CPU-82 is dedicated as an SRAM to store speed-critical sections of code. The CPU-81 and CPU-82 will be available around the middle of the year. The company plans to offer pSOS, VRTX32, and OS-9 from Microware (Des Moines, IA) as real-time operating-system options.

RISC prices are sky high

At present, cost may prove to be the ultimate key to how well a RISC board fits your application. To put it simply, the available RISC boards are very expensive. Memory prices are partly to blame for the high prices. But the newness and

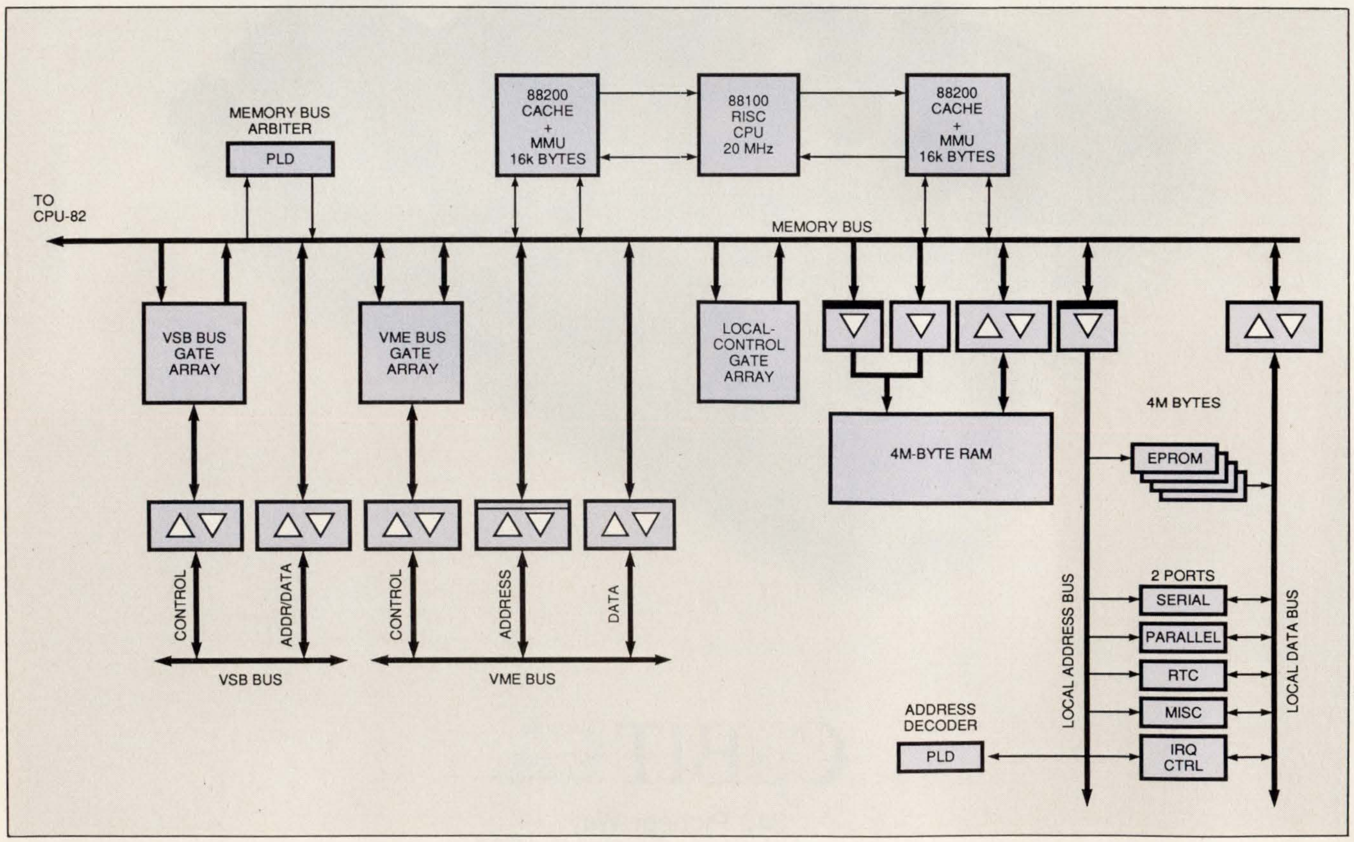


Fig 1—A 4M-byte dynamic-RAM array *and the 88000 chip set make up the CPU-81 board from Force Computers. The board also includes a 100M-byte/sec bus that can connect to a second processor and memory board (the CPU-82).*

RISC boards for real time

sparse availability of the chips has also driven RISC-board prices up.

In fact, the price/performance ratio has kept some CPU-board vendors out of the RISC market. Heurikon Corp, for example, plans to stick with CISC-based products for the time being. Clarence Peckham, the firm's director of engineering, points out that Heurikon's HK32/V532 board, which is based on a 20-MHz National Semiconductor 32532 μP, offers performance comparable to that of RISC-based boards. Furthermore, with 4M bytes of dynamic RAM, the HK32/V532 costs about $5000.

You can expect RISC chip prices to drop sharply in the next year, however. In particular, the price of SPARC processors should drop, because manufacturers are already producing the chips in volume for Sun workstations. Customers for SPARC chips are also likely to benefit because of the large number of semiconductor companies that manufacture or plan to manufacture the chips. Bipolar Integrated Technology, Cypress Semiconductor, Fujitsu Microelectronics, LSI Logic, and Texas Instruments have all licensed the SPARC technology.

The MIPS Computer Systems R2000 and R3000 chip sets will also be available from several vendors. Integrated Device Technology, LSI Logic, and Performance Semiconductor currently offer these chips. NEC Corp (Japan) and Siemens (West Germany) have recently licensed MIPS Computer Systems' RISC technology and plan to offer compatible processors in the future.

Thus far, Motorola plans to remain the only source of the 88000.

Consortium promotes standards

A number of companies have banded together to form the 88open Consortium (Wilsonville, OR), a nonprofit group that is leading the effort to set open hardware and software standards for 88000 products. For example, the Consortium's real-time and embedded-systems committee is working to define a common BIOS for real-time systems. For information, contact John Barr, the committee chairman, at Motorola Computer X (a wholly owned subsidiary of Motorola). His phone number is (312) 576-8706.

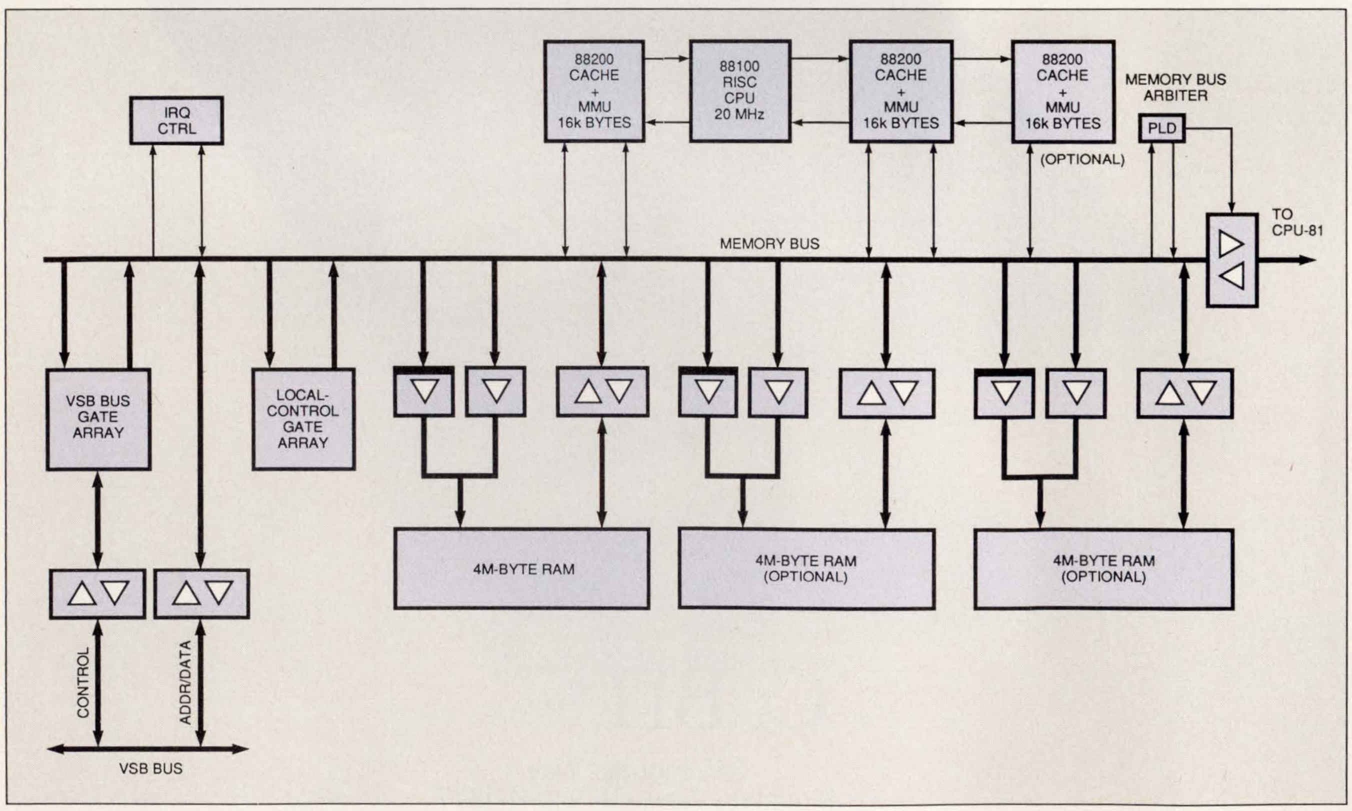


***Fig 2—The three 88200 CMMU ICs** and the 88100 processor on the CPU-82 board from Force Computer can ensure deterministic processor response when the board is paired (in a dyad) with the CPU-81 board. The CPU-82 board also includes 12M bytes of dynamic RAM.*

TEXAS INSTRUMENTS PAL® DEVICES CAN IMPROVE ONE MORE SYSTEM THAN YOU THINK. YOUR NERVOUS SYSTEM.

Sure, IMPACT™ technology from Texas Instruments can improve all your Programmed Array Logic systems. From Zero standby power CMOS to high-speed bipolar PALS, including 6ns ECL devices, Texas Instruments' PAL family can meet your system performance needs.

Now, thanks to Marshall Industries, buying Texas Instruments PAL devices will improve your nervous system, as well. Because Marshall will program your orders at one of their industry-leading programming centers. In fact, Marshall co-designed the very first IMPACT center with Texas Instruments. So your orders are programmed, tested and marked quickly and accurately.

So accurately you don't have to worry about testing incoming devices.

Then they're shipped to you on time. No matter how tight your delivery schedule. Which should all take a big load off your mind. And your nerves.

Call Marshall today for PAL devices from Texas Instruments.

It'll keep all your systems in top shape.

THIRTIETH ANNIVERSARY 1958 1988 INVENTION OF INTEGRATED CIRCUIT BY TEXAS INSTRUMENTS

®PAL is a registered trademark of Monolithic Memories, Inc.
™IMPACT is a trademark of Texas Instruments

TEXAS INSTUMENTS AUTHORIZED DISTRIBUTOR

Marshall

(*Authorized Locations)

AL Huntsville (205) 881-9235*
AZ Phoenix (602) 496-0290*
Tucson (602) 790-5687*
CA Irvine (714) 859-5050*
Los Angeles (818) 407-4100*
Sacramento (916) 635-9700*
San Diego (619) 578-9600*
San Francisco (408) 942-4600*
CO Denver (303) 451-8383*
CT Connecticut (203) 265-3822*
FL Ft. Lauderdale (305) 977-4880*
Orlando (407) 767-8585*
Tampa (813) 573-1399*
GA Atlanta (404) 923-5750*
IL Chicago (312) 490-0155*
IN Indianapolis (317) 297-0483*
KS Kansas City (913) 492-3121*
Wichita (316) 264-6333*
MA Boston (508) 658-0810*
MD Maryland (301) 840-9450*
MI Michigan (313) 525-5850*
MN Minneapolis (612) 559-2211*
MO St. Louis (314) 291-4650*
NC Raleigh (919) 878-9882*
NJ N. New Jersey (201) 882-0320*
Philadelphia (609) 234-9100*
NY Binghamton (607) 798-1611*
Long Island (516) 273-2424*
Rochester (716) 235-7620*
OH Cleveland (216) 248-1788*
Dayton (513) 898-4480*
Westerville (614) 891-7580*
OR Portland (503) 644-5050*
PA Pittsburgh (412) 963-0441*
TX Austin (512) 837-1991*
Brownsville (512) 542-4589*
Dallas (214) 233-5200*
El Paso (915) 593-0706*
Houston (713) 895-9200*
San Antonio (512) 734-5100*
UT Salt Lake City (801) 485-1551*
WA Seattle (206) 486-5747*
WI Wisconsin (414) 797-8400*

The company has taken great pains, however, to encourage all sections of the computer industry to use the 88000 family (see **box,** "Consortium promotes standards").

Your determination of whether to use RISC boards in your system application, as well as your choice of a particular RISC board, might well hinge on unquantifiable factors. Sure, you'll study the hardware and software available for RISC processors in making your decision, but you'll also be influenced by such factors as the industry momentum gathering behind a certain chip.

Ultimately, however, your decision between RISC and CISC boards will be reduced to two technical issues: You must decide whether you can tolerate programming in high-level languages and whether you can work with the complex memory architecture that RISC boards must have in order to be efficient. If you can, RISC boards are for you, if you can't, you should stick with CISC boards.

EDN

References

1. Leibson, Steven H, "RISC design woos 32-bit-μP architects," *EDN*, November 24, 1988, pg 122.

2. Small, Charles H, "RISCs force move to compilers," *EDN*, January 5, 1989, pg 73.

Article Interest Quotient
(Circle One)
High 512 Medium 513 Low 514

For more information . . .

For more information on the RISC boards discussed in this article, contact the following manufacturers directly, circle the appropriate numbers on the Information Retrieval Service card, or use EDN's Express Request service.

Force Computers Inc
3165 Winchester Blvd
Campbell, CA 95008
(408) 370-6300
FAX 408-374-1146
Circle No 720

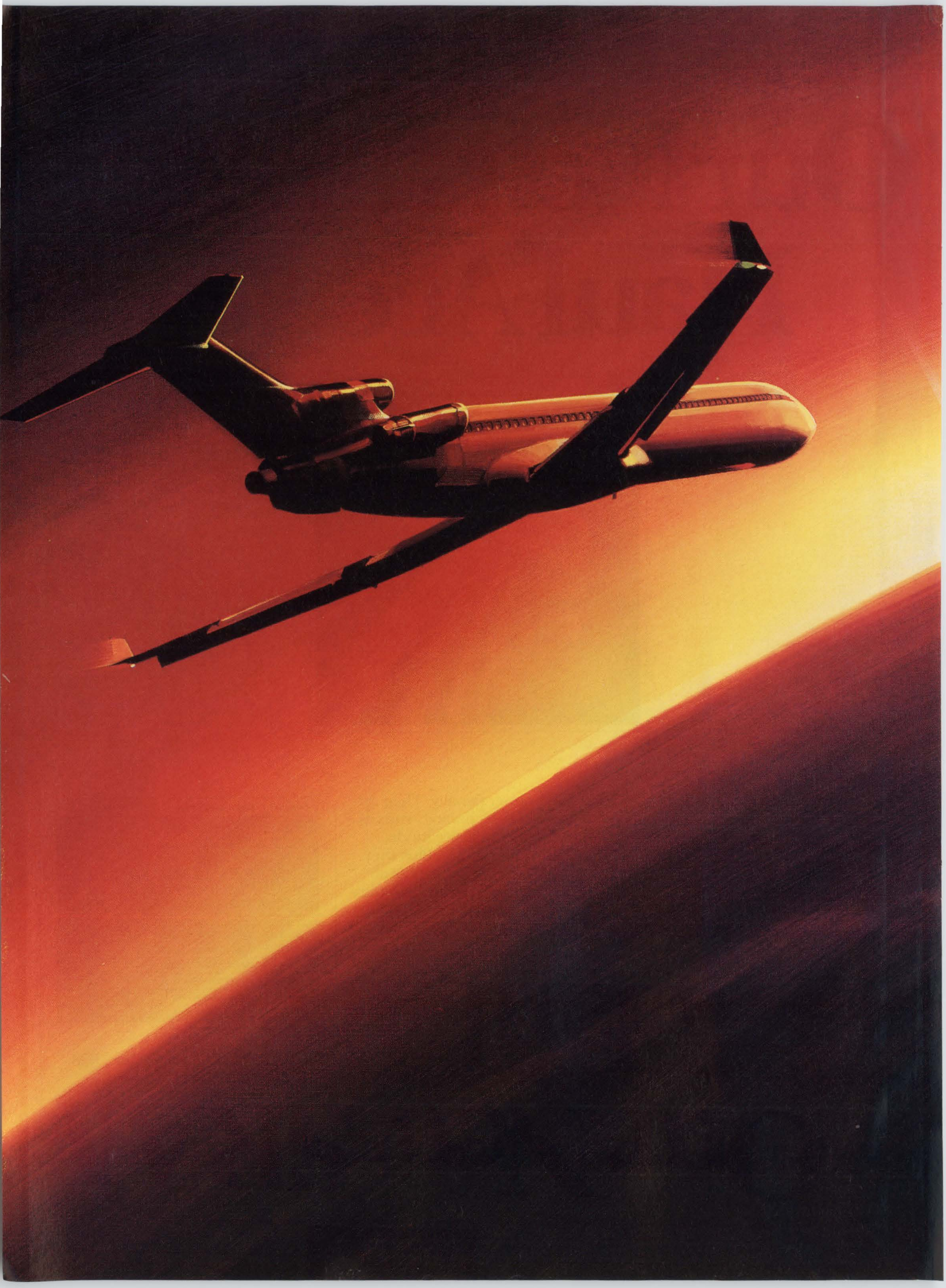
Integrated Solutions Inc
1140 Ringwood Ct
San Jose, CA 95131
(408) 943-1902
FAX 408-943-0626
Circle No 721

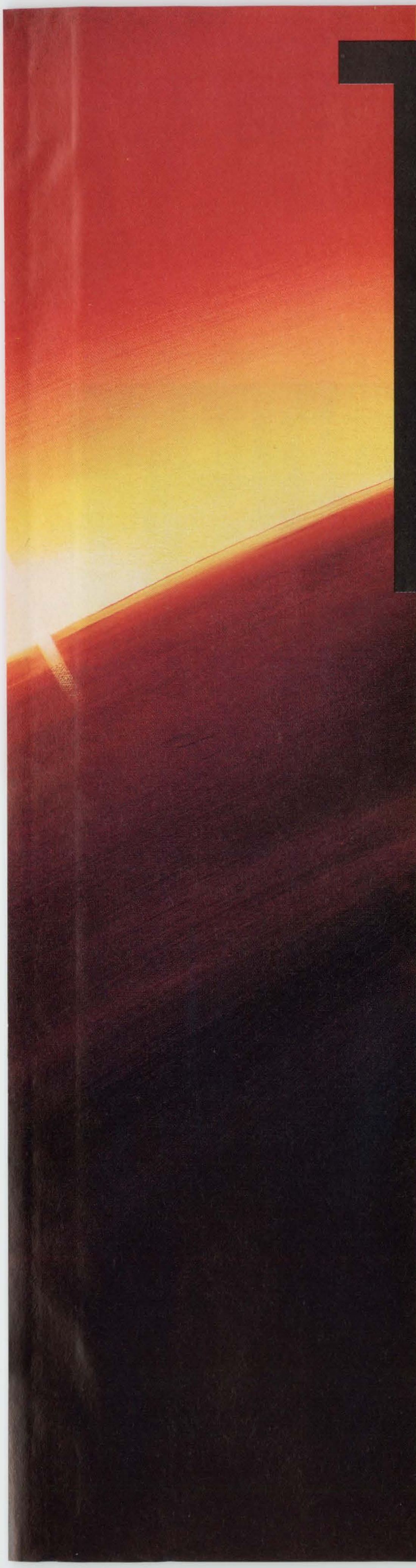
Ironics Inc
798 Cascadilla St
Ithaca, NY 14850
(607) 277-4060
FAX 607-272-5787
TLX 705742
Circle No 722

Mizar Inc
1419 Dunn Dr
Carrollton, TX 75006
(214) 446-2664
FAX 214-242-5997
Circle No 723

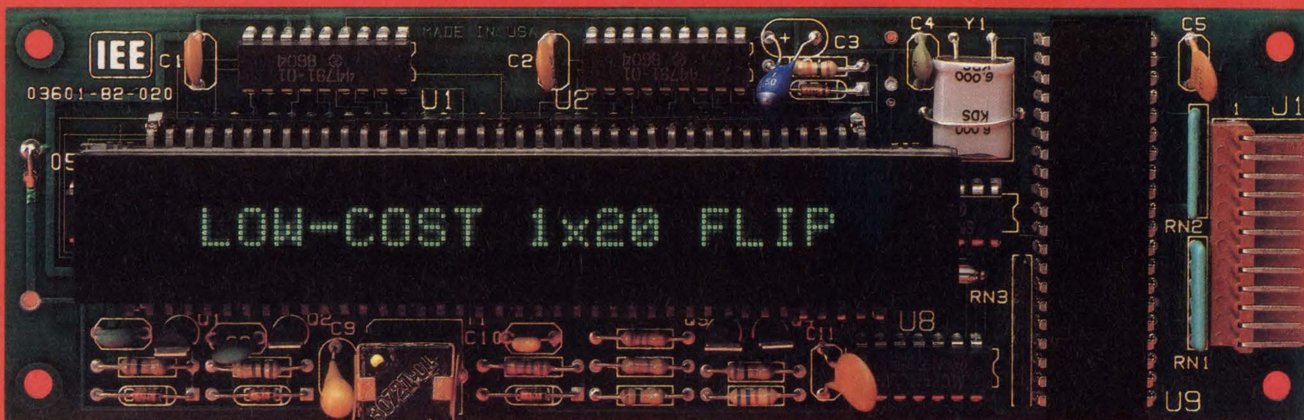
Motorola Microcomputer Div
Marcom Dept DW283
2900 S Diablo Way
Tempe, AZ 85282
(800) 556-1234
In CA, (800) 441-2345
Circle No 724

Tadpole Technology Inc
1601 Trapelo Rd
Waltham, MA 02154
(617) 890-8898
FAX 617-890-7573
Circle No 725





THE $64 ANSWER



3601-82-020
ACTUAL SIZE

Now you can have a good-looking VF display at an **affordable price** with **IEE**'s new line of **"NO-FRILLS" FLIP**™ vacuum fluorescent display modules.

These compact, economical displays share many of the most convenient features of the standard IEE FLIP display line, but at a much lower cost. The 1 × 20 model shown above is priced at only **$64 each in quantities of 100.** Production-quantity pricing is even lower.

"NO-FRILLS" FLIPs are ideal for high-volume OEM applications such as copiers, point-of-sale terminals, pay telephones, and security systems.

And, just look at all of the features:

- Bright, easy-to-read 5 × 7 dot matrix characters
- On-board microprocessor that accepts parallel ASCII data
- Operation from a single +5VDC power supply
- Optional low-cost serial data converter module available

Choose from the following formats:

1 × 16	1 × 20	1 × 24	1 × 40
2 × 16	2 × 20	1 × 32	2 × 40

So, if you want a low-cost, high-quality, front-panel performer, just call IEE and ask the $64 question.

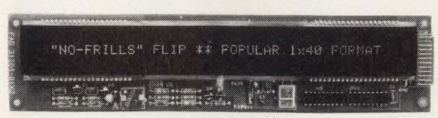
3601-95-040

3600-83-032

3601-88-016

3600-89-024

3601-87-032



3601-84-040

Circle 5 for Immediate Application

See us at ELECTRO booth #s 2160/2162

Circle 6 for Reference Material

IEE®

THE DISPLAY MAKERS

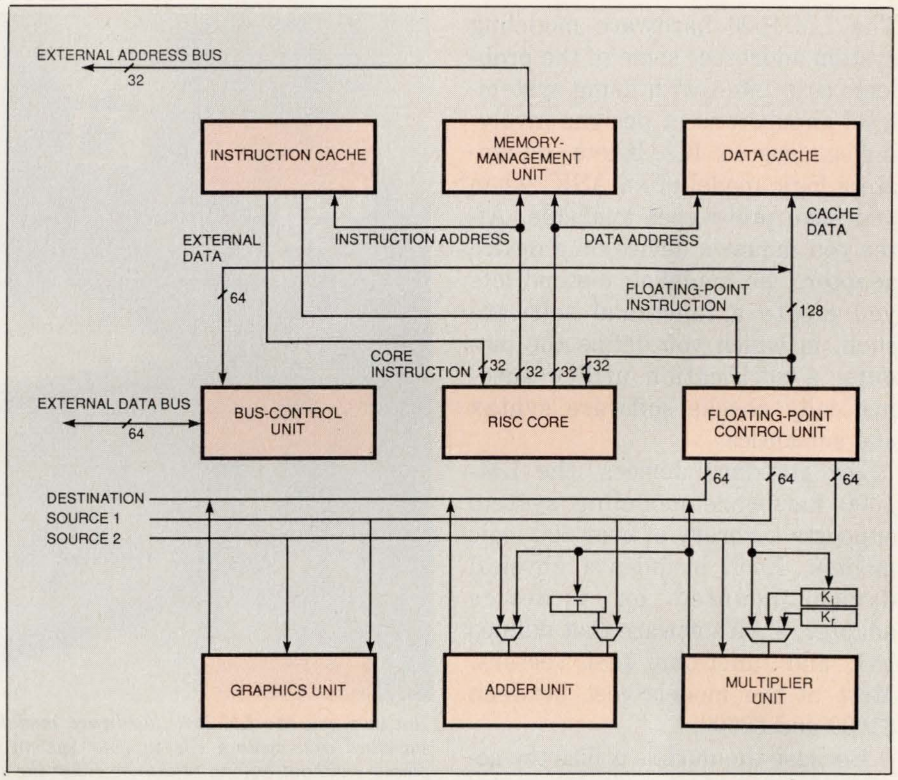
INDUSTRIAL ELECTRONIC ENGINEERS, INC.
Industrial Products Division
7740 Lemona Ave., Van Nuys, CA 91409-9234
Tel.: (818) 787-0311, Ext. 418 • Telex: 4720693 IEE IPD
FAX (818) 901-9046 (G2/G3)

μP packs workstation power and graphics ability in 1M-transistor chip

The 80860 microprocessor, with more than 1,000,000 transistors, integrates a RISC core, a floating-point unit (FPU), a hardware shading unit, and an instruction and data cache. At 40 MHz, the chip achieves 80M flops and can sustain 500,000 4×4 matrix transformations/sec. In addition, the shading hardware can Gouraud-shade 50,000 100-pixel triangles/sec.

The chip comprises six basic units: the integer RISC core, the FPU, the graphics memory-management unit, the data and instruction caches, and the bus-control unit. The RISC core has a 32×32-bit integer register file. It decodes and executes load, store, integer, bit, and control-transfer instructions. It fetches floating-point as well as integer instructions and can operate in parallel with the FPU.

The FPU has a separate register file that you can configure as 8×128, 16×64, or 32×32 bits. Its separate adder and multiplier units both conform to IEEE STD 754. Both the adder and multiplier units can provide one result for every clock cycle. When pipelined, they operate at 2 results/clock cycle, yielding the 80M flops rate. The graphics unit, which provides Gouraud shading and z-buffering as well as clipping capability, is discussed in more detail in the Special Report on pg 96.



Combining a floating-point control unit and wide on-chip data and instruction caches, *the 80860 can sustain an 80M-flops rate. The destination and source buses carry the operands used in pipelining the results of the FPU. K_i and K_r are constants; T is a temporary register.*

The memory-management unit can translate addresses from linear logical space to linear physical space for both instructions and data, although this translation is optional. The processor stores translated address information in a table and caches the table in a 64-entry, 4-way associative memory. The page tables are compatible with those of the 80386. These tables enable you to design a paged, virtual memory with user/supervisor protection, which is important in multitasking systems.

One-third of the chip's area is dedicated to data and instruction caches. The caches' aggregate bandwidth is 1G byte/sec, a speed not possible with off-chip caching. The instruction cache is a 2-way set-associative memory of 4k bytes, divided into 32-bit blocks. The 8k-byte data cache, which is a write-back cache, is also 2-way set-associative and divided into 32-bit blocks.

The bus-control unit works with conventional static-column dynamic RAM. A pin indicates whether the next address takes place using the same page. The unit supports both pipelined and nonpipelined operation. Pipelining allows a new 64-bit word to transfer every two cycles when the pipeline is full, even though the total number of cycles required for the transfer can number as many as six. Note that overall chip performance is often limited by the data-bus width. The 80860's 64-bit external and 128-bit internal buses lessen this possibility. $750.—***Margery Conner***

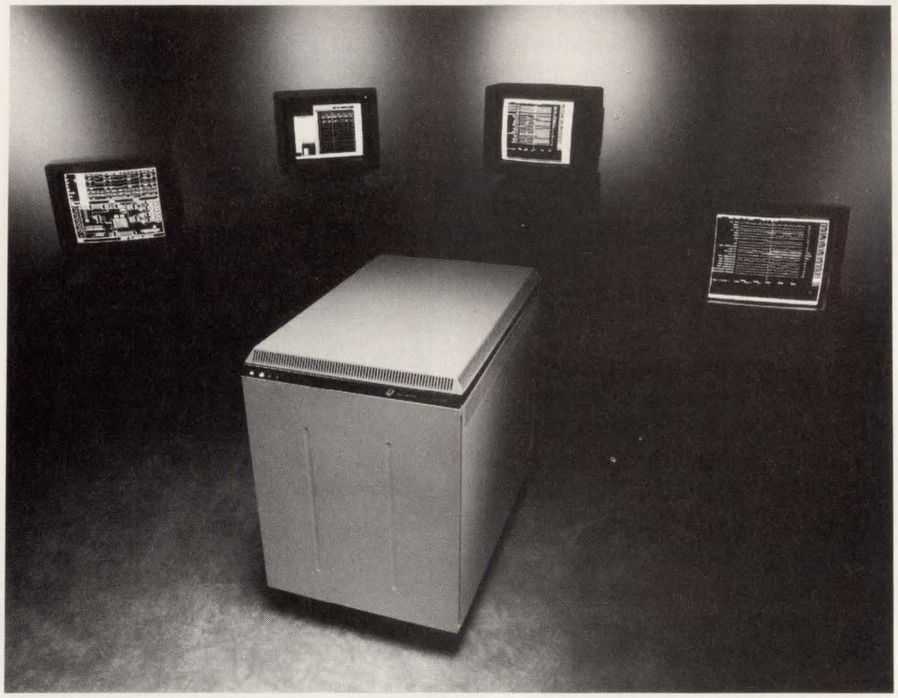
Intel Corp, 3065 Bowers Ave, Santa Clara, CA 95051. Phone (408) 987-8080.

Circle No 734

Hardware modeling system creates simulation models of your ASICs

The LM-1000 hardware modeling system addresses some of the problems associated with doing system-level simulations of designs involving semicustom ICs. It lets you create a logic model of an ASIC when you have prototypes available. After you mount a device on a device adapter, the modeling method lets you create a functional software shell, in which you define the pinouts; a verification utility automatically checks software syntax and semantics.

For standard devices, the LM-1000 hardware modeling system supports a library of over 600 logic models. Each includes a physical device mounted on a device adapter, shell software that defines I/O, and functional test vectors. Most of the models cost between $1000 and $2000.



You can use the LM-1000 hardware modeling system *to simulate the behavior of both standard and custom ICs in your system design—as long as silicon exists for all the pieces—without having to change either the simulator or the host you are already familiar with.*

Because the models utilize the actual physical device, they are by definition correct; as long as the shell software is correct, the model will perform as the actual device—because it is, essentially, the actual device. The shell also lets you control worst-case timing, including minimum, typical, and maximum delays. The pattern clock of the LM-1000 is continuously variable between 150 kHz to 25 MHz with a resolution of 1% and accuracy of ±0.5%. Timing resolution varies from 500 psec at 25 MHz to 50 nsec at 150 kHz; accuracy is ±3 nsec or ±1% of the pattern clock period, whichever is larger.

The LM-1000 currently supports, under OEM agreements, Verilog from Gateway, Hilo from GenRad, Validsim from Valid, the Vantage Spreadsheet from Vantage Analysis Systems, and Viewsim from Viewlogic, although the vendor claims the LM-1000 is simulator independent and can easily adapt the hardware modeling system for any simulator. Because only a simulator function interface and some user utilities reside on the host computer, you can drive the LM-1000 from a variety of computers, including the Sun-3 and Sun-4; Apollo Series 3000, 3500, 4000, and 4500; DEC VAXstation, MicroVAX and VAX; and IBM PC/386 and compatibles.

The base configuration for the hardware modeler allows for one 80-pin device. Through expansion, you can build the pin capacity to 2560 total pins organized as eight slots by four lanes. This organization gives you as many as 32 80-pin devices, 16 160-pin devices, 8 320-pin devices, or some combination thereof. The LM-1000 supports pattern memory from 128k patterns × 80 pins to 2M patterns × 320 pins—you can expand memory with 128k × 80- or 512k × 80-pin modules.

The LM-1000 starts at $50,000 for the minimum unit and is available through Gateway Design Automation, GenRad, Valid Logic Systems, Vantage Analysis, or Viewlogic.

—Michael C Markowitz

Logic Modeling Systems Inc, 1520 McCandless Dr, Milpitas, CA 95035. Phone (408) 954-5200.

Circle No 731

Not Bad For A Five Year Old.

We're showing you our rapid rise into high-speed, high-density SRAMS to dramatize one singular point: *Sony's serious commitment to your SRAM needs.*

Major SRAM investment. Answering your demands for higher speeds, we've beefed-up our SRAM engineering, design and production capabilities. Dramatically.

Already, we're producing 16K x 4-bit models at 25, 30 and 35 ns. 32K x 8-bit models at 25, 30 and 35 ns. 64K x 4-bit models at 35, 45 and 55 ns. And 256K x 1-bit models at 35, 45 and 55 ns.

In a range of DIP, SOP and SOJ packages.

0.8-micron CMOS technology: The best is yet to come. Soon we'll debut all new SRAMs based on our 0.8-micron CMOS technology. With even higher speeds and densities. *In combinations never before available.*

Sony SRAMs are shipping now. And they're available at very competitive prices. Backed by the reliability and responsive service you expect from any Sony product.

Be a part of our success story. When you're considering high-speed, high-density SRAMs, first consider this: Sony's SRAM success story has only just begun.

For full details, call (714) 229-4197 today. Or write Sony Corporation of America, Component Products Division, 10833 Valley View St., Cypress, California 90630, Attn: Semiconductor sales. FAX (714) 229-4271.

SONY®

Sony is a registered trademark of Sony Corporation.

SONY HIGH-SPEED, HIGH-DENSITY SRAMS.

MODEL	CONFIGURATION	SPEED (ns)	PACKAGE
CXX5863P	8K x 8	25/30/35	DIP 300 mil
CXX5863M	8K x 8	25/30/35	SOP 450 mil
CXX5863J	8K x 8	25/30/35	SOJ 300 mil
CXX5464AP	16K x 4	25/30/35	DIP 300 mil
CXX5464AJ	16K x 4	25/30/35	SOJ 300 mil
CXX5465P*	16K x 4	25/30/35	DIP 300 mil
CXX5465J*	16K x 4	25/30/35	SOJ 300 mil
CXX5164P	64K x 1	25/30/35	DIP 300 mil
CXX5164J	64K x 1	25/30/35	SOJ 300 mil
CXX5971P	8K x 9	25/30/35	DIP 300 mil
CXX5971J	8K x 9	25/30/35	SOJ 300 mil
CXX58255AP	32K x 8	25/30	DIP 300 mil
CXX58255AJ	32K x 8	25/30	SOJ 300 mil
CXX58258P	32K x 8	35/45	DIP 600 mil
CXX58258SP	32K x 8	35/45	DIP 300 mil
CXX54256P	64K x 4	35/45/55	DIP 300 mil
CXX51256P	256K x 1	35/45/55	DIP 300 mil

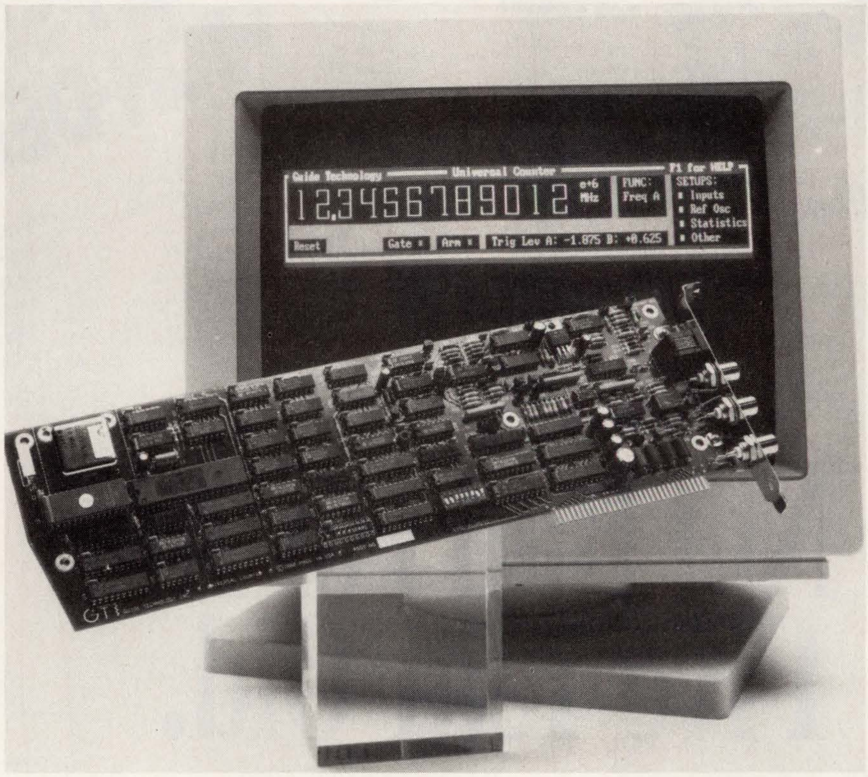
*O/E

CIRCLE NO 112

PC-based precision counter offers high performance and low cost

At $1495, the GT200 is possibly the lowest-priced precision universal counter available. Its performance, however, is far from the lowest for IBM PC/XT-, PC/AT-based, or stand-alone counter/timers. This counter can measure frequencies with 10-digit resolution/sec of gate time, and you can make timing measurements to 100-psec resolution without averaging. If this is more resolution than you need, you can trade it for speed measuring 7 digits of frequency resolution in 1 msec. For example, you can resolve a 10-kHz signal to .001 Hz in 1 msec.

The instrument performs frequency, period, time-interval, delay-time-interval, ratio, totalize, gated-totalize, and pulse-width measurements; it can sustain operation at 2000 measurements/sec. This speed not only gives you the potential for higher system throughput, but also allows you to characterize dynamic signals.



The IBM PC-based GT200 universal counter *can simulate benchtop operation with its 12-digit display. You can also use the GT200 under program control for fully automated testing.*

For example, using this throughput you can quickly compute the drift rate and peak-to-peak jitter of a signal. Indeed, you can make multiple measurements and look at measurement statistics in the same amount of time you might need for single measurements on slower units. Because the counter's statistics software displays a running mean and standard deviation, and minimum and maximum count, you can see the sample results as they occur. This means that you don't need to wait for the instrument to finish taking all samples to see results.

The counter's two dc-coupled input channels are specified for input frequencies of dc to 75 MHz and accept signals from −5 to +5V. To be sure you trigger on the correct signal, you can use auxiliary inputs to arm the trigger. The auxiliary inputs also let you perform gated counting.

Input impedance and trigger threshold levels are programmable. You can select an input impedance of 50Ω or 1 kΩ in parallel with 30 pF. The trigger threshold is programmable from −4.375 to 5V in 0.625V steps. You can also use an automatic trigger mode to automatically set optimum input threshold levels.

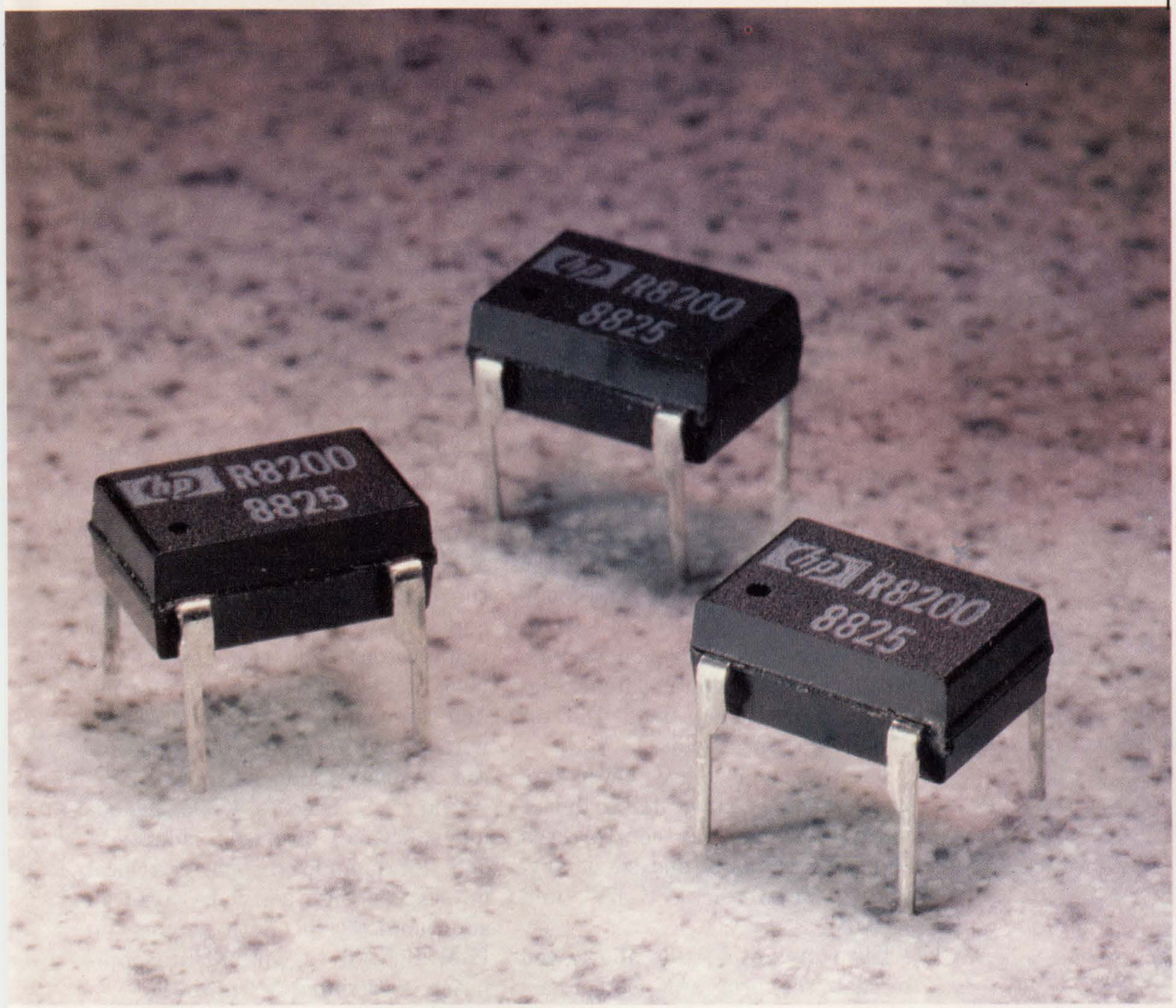
If you need better stability than the standard 5-ppm crystal oscillator provides within the range of 0 to 40°C, you can select either the temperature-compensated or the ovenized crystal oscillator. You can also use an external 10-MHz reference.

The instrument's software supports two user interfaces. A virtual front panel simulates benchtop operation with mouse control of pull-down menus, including built-in statistics. You can also operate the counter under program control with simple English-like commands compatible with any programming language.—***Doug Conner***

Guide Technology Inc, 1940 Fallenleaf Lane, Los Altos, CA 94022. Phone (415) 961-9259.

Circle No 732

Get accurate and reliable small signal switching from HP's first solid state relay.



Introducing the first of a series of solid state relays for small signal switching.

HP's HSSR-8200 delivers the reliability and long operating life you need for process control and test and measurement instrumentation applications.

It eliminates the mechanical or electrical limits associated with electromechanical relays. And its low offset voltage of less than 0.5 μV and low leakage current of 0.02 nA insure greater measurement accuracy.

You also get lower power dissipation and its associated costs, thanks to a control current as low as 1 mA. Which makes our new relay CMOS-compatible.

The HSSR-8200 also provides high-speed switching, typically 50μs, a high transient immunity of greater than 2000 V/μs and standard DIP packaging.

Best of all, you're always assured of worldwide field service and application support.

If you'd like to know more about our innovative solution in small signal switching, circle the reader service number.

CG08804

HEWLETT PACKARD

CIRCLE NO 113

Logic verifier handles ASICs and PLDs

The Personal Logic Design Verification System (PLDVS) allows you to perform functional tests and develop test programs for your ASIC- and PLD-based designs. The system comprises hardware and software that combine with your IBM PC/AT or compatible computer to form a test workstation.

***This logic design verification system** handles both ASICs and PLDs, allowing you to develop test programs and perform functional tests on your design.*

The hardware portion of PLDVS includes plug-in cards for the computer and a generic socket adapter to receive the device under test. The adapter accepts devices with as many as 128 signal pins and is configurable to any device pinout and package style. You can program the system to simultaneously stimulate and read the signal pins, check for pin continuity, and monitor signal-drive current—all at rates as great as 200,000 vectors/sec. The system double-latches signal readings using fixed TTL or CMOS logic thresholds.

The system has five power supplies available to operate the device under test. You can control each supply individually and set it anywhere between −12.5V and +12.5V.

The software portion allows you to create test programs using a Pascal-like language. You can enter test vectors in tabular form or generate them with algorithms. By using algorithms, you can quickly generate large numbers of test vectors, allowing you to exercise your design thoroughly. A 25-line program, for example, generates 65,000 test vectors for a counter design.

The system software also includes a variety of utilities that allow you to design custom test-result displays. One utility, for example, automatically places pin readings at a specified location on the computer's screen whenever the readings change.

When used with the company's Max+Plus logic design software, the design verification system accepts waveform descriptions for test vectors. The test results can also be displayed as waveforms. You can compare simulation results with actual device performance for the company's Max EPLDs.

The PLDVS costs $6595, including software, interface, adapters, and documentation. The graphical interface design software costs an additional $3400. Both require an IBM PC/AT or compatible computer. ***—Richard A Quinnell***

Altera Corp, 3525 Monroe St, Santa Clara, CA 95051. Phone (408) 984-2800.

Circle No 730

Hitachi's HMCS400 Series of CMOS Microcontrollers

The intelligent answer for small system control problems

The raccoon has a remarkable ability to thrive in any type of environment. His sheer intelligence and ingenuity let him adapt to whatever circumstances he may find, and prosper with only minimal resources at hand.

Resourcefulness also characterizes Hitachi's HMCS400 series of CMOS microcontrollers. These sophisticated devices are optimized for real-time control tasks and include a great number of peripheral functions on-chip.

*This **new generation** of 4-bit micros is a far cry from the old 4- or 8-bit designs you're used to.* They execute efficient 10-bit instructions in as little as 0.89μs, and include powerful on-chip peripherals such as large EPROMs, LCD and vacuum fluorescent drives, and multiple serial interfaces.

For example, our new HD4074408 has an 8K one-time-programmable EPROM, a 512 x 4 bit RAM, 58 I/O lines, comparator inputs, PWM timer outputs and serial interfaces—all in a plastic package. Future devices will include A/D converters, phase locked-loop circuitry, DTMF generators, and much more.

Most importantly, Hitachi's ZTAT™ technology gives you Zero Turn-Around Time. The on-board one-time user-programmable EPROM eliminates the need to wait three or four months for mask ROM devices. The very *day* you finish development, ZTAT gets you into production. And, you can implement software changes *immediately*, to stay one step ahead of everyone else.

Put all of Hitachi's HMCS400 series resources to work for you: Ceramic windowed devices for deve-

lopment, ZTAT devices for pilot and small-scale production, and mask ROM devices for large-scale production. And, a full complement of development support tools is available for use with IBM-PC*, DEC VAX*, and Hitachi systems.

Plus, when you consider all the on-chip integration, you also get the lowest-cost solution for your design. The packaging is one of the reasons why ZTAT only costs slightly more than mask ROM microcontrollers, and is _a lot_ cheaper than ceramic reprogrammable devices.

Clearly, Hitachi's HMCS400 series is right for a broad range of today's small systems applications in automotive, consumer, handheld instrumentation, telecom, and industrial products.

There's no need to wait. Hitachi is delivering the 4-bit all-CMOS HMCS400 series _right now_—including EPROM-on-chip ZTAT devices. For more information, call your local Hitachi Sales Representative or Distributor Sales Office today.

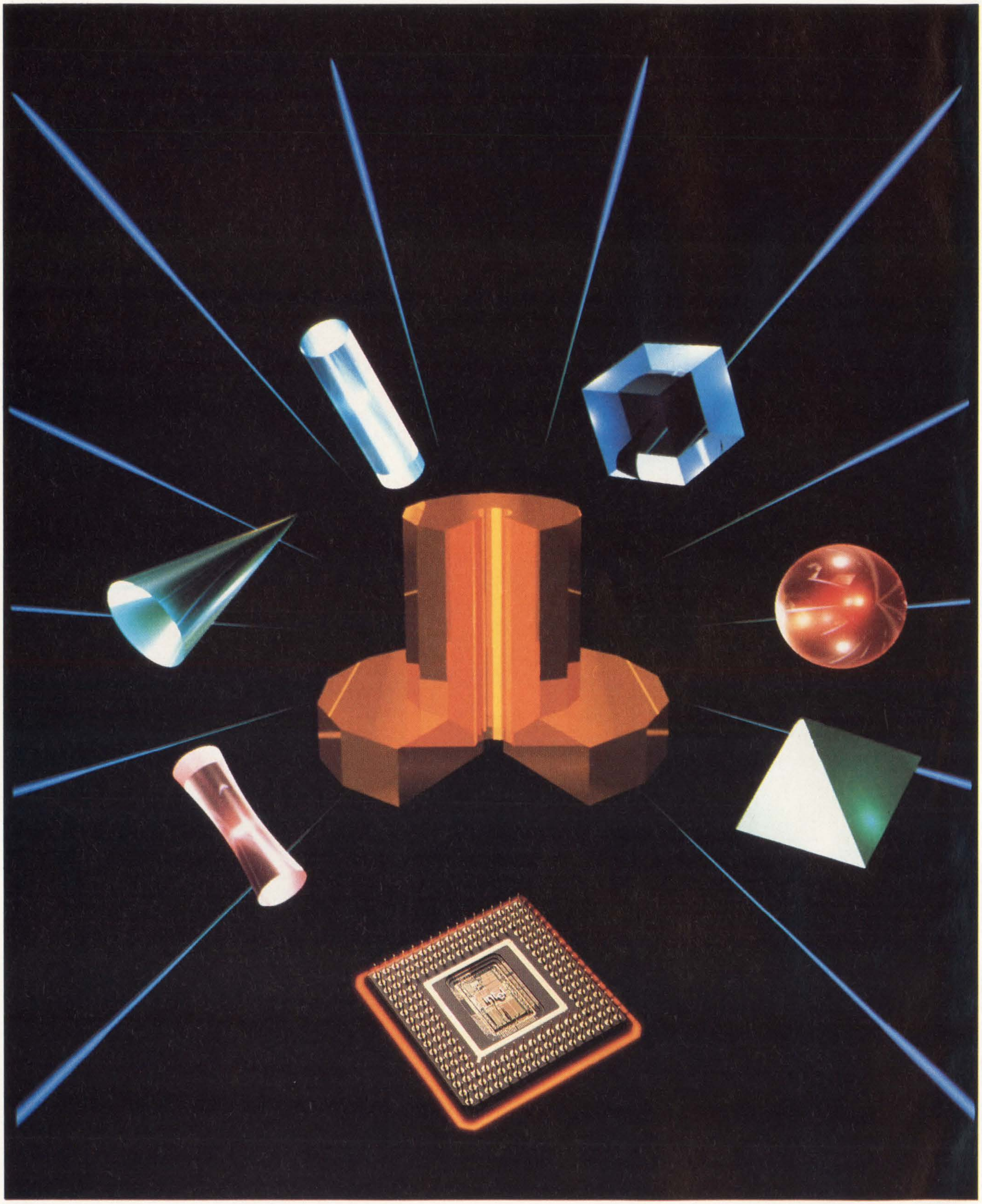
Literature Fast Action: For product literature only, CALL TOLL FREE, 1-800-842-9000, Ext. 6809. Ask for literature number #SB-106.

*IBM-PC and DEC VAX are trademarks of International Business Machines Corporation and Digital Equipment Corporation, respectively.

Hitachi America, Ltd.
Semiconductor & I.C. Division
Hitachi Plaza
2000 Sierra Point Parkway, Brisbane, CA 94005
Telephone 415/589-8300

HITACHI®

We make things possible



The shapes of things to come—realistic 3-D graphics images—will soon be showing up on personal-computer screens. One of three new processing products can give a PC add-in board or embedded graphics system the power to produce high-quality graphics. (Photo courtesy Intel Corp)

Processors for 3-D graphics

Because of their enormous appetite for floating-point operations, 3-D graphics displays were previously limited to high-end workstations. With some powerful new processors, however, you can now bring workstation-quality 3-D graphics to such applications as PC add-in boards and embedded-graphics systems.

Margery S Conner, Regional Editor

Three-dimensional color graphics displays, which are capable of manipulating an image in real time and shading it realistically, require a processor to perform a great number of floating-point and integer calculations. Two recently introduced processors, the 80860 from Intel and the TMS34020 from Texas Instruments, are specifically tailored to produce 3-D graphics. A third chip, the G300 parallel processor from Inmos, makes it easier for you to design the company's fast Transputer (T800) into 3-D displays. With any of these three products, you can design workstation-quality graphics into a personal computer or other graphics application.

Beyond their ability to perform fast floating-point calculations, the three products have little in common. For example, unlike the 80860 and T800/G300, the 34020 requires a coprocessor (TI's 34082) to perform fast floating-point calculations. Both the 80860 and the T800/G300 combination have on-chip floating-point hardware, but the 80860 includes hard-wired shading algorithms; the T800/G300 does not. However, because 3-D graphics suits diverse applications, ranging from workstation displays to PC add-in boards to embedded military displays, there's no one correct design approach. The application determines the cost and size of the system you can build as well as which chip you'll choose. To decide which chip is best for your application, you must first understand how graphics chips perform 3-D manipulations and shading.

In a 3-D color graphics display, the graphics application software stores graphical shapes in world coordinates, which are dimensionless Cartesian coordinates. The scale of a world-coordinate system depends on the application: 3-D applications can require thousands of units of resolution.

The graphics system processor must be able to rotate or tilt any graphical shape to conform to the viewing angle. These manipulations require the processor to perform a matrix transformation. To get an idea of the number of floating-point multiplications and additions the processor must perform, consider the following example. To move a point (x, y, z) to a new position (x', y', z'), you must multiply it by a 4×4 transformation matrix:

$$[x'\ y'\ z'\ w'] = [xyzw]^* \begin{bmatrix} abcd \\ efgh \\ ijkl \\ mnop \end{bmatrix}$$

$$x' = ax + ey + iz + mw$$
$$y' = bx + fy + jz + nw$$
$$z' = cx + gy + kz + ow.$$

A useful guideline for measuring an FPU's performance is the time it takes to do a 4×4 matrix transformation, a basic 3-D operation.

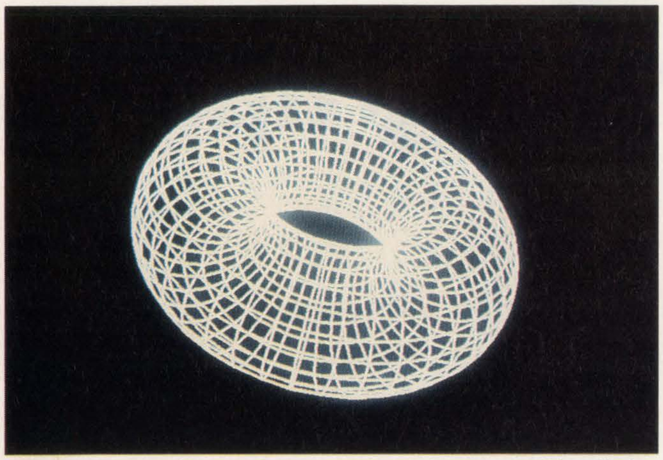


Fig 1—This rendering of a torus *shows how a graphics-display system would draw the shape before applying a hidden-surface removal algorithm. At this stage, all the polygons that the application software uses to represent the shape are visible. (Photo courtesy Weitek Corp, Sunnyvale, CA)*

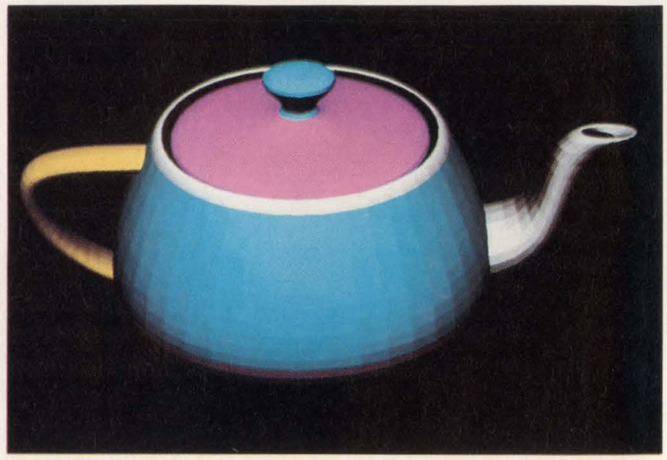


Fig 2—When no shading algorithms are applied *to this graphical rendering of a teapot, each polygon has only one color assigned to it, so the teapot appears to have a nonsmooth surface.*

To multiply the vector representing the pixel position by the transformation matrix, the processor must perform 28 floating-point operations: 16 multiplications and 12 additions. The 4×4 matrix transformation is basic to all 3-D manipulations, so it's a useful guideline for comparing different processors' floating-point capabilities. For example, a representative workstation, the Sun-4, transforms 150,000 vectors/sec.

The graphics application software doesn't store all of a graphical shape's pixels in memory; instead, it divides the shape into a series of polygons and stores only the vertices of the polygons. To transform a graphical shape, therefore, the system must transform the vertices of all the shape's polygons **(Fig 1)**.

After the graphics system processor transforms all of the shape's polygons to the correct viewing angle, the processor performs a clipping test to ensure that the system will display only those pixels that fit into the viewing window. The viewing window can be any size you care to make it.

To display the graphical shapes created by the application program, the processor must convert, or transform, the world coordinates to screen coordinates. Screen coordinates are relatively small, and their size is determined by the physical display. The screen-coordinate system for the IBM PC's VGA display, for example, is 640×480 pixels. The processor converts the coordinates by using a matrix transformation similar to those used for rotation and scaling. Up to this point, all the manipulations performed by the processor consist of floating-point operations.

The next step is for the system to move the graphical entities from 3-D memory to the 2-D screen display. To move the images, the system must use a hidden-surface-removal algorithm, which is necessary to make an image look realistic. When you look at a real object, the visible surfaces obscure surfaces behind them from view. When you move an image stored in three dimensions to the 2-dimensional screen, therefore, you must remove the surfaces that would be hidden from view in a real 3-dimensional object. The hidden-surface-removal algorithm checks each pixel in a scene and determines whether it would be visible from that particular view, and thus should be displayed in the scene, or whether it would be obscured by another pixel, and so should not be displayed.

The hidden-surface-removal algorithm can be performed in integer arithmetic. However, even though the graphics processor doesn't have to use floating-point arithmetic, its calculations are no fewer or less time consuming.

But first, scan convert

Before the graphics-system processor can apply a hidden-surface-removal algorithm, it must scan-convert the polygons to determine where their edges lie. Scan-conversion techniques rely on the fact that the color and visibility of adjacent pixels is usually very similar. The program calculates the horizontal limits of the polygon. Each pixel within the polygon must have its z value and color determined and placed in the z buffer and frame buffer, respectively. As a result of scan conversion, the system knows the color

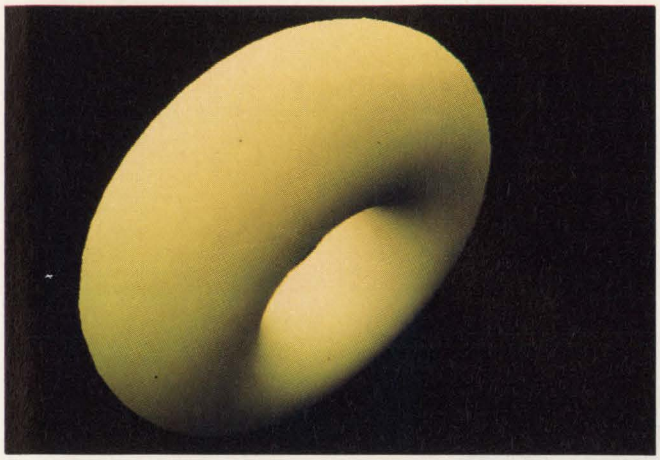


*Fig 3—**This version of the torus** shows how the wireframe version can look after hidden-surface-removal and shading algorithms have been applied. (Photo courtesy Weitek Corp)*

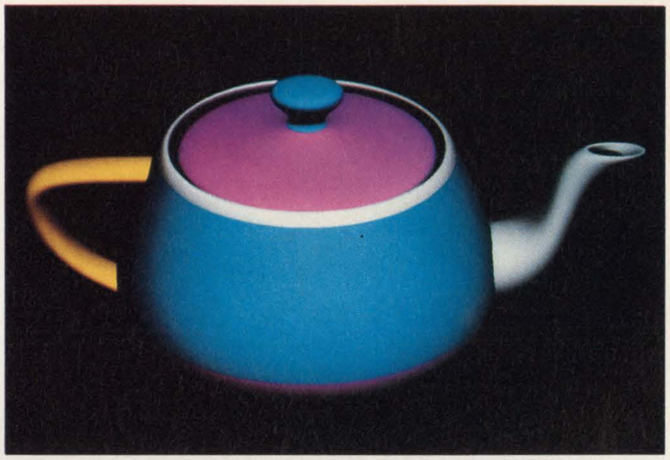


*Fig 4—**With the application of a Phong shading algorithm,** which simulates the effects of a single light source, the teapot takes on a much more realistic look.*

on the edges of the polygon and the z coordinate of each pixel and its color. The graphics-display system needs to know a pixel's z coordinate in order to remove hidden surfaces by using the z-buffer algorithm, and it must be able to identify the polygon's edges and their colors to perform the shading algorithms.

The z-buffer algorithm is the most popular hidden-surface-removal algorithm. It compares the depth of each pixel under examination (that is, its z coordinate) with the value currently in the z buffer. If the current pixel's z coordinate is smaller than the previous one in that position, the processor updates the z buffer with the new pixel's z value, and updates the frame buffer with the new pixel's color.

After performing hidden-surface removal, the graphics system can display a wire-frame representation of the graphical shape. However, to color each polygon with just one color gives a rough, unrealistic rendering of the object **(Fig 2)**.

The next step, therefore, is to use a shading algorithm. In Gouraud shading, the simplest shading scheme, the algorithm uses linear interpolation to determine what the colors on each line should be **(Fig 3)**. That is, if one edge is dark red, and the horizontally opposite edge is light red, fairly realistic shading would go linearly from dark to light red. At the halfway point, a Gouraud-shaded line has gone through half of the total color change.

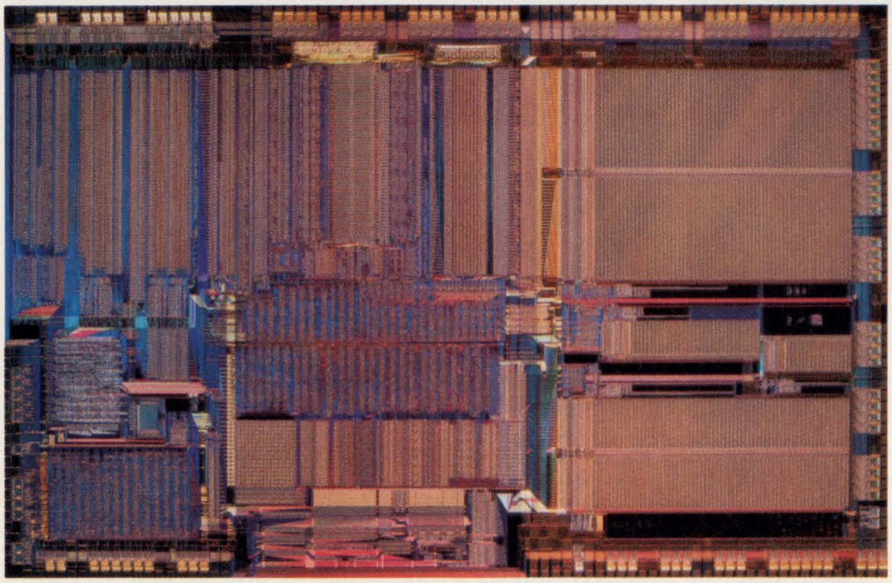
Gouraud shading doesn't allow for the effect of a light source, however, a technique that produces an even more realistic image. The Phong shading technique creates the effect of a single light source. Rather than linearly interpolating across a line of pixels, Phong shading determines the normal vector for each pixel, and calculates the angle of incidence for the light source **(Fig 4)**. The processor still performs a linear interpolation, but it recalculates each pixel's color on the basis of the pixel's normal vector.

There are several different ways to implement the shading algorithms in your graphics system. Only one of the three processors suitable for 3-D graphics display—Intel's 80860—provides the shading algorithms on chip. The others require you to implement the shading algorithms in software or to create an ASIC that can perform shading.

With over one million transistors on a single chip, Intel's 80860 integrates a RISC core, a floating-point unit (FPU), and a hardware shading unit. (For more information on the 80860's general processing capabilities, as well as a block diagram, see the Product Update on pg 87.) The on-chip FPU is capable of peak speeds of 80M flops. Its Linpack number is 10M flops (by comparison, a VAX 8650 has a Linpack rating of 0.7M flops). Keep in mind that Linpack ratings are always considerably lower than peak speed ratings, because the numbers generated in the Linpack benchmark can't fit into most on-chip caches. However, the 80860's cache is big enough to hold an entire 4×4 matrix transformation. Therefore, it can perform the transformation at close to its peak speed of 80M flops, which allows for 500,000 transformations/sec.

One of the most time-consuming parts of the process of rendering the image is the z-buffer check in the hidden-surface-removal algorithm. Even a flat shading

Even a simple shading technique such as the Gouraud scheme can run over 100 times more slowly than the 3-D matrix transformations.



Because it has more than 1,000,000 transistors, *the Intel 80860 processor has the density to pack a RISC core, an 80M-flops floating-point unit, and shading hardware all onto one chip.*

of a 3-D surface is much slower than a simple 2-D fill because the processor must check the buffer for each pixel. When the buffer check is combined with Gouraud shading, the shading process can run about 100 times slower than the transform rate. The 80860 has dedicated hardware that performs the z-buffer comparisons and computes the shading interpolation on all pixels in a 64-bit word simultaneously. (A pixel may be 8, 16, or 32 bits long, so each 64-bit word may have 8, 4, or 2 pixels.) The shading hardware gives you a choice between Gouraud or Phong shading. Its Gouraud-shading speed is 50,000 polygons/sec. By comparison, the Sun-4 workstation's Gouraud-shading speed is 20,000 polygons/sec.

Although the shading agorithms are implemented in hardware on the 80860, they still don't approach the speed of the FPU. If you can't stand letting the FPU idle while the shading hardware completes its tasks, you can put the FPU to work performing application-software tasks such as simulation calculations. In this scenario, the 80860 functions as a workstation on a board. **Fig 5** illustrates the architecture for a PC plug-in board that incorporates the 80860.

Note that the 80860 can operate as a stand-alone microprocessor; it does not require you to use another processor as a host. However, the software for the 80860 is totally incompatible with that for previous Intel processors, so if you wanted to run MS-DOS, you'd need an Intel host processor. Samples of the 80860 are available now. The chip will be in production in the third quarter of this year; it will cost $750 in OEM quantities.

Although the 80860 has 3-D graphics capability, it lacks the display-control hardware that a graphics processor has, and thus shouldn't be considered a true graphics processor. Texas Instruments' 34020, however, is a true graphics processor: It has built-in signals that support direct control of the display. It doesn't have floating-point capability, however; for that function, you need to use TI's recently introduced 34082 floating-point unit. The 34082 has a 50-nsec clock cycle; multiplication and addition occur in parallel, giving the chip a sustained floating-point speed of 40M flops, and a Linpack figure of 5.2M flops. It requires only 130 cycles for a full 4×4 matrix transformation, so it can perform more than 150,000 vector transformations/sec.

The 34082 has its own C compiler and assembler, and it can address as much as 256k bytes of memory over a local bus. These capabilities allow you to write your own routines (such as a rotation algorithm) for the 34082 and store them in the 34082's local memory. As host, the 34020 could command the 34082 to run its own routines from local memory, thus freeing the 34020 from having to oversee the operation of the 34082.

Because the 34020's object code is compatible with that of the chip's precursor, the 34010, a wealth of supporting graphics software already exists for the 34020. An example of such software is the Texas Instruments Graphics Interface (TIGA). The interface runs on 34010/34020 graphics plug-in boards in MS-

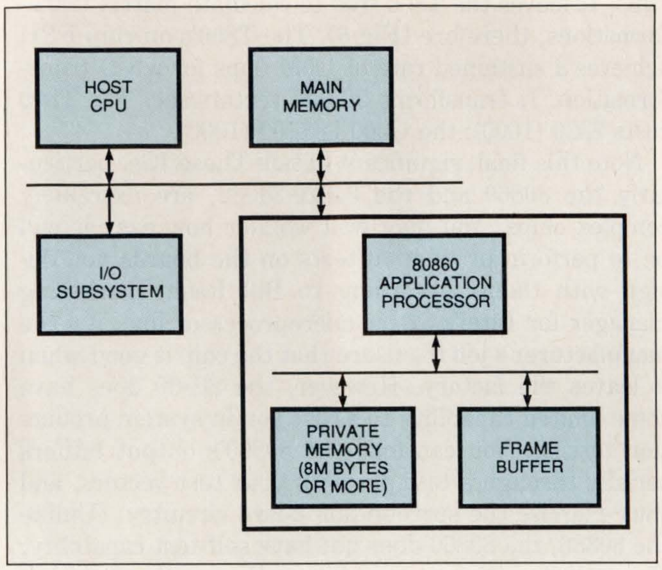
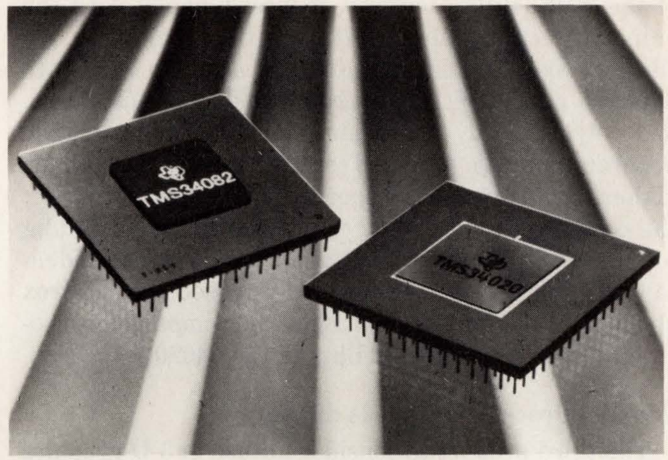


Fig 5—To exploit the power of many of today's PCs, *whose capabilities now approach those of workstations, the PCs' graphics displays will have to be able to support workstation-quality graphics. One way to design a PC-based system with workstation-quality graphics is to plug in an 80860-based 3-D graphics add-in board that runs application software while the host processor runs the PC's operating system.*



When teamed with the TMS34082 floating-point unit, *the TMS34020 32-bit graphics processor from Texas Instruments can perform more than 150,000 vector transformations/sec.*

DOS systems; it standardizes the way that application software and the host processor communicate with the 34010/34020 graphics processor.

According to Karl Guttag, TI graphic-strategy manager and designer of the 34010/34020 family architecture, you must be careful to balance the workloads between the host processor and the graphics processor. Because of the difference in power between the 34010 and the 80286, which is often the host in PC workstations, the 34010 often had to wait for the host processor, an inefficient scheme. In 80386-based systems, the 34010 no longer has to wait for the host. To use the processors most efficiently in such systems, you must give more thought to which tasks you assign to which processor. According to TI, 80386/34010 systems are demonstrating speed increases beyond those you'd expect to obtain by simply adding the faster host processor. The speed increases result from the redistribution of processing tasks.

The 34020 makes no provisions for 3-D color shading. If your application requires shading, you have two choices: You can either implement the algorithm in software, or you can develop your own shading ASIC. In the past, only vendors of high-end workstations could justify the time and expense of developing a shading ASIC, but this situation will soon change. National Semiconductor (Santa Clara, CA), for example, plans to introduce hardware shading chips into its standard-cell ASIC library this year.

Samples of the 34020 will be available this quarter; full production of the chip will start in the fourth quarter of the year. Samples cost $500; in production quantities, the chip will cost $100. The 34082's volume price will be $150. You can expect the quantity pricing for the 34020 to fall below $50 in two years.

Make your graphics system stand out in a crowd

You may be concerned that designs based on single-chip processors such as the Intel and TI ICs will make your system or board too generic. This has indeed been the case with low-resolution graphics boards. There's little to distinguish one VGA-compatible personal-computer board from another, for example, so price has become the determining factor in a customer's decision to buy. That's a nice situation for the customer, but the board manufacturer will want to avoid it.

One way to distinguish your design from others is to develop your own chips to accelerate one part of the graphics pipeline. For example, you could develop hardware-shading ASICs. An add-in graphics-board company with experience in this technique is Matrox (Dorval, Quebec, Canada). According to Ray Snow, graphics-board marketing manager at Matrox, when the company evaluated the various graphics chips two years ago, it particularly liked the programmability

If the shading portion of your graphics display is too slow, consider using a shading-accelerator ASIC.

of the TMS34010. However, it wasn't happy with the chip's relatively slow software bit-block transfer (BitBlit) speeds. Matrox developed its own ASICs to perform all BitBlit operations, windowing functions, and polygon fills. This scheme gave the company the programmability it found so attractive, as well as higher hardware BitBlit speeds. As you might expect, the company is looking for ways to accelerate shading for its next-generation 3-D graphics board. (Incidentally, Texas Instruments obviously agreed with Matrox about the need for faster BitBlits; the company incorporated faster hardware BitBlits in the 34020.)

Parallel processing speeds displays

The third product to consider for use in 3-D graphics systems is a 2-chip set comprising the Inmos T800 Transputer and the G300 color video controller. Inmos's T800 Transputer chip is aimed at parallel-processing applications. Parallel-processing applications are any applications that can be broken down into subtasks and performed by several different processors at the same time, accelerating the system speed. Graphics is a prime candidate for parallel processing. For one thing, the matrix manipulations necessary in graphics processing are very repetitive in nature. Further, parallel processing lets you develop several elements of a picture independently and bring them together just before displaying them on the screen.

The G300, which Inmos recently introduced, includes all CRT control signals and performs interface to the display; it also has a color look-up table and a video DAC. It leaves the T800 free to calculate matrix transformations, therefore (**Fig 6**). The T800's on-chip FPU achieves a sustained rate of 1.5M flops for a 3-D transformation. It transforms 50,000 vectors/sec. The T800 costs $330 (1000); the G300 is $100 (1000).

Note this final, significant detail: These ICs, particularly the 80860 and the 34020/34082, are extremely complex chips. You may well wonder how easy it will be to perform production tests on the boards you design with them. According to Bill Rash, marketing manager for Intel's 32-bit microprocessor line, it's the manufacturer's job to ensure that the chip is good when it leaves the factory. However, the 80860 does have some limited capability to assist you in system production testing. You can load the 80860's output buffers serially through a test pin with your test vectors, and thus exercise the surrounding board circuitry. (Unlike the 80386, the 80860 does not have self-test capability. The 80386's self-test capability relies on the fact that the chip is microcoded; the 80860 is not.)

As you might expect from TI, which has taken a leadership position in developing scan-path test methods, the initial version of the 34020 does incorporate a scan-path test method for emulation support. At present, the test capabilities of the 34082 are limited to forcing all pins to high, low, or 3-state, but the next version of the chip, due in 1990, will incorporate TI's full JTAG scan-path test method.

When you first see the prices of these processors, you may be taken aback. Consider, however, that these chips can give a graphics board or system the graphics

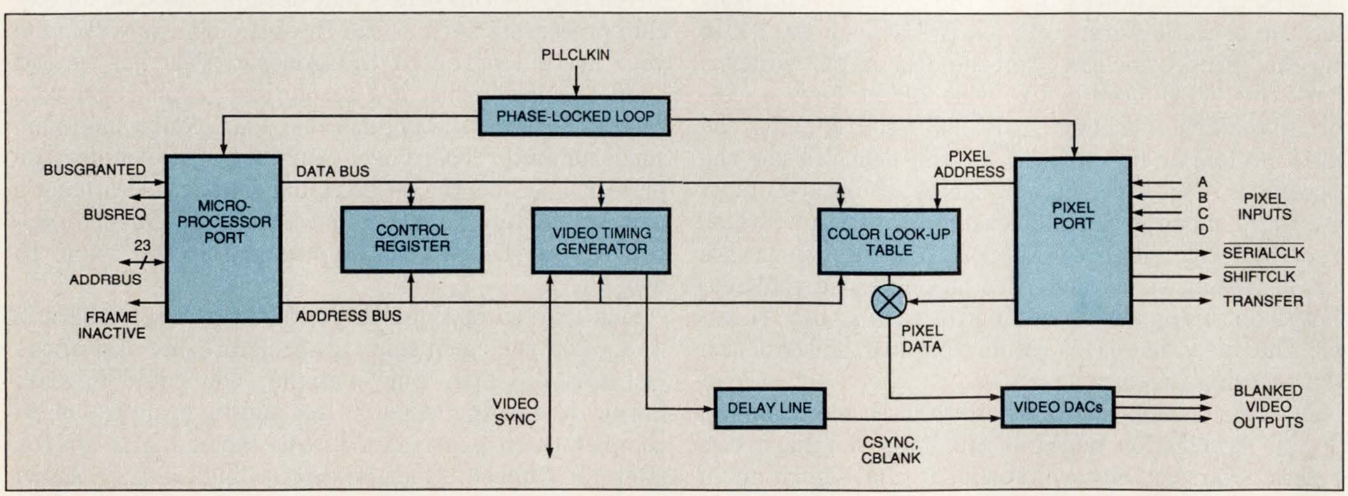


Fig 6—Because graphics is a natural application for parallel processing, *the Inmos T800 Transputer, which is eminently suitable for parallel processing, is a good candidate for a node processor in a 3-D graphics subsystem. The company's IMSG300 chip takes care of video control, including video D/A conversion.*

Manufacturers of processors for 3-D graphics

For more information on processors that implement 3-D graphics, such as the processors described in this article, contact the following manufacturers directly, circle the appropriate numbers on the Information Retrieval Service card, or use EDN's Express Request service.

Inmos Ltd
1000 Aztec West
Almondsbury
Bristol, UK BS12 4SQ
(0454) 616616
FAX (0454) 617910
Circle No 650

Intel Corp
3065 Bowers Ave
Santa Clara, CA 95051
(408) 987-8080
Circle No 651

Texas Instruments Inc
Semiconductor Group SC-879
Box 809066
Dallas, TX 75380
(800) 232-3200 ext 700
Circle No 652

capability of a Sun-4 workstation. In light of their capabilities, the chips are actually quite cost-effective.

What's more, although people tend to think that a PC's number-crunching capability is used mostly to run application software, it's actually the graphics display that causes most of the processing overhead. Similarly, as far as the user is concerned, it's the graphics-display subsystem that determines how fast the computer runs. No matter how quickly a PC performs a function internally, it's the speed with which the results show up on the screen that makes the difference. Fast processors that can handle 3-D graphics, therefore, are not just luxury options anymore; they're going to become necessary parts of graphics systems for many PCs in the near future. EDN

References

1. Foley, J D and A Van Dam, "Fundamentals of Interactive Computer Graphics," Addison-Wesley, 1984.
2. Conner, Margery, "Graphics engines," *EDN*, March 4, 1987, pg 112.

Article Interest Quotient (Circle One)
High 491 Medium 492 Low 493

SIMPLE.

System 120. The first integrated real-time system based on the AT-bus with iRMX® software.

With the addition of the System 120, Intel now offers the widest range of dedicated real-time products.

The System 120 brings the power of iRMX and the 386™ microprocessor to a cost-effective AT-bus system.

Because of iRMX, the System 120 gives you the same optimized real-time response and unique programming features already used in over half a million CPUs.

What's more, System 120 applications can migrate to the world's most popular single board computer family, Multibus® I.

Without recompiling.

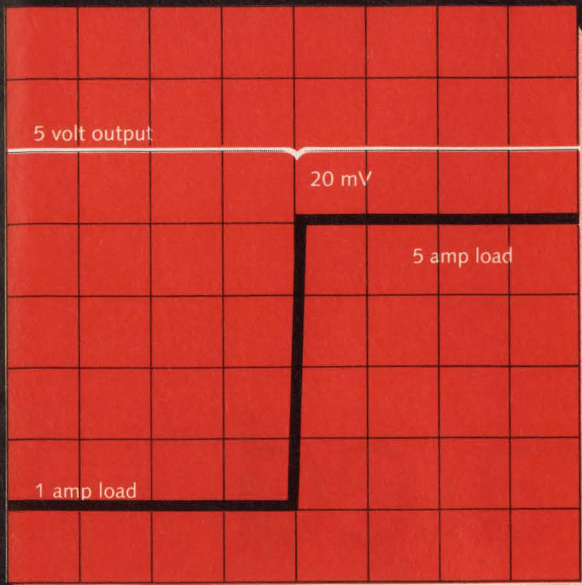
Or move distributed real-time applications to Multibus II for a quantum improvement in performance and functionality. So, one development effort lets you span two orders of magnitude in performance.

To learn more about the System 120, call Intel at 800-548-4725, Dept. AA02.

It's that simple.

intel®

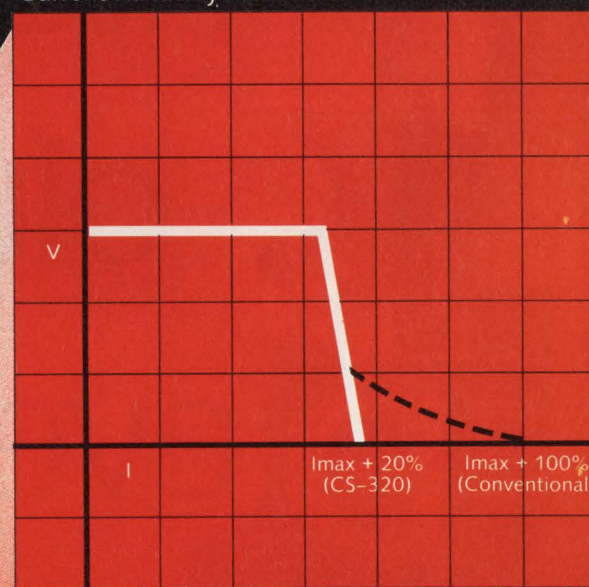
Output Voltage Response to a 5:1 Load Change.

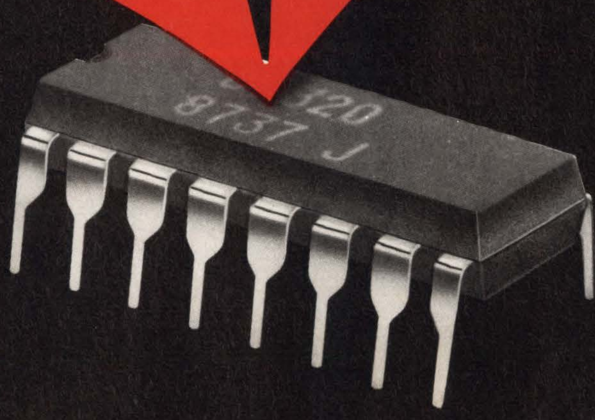


Unconditional Stability.

Hysteretic control directly controls both the peak and valley inductor current. Additionally, slope compensation is not required. A power supply using Hysteretic control is free from subharmonic oscillation and is unconditionally stable. Figure 2 shows the response of a CS-320 controlled Hysteretic DC-DC converter to a 5:1 variation in load current.

Current Runaway Prevented





Unconventional Control of Short Circuits

The unique (patent pending) circuitry of the CS-320 prevents current runaway at or near short circuit conditions during high frequency operation.

All of these advances can be working for you, plus operation at up to 1MHz, flexible current sensing, use in parallel operation of converters without master/slave designation, and Under Voltage Lockout with a choice of start/stop thresholds.

Excellent Application Support

Cherry Semiconductor is a leading producer of power supply control ICs. In addition to product innovation, CSC is recognized for helping customers to anticipate problems, arriving at workable solutions, and effectively integrating CSC ICs into end product designs.

Call or write for more information.

CIRCLE NO 81

ISDN no longer means "I Still Don't Know". The Integrated Services Digital Network is rapidly taking shape. It's opening vast new markets. And NEC has the technology to help you exploit them.

Integrating voice, image and data into a total digital network is NEC's special area of expertise. We offer a basic set of building blocks for your ISDN system.

Five high-performance ISDN devices.

Start building your share of the ISDN future now by designing NEC's high-quality ISDN devices into your terminals or switching equipment.

Digital line interface controller: μPD98001
- □ 2B + D support; Layer 1.
- □ 2-wire, full-duplex operation (ping-pong method).
- □ Communication distance: 2.5Km.
- □ Master/slave operation mode.

S-interface controller: μPD98201
- □ Fully implements CCITT I.430; Layer 1.
- □ 4-wire, full-duplex operation.
- □ Multi-framing capability.
- □ Communication distance: 1Km (point to point).
- □ Master (NT)/slave (TE) operation mode.

LAP-D controller: μPD72305
- □ Fully implements CCITT I.440/I.441; Layer 2.
- □ Memory-based host interface.
- □ On-chip DMAC.
- □ Basic (16Kbps)/primary (64Kbps) interface.

LAP-B controller: μPD72107
- □ Fully implements CCITT X.25/X.75; Layer 2.
- □ Memory-based host interface.
- □ On-chip DMAC.
- □ Baud rate: 4Mbps (max).

SS No. 7 controller: μPD72307
- □ Fully implements CCITT Q.703; Layer 2.
- □ Memory-based host interface.
- □ On-chip DMAC.
- □ Baud rate: 4.8K – 64Kbps.

Now you know.

NEC has the resources, the experience and the commitment to help you succeed in the ISDN era. If you still don't know where to find outstanding ISDN devices, call today and ask about the Integrated Solutions Developed by NEC.

UK Tel:0908-691133. Telex:826791.
Hong Kong Tel:3-755-9008. Telex:54561.
Taiwan Tel:02-522-4192. Telex:22372.
Singapore Tel:4819881. Telex:39726.
Australia Tel:03-267-6355. Telex:38343.

CIRCLE NO 82

NEC

Electro/89

Addressing the present and future needs of design engineers, Electro/89 features information on design, new technologies, and professional career issues.

Richard A Quinnell, *Regional Editor*

New York City is noted for offering something for every interest—at any hour of the day or night. For three days in April, the city will offer the electronics-engineering community much of interest in the form of Electro/89—eastern US's largest design-electronics trade show and convention.

An estimated 45,000 electronics engineers will converge on the Jacob Javits Convention Center, Tuesday, April 11 through Thursday, April 13, to see and hear about the latest developments in electronics technology. The show will feature more than 900 companies exhibiting their products and will offer 25 technical sessions and eight tutorials devoted to the present and future needs of electronics engineers and managers. New to the show this year will be a special exhibit area on design-automation tools.

In keeping with this year's theme, "Building a world class economy," the keynote speaker will be Dr John G Stoessinger, noted political analyst and professor of international affairs at Trinity University in San Antonio, TX. Dr Stoessinger is a member of the Council on Foreign Relations and author of 10 books on world politics, including the Bancroft Prize-winning *The Might of Nations: World Politics in Our Time*. His topic will be "Toward new horizons in the world's economy" at the keynote breakfast to be held on Tuesday, April 11 at 9:00 AM in the Marriott Marquis. Tickets for the breakfast cost $20.

Tracks to professional enhancement

The conference's economic theme continues in one of the six tracks along which conference organizers have arranged the professional program activities. The economic track, Entrepreneurial Activities, comprises two professional sessions. **Session 14** discusses venture capital, which is characterized as an ingredient of, but "only part of the success equation," and **session 18**

Jacob Javits Convention Center

discusses hiring consultants to attain profitability.

The Automated Design/Semiconductor/Systems track (**sessions 1, 4, 5, 16, 17, 20,** and **21**) will bring you up to date on a variety of circuit technologies, including PLDs, RISCs, and ASICs. If you're seeking timely practical advice, you might want to attend **session 1** for a discussion of system-design techniques using ASICs, or **session 4,** which discusses high-density PLDs and their design tools. You also might consider **session 20,** which deals with in-circuit board programming. Those contemplating their next design may be interested in **session 16,** which deals with the second generation of RISC.

Microwaves, optics, and video

If your interests lie outside the digital world, you may want to follow the tracks on communications, (**sessions 3, 7,** and **10**) or video technology, (**sessions 11, 15,** and **24**). They will lead you to "Microwave technology," (**session 3**), "Fiber optics networks," (**session 7**), and two sessions, (**11** and **15**) on aspects of high-definition television.

The New Technologies track (**sessions 6, 8, 13, 19,** and **22**) heads in the direction of tomorrow's engineering solutions. In **session 6,** you can learn the status and possible implications of high-temperature superconductors in electronics. **Session** 8 introduces you to the quantum world of "Nanoelectronics," where dimensions are small enough to allow adjacent circuits to interact because their electron wave functions overlap. You may come away from **session 22** with new

Electro shuttle bus stops

The Electro shuttle bus will operate on show days from 8:00 AM to 7:00 PM. Here is a list of the shuttle stops:

- Lexington Ave at 42nd St, Grand Central Station
- 7th Ave between 51st and 52nd Sts
- 45th St, just west of Broadway
- 7th Ave at 31st St, Pennsylvania Station
- 41st St between 8th and 9th Sts (Port Authority Bus Terminal)
- 49th St and 8th Ave, northeast corner

ELECTRO PROFESSIONAL-PROGRAM SCHEDULE

TUESDAY APRIL 11, 1989 10 AM TO NOON	**SESSION 1** SUCCESSFUL SYSTEM DESIGN TECHNIQUES USING ASICs	**SESSION 2** CHALLENGES FOR THE ENGINEER IN THE NEXT DECADE	**SESSION 3** MICROWAVE TECHNOLOGY	ELECTRONIC THEATER* DIGITAL VIDEO INTERACTIVE SYSTEMS	**SESSION 4** HIGH DENSITY PROGRAMMABLE LOGIC DEVICES AND THEIR DESIGN TOOLS	**TUTORIAL** SUPERCONDUCTORS IN INSTRUMENTATION AND STANDARDS 9 AM TO NOON
1:30 PM TO 3:30 PM	**SESSION 5** 16/32 BIT MICROCONTROLLERS—SOFTWARE AND HARDWARE FEATURES	**SESSION 6** SUPERCONDUCTIVITY: TECHNOLOGY/ APPLICATIONS	**SESSION 7** FIBER OPTICS NETWORKS	ELECTRONIC THEATER ACM/SIGGRAPH REVIEW	**SESSION 8** NANOELECTRONICS	**TUTORIAL** LEGAL CHALLENGES TO MANAGING THE WORKPLACE 1 PM TO 4:30 PM
WEDNESDAY APRIL 12, 1989 10 AM TO NOON	**SESSION 9** OPPORTUNITIES FOR EXPERIENCED ENGINEERS	**SESSION 10** NEW TRENDS IN MICROWAVE, MILLIMETER-WAVE AND PHOTONIC DEVICE TECHNOLOGY	**SESSION 11** PROGRAM PRODUCTION IN HIGH DEFINITION TELEVISION	ELECTRONIC THEATER* HIGH TECH VIDEOS	**SESSION 12** WOMEN IN ENGINEERING	**TUTORIAL** INTELLECTUAL PROPERTY FOR ENGINEERS AND MANAGERS 9 AM TO 12:30 PM **TUTORIAL** FUNDING TECHNOLOGY DEVELOPMENT IN SMALL FIRMS 1 PM TO 4:30 PM
1:30 PM TO 3:30 PM	**SESSION 13** NEW APPLICATIONS FOR ELECTRO-OPTICAL COMPONENTS	**SESSION 14** VENTURE CAPITAL—AN INGREDIENT BUT ONLY PART OF THE SUCCESS EQUATION	**SESSION 15** TRANSMISSION SYSTEMS FOR HIGH DEFINITION TELEVISION	ELECTRONIC THEATER ACM/SIGGRAPH REVIEW	**SESSION 16** RISC: THE SECOND GENERATION	**TUTORIAL** FIBER-OPTIC COMMUNICATIONS 1 PM TO 4:30 PM
THURSDAY APRIL 13, 1989 10 AM TO NOON	**SESSION 17** WHAT SHOULD YOU KNOW ABOUT VHDL, EDIF AND IGES?	**SESSION 18** MANAGING FOR PROFITABILITY—THE SMART USE OF CONSULTANTS	**SESSION 19** ELECTROMAGNETIC INTERFERENCE—PROBLEMS AND SOLUTIONS	ELECTRONIC THEATER* ACM/SIGGRAPH REVIEW	**SESSION 20** IN-CIRCUIT BOARD PROGRAMMING	**TUTORIAL** HIGH-DEFINITION TELEVISION 9 AM TO 12:30 PM **TUTORIAL** NEURAL NETWORKS 1 PM TO 4:30 PM
1:30 PM TO 3:30 PM	**SESSION 21** ADVANCED LOGIC—MEETING DESIGNER NEEDS	**SESSION 22** PERSONAL COMPUTER FOR AUTOMATIC TEST AND MEASUREMENT	**SESSION 23** MEETING THE NEEDS OF THE EE PROFESSION	**SESSION 24** SPACE PHOTOGRAPHY	**SESSION 25** OFF CAMPUS EDUCATION FOR THE WORKING ENGINEER	**TUTORIAL** TRANSFER IMPEDANCE METHOD OF MEASURING QUALITY OF EMI GASKETED JOINTS AND SHIELDING EFFECTIVENESS OF JOINTS 1 PM TO 4:30 PM

*NOON-1:30 PM EACH DAY: MISCELLANEOUS VIDEOS

Worming your way into the Big Apple

Whether you're staying in the city or just coming in for the day, the Jacob Javits Convention Center—located on 11th Ave between W 34th and W 39th Sts—is easily accessible. Both public transportation and a free Electro shuttle have stops at the center. The shuttle also has stops near hotels and transit terminals.

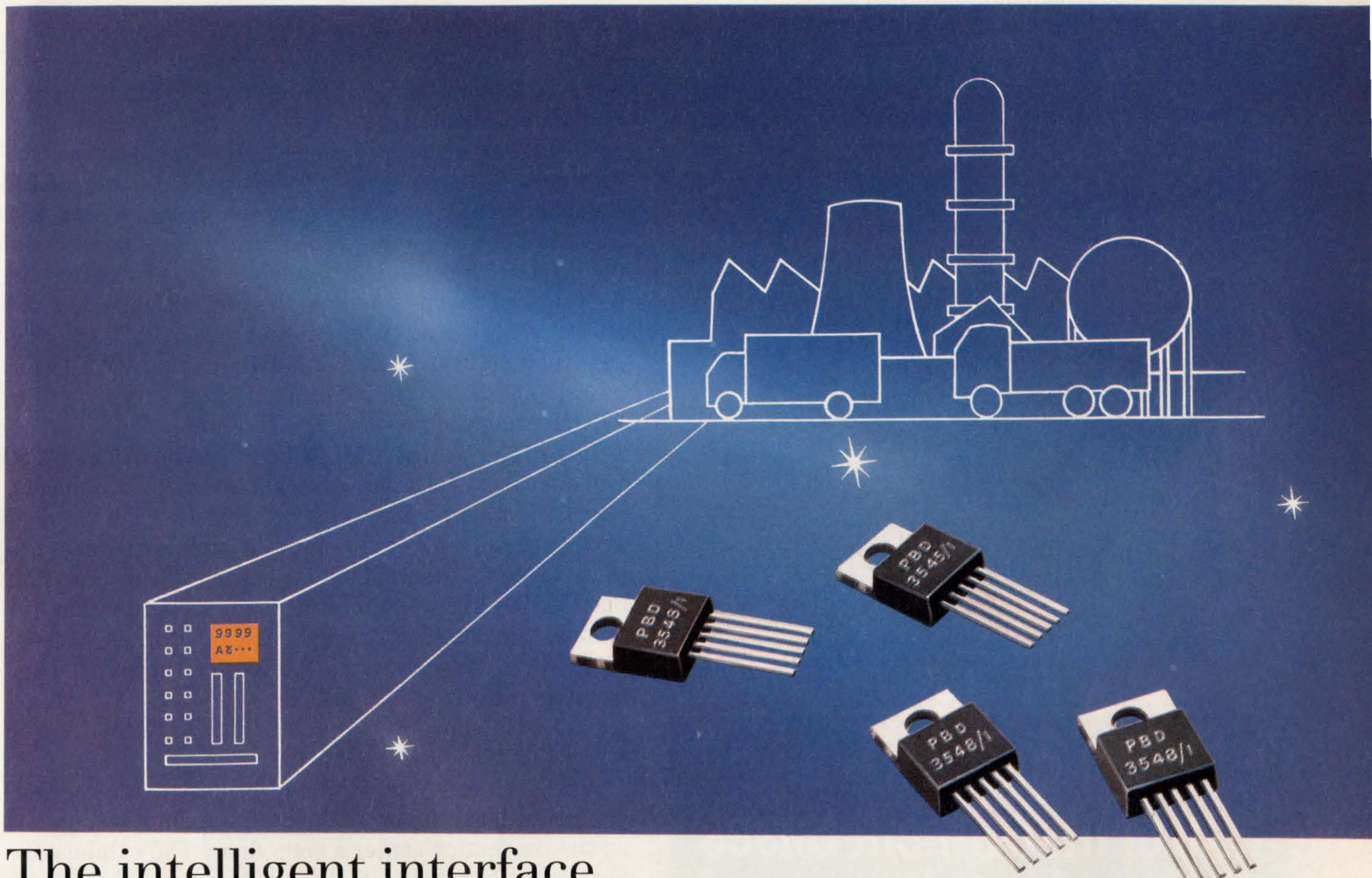
If you're coming in by plane, take Carey Bus from Kennedy ($8) or from LaGuardia ($6) Airports, or NJ Transit from Newark Airport ($6) to the Port Authority Bus Terminal. There you can catch either a crosstown bus or the Electro shuttle to the Javits Center. If you're coming by rail to Pennsylvania Station or Grand Central Terminal, you can catch either a crosstown bus or an Electro shuttle near the station.

The Center is served by two crosstown buses, the M-34, which runs along 34th St, and the M-42, which runs along 42nd St. Both buses stop at every block from river to river and are identified with Javits Center signs. The M-34 stops across the street from the center at 11th Ave. The M-42 stops at the north end of the center's internal roadway. The fare is $1 in either coins or tokens and transfers to north/south bus routes are free.

If you're trying to get to Electro by car, you have a challenge ahead of you. There is no parking available at the Jacob Javits Convention Center. Your best bet is to park at either the Manhattan Plaza Garage (on 42nd Street between 9th and 10th Avenues) or at the Port Authority Bus Terminal garage—accessible directly from the Lincoln Tunnel or from 40th Street. Once parked, catch either the Electro shuttle in the Port Authority terminal complex or the M-42 crosstown bus. Otherwise, it's a 10-minute walk.

An alternative to downtown parking is available if there are no afternoon baseball games scheduled. Park at either Yankee Stadium or Shea Stadium, and take the subway to 8th Ave at either 34th or 42nd. The fare is $1.

Smart Drivers for Industrial and Automotive applications.



The intelligent interface for micro-controllers.

To manufacturers of automotive electronics and industrial controllers, Ericsson Components offers this latest range of compact, cost-effective, rugged Smart Drivers.
Full protection against short circuits and over-temperatures, plus open-circuit detection and error reporting in microprocessor language.
Ideal for driving Solenoids, Valves, Actuators and inductive loads of all kinds.
Ericsson's experience, plus high-quality design and manufacturing, gives you intelligent, hard-working devices, built to operate in the most severe industrial and automotive environments.
Don't let your controllers leave home without one.
Contact us for more information.

Ericsson PBD 3545/1 (Low-side switch)
& PBD 3548/1 (High-side switch)

- ★ Efficient short-circuit protection.
- ★ Up to 2A continuous drive current.
- ★ Up to 45V supply voltage.
- ★ Built-in situation-monitoring/ERROR—reporting.
- ★ Built-in protection diodes for inductive loads.
- ★ TTL/CMOS compatible logic input.
- ★ Operating range −40°C to +85°C.
- ★ Reliable, cost-effective Bipolar Design.

ERICSSON

Ericsson Components Inc.
403 International Pkwy
Richardson, TX 75085-3904
Telephone (214) 480-8300
Telefax (214) 680-1059

We're in the lead

CIRCLE NO 83

Electro/89

ideas for using a "personal computer for automatic test and measurement."

Because an engineer's career is not based on technology alone, you may wish to follow the Professional and Personal Concerns track (**sessions 2, 9, 12,** and 25). **Session 2** focuses on personal career development and management. **Session 9** explores "Opportunities for experienced engineers," and **session 12** examines the special concerns of "Women in engineering." You may also want to hear EDN's Jon Titus, along with IEEE officers and the editors of other publications at **session 23,** "Meeting the needs of the EE profession."

In addition to the professional sessions, Electro/89 will offer eight tutorials, covering a variety of subjects. Some tutorials of particular interest to EDN readers are "Neural networks—Models and hardware implementation," held Thursday, April 13 at 1:00 PM, and "Fiber optic communications," scheduled for Wednesday, April 12 at 9:00 AM. Tutorials are not covered by the show's registration fee, however. They range in price from $70 to $285.

Don't forget the exhibits

When you are done with the professional program, you'll still have time to explore the exhibitors' booths on the convention center's main floor. The exhibits are open from 9:30 AM to 6 PM on Tuesday and Wednesday, and 9:30 AM to 4 PM on Thursday. Included in the exhibits are products in a category new to Electro—design-automation tools. A cluster of more than 50 exhibitors will provide an automated design center where you can try out new developments in this growing field.

Whatever your interests, Electro/89 in New York offers something to make your day. What New York has to offer at night is yours to discover. EDN

Article Interest Quotient (Circle One)
High 494 Medium 495 Low 496

The comfort of analog... the power of digital.

Full 100MHz performance in a compact 15-lb scope.

The new Hitachi Real-time Storage Oscilloscopes (R.S.O.s) store signals, provide bright, flicker-free displays, deliver hard copy from a digital plotter, and capture elusive transient events with pre- or post-triggering.

And Hitachi's R.S.O.s act and feel like real-time scopes. Providing full 50 or 100MHz analog capability, the R.S.O.s can also present two saved waveforms from battery-backed memory for comparison with two waveforms of current data.

All three storage modes are automatically selected for maximum waveform fidelity with options to:

- ☐ Extract signals from noise with averaging.
- ☐ Smooth waveforms with dot-joining.
- ☐ Provide waveform insight with sine or pulse interpolation.

HITACHI

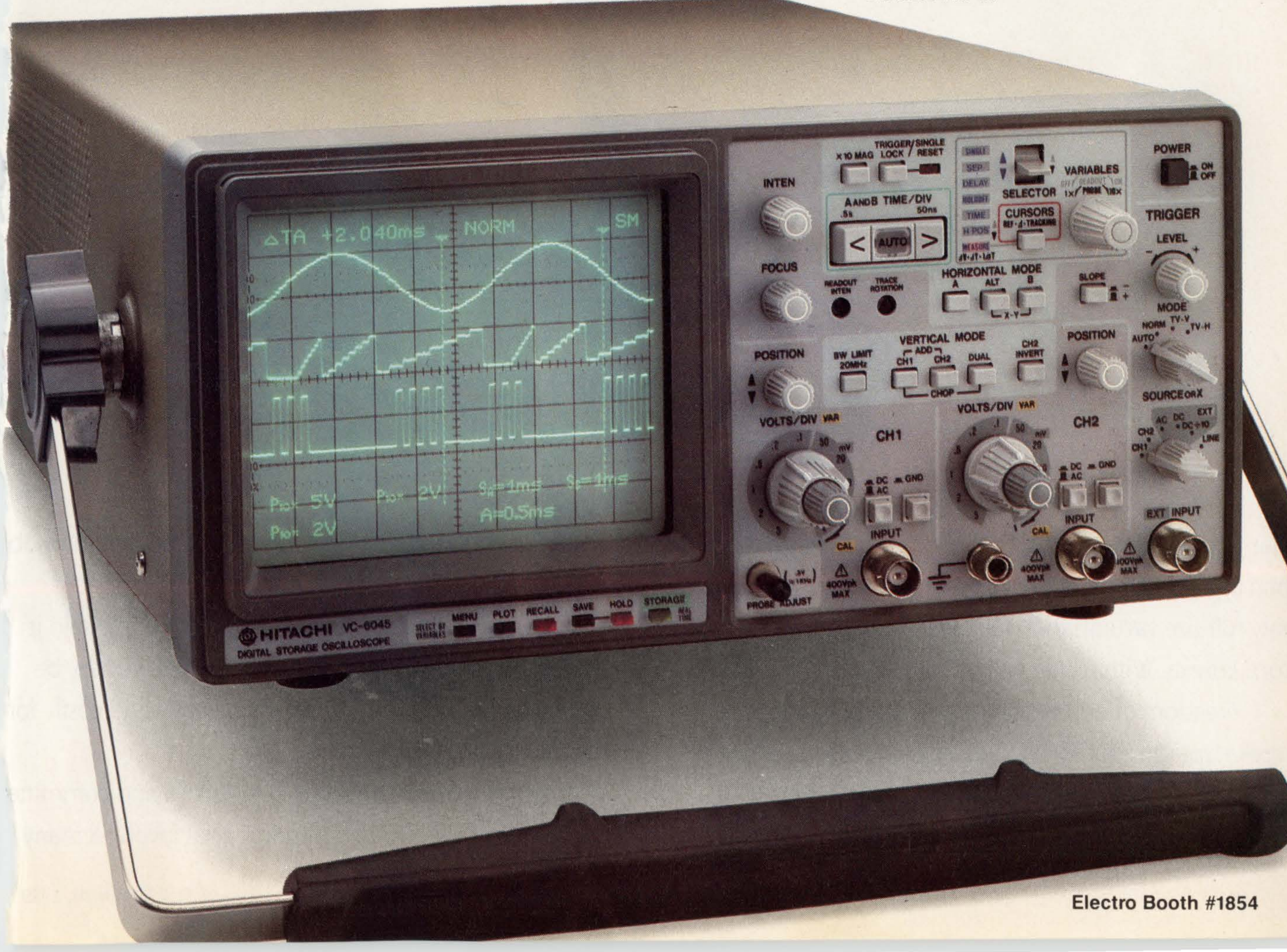
Hitachi Denshi, Ltd.
Tokyo, Japan.

And these compact (the 6″ CRT front panel fits on this page) ... lightweight (15.5 lbs.) high performance ... popular R.S.O.s are priced right: *VC6045*-100MHz, 40Ms/s, 2KW/channel @ $3,295, *VC6025*-50MHz, 20Ms/s, 2KW/channel @ $2,195.

Find out more about the R.S.O. benefits by calling or writing **Hitachi Denshi, America, Ltd.,** 175 Crossways Park West, Woodbury, NY 11797. 516-921-7200. LA area 213-328-6116. Dallas area 214-233-7623.

DIMENSIONS: 5.1″ H x 10.8″ W x 14.2″ D

CIRCLE NO 87



Electro Booth #1854

The most uninhibited vacuum in history.

Four and a half years ago, Freedom™ was nothing more than a great idea. Today it's a great product. The world's only full-size vacuum that operates totally cord-free. Only from Eureka. With a little help from Gates Energy Products.

Freedom offers everything you'd ever expect from a Eureka upright–durability, quality and cleaning effectiveness. And, thanks to its revolutionary design, the convenience of cordlessness. Made possible by a rechargeable Gates battery. A 12-volt, 5-amp hour sealed-lead monob battery mounted in a portable snap-in battery pack.

Of course, it wasn't easy. And some people said it couldn't be done. How, they asked, could a battery be powerful enough without being too heavy and costly for the market to bear?

But at Gates we believed in Freedom and committe our resources to making it happen. That involved many

TWISTITE™
MAGNET WIRE

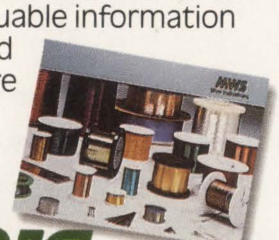
For superior performance and tighter control over twisted wire construction.

Developed for use in the production of custom toroid, ferrite or recording head coils, specialty audio and R.F. transformers, TWISTITE offers a number of distinct advantages.

TWISTITE is custom produced to offer a wider range of twisting construction. Manufacturing capabilities include:

- Up to 33 Twists Per Inch on fine wire.
- Twisting tolerance as tight as ±1%.
- Tightly controlled capacitance, inductance and impedance characteristics.
- Up to 10 colors in some sizes for conductor identification.
- Huge selection of insulations: NEMA MW 1000, JW1177, 105–220°C (single through quadruple film builds).
- Wide range of sizes: 24 AWG and finer.
- Wide variety of conductor materials: copper, silver, plated conductors, and special alloys.

Call or write for your free copy of our Technical Data Booklet and Capabilities Brochure. Both contain valuable information on all wire produced and inventoried by MWS Wire Industries. Samples of TWISTITE are available upon request.



MWS

Wire Industries

31200 Cedar Valley Drive, Westlake Village, CA 91362
CALL TOLL FREE 800 423-5097
In California 800 992-8553. In L.A., 818 991-8553

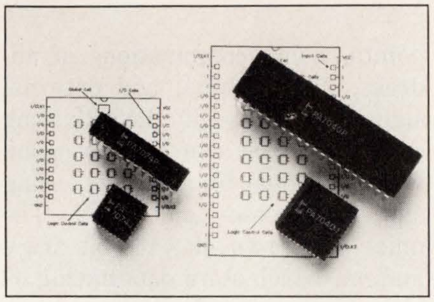
TWISTITE is a trademark of MWS Wire Industries

CIRCLE NO 89

Electro/89 Products

Programmable device combines features of PLDs and programmable gate arrays

The PA7024 is the first member of a CMOS programmable-device family, PEEL (programmable electrically erasable logic) ARRAYS, which combines elements of both PLDs and programmable gate arrays. The foundation of the PA7024 is its logic-control cell (LCC).



Each LCC has four primary input lines and produces two independent output signals. LCCs contain registers that can operate as synchronous or asynchronous D, T, or JK flip-flops. The input signals for each LCC are four of 80 possible sum-of-product terms, selected by programming.

The four input signals can be used as data for the register or to clock and control the register. An LCC's two output signals are selectable from three of its input signals or the register's output signal. One output of each LCC connects to an I/O cell, and the other is available for creating the sum-of-product terms.

The PA7024 has 20 I/O pins and two dedicated clock-input pins. Internal to the device are 20 LCCs, 20 I/O cells, and a global cell interconnected through a programmable logic matrix. The device allows you to define signals in PLD-like sum-of-product terms but, as with gate arrays, creating internally used signals does not force you to sacrifice an I/O pin.

The global cell controls selection and routing of clock signals to both the I/O cells and the LCCs. This cell can treat all cells as a single group with a common set of clocks or divide them into two independent groups. The internal clocks can operate as fast as 50 MHz. The propagation delay from one I/O pin through an LCC to another I/O pin is 23 nsec. $22.50 (100). Samples will be available in the second quarter of 1989.

International CMOS Technology Inc, 2125 Lundy Ave, San Jose, CA 95131. Phone (408) 434-0678. TWX 910-997-1531. No booth. Product to be reviewed at session 4.

Circle No 658

100-MHz digital-storage oscilloscope travels to the field

The PM 3308 looks like a portable typewriter, but it's actually a full-featured digital-storage oscilloscope. It features a maximum single-channel sampling rate of 40M samples/sec and a sample memory of 8k bytes. The scope also has a battery-backed 180k-byte RAM-disk, allowing storage of as many as 100 setup menus and waveforms.

The oscilloscope has a 100-MHz bandwidth and two input channels. It can display as many as four traces, however, allowing simultaneous display of input signals and computed traces. The computed traces can be based on addition, subtraction, multiplication, division, integration, and differentiation of signals.

In addition to displaying waveforms, the oscilloscope allows you to make a variety of waveform measurements. These include time between reference points, voltage differences, p-p and rms voltages, mean and average voltages across a trace, rise time, frequency, period, and phase. A glitch-capture capability registers the occurrence of transient signals that are as fast as 10 nsec. You can make all measurements either relative to a reference or as absolute values.

The unit features an electroluminescent display screen that folds down for transporting. It weighs 14.5 lbs and comes with a shoulder strap to make carrying it to field sites easier. The PM 3308 costs $7500. Delivery, eight weeks ARO.

John Fluke Mfg Co Inc, Box C9090, Everett, WA 98206. Phone (800) 443-5853; in OR, (206) 356-6433. TLX 185102. Booth No 1559.

Circle No 657

Emulator series supports 68020 processor with clock rates as fast as 25 MHz

The HMI-200 Series in-circuit emulators now include units that support 16- and 25-MHz 68020 microprocessors. Both units are functionally identical, differing only in operating speed. Like other members in the series, each unit operates with either a terminal or host computer controlling the unit through an RS-232C data link. The emulators have two RS-232C ports; one attaches to the controller, and the other allows data transfers such as downloading data files from a second source or printing the trace buffer's contents. The ports support data rates to 19.2k baud.

The units allow both single-step and real-time emulation of the processor. You can program as many as four complex break and trigger points, using combinations of address, data, status, and external signal lines to specify the activating condition. You can also program four additional break points, using simple addresses and ranges. The units offer two 4k × 136-bit trace buffers, which store data having 32 bits of time-tag information.

The emulators offer a number of built-in functions. For example, you can use the break points singly or in a conditional sequence to stop emulation, to trigger acquisition of data to the trace buffer, to generate an output signal for external triggering, or to measure time between break points. You can also examine and modify memory and registers, search memory for data strings, test memory, and read and write hex files in a variety of formats.

When connected to an IBM PC- or Unix-based system, the emulators allow symbolic and source-level debugging, using the optional SourceGate software. The software supports C, PL/M, and Pascal compilers from several manufacturers. You can display source code only, source and assembly, or assembly only when reading the trace buffer.

The 16-MHz version of the HMI-200 base unit costs $10,500, and the price of the 25-MHz version is $16,000. Delivery, six to eight weeks ARO.

Huntsville Microsystems Inc, Box 12415, Huntsville, AL 35802. Phone (205) 881-6005. TWX 510-600-8258. Booth No 971.

Circle No 654

Data-acquisition mainframe communicates over IEEE-488 bus

The Model 556 data-acquisition mainframe allows you to connect a variety of digital and analog signals and controls to any computer that supports IEEE-488 communications. The mainframe can accept as many as 10 plug-in cards and present them to a host computer as a single remote instrument.

The device comprises a 10-slot card cage, a power supply, and IEEE-488 interface control logic. The unit communicates on the IEEE-488 bus as a single instrument, regardless of the number of plug-in cards inserted. To control individual cards, you must send device-dependent commands to the unit; that is, commands that include the card's location. The unit's control logic can read card identifiers, allowing you to query the unit to determine your setup. The control logic is also compatible with test-instrument software such as LabView and Labtech Notebook.

The unit is self-contained, requiring no special controller cards in the host computer. It supplies all needed power to the plug-in cards, providing as much as 800 mA at ±15V and 3A at 5V.

The manufacturer offers a choice of 28 boards for use in the mainframe. These boards have a variety of signal input and output characteristics and provide functions such as strain-gauge signal conditioning, thermocouple sensing, and data acquisition. You can also use boards for the Model 556 with other mainframes from the same manufacturer. The Model 556 costs $1395.

Keithley Instruments Inc, 28775 Aurora Rd, Cleveland, OH 44139. Phone (800) 552-1115; in OH, (216) 248-0400. TLX 985469. Booth No 2826.

Circle No 653

Fast response time, less than 5 ms, gives Finlux Electroluminescent displays video capability. In laptop PCs, the cursor is visible during all rapid movements or data changes.

As for picture quality, you can see for yourself: it's worth a thousand words. Here are just a few: Crisp. Stable. Bright. Wide-angle viewing. Finlux EL is easy on the eyes, even during a long workday.

The big little EL display

The display above is shown as large as life. Just 18 mm thin and weighing less than 500 grammes, this Finlux EL shows as much text as an 11" CRT: 25 lines of 80 characters, or full graphics. Finlux EL displays are available in a range of 320 x 256 to 640 x 400 pixels.

Wherever your customers need compact clarity

Finlux EL displays are easily interfaced for high-resolution graphics, word processing, medical and industrial applications. The fully solid-state flat EL panel and electronics are assembled into a sturdy, compact package ready for mounting in even the most demanding environments.

Lohja Finlux is the only European manufacturer of flat panel Electroluminescent displays.

To see more, get in touch with:

FINLUX

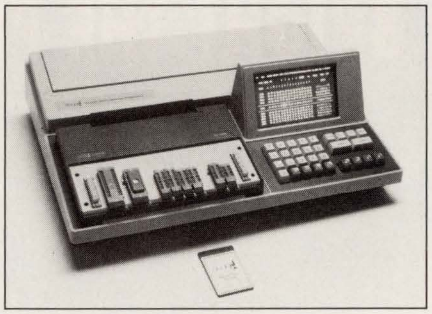
LOHJA CORPORATION
FINLUX Display Electronics
Box 46
SF-02201 ESPOO 20, FINLAND
Telephone (+358-0) 420 01
Telecopy (+358-0) 422 143
Telex 125023 ldis sf

In the USA:
FINLUX INC.
20395 Pacifica Drive
Suite 109
Cupertino, CA 95014, USA
Telephone (408) 725-1972
Telecopy (408) 996-7547

CIRCLE NO 90

Universal device programmer handles all available technologies

The System 3000 simplifies your device-programming operation by giving you a single set of hardware for all your programming needs. The system can handle more than 1600 device types, including PLDs, PROMs, EEPROMs, and microcomputers. The unit has 2M bits of onboard RAM as standard and is expandable to 64M bits, allowing it to handle high-density devices.



The programming section accepts DIPs with pin counts from 16 to 40 and widths from 0.3 to 0.6 in. An optional SMD chip station handles PLCC and LCC surface-mount devices with 20- to 68-pin packages. Each pin location in the programming section has programmable voltage, current, and rise-time output characteristics as well as the ability to sense conditions such as open and short circuits.

System 3000 handles all available programmable device technologies, including NMOS, CMOS, bipolar, and fuse-link memories. It reads electronic identifier bytes, when available, and retains its configuration on power-down, thereby making setup and use easier. A user-inserted IC memory card contains all the device libraries and programming algorithms needed by the unit.

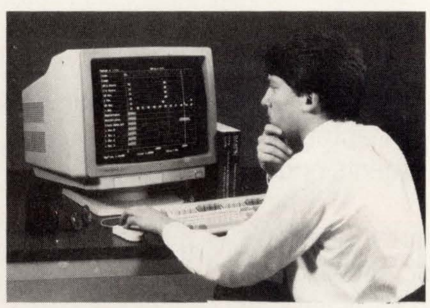
The unit features a built-in keyboard and CRT display that allow you to use it as a stand-alone programmer. Offering four interface ports—two RS-232C, an IEEE-488, and a handler port, the unit lets you communicate with a host computer or peripheral equipment. $9495.

Stag Microsystems Inc, 1600 Wyatt Dr, Santa Clara, CA 95054. Phone (408) 988-1118. Booth No 2827.

Circle No 656

IBM PC-based software supports PLD design and modeling

The OrCAD/PLD and OrCAD/MOD software tools allow you to design and simulate PLD functions on an IBM PC, PC/XT, PC/AT, PS/2, or a compatible computer. The OrCAD/PLD design package is either integrated with schematic capture and simulation software or can function as a stand-alone design aid. It allows you a choice of methods for describing your design. You can use schematics, Boolean equations, truth tables, or procedural state-machine programs to define your circuit's operation. The program also supports indexed equations; as a result, counters, Gray code converters, addressable latches, and other structured designs are definable with a single equation.

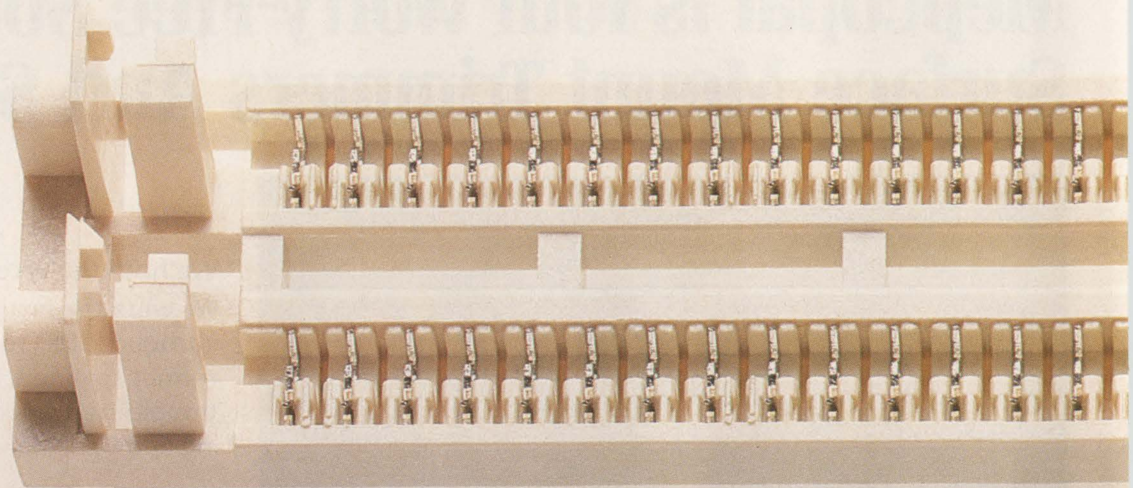


The PLD package generates standard JEDEC files for programming a device. It also features a logic simulator, allowing you to create test-vector files for later design verification. When used as part of an integrated design package, the software allows you to back-annotate your schematic with text files that describe the PLD's function; it also automatically updates the schematic files whenever programming changes are made.

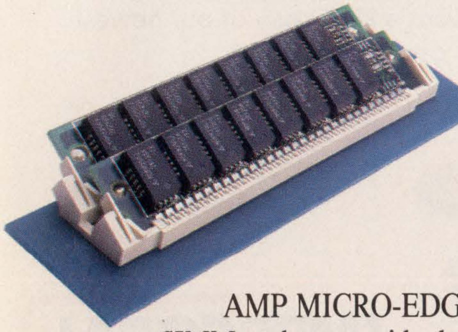
The modeling program, OrCAD/MOD, serves as an extension to the OrCAD/VST verification and simulation software. MOD allows you to create simulation models based on the PLD's definition and the JEDEC file. The program combines the design information with the structure and timing characteristics of specific PLD devices. The characteristics are stored in a library file that comes with MOD. The file contains more than 300 entries and offers utility programs for creating additional models. The software packages cost $495 each.

OrCad Systems Corp, 1049 SW Baseline St, Suite 500, Hillsboro, OR 97123. Phone (503) 640-9488. TWX 910-240-2090. Booth No 360.

Circle No 655



High sec



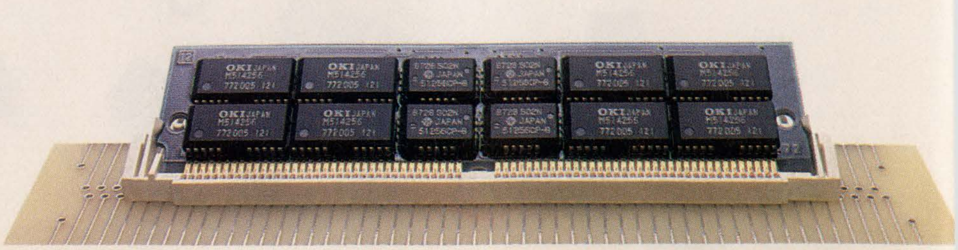
AMP MICRO-EDGE SIMM sockets provide the highest security your memory or logic module could ask for: Each contact produces 200 grams normal force on each module pad. Minimum.

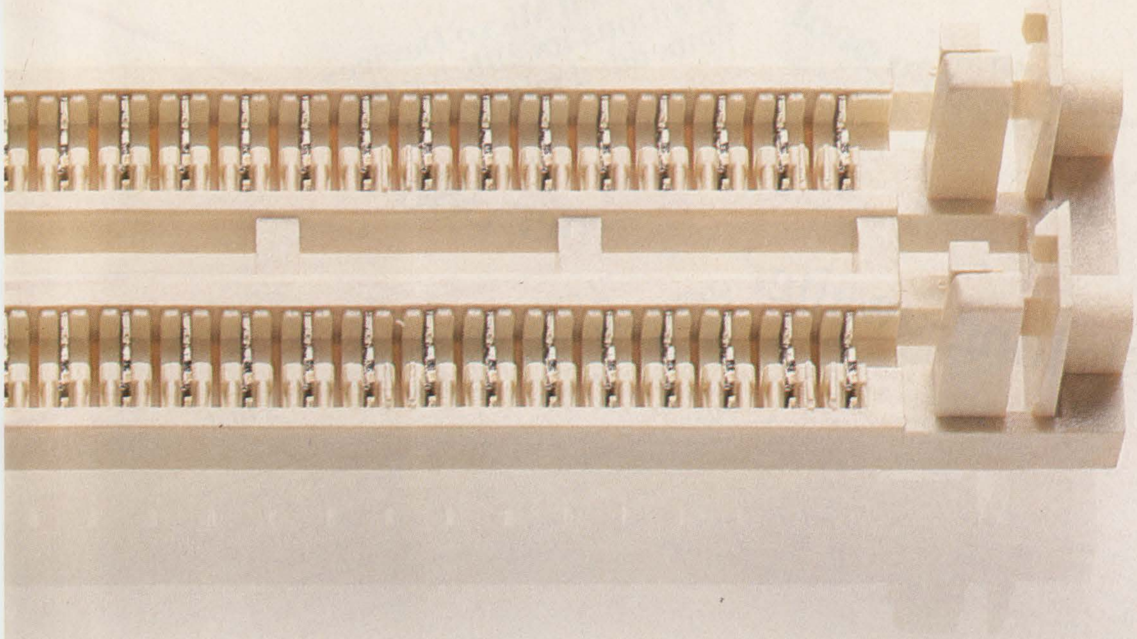
And the contacts float. They're free to move laterally, so uneven thermal expansion can't separate contacts from pads. Goodbye, fretting corrosion, opens and intermittents. Hello, reliable performance on 100 mil and 50 mil center modules.

We've also thought about the effects of use on long-run reliability. So our MICRO-EDGE SIMM sockets provide positive wiping action during insertion. And contacts are designed to deflect up to .017″, with full anti-overstress protection—forgiving enough to handle any standard (.047″ to .054″ thick) module board.

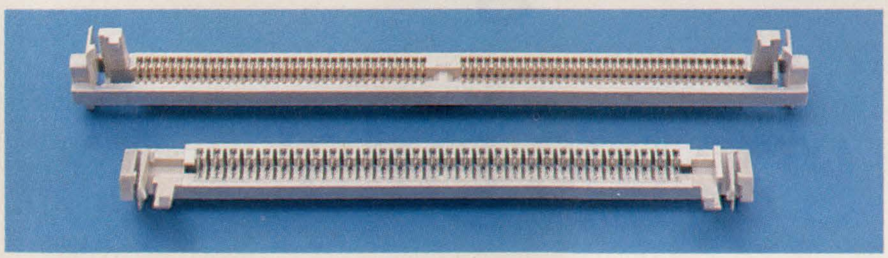
Over the life of your product, the socket housing can take a real beating. We've thought that through, too. Our liquid crystal polymer housings, rated for continual use at 200°C, give ramps and latches the strength and dimensional stability that promise a long, useful life.

We've also seen to it that contact retention in the housings allows robotic application, as well as inde-





urity area.



pendent repair or replacement. Closed bottom design prevents solder wicking and bridging. And, naturally, latching ears are protected against overstress, and module polarization is designed in.

Now the best part: MICRO-EDGE SIMM sockets are available in the style you need. We have .100″ or .050″ centerlines in a wide selection of singles and duals, vertical and slanted. Plus options, including a choice of gold or tin on contact mating surfaces.

Our very-low-insertion-force design and high-reliability contacts make the 50 mil versions especially attractive *Every* version comes with the quality and support you expect from AMP.

For literature and product information, contact the AMP Information Center, toll-free, at 1-800-522-6752. AMP Incorporated, Harrisburg, PA 17105-3608.

AMP Interconnecting ideas

CIRCLE NO 93

Now, what about the other 95% of your design?

We've got the guts!

Make us prove it. Call (800) 227-1817, ext. 982 and ask for our new capabilities brochure.

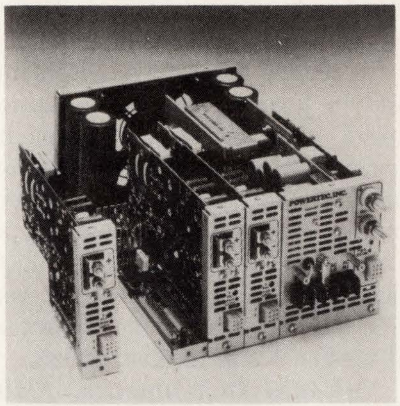
One standard. 0 defects.

Signetics

a division of North American Philips Corporation

PHILIPS

CIRCLE NO 94



POWER SUPPLIES

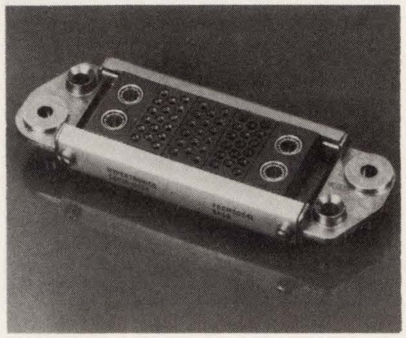
Series 6A, 6B, and 6C power supplies feature a mainframe enclosure that provides the main output. The mainframe accommodates and powers as many as three auxiliary modules with 2 to 48V outputs; the overall power ratings are 600W for the 6A series, 800W for the 6B series, and 1000W for the 6C series. The main output values range from 2 to 24V; a 5V main output provides currents of 90 to 150 mA.

You can connect outputs with identical voltages in parallel, regardless of current ratings. When so configured, outputs automatically current-share in proportion to their current ratings. Standard supply features include overvoltage protection, remote sense, automatic thermal shutdown, and soft start. The units feature an EMI filter and also include reverse-voltage protection. $939 to $1079. Delivery, stock to eight weeks ARO.

Powertec, 20550 Nordhoff St, Chatsworth, CA 91311. Phone (818) 882-0004. TLX 277483. Booth No 313.

Circle No 659

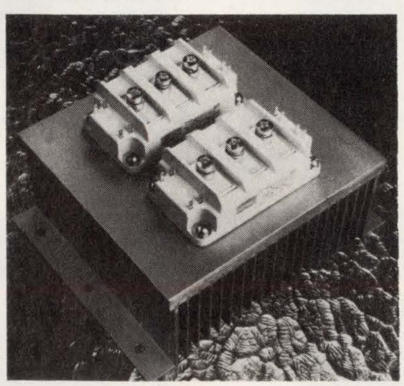
CONNECTORS



L Series low-insertion-force (LIF) connectors provide the combination of small size and low contact resistance required for plug-in power supplies. These rugged rack-and-panel connectors are available with contacts rated for 8, 15, 25, 50, and 200A. The L Series product line utilizes a hyperboloid-type LIF socket. In addition to LIF, the socket design provides inherent immunity to shock and vibration. Socket contact resistance ranges from 0.25 to 2.5 mΩ. The float-mounting socket design accommodates as much as 0.049 in. of radial misalignment in blind-mating situations. The connectors are available with solder cup, crimp, and flow-solder terminations, depending on the contacts selected. The L Series units meet the performance requirements of MIL-C-28748A. $40 to $100 (1000). Delivery, 14 to 16 weeks ARO.

Hypertronics Corp, 16 Brent Dr, Hudson, MA 01749. Phone (800) 568-9228; in MA, (508) 568-0451. FAX 508-568-0680. Booth No 503.

Circle No 660



HEAT SINKS

Series 6760 heat sinks provide low thermal resistance in both natural-convection and forced-air applications. The units feature aluminum fins that are bonded to the mounting surface with epoxy. The nine standard units in the line have hole patterns that accommodate all standard power modules.

Forced-air models will accept muffin fans that have a 4.12-in.-square mounting-hole pattern. Mounting surfaces range from 7×4.78 to 16×10.78 in., and thermal-resistance values range from 0.024 to 0.08°C/W. Natural-convection models are 3.13 in. high and are available in 7- and 12-in. lengths. The heat sinks have a 7.375-in.-wide mounting surface and are available with or without mounting flanges. Thermal resistance ranges from 0.22 to 0.3°C/W. The 7-in. natural-convection model, $39.37 (100). Delivery, eight to 12 weeks ARO.

Aavid Engineering Inc, Box 400, Laconia, NH 03247. Phone (603) 528-3400. Booth Nos 2660 and 2662.

Circle No 661

SIGNAL GENERATORS

Models 2040 and 2045 arbitrary waveform generators convert data from 8-bit bytes to analog voltages at the rate of 800M points/sec. You can describe the desired waveforms as mathematical equations, graphics sketches, or line segments, or you can download them from a host computer. The generators feature 512,000 points of memory that you can divide into multiple segments and 78k bytes of battery-backed RAM that stores files containing polynomial waveform definitions. You can trigger the output waveforms or you can synchronize them to an external source.

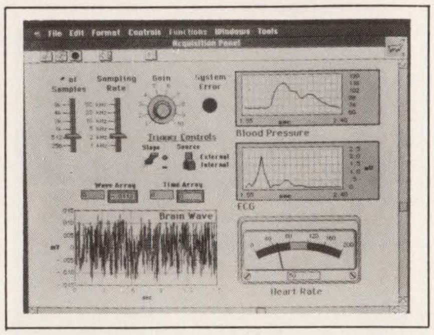
Both generators provide a pair of analog outputs. The 2040's outputs, which are in phase opposition, have internal impedances of 50Ω and supply a 1V p-p signal to a 50Ω load. One output of the 2045 is obtained directly from the main D/A converter, and the other passes through a programmable 64-dB attenuator and Bessel filter. Model 2040, $13,500; Model 2045, $14,500. Delivery, 90 days ARO.

Analogic Corp, 8 Centennial Dr, Peabody, MA 01961. Phone (508) 977-3000. FAX 508 531-1266. TLX 949307. Booth No 2812.

Circle No 663

PROGRAMMING SYSTEM

LabView version 2, an upgrade of version 1.2, has a compiler that significantly reduces the execution



time, provides editing capabilities like rubberbanding, and offers graphics controls such as panning and zooming. This color, icon-based programming system simplifies engineering and scientific programming on Apple Macintosh computers by permitting you to design software-generated virtual instruments. You produce these instruments by drawing block diagrams that represent test and measurement functions. You then control the instruments via pictorial renditions of the types of switches, dials, and levers you might actually find on 3-D versions of such equipment.

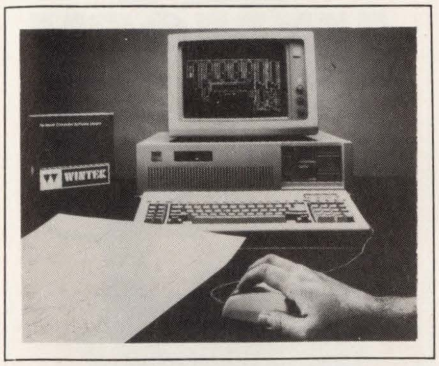
To reduce memory requirements and to further increase execution speed, LabView 2 adds multiple integer and floating-point data formats to 1.2 version's extended-precision floating-point data type. LabView 2 can run all the applications you've developed under version 1.2 and is available to owners of version 1.2 at no cost. $1995.

National Instruments, 12109 Technology Blvd, Austin, TX 78727. Phone (800) 531-4742; in TX, (800) 433-3488. TLX 756737. Booth No 524.

Circle No 662

IBM PC-BOARD ROUTER

The HiWire-Plus Autorouter is a gridless, via-minimizing, multilayer, IBM PC-based autorouter. It lets you make trace-specific design



rules; for example, you can tell the autorouter to route power networks with 21-mil width and 11-mil spacing, some signal traces with 12-mil width and 8-mil spacing, and other signal traces with 5-mil width and 5-mil spacing. The HiWire Plus Autorouter completes board routing; it lets traces cross each other and violate other design rules during the early stages of routing.

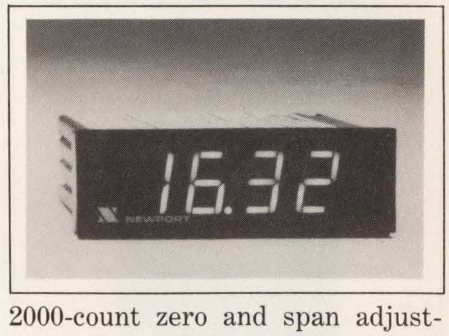
In subsequent phases of routing, the Autorouter optimizes, rips up, and reroutes vias for each network. During the final passes, the router centers traces in the routing channels and further optimizes vias. For critical traces, you can prewire before starting the autorouter. To operate the HiWire Plus Autorouter, you need the HiWire Plus CAD package and an IBM PC, PC/XT, PC/AT, or PS/2 with 640k bytes of RAM. A utility program can translate FutureNet, OrCAD, Schema, and Tango netlists. $895.

Wintek Corp, 1801 South St, Lafayette, IN 47904. Phone (800) 742-6809; in IN, (317) 742-8428. TLX 709079. Booth No 760.

Circle No 665

PROCESS METER

The model 205-P digital process meter features 0.56-in. characters and includes a power supply. It provides a 3½-digit display span. Potentiometers allow you to achieve

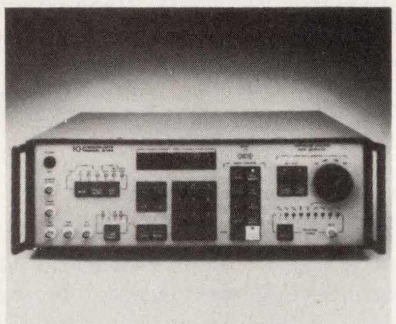


2000-count zero and span adjustments from the front of the meter's panel. The full-scale signal ranges of 4 to 20 mA, 0 to 199.9 mV, 1 to 5V, 0 to 10V, and 0 to 100V are jumper selectable. The input is true differential and features 56 dB of normal-mode noise rejection. The meter operates either from 24, 100, 115, or 230V ac or from 5 or 7 to 32V dc power sources. All power options feature EMI filtering, which prevents power-line noise from disrupting the meter reading. The meters are housed in a polycarbonate plastic case that carries a

94V-0 UL rating. Removable screw-clamp cable connectors for signal and power terminations comply with VDE and UL requirements. From $139.

Newport Electronics Inc, 630 E Young St, Santa Ana, CA 92705. Phone (714) 540-4914. FAX 714-546-3022. TWX 910-595-1787. Booth No 2113.

Circle No 664



SIGNAL GENERATOR

The Model 2100A-7 synthesized function/pulse generator produces sine, square, and triangular waves as well as positive and negative programmable-width pulses. It covers the frequency range of 0.01 Hz to 31.16 MHz (to 10 MHz for pulses) with 7-digit resolution and accuracy of 0.5 ppm. The main output provides open-circuit voltages that you can set from 10 μV to 30V p-p. You can also obtain outputs whose amplitude accuracy is 0.05 dB, as an option.

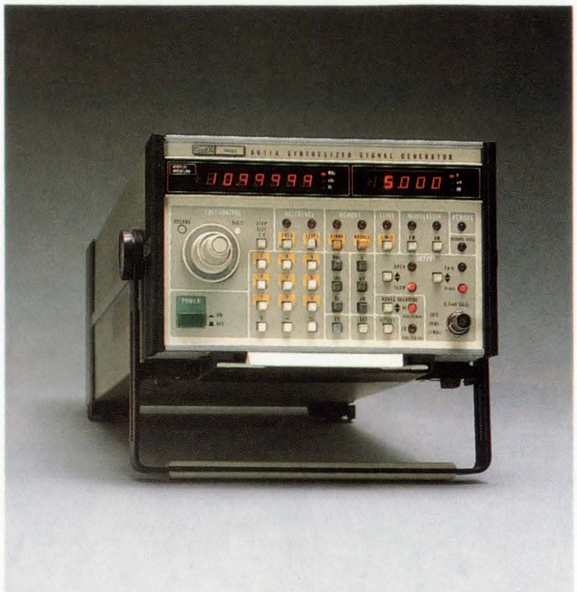
An auxiliary output supplies TTL levels. The pulse rise and fall times are <11 nsec. The unit sweeps the output frequency linearly or logarithmically between start and stop frequencies that you program. You can also vary the frequency by supplying a programming voltage. Below 30 kHz, the unit can produce bursts of 1 to 255 waveforms with start and stop points programmable in 1° increments from −90 to +267°. $4750. Delivery, six weeks ARO.

Krohn-Hite Corp, Avon Indus-

Text continued on pg 146

Fluke signals the end of the generation gap.

That was then.



The Fluke 6011A Signal Generator. This innovative product featured a crystal reference oscillator, and could output frequencies from 10 Hz to 11 MHz. It signalled Fluke's major entrance into the generator market, and continued the tradition of excellence Fluke had established with their multimeter and calibration product lines for years. Introduced in the 1970's, the 6011A was Fluke's first microprocessor-based signal generator, and had an incredible 0.15 dB amplitude accuracy specification (0.07 dB typical). Even today, for certain applications, the 6011A remains to be the best signal generator available.

99.9992% pure sine waves. Within 0.001Hz.

High speed at high purity makes this easy-to-use high precision Bruel & Kjaer 1051 sine generator the instrument of choice for ADC characterization, product or system calibration requiring many frequencies/levels.

With distortion less than 0.0008% (− 102 dB) in the 20 Hz to 20 kHz range, and frequency accuracy + 180/ − 0 μHz throughout its 1 mHz to 200 kHz operating range, the 1051 combines production-line speed with laboratory-instrument accuracy to give you the best of both in a single integrated package.

You get plenty of convenience features, too. Like easy external control (English language commands) via IEEE-488 interface, a 1024-point amplitude memory, storage of up to 9 user-defined test setups, calibrated output from 100 μV to 5 V, accuracy within 0.05 dB from 20 Hz to 20 kHz, and six-decade log or linear frequency sweep in one continuous range with selectable upper and lower limits.

For ADC characterization, Automated Test Systems, or any kind of product or system calibration application, our 1051 gives you precisely what you've always needed in a sine wave generator — precision. Coupled with what you've always wanted and never had — speed.

For complete information on the 1051 sine generator that's both pure and fast, call Bruel and Kjaer today or circle reader service number.

CIRCLE NO 64

Brüel & Kjær

Bruel & Kjaer Instruments, Inc.

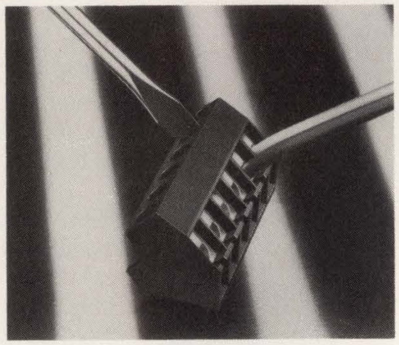
185 Forest Street, Marlborough, MA 01752 USA • Telephone 508/481-7000

WORLD HQ: DK-2850 Naerum • Denmark • Tel: + 452800500 • Telex: 37316 bruka dk

Australia (02) 450-2006 • Austria 02235/7550*0 • Belgium 02-242-9745 • Brazil 11-246-8166 • Canada (514) 695-8225 • Finland (90) 8017044 • France (1) 64572010 • Federal Republic of Germany (04106) 4055 • Holland 03402-39994 • Hong Kong 5-487486 • Italy (02) 5244141 • Japan 03-438-0761 • Republic of Korea 02-554-0605 • Norway 02-787096 • Singapore 2258533 • Spain (91) 2681000 • Sweden (08) 7112730 • Switzerland (042) 651161 • Taiwan (02) 7139303 • United Kingdom (01) 954-2366 • USA (508) 481-7000 • Local representatives and service organizations world-wide.

trial Park, Bodwell St, Avon, MA 02322. Phone (508) 580-1660. TWX 710-345-0831. Booth No 1436.

Circle No 666



TERMINAL STRIPS

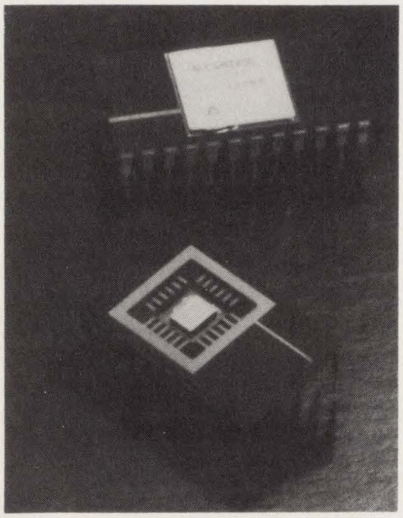
Featuring a 45° entry, Eurostyle terminal strips save space and provide easy, safe access for wiring on crowded pc boards. The 0.197-in. contact spacing provides five terminations in less than an inch. The strips have touch-proof terminals and wire-ready captive screws that won't fall out and cause shorts. The terminals have UL ratings of 15A and 300V max. Other features include wire entries that accept wires as large as #14 AWG, a closed side that acts as a wire stop, and thermoplastic insulator material that has a UL flame-retardant rating of 94V-0 and a UL temperature index of 130°C. $0.18 (500).

Vernitron Corp, Beau Products Div, Box 10, Laconia, NH 03247. Phone (603) 524-5101. FAX 603-524-1627. TWX 710-364-1843. Booth Nos 645 and 649.

Circle No 667

8-BIT FLASH ADC

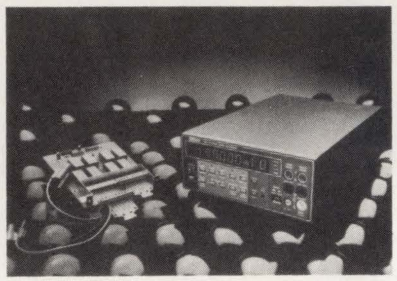
Fabricated in low-power CMOS, the ADC-208 flash A/D converter provides an 8-bit sampling rate of 20 MHz and effective bit rates to 30 MHz in the burst mode. The video flash converter operates from a 5V supply and consumes 500 mW of power. Other features include a



1-shot-mode conversion time of 35 nsec and a mid-point tap for use with an external voltage source to improve integral linearity. The ADC-208 also provides latched 3-state outputs for μP interfacing. Housed in a hermetic 24-pin ceramic DIP, the device is available in both commercial and military temperature-range versions. \$50 to \$158 (100).

Datel Inc, 11 Cabot Blvd, Mansfield, MA 02048. Phone (508) 339-3000. TWX 710-346-1953. Booth No 1704.

Circle No 668



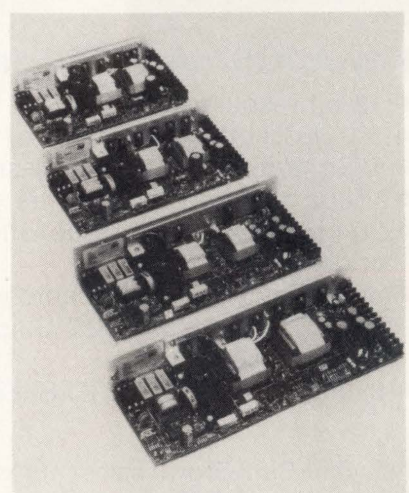
MULTIMETER

The Model 199 digital multimeter measures dc and ac voltage, dc and ac amps, ohms, and decibels. By adding an 8-channel scanner option, you can transform the instrument into a complete multichannel measurement system. The instrument's sensitivity specs are 1 μV, 1 mΩ, and 100 nA, and its best 1-year dc-voltage accuracy is 0.007% of reading. You can take 150 readings/sec at a resolution of 4½ digits and store them in an internal buffer. You can trigger the readings externally.

The optional scanner, which you can install at your site, offers a switching speed of 400 channels/sec, including measurement time, 2-pole and 4-pole switching, and <1 μV thermal offset in switch contacts. The low thermal offset lets the Model 199 accurately switch and measure low signal levels. Further, the scanner's 4-pole switching mode provides Kelvin-type (4-wire) resistance measurements. The unit can switch and take measurements across 40 channels/sec. With scanner, \$1395; without scanner, \$995.

Keithley Instruments Inc, 28775 Aurora Rd, Cleveland, OH 44139. Phone (216) 248-0400. TLX 985469. Booth No 2826.

Circle No 669



POWER SUPPLIES

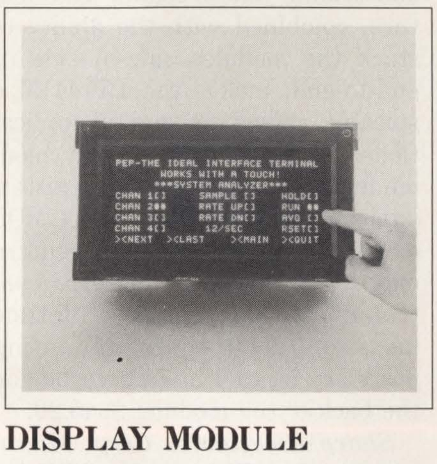
The SQM International Series switchers offer a 150 to 350W continuous-output capability. All units feature peak-power capabilities to accommodate the initial turn-up/

spin-up loads required by peripherals such as disk or tape drives and printers. The switchers feature main 5V outputs with current capabilities of 20 to 50A. Auxiliary 5, 12, 15, and 24V outputs are available with as much as 16A of peak current. All units are available with as many as four outputs.

The supplies feature built-in line filtering, 3750V ac safety isolation, shielded power transformers, built-in overload and overvoltage protection, overtemperature shutdown, remote-sensing capability, vacuum-impregnated magnetics, and fixed-frequency pulse-width modulation. You can also opt for a power-valid indicator and for TTL-high or TTL-low power-fail detection circuitry. All units meet VDE, IEC, UL, CSA, FCC, and British Telecon specifications for safety isolation and EMI/RFI emissions. $266 to $358. Delivery, six to 10 weeks ARO.

Switching Systems International, Box 1599, Placentia, CA 92670. Phone (714) 996-0909. FAX 714-996-2753. Booth No 2324.

Circle No 670



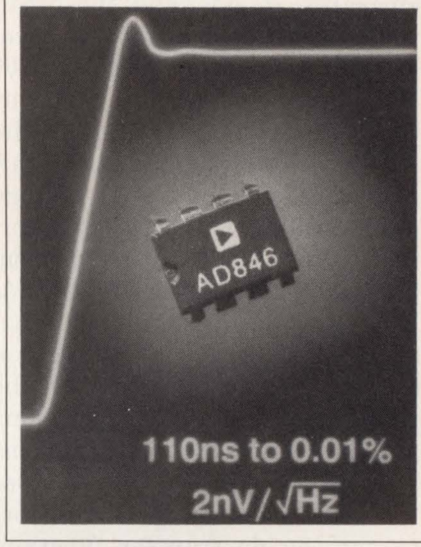
DISPLAY MODULE

The Model 4285-XX canned-message module combines an 8-line × 32-character dc gas-plasma display with an infrared touch-screen. The module provides 16k bytes of RAM, which can store as many as 127 canned messages; the memory is backed by an onboard battery. The touch-screen IR switch matrix provides 128 switch locations. The alphanumeric display provides a 64-character ASCII character set as well as several European character sets in a 5×7 dot-matrix format.

The software can adjust the green or neon-orange characters to three brightness levels. The module accepts RS-232C or RS422 data at 1200 or 9600 baud. The unit supports CTS (clear to send) and DTR (data terminal ready) signals and can detect parity and rate errors in transmission. Options include mounting subpanels, drip-proofing, and EMI/RFI shielding. Neon-orange or red display, $1089; green display, $1242 (100).

IEE Inc, 7740 Lemona Ave, Van Nuys, CA 91409. Phone (818) 787-0311. FAX 818-902-3723. TLX 4720556. Booth Nos 2160 and 2162.

Circle No 671



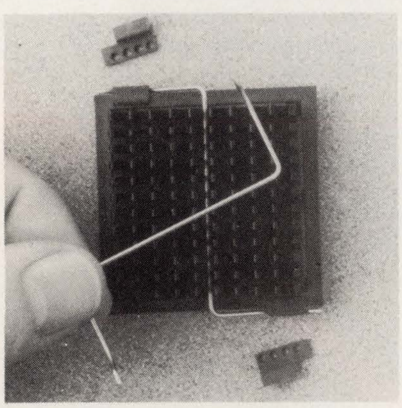
OP AMP

The AD846 op amp uses current feedback to provide a 46-MHz gain-bandwidth product at a gain of −1 and 31 MHz at a gain of −10. Settling time to 0.01% equals 110 nsec for a 10V step. The offset voltage measures 75 μV, and the offset voltage drift is 3.5 μV/°C; the open-loop transimpedance measures 200 MHz. Although the quiescent current measures only 6 mA, the AD846 delivers as much as 65 mA of output current. Input voltage noise equals 2 nV/$\sqrt{\text{Hz}}$; input current noise for the inverting and noninverting inputs measures 20 pA/$\sqrt{\text{Hz}}$ and 6 pA/$\sqrt{\text{Hz}}$, respectively.

The total harmonic distortion of 0.0005% at 100 kHz makes the AD648 well suited for high-performance audio-circuit applications. To implement the AD648, you use the source and feedback resistors to set the dc transfer function. However, the feedback resistor alone determines the closed-loop ac response. This eliminates the usual design tradeoffs between required gain and achievable bandwidth. The device is available in plastic mini-DIPs, hermetic ceramic DIPs, and hermetic metal cans. Two operating ranges are available: −40 to +85°C and −55 to +125°C. From $7.45 (100).

Analog Devices, Literature Center, 70 Shawmut Rd, Canton, MA 02121. Phone (617) 935-5565. Booth No 2518.

Circle No 673



HEAT-SINK MOUNT

The E-Z Mount assembly provides a mechanical means of attaching a heat sink to a pin-grid array (PGA). Thus, it eliminates the mess and the thermal expansion problems associated with adhesive bonding. The assembly consists of a spring clip and either a plastic frame or shoes for the PGA. You start the assembly procedure by inserting the PGA into the frame. The spring fits into the heat sink and over the ridges of the frame, securely attaching the heat sink to the PGA.

The shoes are useful when board space is tight. The two shoes slip under the four outer pins of the PGA and the spring snaps onto the shoes rather than the frame. You then wave-solder the entire assembly to the board. Mounts are available for 11×11-, 14×14-, 15×15-, and 21×21-pin PGA packages. You can use this assembly for extruded-pin or radial-machined heat sinks. 15×15-pin mount, $0.40 (1000).

Thermalloy Inc, Box 810839, Dallas, TX 75381. Phone (214) 243-4321. TLX 203965. Booth No 3029.

Circle No 672

BOARD TESTER

Without any programming, the Model 900 Troubleshooter captures timing and intermittent faults as well as static device failures. It dynamically tests each digital IC on the unit under test (UUT) while in circuit and provides 10-nsec fault detection at data rates as high as 20 MHz. The board tester tests each IC on the UUT by comparing its performance with that of a known-good reference chip. It automatically synchronizes the test device and the reference chip before beginning the test. This procedure eliminates the need to define test vectors or even to describe the devices. You simply plug in the reference chip and clip the Model 900 to the chip under test in the UUT. The unit can test standard chips from SSI to VLSI, RAM and ROM, and custom PALs, ASICs, and gate arrays. The tester is equipped with an RS-232C port and data-logging software that allows you to upload data to an IBM PC. $7990.

John Fluke Mfg Co Inc, Box C9090, Everett, WA 98206. Phone (800) 443-5853, ext 88; in WA, (206) 347-6100. TWX 910-445-2943. Booth No 1559.

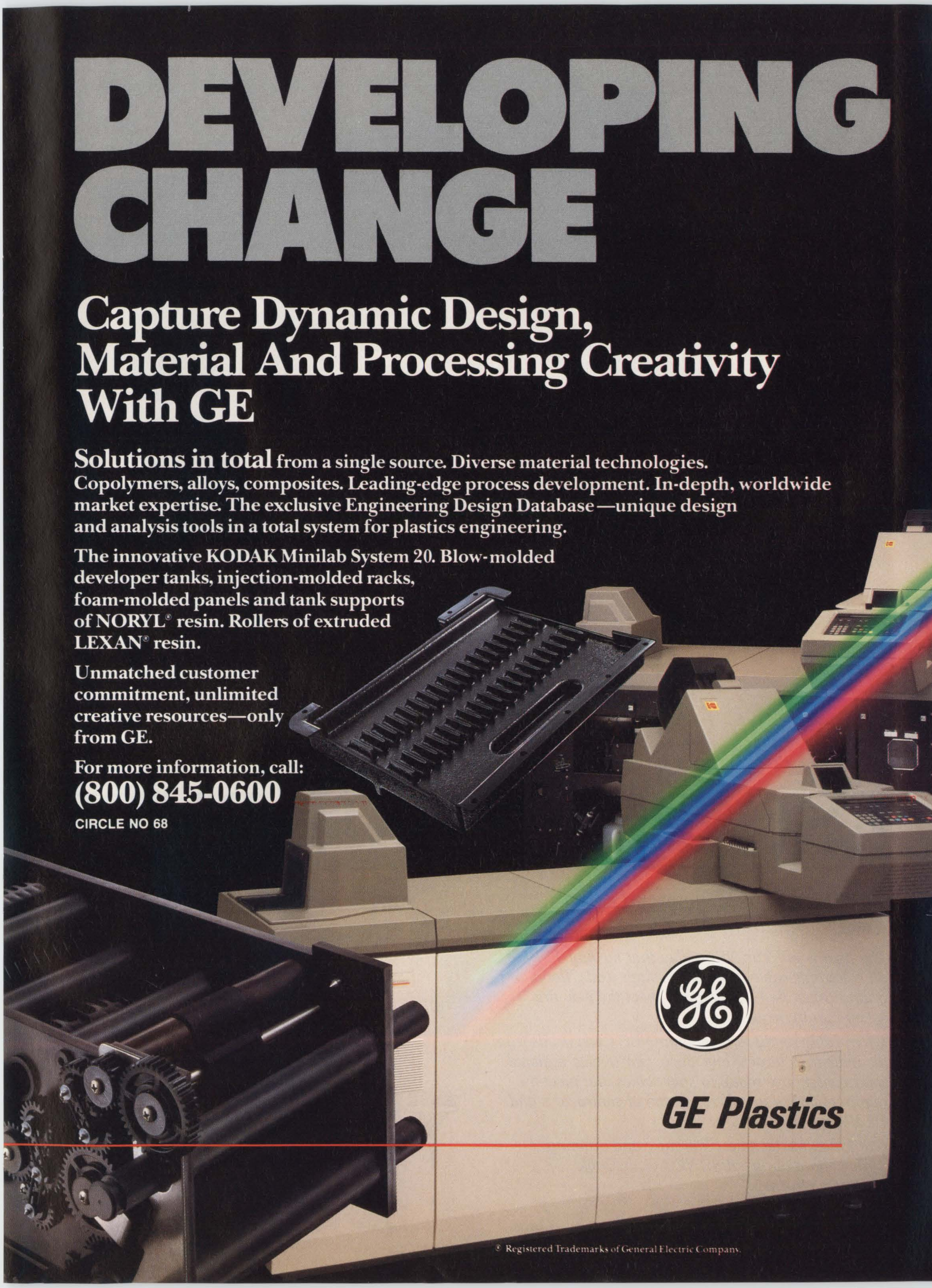
Circle No 675

DISPLAY MODULE

The Model LT1441M, a multicolor display module, uses high-luminosity LEDs to improve visibility in outdoor applications. Completely prepackaged, the module is ready to plug in, program, and play. The LEDs used in the 16×16 array are dichromatic, producing red, green, and orange-yellow colors. This feature, combined with the ability to stack the modules side-by-side or end-to-end, makes the LT1441M a suitable choice for many applications. Each LT1441M display module features a built-in shift register, latch circuits, and low-power CMOS driver ICs. The modules require only 5V of power and a serial control input. The device's lifetime measures 2000 hours. Mounting posts are located in each corner on the back of the module. $545.20.

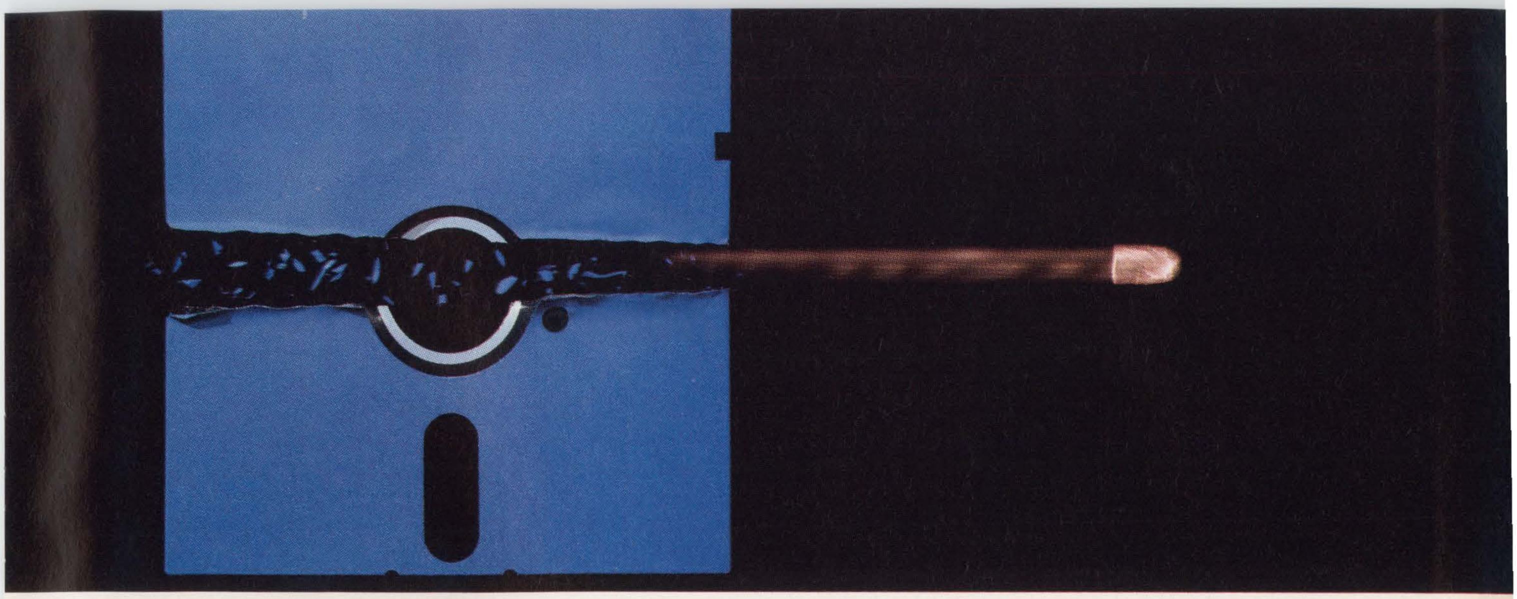
Sharp Electronics Corp, Microelectronics Div, Sharp Plaza, Mahwah, NJ 07430. Phone (201) 529-8757. FAX 201-529-8759. Booth No 2859.

Circle No 674



DEVELOPING CHANGE
Capture Dynamic Design, Material And Processing Creativity With GE
Solutions in total from a single source. Diverse material technologies. Copolymers, alloys, composites. Leading-edge process development. In-depth, worldwide market expertise. The exclusive Engineering Design Database—unique design and analysis tools in a total system for plastics engineering.
The innovative KODAK Minilab System 20. Blow-molded developer tanks, injection-molded racks, foam-molded panels and tank supports of NORYL® resin. Rollers of extruded LEXAN® resin.
Unmatched customer commitment, unlimited creative resources—only from GE.
For more information, call:
(800) 845-0600
CIRCLE NO 68
GE Plastics
® Registered Trademarks of General Electric Company.


UL TYPE CL2
UL TYPE CL 2
UL TYPE FPL



NEW AVOCET C™ FOR MICROCONTROLLERS-A BREAKTHROUGH IN SPEED AND QUALITY.

Introducing Avocet C.™ Fast, *optimizing* cross-compilers that can cut microcontroller development time in half—without sacrificing code quality.

From concept to code in a fraction of the time.

Programming in C lets you concentrate on end results, not annoying details—so you get more done, faster. And rapid compilation takes the frustration out. But for microcontrollers, you need more than speed. You need tight, high-quality code.

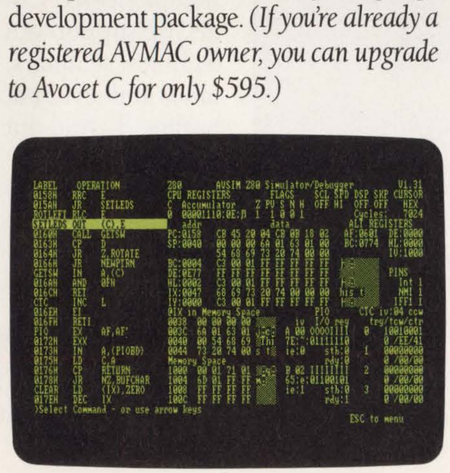
That's why we spent two years field-testing and perfecting Avocet C for both speed and quality. We built in three separate phases of optimization—for object code tight enough for real applications. And we integrated Avocet C with an assembler package that's mature in its own right—not an afterthought. So you can still work magic at the bits-and-bytes level.

Avocet C saves you time in all phases of development. Our run-time library is extensive—no need to write the routines yourself. You'll arrive at bug-free code faster, thanks to LINT-like type checking. And your program's useful life is extended, because you can recompile for other target chips.

Testing is easier, too. Avocet C is ANSI-standard—so you can test generic parts of your program with host-resident systems like Microsoft Quick-C™ and Codeview.™ And when you're ready for hardware-specific testing, Avocet's AVSIM Simulator/Debugger tests microcontroller code right on your PC.

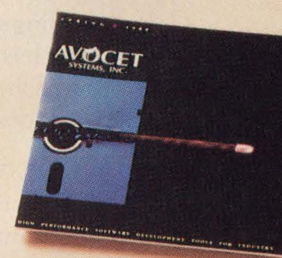
An excellent value.

Just $895 buys Avocet C for your favorite chip: Intel 8051 or 8096, Hitachi 64180, or Zilog Z80—with more to follow. And Avocet C includes the latest version of AVMAC—Avocet's super-fast, professional assembly-language development package. *(If you're already a registered AVMAC owner, you can upgrade to Avocet C for only $595.)*



The AVSIM Full-Screen Display

Free Catalog



Call Toll-Free 800-448-8500*

For your free Avocet catalog—to order—or for more information about Avocet C and other Avocet products.

The best technology—responsive, personal service.

Avocet offers a powerful, comprehensive approach to microcontroller development.

Avocet development tools put the most advanced technology at your fingertips. The Avocet staff stands ready to give you complete support—including technical assistance—on a moment's notice. And we'll ship your order in 48 hours or less.

Call 800-448-8500. Discover how Avocet can speed up your next project.

Avocet Systems, Inc., 120 Union Street
P.O. Box 490BP, Rockport, Maine 04856
*In Maine, or outside U.S., call (207) 236-9055
TLX: 467210 Avocet CI, FAX: (207) 236-6713

AVOCET
SYSTEMS, INC.®
THE SOURCE FOR QUALITY PERSONAL μP DEVELOPMENT TOOLS.

MORE ADC FLASH, ie:

'0820, MP7682, MP7683, MP7684, MP7685, MP7
'7688, MP7690, MP7783, MP0820, MP7682, MP7

Micro Power Systems—the USA's leading supplier of CMOS flash converters—has extended its ADC flash product line to now offer you a broader selection than ever before.

Our 6 to 11 bit converters offer:

- CMOS Technology for low power consumption and high reliability
- More Surface Mount Package Options (SO, PLCC and LCC) than anyone
- Lowest differential non-linearity for accurate conversions
- High Speed Processing to 11 bits with no offset or drift

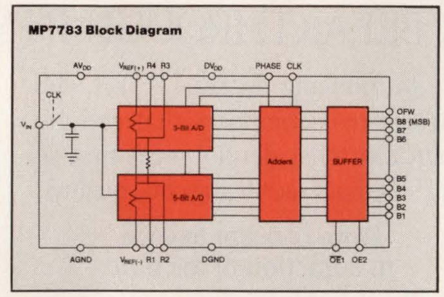
The Industry's Broadest Line of Flash ADC's

Device	Resolution (Bits)	Sampling Rate (MHz) (Typical)	DNL (+/− LSB)		Clock (MHz)	Power Dissipation (mW) (Typical)
MP7682	6	20.0	1/2	at	15.0	160
*MP7686	6	45.0	1/4	at	30.0	200
MP0820	8	0.5	1	at	2.0	80
*MP7783	8	2.5	1/4	at	2.5	75
MP7683	8	3.0	1/2	at	3.0	75
MP7690	8	20.0	1/2	at	10.0	250
MP7684	8	20.0	1/2	at	10.0	250
*MP7688	8	35.0	1/2	at	20.0	350
MP7685	11	2.0	2	at	1.0	100

*New product

Micro Power Systems' flash ADC s accommodate any board design and are TTL compatible. Their single supply operation simplifies design. Our flash converters can also provide pin compatibility, bit resolution, no missing codes, sampling rates to 30 MHz and full power bandwidths.

Micro Power offers more flash ADC s to fit your application needs:



Broadcast
- Time base correction and rebroadcast
- Video digitizing

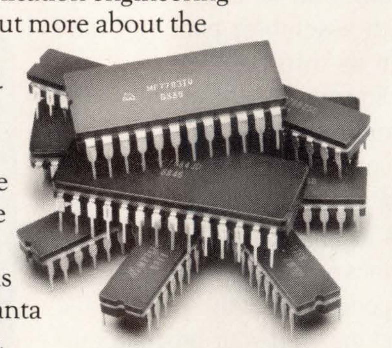
Data Acquisition
- Environmental control
- Process control

Computer
- FAX
- Scanner

Computer Peripherals
- Disk drive
- Tape drive

Medical
- Ultrasound imaging

Micro Power Systems is the company that pioneered CMOS flash converters. We support our products with technical seminars, application assistance and an application engineering hotline. To find out more about the broadest line of CMOS flash converters available, phone (408) 562-3615 or circle the reader service card number below. Or write us at 3151 Jay St., Santa Clara, CA 95054.



MICRO POWER SYSTEMS

DESIGNER'S GUIDE

dynamic RAMs
Part 1

Unraveling the intricacies of dynamic RAMs

Although designers often prefer dynamic RAMs (DRAMs) to their static counterparts, they sometimes shy away from using DRAMs because of the devices' added complexity. This article, part 1 of a 4-part DRAM series, sheds light on some of the complex issues surrounding DRAMs and describes the different DRAM architectures. The succeeding articles will cover memory-system architectures, DRAM controllers, and DRAM-board design.

Steve Gumm and Carl T Dreher,
Texas Instruments

When constructing a memory system, designers most commonly choose the dynamic RAM (DRAM) as the basic building block. The DRAM owes its popularity to the fact that it costs less than the static RAM (SRAM), yet has a higher bit density, an advantage that stems from the DRAM's simple, tiny memory cells. It's true that DRAMs require more housekeeping than SRAMs do: The term "dynamic" implies that the data in the memory cells must continually be accessed or refreshed to ensure that the stored data is valid. Nevertheless, DRAMs' lower cost and smaller size more than make up for any deficiencies.

A designer's first encounter with DRAMs can often be intimidating. The uninitiated engineer must confront such terms as "page-mode access," "static-column mode access," and "nibble-mode access," as well as "refresh rate," and "precharge period." The designer also faces a host of timing parameters, which can be perplexing. Even after you understand these bewildering terms, you must choose from among a vast number of options the DRAM architecture that best suits your needs.

The most common type of DRAM, which is classified as N×1, stores 1 bit of data in N addressable locations. Each device has a 1-bit input and a 1-bit output data bus. Current single-package bit densities for this family range from 16k bits to 1M bits; 256k bits is the most popular. Other less-common types include the N×4 and N×8 DRAMs, which have 4- and 8-bit data buses, respectively. Although this discussion is restricted to N×1 DRAMs, you can easily apply the information presented here to DRAMs with wider buses.

The difference between SRAMs and DRAMs

Accessing data in a DRAM is different from accessing data in an SRAM. The DRAM has a multiplexed-address arrangement, which conserves package space. To access data, a 256k-byte DRAM requires 18 addresses ($2^{18}=256k$). To accommodate these addresses on separate pins—along with the normal complement of pins for power, control, and I/O data—would require a 24-pin package. The DRAM has nine address lines (A_0 through A_8) and two strobe lines for accessing data. Essentially, the DRAM accesses a row and a column of an array by internally latching a row address with

Even though they require more housekeeping than SRAMs do, DRAMs' lower cost and component size more than make up for any deficiencies.

the Row Address Strobe (RAS) and a column address with the Column Address Strobe (CAS). Because both addresses are multiplexed onto the same pins, 256k-bit DRAMs come in 16-pin packages and 1M-bit DRAMs come in 18-pin packages.

Besides multiplexed addressing, the most significant differences between SRAMs and DRAMs are their refresh and precharge requirements. A DRAM's memory cell consists of a storage capacitor. When a charge is placed on this capacitor for data storage, the charge must be periodically refreshed; otherwise, the capacitor will discharge, invalidating the stored data. Some of the older 16k-bit DRAMs must be refreshed every 2 msec; newer 1M-bit DRAMs specify a 10-msec refresh rate.

The DRAM's architecture simultaneously refreshes all of the column cells for a selected row every time the row is accessed. Furthermore, some DRAMs reserve the most significant bit (MSB) as a select bit for an internal multiplexer that selects data in two banks of arrays. In these DRAMs, the lower address bits access the memory cells in both banks simultaneously. This arrangement cuts the required number of refresh cycles in half. For example, a 64k-bit DRAM, which has eight row- and column-address lines, requires a refresh cycle for only 128 rows instead of 256. Similarly, a 256k-bit DRAM requires only 256 cycles, and a 1M-bit DRAM requires only 512 cycles.

Another peculiarity of the DRAM is precharge. Performing a memory-read operation from a DRAM cell causes its capacitor to discharge slightly. Therefore, data must be written back into the cell after each read operation. This write-back operation is called "precharge" and is automatically handled by the DRAM. The time it takes to perform this operation is called the precharge period, and you must account for it when you determine the read-cycle time for the DRAM.

An N×1 DRAM has two pins, D and Q, for handling the input and output (I/O) data. In most of these DRAMs, the data-out line (Q) goes to the high-impedance state when inactive, so you can tie it to the data-input line (D) in order to handle bidirectional data. Other DRAMs require external 3-state buffers to handle bidirectional data. In order to conserve package size, N×4 and N×8 DRAMs share a set of bidirectional pins.

Perhaps the most intimidating features of DRAMs are their timing diagrams. Most of the turmoil centers on the sheer number of timing specifications and the combination of abbreviations used to describe them.

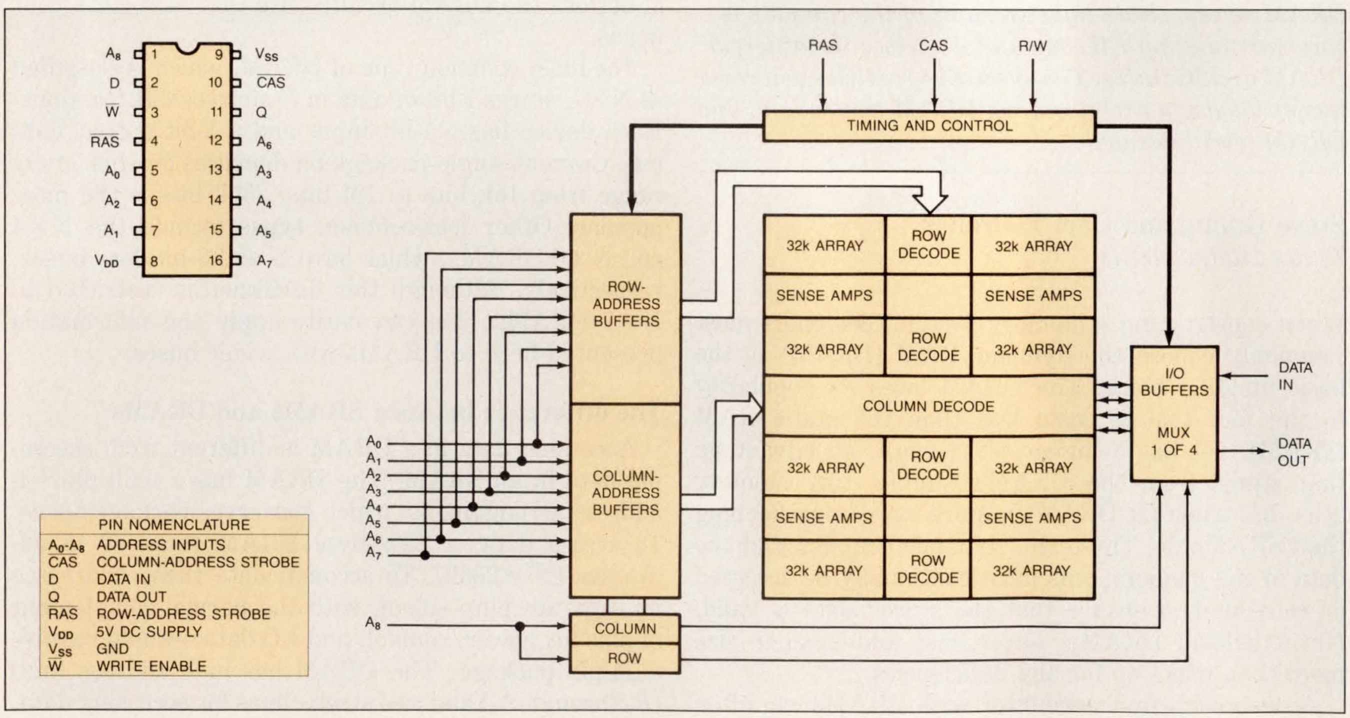


Fig 1—A DRAM's internal architecture *determines which of the variety of DRAM modes it can support. The TMS4256-12 DRAM, for example, has a 4-to-1 multiplexer that can access four memory arrays to support nibble-mode access.*

TABLE 1—PARAMETER ABBREVIATIONS

PARAMETER	ABBREVIATION
COLUMN OR $\overline{\text{CAS}}$	C
ROW OR $\overline{\text{RAS}}$	R
LOW SIGNAL	L
HIGH SIGNAL	H
ACCESS TIMES	a
HOLD TIMES	h
SETUP TIMES	su
PULSE WIDTH	w
READ OPERATION	rd
WRITE OPERATION	W
CYCLE	c
ADDRESSES	A
DATA	D

The abbreviations listed in **Table 1** will help you decipher the timing specifications. For example, the minimum pulse width during which the $\overline{\text{CAS}}$ line is low is abbreviated as "tw(CL)." The w indicates pulse width, the C indicates $\overline{\text{CAS}}$, and the L means "low." Similarly, the setup time for a row address is abbreviated as "tsu(RA)."

To accommodate a DRAM's timing requirements, the memory system requires a DRAM controller, which generates the control signals and interfaces the DRAM to the system's CPU. Some CPUs, such as the Z80, include a DRAM controller on chip. Most CPUs, however, require an external circuit that functions as the DRAM controller. The controller must coordinate the system access while guaranteeing that the DRAM is refreshed within its specified period. Ideally, the DRAM controller fools the system CPU into believing that it's communicating with an SRAM.

To use a DRAM effectively, you must pay attention to a number of timing parameters. The read cycle is probably the easiest of these parameters to understand, and it also demonstrates many of the DRAM's timing principles. **Fig 1** shows the timing parameters for a 256k-bit DRAM (the TMS4256-12).

Reading and writing

A read cycle begins when the controller issues a row address and drives the $\overline{\text{RAS}}$ line low, thus strobing the address into the DRAM. The address must be stable for tsu(RA) seconds (row-address setup time) before the falling edge of the $\overline{\text{RAS}}$ line, and it must remain stable for a minimum of th(RA) seconds (row-address hold time) after the falling edge **(Fig 2a)**. The $\overline{\text{RAS}}$ line must remain low during the entire read cycle. Because the $\overline{\text{CAS}}$ line not only strobes in the column address but also enables the output buffer, it should be high when strobing the row address into the DRAM. Keeping the $\overline{\text{CAS}}$ line high ensures that the Q output is in a high-impedance state.

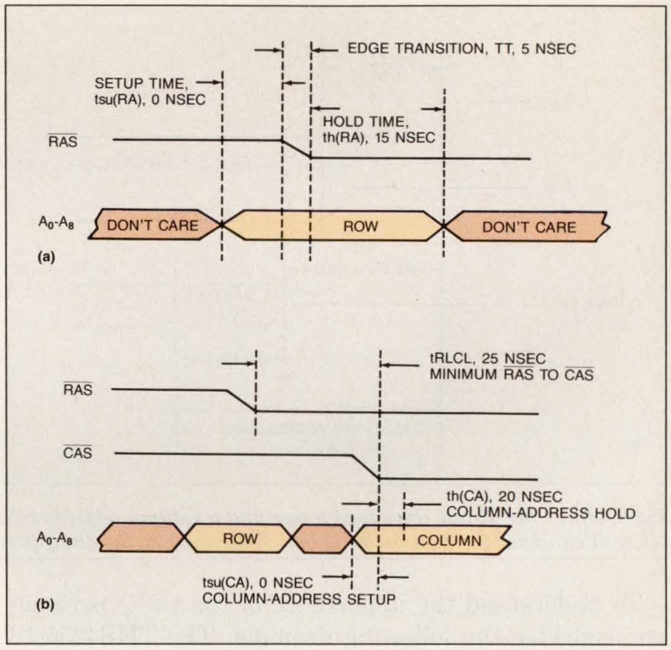


Fig 2—The timing diagrams for a DRAM's read cycle illustrate *many of the device's timing constraints. The timing parameters shown here are for the TMS4256-12 DRAM's $\overline{\text{RAS}}$ **(a)** and $\overline{\text{CAS}}$ **(b)** lines, which strobe a row and a column address, respectively, into the DRAM.*

Next, the controller must issue a column address to the DRAM. Once the column address is stable for the minimum setup time of tsu(CA) seconds, the controller drives the $\overline{\text{CAS}}$ line low to strobe the address into the DRAM. The falling edge of the $\overline{\text{CAS}}$ line should not occur any sooner than tRLCL (RAS-low to CAS-low time) seconds after the falling edge of the $\overline{\text{RAS}}$ line **(Fig 2b)**. Because the $\overline{\text{CAS}}$ line also enables the output buffer, the $\overline{\text{WRITE}}$ line should be high in order to activate the read cycle when $\overline{\text{CAS}}$ is low. After the falling edge of the $\overline{\text{CAS}}$ line, there is an access delay of ta(C) seconds before the output buffer is enabled.

To ensure that the output data is valid, you must observe one more critical timing parameter, ta(R). This parameter specifies the minimum time that must elapse after the falling edge of the $\overline{\text{RAS}}$ line before the output data is valid. Even though the controller satisfies the requirements for the other delays, such as ta(C), the output data is not valid until ta(R) seconds. For this reason, manufacturers quote ta(R) when specifying a DRAM's speed.

The DRAM's multiplexed-address arrangement conserves package size.

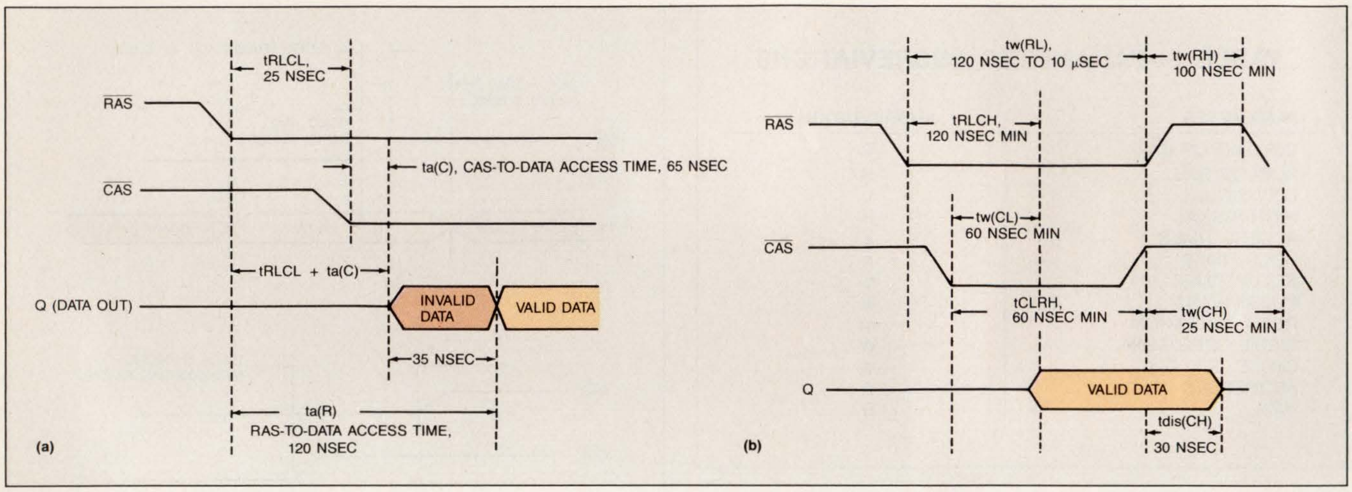


Fig 3—Once the strobe lines load a row and a column address into the DRAM, *the controller must wait until the data becomes valid **(a)** before it can read the data on the Q bus. After reading the data, the controller resets the strobe lines high **(b)**.*

To understand the importance of the ta(R) parameter, consider the following example. The TMS4256-12 DRAM specifies a minimum time of 25 nsec for the tRLCL parameter, and it specifies ta(C) as 60 nsec. Therefore, data appears at the output 85 nsec after the falling edge of the RAS line. However, the DRAM's ta(R) specification is 120 nsec. Even though data is available at the output 85 nsec after the falling edge of the RAS line, it is not valid until 120 nsec after the falling edge—an additional 35 nsec **(Fig 3a)**.

To terminate the read operation, the controller must bring the RAS and CAS lines high. Each line, however, must remain low for a minimum pulse width (tw(RL) and tw(CL), respectively) before returning to the high state. For the TMS4256-12 DRAM, tw(RL) and tw(CL) are specified as 120 nsec and 60 nsec, respectively. In addition, the RAS line should not return high until tCLRH seconds (CAS-low to RAS-high time) after the falling edge of the CAS line. Similarly, the CAS line should not return high until tRLCH seconds (RAS-low to CAS-high time) after the falling edge of the RAS line. For the TMS4256-12, tCLRH and tRLCH are 60 nsec and 120 nsec, respectively **(Fig 3b)**.

Returning the CAS line high disables the DRAM's output buffer. However, the output line is not in a high-impedance state until tdis(CH) seconds (disable time after CAS-high) after the rising edge of the CAS line. A typical value for tdis(CH) is 30 nsec.

Driving the RAS and CAS lines high does not completely terminate the read cycle. The next cycle can't begin until the DRAM automatically writes data back into the previously accessed location during the precharge period. The precharge period occurs while both the strobe lines are held high for a minimum specified pulse width, tw(RH) and tw(CH). For the TMS4256-12 DRAM, tw(RH) is 100 nsec and tw(CH) is 25 nsec. Because tw(RH) is longer, you must observe it when calculating the read-cycle time.

The only restrictions placed on the WRITE line during the read cycle are that it must be high for tsu(rd) seconds before the falling edge of the CAS line, and that it must remain high for th(CHrd) seconds after the rising edge of the CAS line. Because the TMS4256-12 specifies these times as 0 nsec, the WRITE line must simply be high during the time that CAS is low.

You can now piece together the timing parameters for determining the DRAM's minimum read-cycle time. Because ta(R) is longer than the sum of tRLCL and ta(C) for the TMS4256-12, it dominates this portion of the cycle. The remainder of the cycle consists of the 25-nsec tw(CH), the 100-nsec tw(RH), the 60-nsec tCLRH, and 30-nsec tdis(CH) minimum time periods. Because all of these time periods occur simultaneously, and tw(RH) is the longest period that must be maintained, the read cycle consists of the sum of ta(R) and tw(RH), or 120 + 100 = 220 nsec. Strictly speaking, you should add the maximum time allotted for the RAS to make a transition between logic levels; this maximum time is specified as 5 nsec. Adding 5 nsec for each of the cycle's two transitions produces a minimum read-cycle time of 230 nsec **(Fig 4)**.

Writing to a DRAM involves most of the same timing parameters that a read operation does. The primary difference between the read and write operations lies in the timing parameters associated with the $\overline{\text{WRITE}}$ line. Essentially, you can use one of two methods to write to a DRAM—the early-write cycle or the delayed-write cycle. Your choice of write cycle will depend on your application (see **box,** "Weigh early- vs delayed-write cycles").

The early-write and delayed-write cycles are distinguished by whether the $\overline{\text{WRITE}}$ line is asserted before or after the $\overline{\text{CAS}}$ line is asserted. During an early-write cycle, the controller drives $\overline{\text{WRITE}}$ low prior to driving $\overline{\text{CAS}}$ low. Fundamentally, the falling edge of the $\overline{\text{CAS}}$ line strobes the input data into the DRAM and acts as a reference for the address setup and hold times. During a delayed-write cycle, $\overline{\text{WRITE}}$ strobes the data into the DRAM after the controller asserts the $\overline{\text{CAS}}$ line low. The address setup and hold times are referenced to the falling edge of the $\overline{\text{WRITE}}$ line.

During a delayed-write cycle, $\overline{\text{CAS}}$ is low for a certain time while $\overline{\text{WRITE}}$ is high, so the output drivers are briefly enabled as if the DRAM were executing a read operation. Therefore, unless the memory array has separate input and output buses, the delayed-write operation can cause bus conflicts **(Fig 5)**. In the early-write cycle, the output drivers are not enabled, because the controller asserts the $\overline{\text{WRITE}}$ line low before setting the $\overline{\text{CAS}}$ low. Therefore, you can tie the D input line directly to the Q output line in order to accommodate a bidirectional bus.

The $\overline{\text{WRITE}}$ line must remain low for at least the period specified by tw(W). (For the TMS4256-12, tw(W) is specified as 40 nsec.) During a delayed-write cycle, the $\overline{\text{WRITE}}$ pulse must also remain low for tw(CLW) and tw(RLW) seconds after the falling edges of the $\overline{\text{CAS}}$ and $\overline{\text{RAS}}$ lines, respectively. (For the TMS4256-12, tw(CLW) is 35 nsec, and tw(RLW) is 95 nsec.) Further, the falling edge of the $\overline{\text{WRITE}}$ line must occur at least tsu(WCH) and tsu(WRH) seconds, respectively, before the $\overline{\text{CAS}}$ and $\overline{\text{RAS}}$ lines return to their high states. Both these setup times are specified as 40 nsec for the TMS4256-12 DRAM.

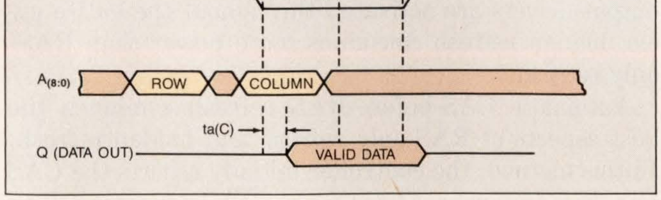


Fig 4—Before the controller can execute two successive reads, it must wait for the DRAM to refresh the previously accessed cell during the precharge period. The minimum read-cycle time for the TMS4256-12 DRAM—230 nsec—includes a 100-nsec minimum precharge period.

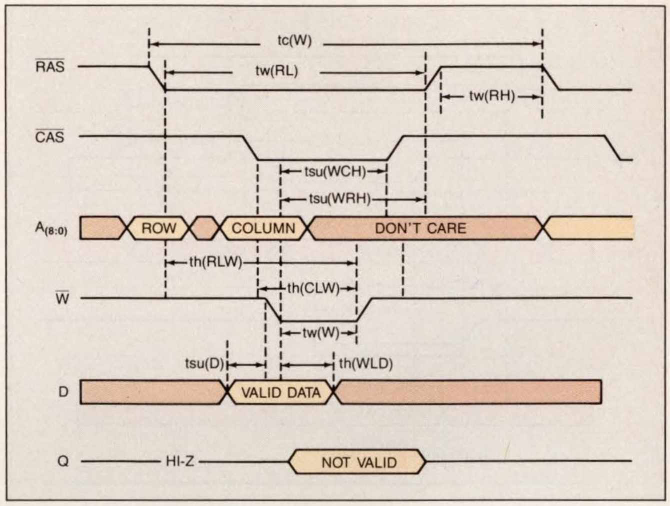


***Fig 5—The timing parameters for the delayed-write cycle** are appealing for many applications. However, asserting $\overline{\text{CAS}}$ while the $\overline{\text{WRITE}}$ line is high causes the DRAM's output buffers to turn on, which, in turn, causes a potential bus conflict.*

In a delayed-write cycle, the data must be stable for at least tsu(D) seconds before the falling edge of the $\overline{\text{WRITE}}$ pulse, and it must remain stable for at least tw(WLD) seconds after the same falling edge. The TMS4256-12 specifies tsu(D) as 0 nsec and tw(WLD) as 35 nsec. Because there is no time limit on the $\overline{\text{WRITE}}$ pulse after the $\overline{\text{CAS}}$ line is driven low, the write operation can be delayed for as long as the refresh period demands.

Don't forget to write

The difference between the early-write cycle and the delayed-write cycle lies mainly in the data setup and hold requirements. In the early-write cycle, the data must be stable for at least tsu(D) seconds before the falling edge of the $\overline{\text{CAS}}$ line. In addition, the data must remain stable for at least tw(CLD) seconds after this falling edge and also for tw(RLD) seconds after the falling edge of the $\overline{\text{RAS}}$ line. The th(CLD) and th(RLD) specifications for the TMS4256-12 are 35 nsec

Besides multiplexed addressing, the most significant differences between SRAMs and DRAMs lie in the devices' refresh and precharge requirements.

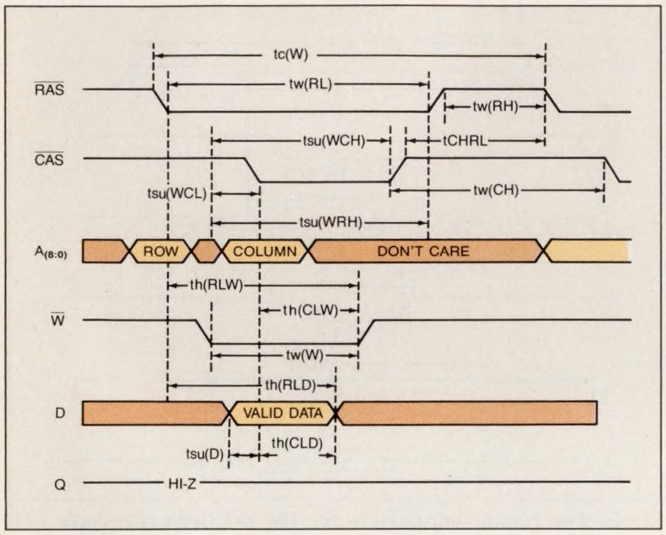


***Fig 6—In the early-write cycle, the DRAM controller drives the $\overline{\text{CAS}}$ line low** after it sets the $\overline{\text{WRITE}}$ line low. Therefore, the DRAM's Q-output buffers remain in the high-impedance state.*

and 95 nsec, respectively. **Fig 6** shows a complete early-write cycle.

Like the read-cycle time, the minimum tw(RL) time exceeds the sum of the other overlapping timing parameters once the controller drives the $\overline{\text{RAS}}$ line low. Therefore, you calculate the minimum write-cycle time (tw(W)), by simply adding tw(RL), tw(RH), and the edge-transition times. The minimum write-cycle time for the TMS4256-12 is 230 nsec ($120+100+2\times5=230$). Because tw(RL) is the dominant write-cycle timing parameter, the minimum write-cycle time is the same for both the early- and the delayed-write cycles.

Before you can read or write to a DRAM, the DRAM controller must execute a power-up sequence that initializes the data in the DRAM. The sequence consists of a short delay followed by a number of write cycles, which charge the memory-cell capacitors. The TMS4256 specifies the delay as 200 μsec plus eight initialization cycles. If you don't include the power-up sequence in the design, a diagnostic test will erroneously detect failures in a perfectly good memory system.

The pause that refreshes

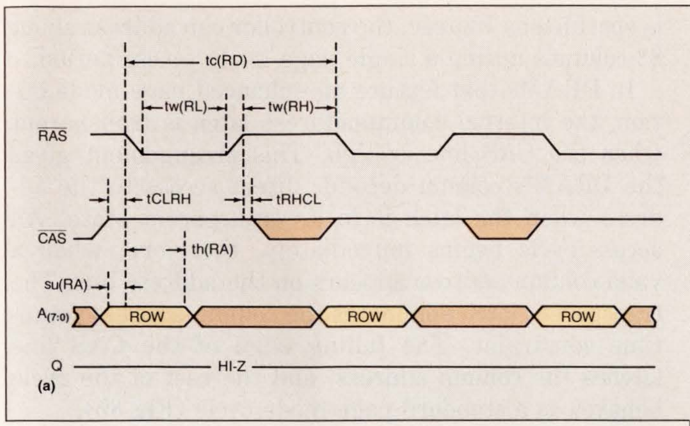
The DRAM controller's highest priority task is to ensure that the DRAM experiences a complete refresh cycle during the specified refresh period. A refresh can occur through a read or write operation or through a specific refresh operation. The TMS4256-12 specifies a refresh period of 4 msec. Because the DRAM's internal architecture has two simultaneously addressed memory banks, the controller needs to refresh only 256 rows during the 4-msec period.

When the controller accesses a row during the refresh cycle, it must adhere to the same timing constraints that it observes for the read and write cycles. Therefore, refreshing all the rows in the TMS4256-12 DRAM takes 256×230 nsec$=58.8$ μsec. This worst-case refresh-cycle time (58.8 μsec) occupies 1.5% of the allotted 4-msec refresh period. Slower versions of the same DRAM have the same 4-msec refresh-period specification, but occupy a greater bandwidth because of the longer access times.

RAS-only refresh is one of a variety of methods for refreshing DRAMs. In this method, the controller holds the $\overline{\text{CAS}}$ line high while using the $\overline{\text{RAS}}$ line to strobe a row address into the DRAM. The controller remembers which rows have been accessed during a refresh period to ensure that it services all the rows **(Fig 7a)**. The DRAM's output drivers are never enabled during a refresh, because the $\overline{\text{CAS}}$ strobe is always high. The minimum time it takes to refresh an entire row is the same as the minimum read-cycle time.

The hidden-refresh method attempts to make refreshing transparent by inserting a refresh cycle when the CPU is decoding an op code after a memory read **(Fig 7b)**. For many of today's high-speed μPs, this method is too slow to be practical. The controller initiates the refresh by strobing a row and a column address into the DRAM during a standard memory-read operation. However, instead of going high again at the end of the cycle, the $\overline{\text{CAS}}$ line remains low, latching the output data on the Q bus. Subsequently, the controller toggles the $\overline{\text{RAS}}$ line, causing the DRAM to generate a row address internally. The DRAM contains an internal address generator that sequentially generates a row address on each rising edge of the $\overline{\text{RAS}}$ line when the $\overline{\text{CAS}}$ line is low. During this time, the DRAM ignores the external address bus. Because the DRAM's output drivers are activated throughout the entire cycle, hidden refresh consumes more power than RAS-only refresh.

Automatic CAS-before-RAS refresh combines the best aspects of RAS-only refresh and hidden refresh. In this method, the controller initially asserts the $\overline{\text{CAS}}$ line low before asserting the $\overline{\text{RAS}}$ line low. The DRAM's internal address generator then sequentially generates the row addresses after the controller has toggled the $\overline{\text{RAS}}$ line. Because this method asserts the $\overline{\text{CAS}}$ line low when the $\overline{\text{RAS}}$ line is high, the DRAM's



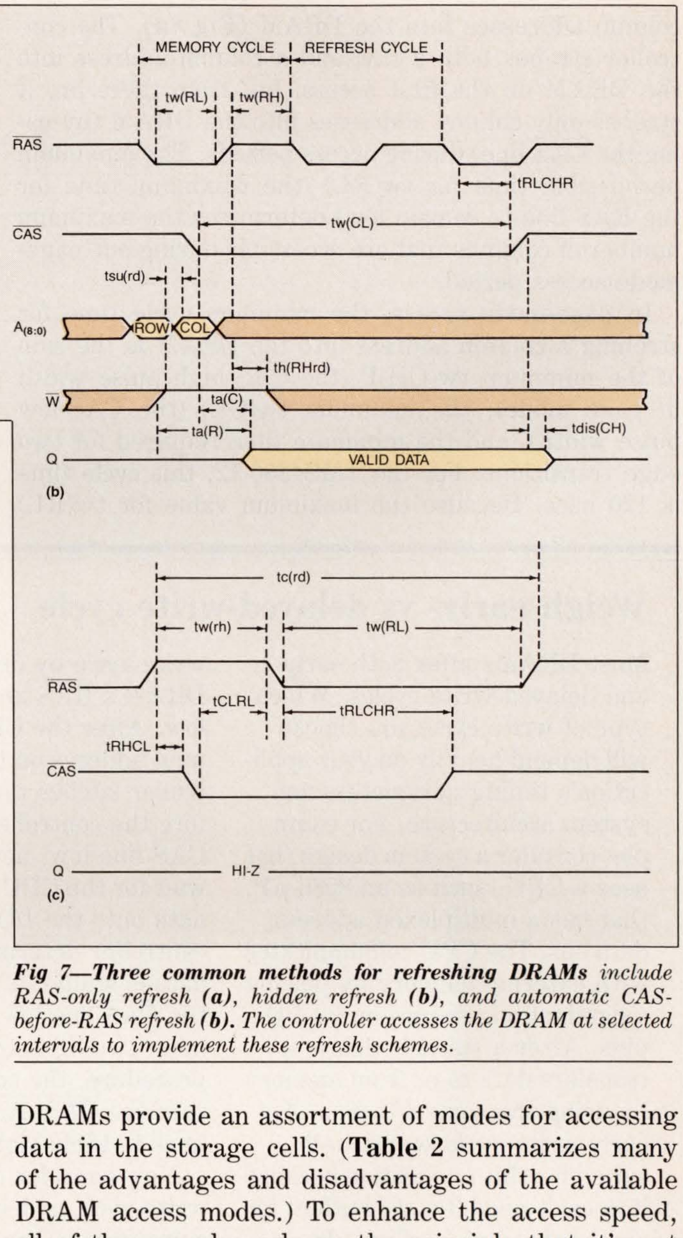


*Fig 7—**Three common methods for refreshing DRAMs** include RAS-only refresh **(a)**, hidden refresh **(b)**, and automatic CAS-before-RAS refresh **(b)**. The controller accesses the DRAM at selected intervals to implement these refresh schemes.*

output drivers are not enabled, and the DRAM maintains low power consumption (**Fig 7c**).

Tradeoffs, tradeoffs, tradeoffs

The previous refresh methods access the rows in the DRAM at selected intervals within the refresh period. For example, a controller can refresh a TMS4256-12 by using RAS-only refresh every 4 msec/256 = 15.6 μsec. The controller must contain a row sequencer in order to implement RAS-only refresh. At selected intervals, it must multiplex the row sequence to the address bus. Hidden-refresh and automatic CAS-before-RAS refresh rely on the DRAM's having an internal row sequencer; the controller design is therefore less complicated.

Instead of refreshing the DRAM at selected intervals, burst refresh rejuvenates all the rows in one burst. Although this method furnishes the CPU with a longer period of uninterrupted access time, it produces a very long latency period if the CPU desires access to the DRAM during the refresh burst. Therefore, burst refresh is used only in applications in which the long uninterrupted access time is a must.

Some refresh methods even scrub the data in the DRAM, occasionally removing any soft errors incurred over time. DRAMs are more susceptible to soft errors than are SRAMs. Soft errors are often caused by alpha particles that are emitted by radioactive impurities in a DRAM's package. Although the probability of an individual soft error is small, the cumulative probability of an error increases as the memory size increases. During a scrubbing refresh cycle, the controller reads the accessed data and provides error detection and correction (EDC). The controller then rewrites any corrected data back into the DRAM.

Besides offering various refresh methods, modern DRAMs provide an assortment of modes for accessing data in the storage cells. (**Table 2** summarizes many of the advantages and disadvantages of the available DRAM access modes.) To enhance the access speed, all of these modes rely on the principle that it's not necessary to strobe both the row and the column addresses into the DRAM when you access small portions of consecutive memory space. By eliminating some of the address strobes, these access modes shorten the overall access time and reduce the overall precharge time. Because most DRAMs support only one option, the DRAM controllers for a particular design are often unique, preventing you from mixing DRAMs that have different access modes.

Page-mode memory access establishes a constant row address, while the controller strobes a series of

Performing a read operation from a DRAM cell causes the capacitor to discharge slightly.

column addresses into the DRAM (**Fig 8a**). The controller strobes both a row and a column address into the DRAM on the first access, but from there on, it strobes only column addresses into the DRAM (by using the $\overline{\text{CAS}}$ line) during access periods. The maximum permissible time for tw(RL) (the maximum time for the $\overline{\text{RAS}}$ line to remain low) determines the maximum number of columns that are accessible during one page-mode access period.

In page-mode access, the minimum cycle time for strobing a column address into the DRAM is the sum of the minimum tw(CH)P (the $\overline{\text{CAS}}$-high pulse width in page mode), the minimum tw(CL) (the $\overline{\text{CAS}}$-low pulse width), and the minimum time required for two edge transitions. For the TMS4256-12, this cycle time is 120 nsec. Because the maximum value for tw(RL) is specified as 10 μsec, the controller can address about 83 columns during a single page-mode access period.

In DRAMs that feature an enhanced page-mode option, the internal column-address latch is transparent when the $\overline{\text{CAS}}$ line is high. This arrangement gives the DRAM's column decoder direct access to the address when the latch is in its transparent state. An access cycle begins immediately, therefore, when a valid column address appears on the address bus. The transparent latch eliminates the column-address setup-time constraint. The falling edge of the $\overline{\text{CAS}}$ line latches the column address, and the rest of the cycle behaves as a standard page-mode cycle (**Fig 8b**).

Some DRAMs feature a static-column mode for high-speed read and write access. These DRAMs have a 3-state input column-address buffer instead of a col-

Weigh early- vs delayed-write cycle

Most DRAMs offer both early- and delayed-write cycles. Which type of write cycle you choose will depend heavily on your application's timing parameters and system architecture. For example, consider a system design that uses a CPU, such as an 8086 μP, that has a multiplexed address/data bus. The CPU communicates with external memory by placing a destination address on its I/O pins. After a suitable delay, it transfers data to or from memory by using the same I/O pins. An early-write cycle seems well suited for this application because it doesn't need 3-state buffers for eliminating bus conflicts. In either case, you need a DRAM controller to coordinate the action between the two devices.

In the early-write cycle, the CPU initiates a write cycle by placing a row address on its I/O pins. The DRAM controller, which is located between the CPU and the memory, latches the address and begins an early-write cycle by driving the DRAM's $\overline{\text{RAS}}$ and $\overline{\text{WRITE}}$ lines low. After the CPU places a column address on the bus, the controller latches the address. Before the controller can drive the $\overline{\text{CAS}}$ line low, however, it must wait for the CPU to multiplex the data onto the I/O pins. Once the controller determines that the data is stable, it can then drive the $\overline{\text{CAS}}$ line low for the minimum tw(CL) seconds. After this procedure, the controller can return the $\overline{\text{CAS}}$, $\overline{\text{RAS}}$, and $\overline{\text{WRITE}}$ lines to their high state.

Now consider using a delayed-write cycle under the same circumstances. Once again, the CPU initiates a write cycle by placing a row address on its I/O pins. The controller latches the address and begins a delayed-write cycle by driving the $\overline{\text{RAS}}$ line low. Because the controller holds the $\overline{\text{WRITE}}$ line high, it can issue a low on the $\overline{\text{CAS}}$ line while it's waiting for the data to stabilize. By driving the $\overline{\text{CAS}}$ line low, the controller enables the DRAM's output buffers. Therefore, your system requires additional 3-state buffers in order to prevent bus conflicts. When the controller detects that the data from the CPU is stable, it writes the data into the DRAM by driving the $\overline{\text{WRITE}}$ line low for a minimum of tw(WL) seconds during the remainder of the cycle.

In this sample application, the difference between an early-write cycle and a delayed-write cycle is the difference between the DRAM's minimum tw(CL) and tw(WL) specifications. The TMS4256-12 DRAM specifies the minimum tw(CL) time as 60 nsec and the minimum tw(WL) time as 40 nsec. For this application, therefore, the delayed-write cycle is the cycle of choice, even though it will force you to use additional hardware, because it's 20 nsec faster than the early-write cycle. For slower DRAMs, the difference can be even more pronounced.

TABLE 2—COMPARISON OF DRAM MODES

Group	MODE	ADVANTAGES	DISADVANTAGES
WRITE MODES	EARLY-WRITE	CAN TIE DRAM INPUT TO OUTPUT; NO 3-STATE BUFFER NEEDED	SLOWER THAN DELAYED-WRITE
	DELAYED-WRITE	FASTEST ACCESS	REQUIRES 3-STATE BUFFER
REFRESH MODES	RAS-ONLY	LOW POWER; ALL Q BUFFERS ARE IN HIGH-IMPEDANCE STATE	EXTERNAL CIRCUIT MUST GENERATE ROW ADDRESS
	HIDDEN	DRAM GENERATES ROW ADDRESS INTERNALLY, SIMPLIFYING DRAM-CONTROLLER DESIGN; REFRESH IS HIDDEN DURING SLOW CPU CYCLES	Q BUFFER IS ON DURING REFRESH; HIGHER POWER THAN RAS-ONLY; USEFUL ONLY FOR SLOW CPUs
	CAS-BEFORE-RAS	DRAM GENERATES ROW ADDRESS INTERNALLY, SIMPLIFYING DRAM-CONTROLLER DESIGN; LOW POWER	REQUIRES DRAMs THAT SUPPORT THIS MODE
	BURST	AFTER REFRESH BURST, MEMORY IS AVAILABLE FOR MAXIMUM REFRESH PERIOD (4 TO 15 mSEC)	DURING REFRESH BURST, MEMORY IS UNAVAILABLE; REQUIRES SPECIAL DRAM CONTROLLER
	SCRUBBING	PREVENTS SOFT ERRORS IN HIGH-RELIABILITY AND LARGE-MEMORY SYSTEMS	REQUIRES EXTERNAL EDC CIRCUITS; MEMORY ACCESS USUALLY SLOWER DUE TO EXTRA BUFFERS IN DATA PATH
ACCESS MODES	PAGE	LOW POWER; ALLOWS RANDOM ACCESS WITHIN ANY ROW; DOES NOT REQUIRE SPECIAL DRAMs	NEEDS SOPHISTICATED DRAM CONTROLLER; ACCESS USUALLY SLOWER WHEN CONTROLLER ACCESSES RANDOM ROWS
	ENHANCED PAGE	FASTER THAN PAGE-MODE SINCE COLUMN DECODE OCCURS BEFORE CAS; LOW POWER; ALLOWS RANDOM ACCESS WITHIN ANY ROW; DOES NOT REQUIRE SPECIAL DRAMs	NEEDS SOPHISTICATED DRAM CONTROLLER; ACCESS USUALLY SLOWER WHEN CONTROLLER ACCESSES RANDOM ROWS
	STATIC-COLUMN	VERY FAST ACCESS; ALLOWS RANDOM ACCESS WITHIN ANY ROW	HIGH POWER BECAUSE Q BUFFERS ARE ON BETWEEN ACCESSES; REQUIRES 3-STATE BUFFERS; NEEDS SOPHISTICATED DRAM CONTROLLER, SPECIAL DRAMs; ACCESS IS USUALLY SLOWER WHEN CONTROLLER ACCESSES RANDOM ROWS
	CYCLIC	FASTEST ACCESS FOR SYSTEMS DOING CACHE BURST FILL	NEEDS SPECIAL DRAMs, SOPHISTICATED DRAM CONTROLLER; IS SLOW IF ADDRESSES ARE NOT SEQUENTIAL

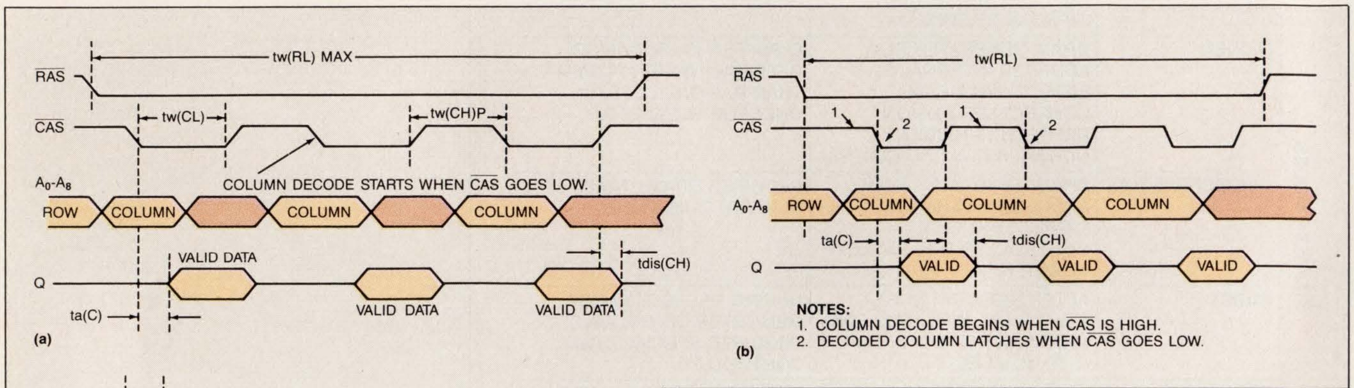
umn-address latch. When the $\overline{\text{CAS}}$ line is high, this input buffer is in the high-impedance state. The controller initiates the first static-column access by asserting the $\overline{\text{RAS}}$ line and then the $\overline{\text{CAS}}$ line. Holding both lines low throughout the access period, the controller accesses the subsequent columns by altering the column address. This method eliminates the setup, hold, transition, and precharge times associated with toggling the $\overline{\text{CAS}}$ line **(Fig 8c)**.

Because DRAMs inherently can't support both page-mode and static-column-mode access, you must choose the mode that best suits your system. Essentially, both modes provide the CPU with a low-cost cache memory by virtue of their fast access to a small block of the system's memory (there are many columns within a single row). One factor in your choice is access-mode speed. Although static-column mode is faster than page mode (because static-column mode eliminates some timing restrictions), the controller must alter the column address quickly enough to realize the speed advantage.

Power consumption is another consideration. Because the output buffers are continually enabled during static-column access, a DRAM that uses static-column mode consumes more power than does a DRAM that uses page-mode access. In either case, when there are frequent row changes, both modes can often be slower than direct read and write cycles because of the extra overhead in the DRAM controller.

The TMS4256 DRAM's architecture offers the use

Ideally, the DRAM controller fools the system CPU into believing that it's communicating with an SRAM.



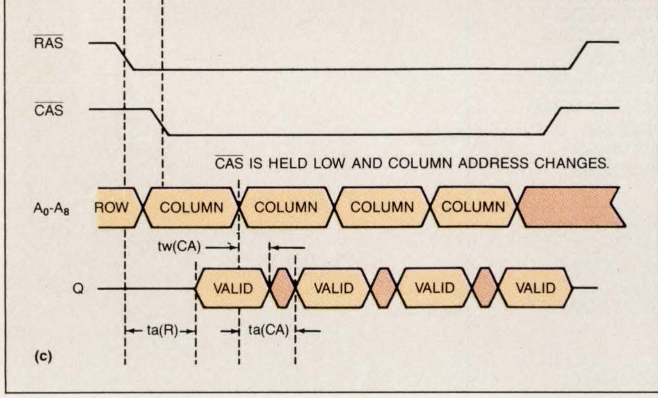


Fig 8—When designing a memory system, *you must choose from a number of access-mode options before selecting a DRAM for a particular application. To implement page-mode **(a)**, enhanced page-mode **(b)**, or static-column mode **(c)** access, for example, you require a controller that's customized to support the mode you choose.*

of nibble mode for reading and writing data. As shown in **Fig 1**, each of the DRAM's dual memory banks are further subdivided into dual 64k-bit blocks. Furthermore, the DRAM contains a 4-to-1 multiplexer, which selectively enables one of the four 64k-bit blocks. Bit A_8 for the row and column addresses determines which block is initially selected. After accessing an initial block, the controller indexes the other three blocks by toggling the $\overline{CAS}$ line three times while maintaining a low on the $\overline{RAS}$ line. Each falling edge of the $\overline{CAS}$ line exercises the multiplexer-select lines circularly through the following sequence:

$$\rightarrow (0,0) \rightarrow (0,1) \rightarrow (1,0) \rightarrow (1,1)$$

In this way, the controller can access 4 bits (a nibble) of data with one set of row and column addresses. Typically, the access time for the final 3 bits is 60 nsec/bit.

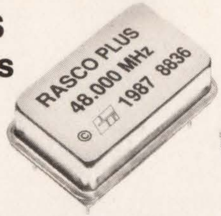
DRAMs offer two other modes of access: byte mode and serial mode. Byte mode is identical to nibble mode, except that in byte mode, the DRAM contains an 8-to-1 multiplexer. To select the initial block, the 8-to-1 multiplexer selects data from one of eight memory blocks based on address bits A_8 and A_9. Serial mode is similar to byte mode, except that in serial mode, the controller can sequentially access all of the columns for a particular row address by toggling the $\overline{CAS}$ line. In serial mode, for example, a controller can access 512 bits in a 256k-bit DRAM (arranged as a 512-row × 512-column array) by simply establishing a row address and toggling the $\overline{CAS}$ line 511 times (after the initial access).

Some access-mode comparisons

In sum, your application will ultimately determine the access mode you choose. All the modes have advantages and disadvantages, and the tradeoffs they present are the familiar ones: performance vs cost and complexity. Page-mode access, for example, requires one row and a separate column address for each location in the DRAM, whereas nibble mode requires only one address and four $\overline{CAS}$ strobes to access data. Therefore, nibble mode is faster than page mode for short, sequential read operations such as fetching 4 bytes of data for a 32-bit CPU via an 8-bit port. However, nibble mode requires a precharge period when the $\overline{RAS}$ line returns high after four successive reads.

Because page mode holds the $\overline{RAS}$ line low throughout the access period, it's well suited to long, uninterrupted data transfers. Although nibble mode may be faster than page mode for long data transfers, when the DRAM controller employs nibble mode it must supply a new set of addresses on every fourth transfer. In addition, page mode can randomly access the columns within a row, whereas nibble-mode access is sequential.

RASCO© PLUS Oscillator Drives CMOS up to 50 MHz



From 1.25 to 50 MHz, drives high speed microprocessors (68020, 68030, 80386, etc.), with ±0.01% stability from 0° C to +70° C. TTL compatible (up to 5 gates), or CMOS compatible (50 pF load). Optional ±0.005% stability, enable/disable. Optional tight symmetry to 50 MHz TTL, or to 20 MHz in CMOS.
John Keilman, 312-451-1000

MSO Surface Mount Data Clocks from 1.25 to 35 MHz

Hermetically sealed ceramic package only 0.560" by 0.360" with 0.160" seated height. "C" lead configuration. Tape-and-reel or anti-static tubes for standard pick-and-place. Vapor phase or wave solder reflowable. ±0.01% stability, CMOS or TTL compatible; 5,000g shock rating. Optional tight symmetry, enable/disable.
John Keilman, 312-451-1000

Crystal Controlled MSO Surface Mount Oscillators

pick & place from anti-static tube or 24mm tape & reel

- 1.25 to 35 MHz Frequency Range
- 0.560" by 0.360" (14,22 by 9,14 mm) footprint
- Compatible with high speed CMOS or TTL logic
- 5,000g Shock Rating
- Custom IC Chip – Fewer Components, Fewer Interconnects
- Optional Enable/Disable With CMOS or TTL

Automatic Placement - Ideal for use with the latest pick-and-place automated assembly equipment. Available with either tape and reel or anti-static tube packaging, MSO oscillators are vapor phase/wave solder reflowable.

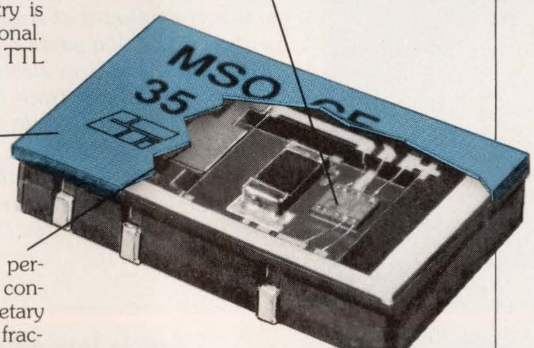
Product Features - Available over a frequency range of 1.25 to 35 MHz, with stability of ±0.01% over the temperature range of 0° C to +70° C. Symmetry is 40/60% standard, 45/55% optional. Compatible with either CMOS or TTL logic.

Total Ceramic Package - For better long term stabillity; provides more complete hermetic seal than available with most plastic packages.

5,000g Shock Rating - Uses AT strip crystal with mechanical shock performance greatly superior to that of conventional crystals – made by a proprietary process that avoids the edge faults, fractures, and weaknesses inherent to conventional processes.

Second Sourcing Available

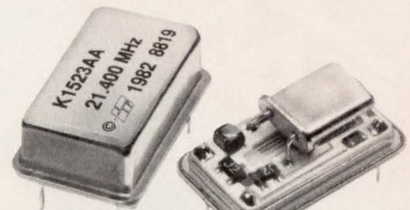
Custom IC Chip - patented custom IC chip replaces hybrid components , allows fewer processing operations and fewer circuit interconnects. Class 100 clean room, completely automatic processing, statistical process control, and 100% computer-automated testing provide uniform high quality and reliability.



Champion Technologies, Inc.

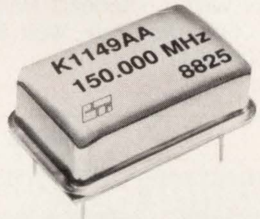
2553 N. Edgington Street, Franklin Park, IL 60131 (312) 451-1000
FAX: 312-451-7585 EasyLink: 62931824 TELEX: 499-0104 CTI UD

Voltage Controlled Oscillator for Phase Locked Loop



The K1523AA Voltage Controlled Crystal Oscillator allows system designer to phase lock to a reference standard. For LANs, computer shared management systems, communications, A/D interface. 3 MHz to 35 MHz, ±50 ppm per volt sensitivity. ±25 ppm stability. TTL or CMOS compatible.
John Keilman, 312-451-1000

ECL-Compatible Oscillator 40 to 150 MHz



MECL 10KH-based design for improved rise and fall times, duty cycle, noise margin, and power supply rejection. Open emitter output for user selection of load. Complementary outputs available, various pinouts also available.
John Keilman,312-451-1000

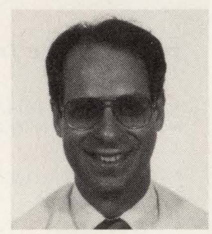
Miniature Memory Backup Battery

Rechargeable NiCd batteries use less area than a dime on a pc board, deliver 35 mAh of memory backup power. MMB "C" series batteries are available in 2.4, 3.6, or 4.8V EMF, with seated heights of .280", .450" and .650"; slightly larger "B" series batteries offer 110 mAh capacity. Can be wave soldered, no tie-downs needed.
John Keilman, 312-451-1000

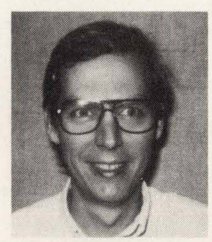
Static-column mode offers all of the speed advantages of nibble mode and also provides the random-access capability of page mode. Although static-column mode is more difficult to implement, it's rapidly becoming the mode of choice for high-speed memory systems.

Of course, a DRAM's cost, availability, packaging, and alternate sources will also weigh heavily in your choice of a memory unit for a particular application. Remember, however, that once you select a DRAM, your system's access mode is fixed. A page-mode DRAM, for example, can't operate in a system designed for static-column or nibble-mode DRAMs. You must customize the DRAM controller and the system architecture for your chosen access mode. EDN

Authors' biographies

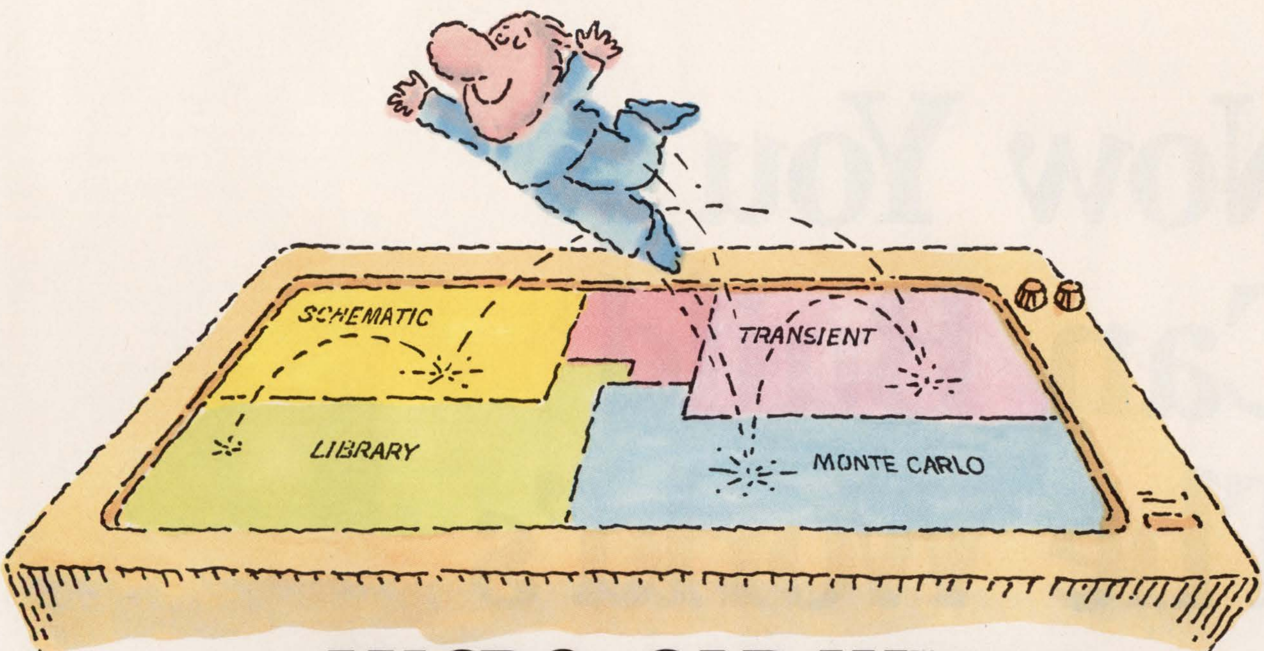


Steve L Gumm is a senior member of the technical staff at Texas Instruments' Information Systems & Services Div (Dallas, TX). He has been with the company for five years. Steve, who earned a BSEE in 1974 from the Tennessee Technological University, has also worked at General Dynamics and the Tennessee Valley Authority. He's currently a member of the IEEE Computer Society. Steve devotes some of his leisure hours to bicycling, scuba diving, and camping.



Carl T Dreher is a technical writer in the ASIC Marketing Div of Texas Instruments (Dallas, TX). He was previously self-employed at Analytic Instruments and is still a partner in that firm. Carl received a BS in electrical engineering and physics from Rose-Hulman Institute of Technology, and MS and PhD degrees from the University of Virginia. He holds three patents. In his spare time he teaches English ritual dancing and plays the concertina.

Article Interest Quotient (Circle One)
High 482 Medium 483 Low 484

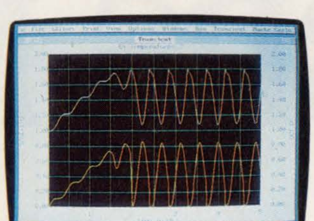


MICRO-CAP III.™
THIRD-GENERATION INTERACTIVE CIRCUIT ANALYSIS. MORE POWER. MORE SPEED. LESS WORK.

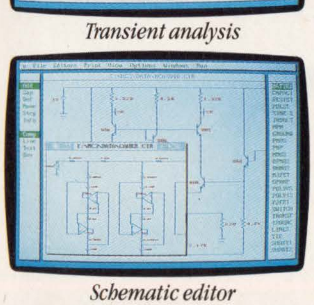
MICRO-CAP III,™ the third generation of the top selling IBM® PC-based interactive CAE tool, adds even more accuracy, speed, and simplicity to circuit design and simulation.

The program's window-based operation and schematic editor make circuit creation a breeze. And super-fast SPICE-like routines mean quick AC, DC, Fourier and transient analysis — right from schematics. You can combine simulations of digital and analog circuits via integrated switch models and macros. And, using stepped component values, rapidly generate multiple plots to fine-tune your circuits.

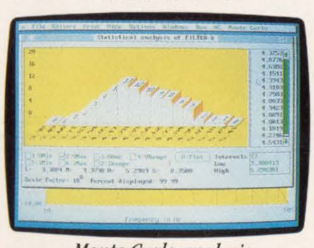
We've added routines for noise, impedance and conductance — even Monte Carlo routines for statistical analysis of production yield. Plus algebraic formula parsers for plotting almost any desired function.



Transient analysis



Schematic editor



Monte Carlo analysis

Modeling power leaps upward as well, to Gummel-Poon BJT and Level 3 MOS — supported, of course, by a built-in Parameter Estimation Program and extended standard parts library.

There's support for Hercules,® CGA, MCGA, EGA and VGA displays. Output for laser plotters and printers. And a lot more.

The cost? Just $1495. Evaluation versions are only $150.

Naturally, you'll want to call or write for a free brochure and demo disk.

spectrum

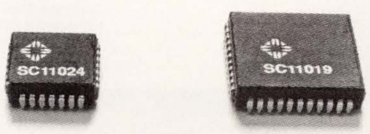
1021 S. Wolfe Road,
Sunnyvale, CA 94086
(408) 738-4387

MICRO-CAP III is a registered trademark of Spectrum Software.
Hercules is a registered trademark of Hercules Computer Technology.
IBM is a registered trademark of International Business Machines, Inc.

CIRCLE NO 121

Now You Can Build The World's Smallest, Lowest Power 2400 BPS Modem Using...

...Only Two Chips



(Actual Size) (Actual Size)

Great for battery operated, portable applications — especially lap tops. This remarkable 5.0 V chip set includes all the features you need in a 2400 BPS Hayes compatible modem.

This powerful pair consumes only 300mW when operating and less than 100mW in Auto Power Down.

The SC11019 controller's 16K bytes of ROM contains all code for DSP, Call Establishment and Command with plenty of space left over for customization. An on-board UART allows direct PC BUS interface.

The SC11024 modem's built-in Hybrid provides interface directly to the DAA. However, it can be disabled to allow for use of an external Hybrid. And there's an external port for EEPROM default memory.

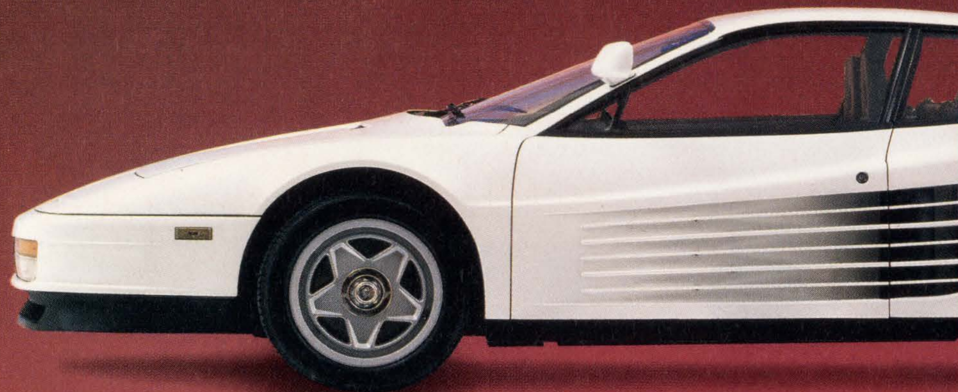
This pair isn't all we have — Sierra's Data Communications Products span the data rate range of 300 BPS to 14,400 BPS and conform to CCITT and Bell Standards. And we offer MNP solutions for error free communications.

FAX, Write or Call today for more information. Data Communications Marketing, Sierra Semiconductor, 2075 N. Capitol Avenue, San Jose, CA 95132. (408) 263-9300 FAX (408) 263-3337

Triple Technology™ In CMOS

SIERRA SEMICONDUCTOR

Now run on micropower without cutting corners



You wouldn't want compromises if you bought the classiest car in the world. So, we think you expect that same quality in your micropower op amp.

Our LT1078 dual and LT1079 quad micropower op amps are optimized for micropower operation. This means no sacrificing precision, noise, speed and output drive specifications in your 5V single supply or ±15V applications.

We've concentrated on reducing supply current (50μA max.) without affecting other parameters. Our 70μV max. offset voltage is the lowest for any non-chopper-stabilized dual or quad op amp, regardless of power consumption. The 1/f corner of the voltage noise spectrum is set at 0.7Hz—three times lower than any other monolithic op amp. You achieve a 0.1Hz to 10Hz noise performance of 0.6μV p-p found only on devices with an order of magnitude higher supply current.

Other features include: offset current of 250pA max., 0.4μV/°C drift, current noise of 3pA p-p, a slew rate of 0.07V/μs, gain bandwidth of 200kHz and guaranteed output drive of 5mA.

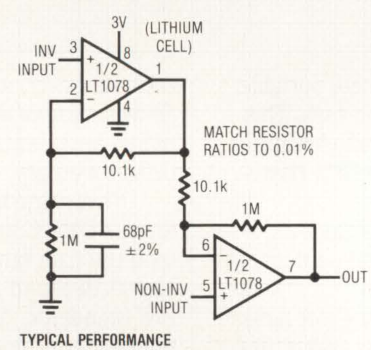
These op amps operate from low supply voltage—as low as one lithium cell or two Ni-cad batteries. The input common-mode range goes below ground. The all-NPN output stage swings to within a few millivolts of ground while sinking current. This means you don't need pull-down resistors to pull the output to ground. In competitive micropower op amps, the required pull-down resistors sometimes draw significantly more battery current than the entire amplifier.

Applications include battery-powered portable instruments, remote sensor amplifiers, micropower sample-and-holds and thermocouple amplifiers. The LT1078/79 also offer performance advantages in non-micropower applications.

LT1078 comes in 8-pin DIP or metal can versions, and LT1079 in a 14-pin DIP. Both military and commercial versions are available. In lots of 100, LT1078CN8 and LT1079CN op amps are priced at \$2.80 and \$3.50 each.

Stop cutting corners. Ask for the world class op amps with no tradeoffs. For details on our LT1078/79 series, contact Linear Technology Corporation, 1630 McCarthy Blvd., Milpitas, CA 95035. Or call **800-637-5545.**

Single Battery, Micropower, Gain = 100, Instrumentation Amplifier



TYPICAL PERFORMANCE
INPUT OFFSET VOLTAGE = 40μV
INPUT OFFSET CURRENT = 0.2nA
TOTAL POWER DISSIPATION = 240μW
COMMON MODE REJECTION = 110 dB AT DC
= 80 dB AT 500Hz
GAIN BANDWIDTH PRODUCT = 200kHz
OUTPUT NOISE = 85μVp-p 0.1Hz TO 10Hz
= 300μV_{RMS} OVER FULL BANDWIDTH
INPUT RANGE = 0.03V TO 1.8V
OUTPUT RANGE = 0.03V TO 2.3V (0.3mV $\le V_{IN} \le$ 23mV)
OUTPUTS SINK CURRENT — NO PULL DOWN RESISTORS ARE NEEDED

LINEAR TECHNOLOGY

TOUGH PRODUCTS
FOR TOUGH APPLICATIONS.

CIRCLE NO 77

Antialiasing filters reduce errors in A/D converters

The need for effective antialiasing filters closely matches the growing number of applications for A/D converters. These filters reduce converter errors by limiting the input signal bandwidth. To correctly specify the filter, you need to consider the appropriate frequency band and the filter's characteristics.

Robert W Steer Jr, *Frequency Devices Inc*

The growing number of applications for analog-to-digital converters (ADCs) in data-acquisition systems, image processing, and industrial controls is driving the need for antialiasing filters that reduce errors in many converter-based systems. By limiting the bandwidth of a converter's input signal, antialiasing filters inhibit the generation of false (aliased), low-frequency signals caused by too low a sampling rate (f_{sr}).

Limiting the converter's input-signal bandwidth reduces the highest frequency (f_m) whose amplitude is greater than or equal to the weight of an LSB (least significant bit). Lowering f_m reduces the rate at which the ADC must sample the input signal to avoid aliasing errors or at least to limit them to an acceptable level. Putting a value on the term "acceptable" requires a knowledge of the specific application and of sampling theory. (See **box**, "Sampling theory sets inviolable limits.") A converter whose sampling rate is finite may be capable of error-free conversions, but if you present such an ADC with an improperly band-limited input signal, the output will contain aliasing errors.

Prefiltering lets a slower ADC do the job

At first glance, a faster A/D converter might appear to provide an obvious and immediate answer to the aliasing problem. However, if you can't accept lower resolution, you'll have to pay more for a faster ADC. Furthermore, regardless of how much you are willing to pay for a converter, you can't get one with unlimited speed or resolution. In addition, noise frequencies extend well beyond the sampling rate of present-day ADCs. The sampling-rate requirements imposed by broadband noise are important because aliased high-frequency noise components can "fold back" and appear as lower frequencies that you can't distinguish from valid sampled data. Moreover, the system itself can generate "spurs"—spurious high-frequency signals, which will introduce errors if aliased.

By precisely limiting the bandwidth at the input of the ADC, active lowpass filters can reduce the need for brute-force increases in conversion speed. The restricted bandwidth lowers the maximum frequency of signals and noise that reach the ADC's input, and hence reduces the sampling (conversion) rate needed to avoid aliasing. Lowpass filters can exhibit a virtually flat, non-attenuating passband response that extends from

An obvious solution to aliasing is the use of a faster ADC, but prefiltering the ADC's input can let a slower converter do the job.

dc to the cutoff frequency f_r. Beyond f_r, the gain can roll off steeply at rates that exceed −90 dB per octave. However, for technical as well as economic reasons, a filter with a flat passband response and the steepest available stopband roll-off characteristic isn't necessarily the best choice for a particular application.

By band limiting the ADC input, a prefilter (**Fig 1**), prevents the ADC from digitizing alias-producing signals. A properly chosen filter attenuates signal components at frequencies greater than f_m to levels well below the quantizing threshold of the ADC. (Here $f_m \leq f_{sr}/2$.) A binary-coded n-bit A/D converter digitizes

Sampling theory sets inviolable limits

Signal sampling, such as that occurring during A/D conversion, can generate lower frequency, inband error signals when the sampled signal contains higher frequency components at or above half the sampling frequency, that is, above $f_{sr}/2$. **Fig A** illustrates the alias that would result from a single-frequency sine wave sampled at too low a rate.

The sampling theorem, which deals with sampling at a theoretical, mathematical level, states that a signal sampled at a rate, f_{sr}, equal to or greater than twice the maximum signal-frequency component, f_m, can be exactly reconstructed from the data samples. If frequency components greater than $f_{sr}/2$ are present, they "fold back"into the 0-to-f_m frequency band. **Fig B** illustrates a simple graphical derivation of the folding frequency ($f_f = f_m/2$). Above f_f, aliasing commences as the first harmonic spectrum begins folding over into the original spectrum.

Conversely, sampling rates less than $2f_m$ introduce aliases in the sampled signal that begin at $f_{sr} - f_m$ and range about each harmonic of f_{sr}, extending to $nf_{sr} \pm f_m$. (Here, n equals the harmonic number.) Because you can't distinguish the aliases from the valid data sharing the dc-to-f_m passband, accurate retrieval of the original signal is impossible. In real-world situations, the input signals are usually nonsinusoidal, are often random, and always contain noise. The noise, randomness, and high-frequency components of such signals are all potential sources of aliasing.

The elimination of frequency components above $f_{sr} - f_m$ requires a lowpass filter—usually one with sharp cutoff characteristics. With zero attenuation in its passband and infinitely sharp and deep attenuation beyond, the ideal filter of **Fig Ca** completely eliminates aliasing and passes all desired signals unattenuated. However, this ideal filter is not attainable. Fortunately, various filter designs approach this ideal closely enough to achieve control of aliasing.

The response of the real-world filter in **Fig Cb** more nearly represents the response of an actual, realizable antialiasing filter. The finite roll-off and attenuation floor allow higher frequency signal and noise components to arrive at the sampler input. In some cases, these components can cause aliasing. The quantizing threshold of the sampler—an A/D converter for purposes of this discussion—determines whether these signals will be digitized.

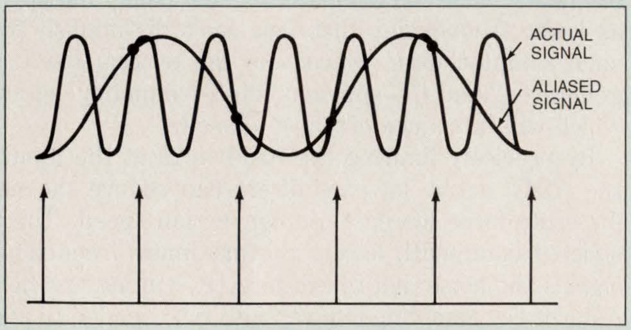


***Fig A—Insufficient sampling can produce** a false lower frequency, in-band signal (an alias).*

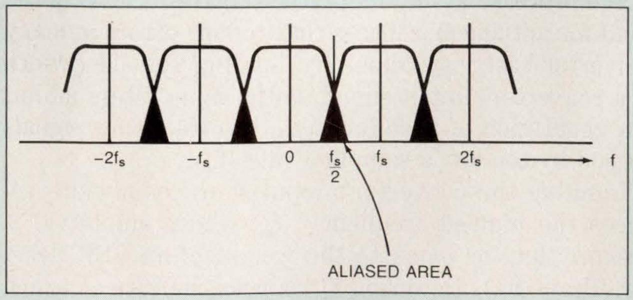


***Fig B—Frequency folding (aliasing)** sets in when too low a sampling rate causes fundamental frequencies and harmonic spectra to overlap.*

its analog input into 2^n discrete levels, with the nth or least-significant bit being the smallest resolvable level. The LSB has a weight of $1/2^n$ of the full-scale input voltage range and each higher order bit carries twice the weight of its lower order neighbor.

An ADC with a unipolar input range generates 2^n output codes as you vary the input from 0V to the full-scale voltage, V_{fs}. Ideally, the midpoint of each input increment occurs at an exact integer multiple of $V_{fs}/2^n$, and each output transition occurs at the exact midpoint of a given analog increment, or at a multiple of $V_{fs}/2^{n+1}$. **Table 1** shows that the LSB threshold of a

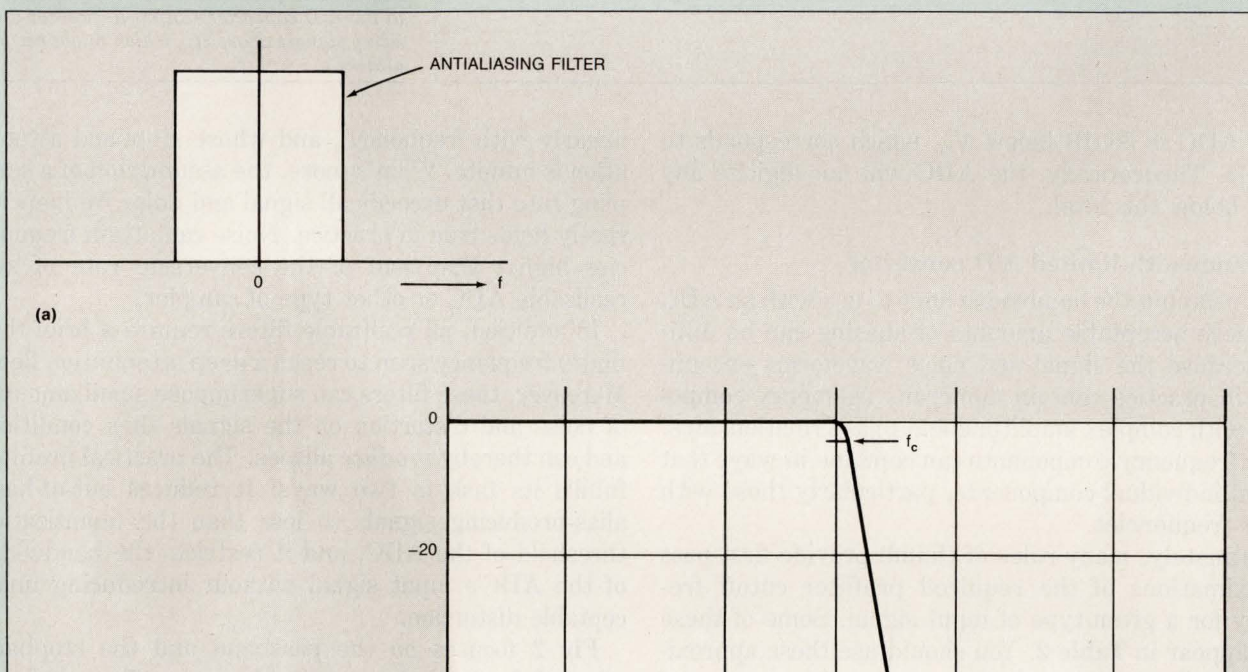


***Fig C—An ideal filter (a) removes all frequencies** beyond its stopband edge. A real-world filter **(b)** can approach this ideal of infinitely sharp cutoff.*

The role of an antialiasing prefilter is to minimize ADC errors by attenuating high-frequency signals before they reach the ADC.

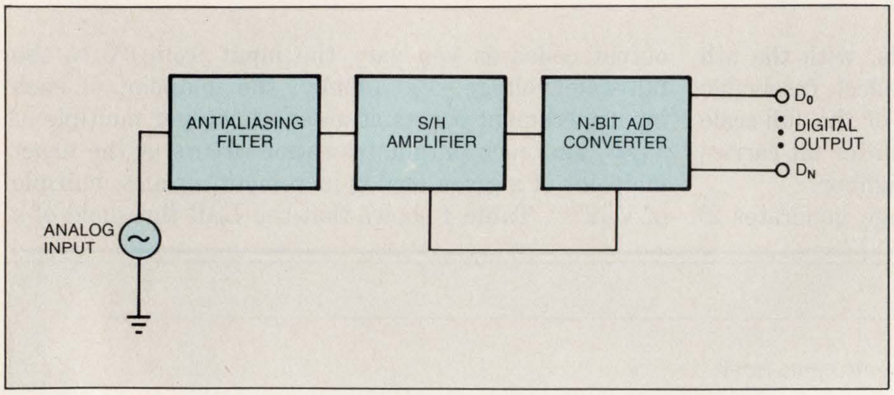


***Fig 1—The prefilter limits the bandwidth** to the A/D converter's input to prevent digitizing signals above $2f_{sr}$, which might become aliases.*

10-bit ADC is 66 dB below V_{fs}, which corresponds to $V_{fs}/2048$. Theoretically, the ADC will not digitize any signal below this level.

The bandwidth-limited A/D converter

Determining the bandwidth limit to use with an ADC to achieve acceptable amounts of aliasing can be difficult because the signal and noise waveforms encountered in practice contain numerous frequency components with complex amplitude and phase relationships. These frequency components can combine in ways that conceal individual components, particularly those with higher frequencies.

Fortunately, many rules of thumb provide first-pass approximations of the required prefilter cutoff frequency for a given type of input signal. Some of these rules appear in **Table 2**. You should use these approximations only as starting points.

A perfect antialiasing filter simply does not exist no matter how you synthesize it. Indeed, even in theory, you *cannot* create a perfect lowpass filter; that is, one that has no passband attenuation, that has no passband phase shift (or whose passband phase shift varies linearly with frequency), and whose stopband attenuation is infinite. What's more, the assumption of a sampling rate that exceeds all signal and noise frequencies rarely holds true in practice. Noise can attain frequencies higher than half of the conversion rate of any realizable ADC or other type of sampler.

In addition, all realizable filters require a brief (but finite) frequency span to reach a deep attenuation floor. Moreover, these filters can superimpose small amounts of noise and distortion on the signals they condition, and can thereby *produce* aliases. The practical prefilter fulfills its task in two ways: It reduces out-of-band alias-producing signals to less than the quantization threshold of the ADC, and it restricts the bandwidth of the ADC's input signal without introducing unacceptable distortion.

Fig 2 focuses on the passband and the stopband edge of four popular, realizable active filter designs. The filters' characteristics are discussed in detail further on. The passband is the range of frequencies over which the filter exhibits flattest gain and imposes least attenuation, typically 0 dB at and near dc. The passband of lowpass filters extends from dc to the stopband edge—the transition point where filter attenuation first increases sharply for a small frequency increase.

You can define the stopband edge and the passband

TABLE 1—LSB WEIGHT VS FILTER ATTENUATION FOR A BINARY-CODED ADC

RESOLUTION OF BINARY-CODED A/D CONVERTER				DESIRED FILTER RESPONSE
A/D RESOLUTION (BITS)	LSB WEIGHT $1/2^n$	APPROXIMATE LSB WEIGHT	½ LSB WEIGHT $(1/2^{n+1})$	ATTENUATION AT f_m
8	1/256	−48 dB	−54 dB	≥ −54 dB
10	1/1024	−60 dB	−66 dB	≥ −66 dB
12	1/4096	−72 dB	−78 dB	≥ −78 dB
14	1/16,384	−84 dB	−90 dB	≥ −90 dB

TABLE 2—APPROXIMATIONS OF PREFILTER CUTOFF FREQUENCY FOR VARIOUS INPUT WAVEFORMS

INPUT SIGNAL	PREFILTER CUTOFF FREQUENCY ($f_c \le f_m$)
PULSATING DC	RATE OF CHANGE (V/SEC)/1V
SINUSOIDAL	1/PERIOD
COMPLEX PERIODIC	20/FUNDAMENTAL PERIOD
SINGLE EVENTS	1/PULSE WIDTH

ripple to comply with system accuracy requirements. (Passband ripple is the peak-to-peak variation in a filter's passband frequency response.) One popular method locates the stopband edge at the break (corner) frequency, f_c, where attenuation first becomes 3 dB—that is, where, for a constant input amplitude, the filter's output amplitude is 70.7% of its amplitude at very low frequencies. In commercial filters, passband ripple usually exhibits typical values of 0.2, 0.5, or 1 dB. To allow comparison of filter types, **Fig 2** normalizes the four filter responses to coincide at f_c.

An alternative method locates the filter's stopband edge at the passband ripple frequency f_r, the highest frequency at which the passband ripple remains within the filter's passband-ripple (passband response flatness) specification. Applicable to curves 3 and 4 of **Fig 2**, this approach yields a narrower—but much flatter—passband than does the 3-dB method. To repeat, you can locate the stopband-edge frequency at an attenuation level dictated by system tolerances.

Fig 3 views the responses of **Fig 2** over a wider bandwidth to allow a comparison of filter roll-off characteristics and the definition of two key frequencies for curve 4. For antialiasing applications, f_a, the frequency at which attenuation first becomes $6(n+1)$ dB, is the next highest frequency of interest; n is the ADC resolution in bits. The final and highest frequency, f_s, the attenuation-floor frequency, locates the lowest fre-

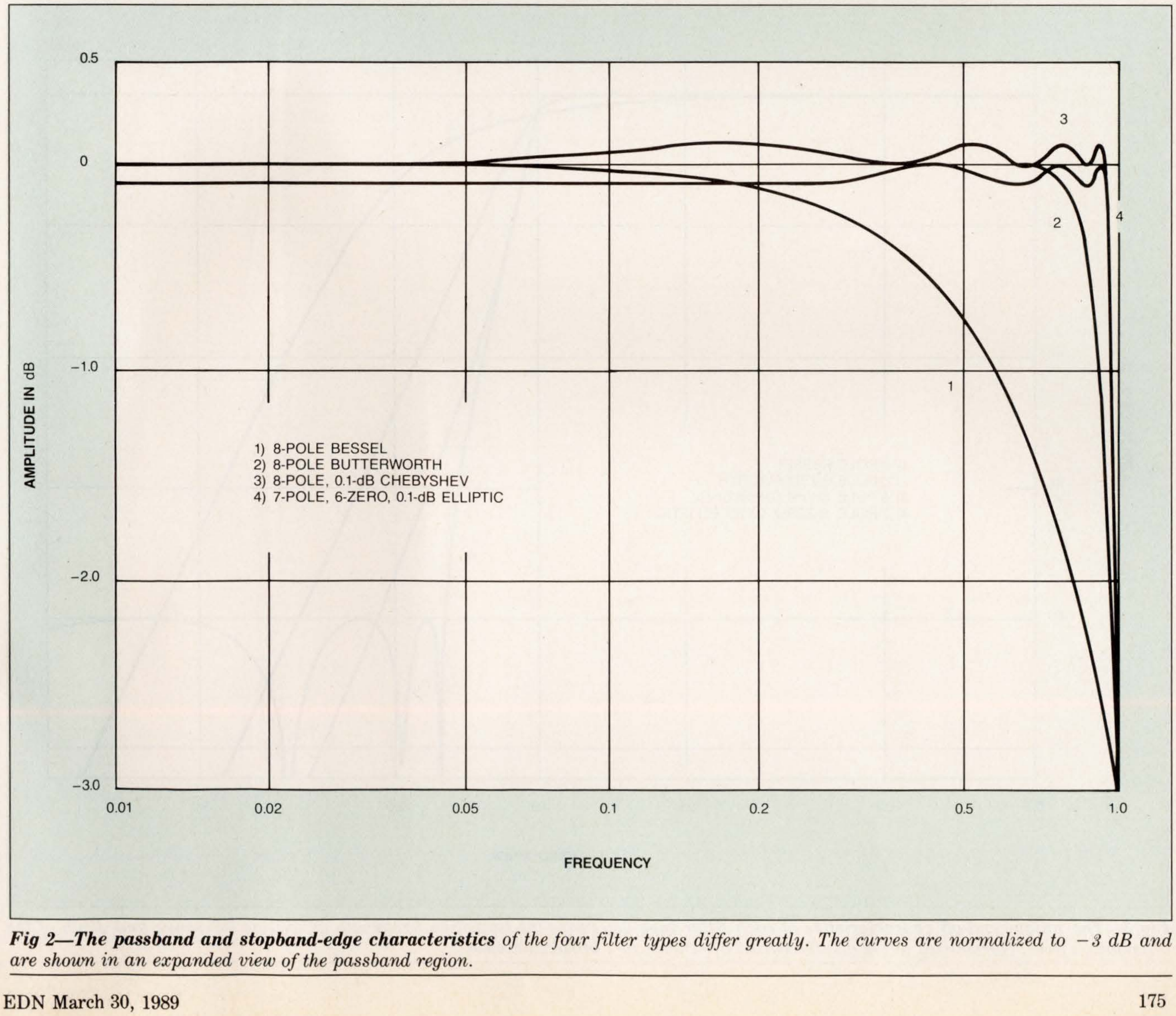


Fig 2—The passband and stopband-edge characteristics *of the four filter types differ greatly. The curves are normalized to −3 dB and are shown in an expanded view of the passband region.*

In theory, you can exactly reconstruct a signal sampled at twice its maximum signal frequency.

quency at which the stopband response drops below a specified attenuation floor and remains there. The floor defines the minimum attenuation a filter imposes at and beyond f_s.

Three additional parameters can simplify filter selection. Bounded by stopband edge-frequency f_r or f_c and by f_s, the transition band, β_t, is, depending on the application, the range from f_s to f_r or from f_s to f_c. This parameter measures the frequency span required to reach the attenuation floor. A narrower transition band provides faster roll-off and sharper, better-defined frequency discrimination.

The shape factor, Ω_s, is the ratio of the attenuation-floor frequency, f_s, to either f_r or f_c (In equation form, $\Omega_s = f_s/f_r$ or $\Omega_s = f_s/f_c$.) Shape factor, which provides the designer with a scale factor, is a useful figure of merit for comparing filters and is another measure of a filter's attenuation steepness or roll-off rate.

A lowpass filter is said to be monotonic within a specified frequency band when its attenuation beyond the stopband edge increases with increasing frequency. Curves 1, 2, and 3 of **Fig 3** illustrate monotonic responses. Curve 4 shows a nonmonotonic response. Illustrating this relationship, **Table 3** tabulates the shape factor of each filter, based on the ratio of the frequencies occurring at −80 and −3 dB ($\Omega_s = f_{-80}/f_{-3dB}$). The table includes comments about comparative behavior beyond the stopband edge.

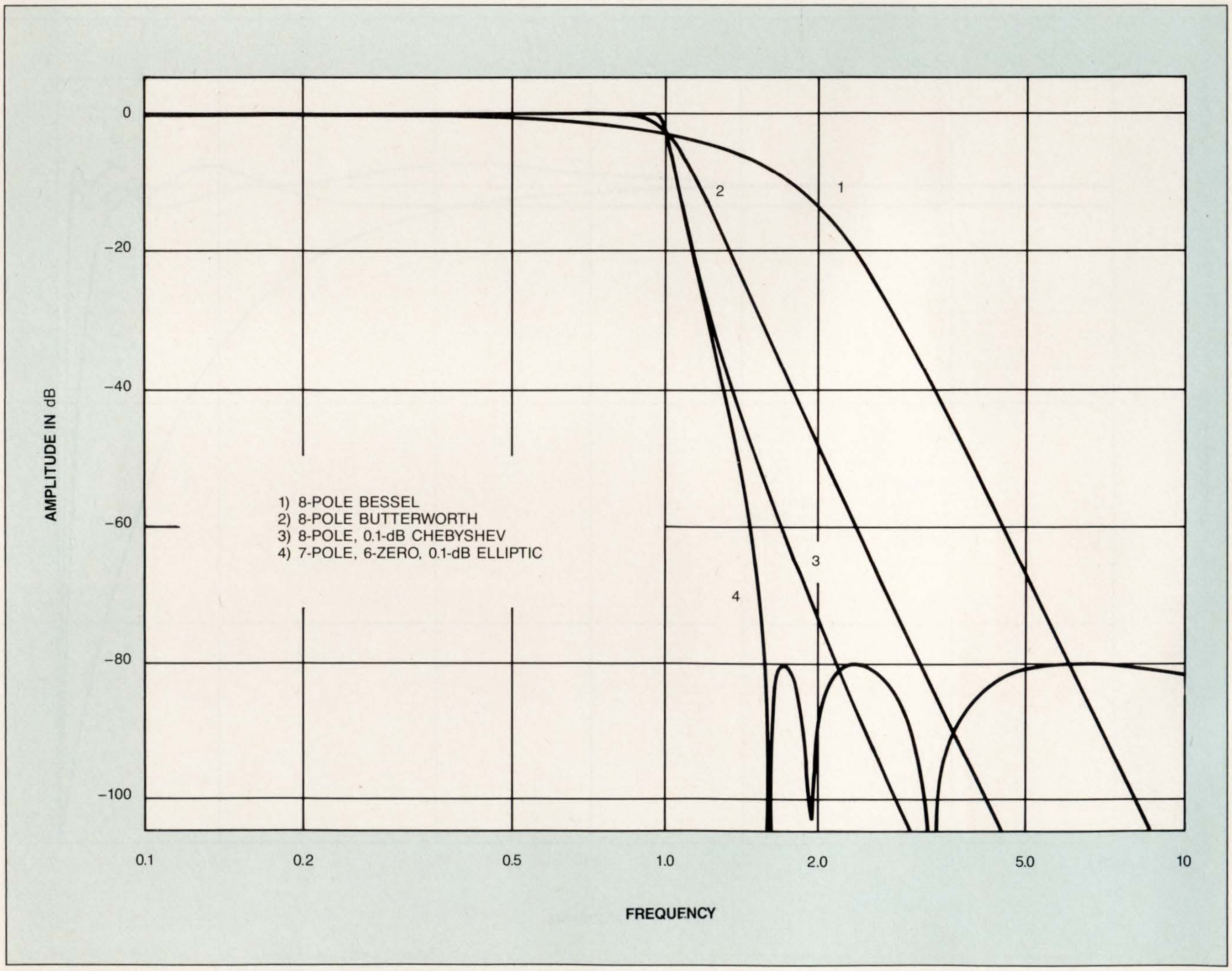


Fig 3—The unique roll-off characteristics of each filter type *determine the transition bandwidth as well as the shape and depth of the attenuation floor. Normalized to −3 dB, the curves are shown in a broadband view.*

Table 3 shows that the Cauer elliptic filter (curve 4) rolls off fastest, the Chebyshev filter (curve 3) second fastest, the Butterworth filter (curve 2) third fastest, and the Bessel filter (curve 1) slowest. However, the attenuation of the Cauer elliptic filter is not monotonic because it varies in a cusp-like manner at frequencies above f_s. Note, however, that the 7-pole, 6-zero, elliptic filter rolls off faster than its 8-pole monotonic companions.

In theory, the attenuation shown in the first three curves increases without limit as frequency increases, but the Cauer elliptic filter exhibits a finite attenuation floor. As shown later, the Bessel filter fills an important need, and the Cauer elliptic filter's exchange of attenuation depth for faster roll-off is a worthwhile tradeoff for certain applications. Playing a key role in determining system bandwidth, transient response, and accuracy, the width and flatness of the A/D converter's prefilter passband warrants a closer look. **Fig** 4 displays the same four curves normalized to their −80-dB frequencies.

With all filters normalized to −80 dB at the attenuation-floor frequency, f_s, **Table** 4 lists the passband of each filter and compares the ratio of the Cauer elliptic filter's passband to that of each of the remaining filters at both the −0.1-dB and the −3-dB corner frequencies. The choice of these corner frequencies was arbitrary, based on the assumed requirement for passband

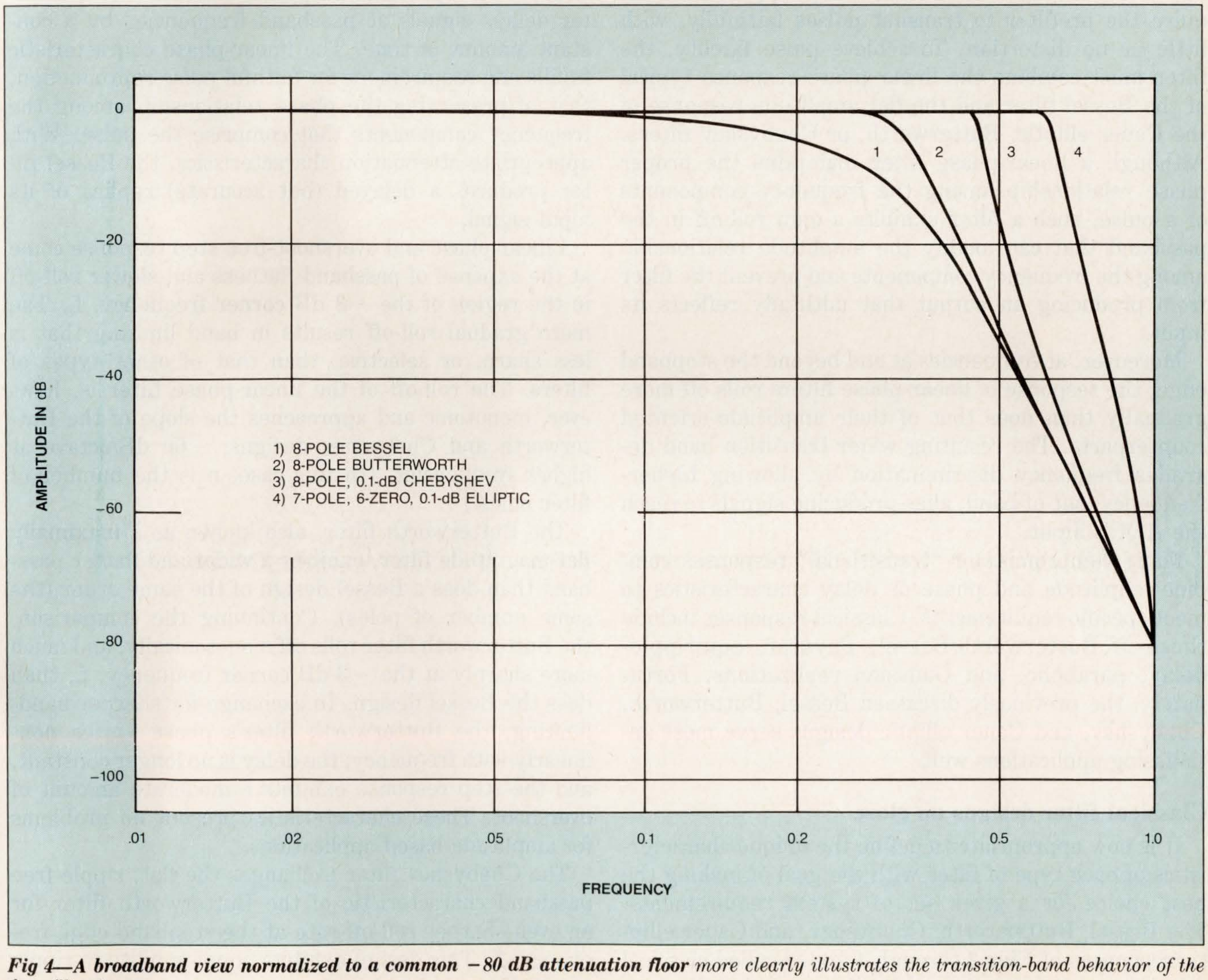


Fig 4—A broadband view normalized to a common −80 dB attenuation floor *more clearly illustrates the transition-band behavior of the four filter types.*

The phase of a Bessel filter varies linearly with frequency within a ripple-free passband and delays passband frequencies by a constant amount of time.

amplitude ripple of 0.1 dB and 3 dB.

This table shows that the Cauer elliptic filter provides a 0.1-dB passband approximately 12 times as wide as the Bessel filter's, five times as wide as the Butterworth filter's, and 1.5 times as wide as the Chebyshev filter's.

For a −3-dB corner, **Table 4** shows that the width of the Cauer elliptic filter's passband is approximately four times that of the Bessel's, twice that of the Butterworth's, and 1.5 times that of the Chebyshev's. These ratios lead to the obvious conclusion that the Cauer elliptic filter surpasses the other designs for amplitude-critical applications.

Though carefully controlled frequency response is important in some situations, many applications require the prefilter to transmit pulses faithfully, with little or no distortion. To achieve pulse fidelity, the filter must combine the linear phase response typical of the Bessel filter and the flat amplitude response of the Cauer elliptic, Butterworth, or Chebyshev filters. Although a linear-phase filter maintains the proper phase relationship among the frequency components of a pulse, such a filter exhibits a gain roll-off in the passband that can modify the amplitude relationship among the frequency components and prevent the filter from producing an output that faithfully reflects its input.

Moreover, at frequencies at and beyond the stopband edge, the response of linear-phase filters rolls off more gradually than does that of their amplitude-oriented counterparts. The resulting wider transition band degrades frequency discrimination by allowing higher-frequency, out-of-band, alias-producing signals to reach the ADC's input.

Many compromise or "transitional" responses combine amplitude and phase or delay characteristics to meet specific requirements. Classical responses include those of Butterworth/Bessel, Paynter, equiripple-delay, parabolic, and Gaussian realizations. Fortunately, the previously discussed Bessel, Butterworth, Chebyshev, and Cauer elliptic designs serve most antialiasing applications well.

Classical filter designs up close

It is now appropriate to define the unique characteristics of each type of filter with the goal of making the best choice for a given set of system requirements. The Bessel, Butterworth, Chebyshev, and Cauer elliptic responses of **Figs 2** through **4** are so-called classical responses that meet the needs of most antialiasing applications. The phase of the Bessel filter varies linearly with frequency within a ripple-free passband. This filter delays signals at passband frequencies by a constant amount of time. The linear-phase characteristic fulfills one requirement for faithful pulse reproduction, that of preserving the phase relationship among the frequency components that comprise the pulse. With appropriate attenuation characteristics, the Bessel filter produces a delayed (but accurate) replica of its input signal.

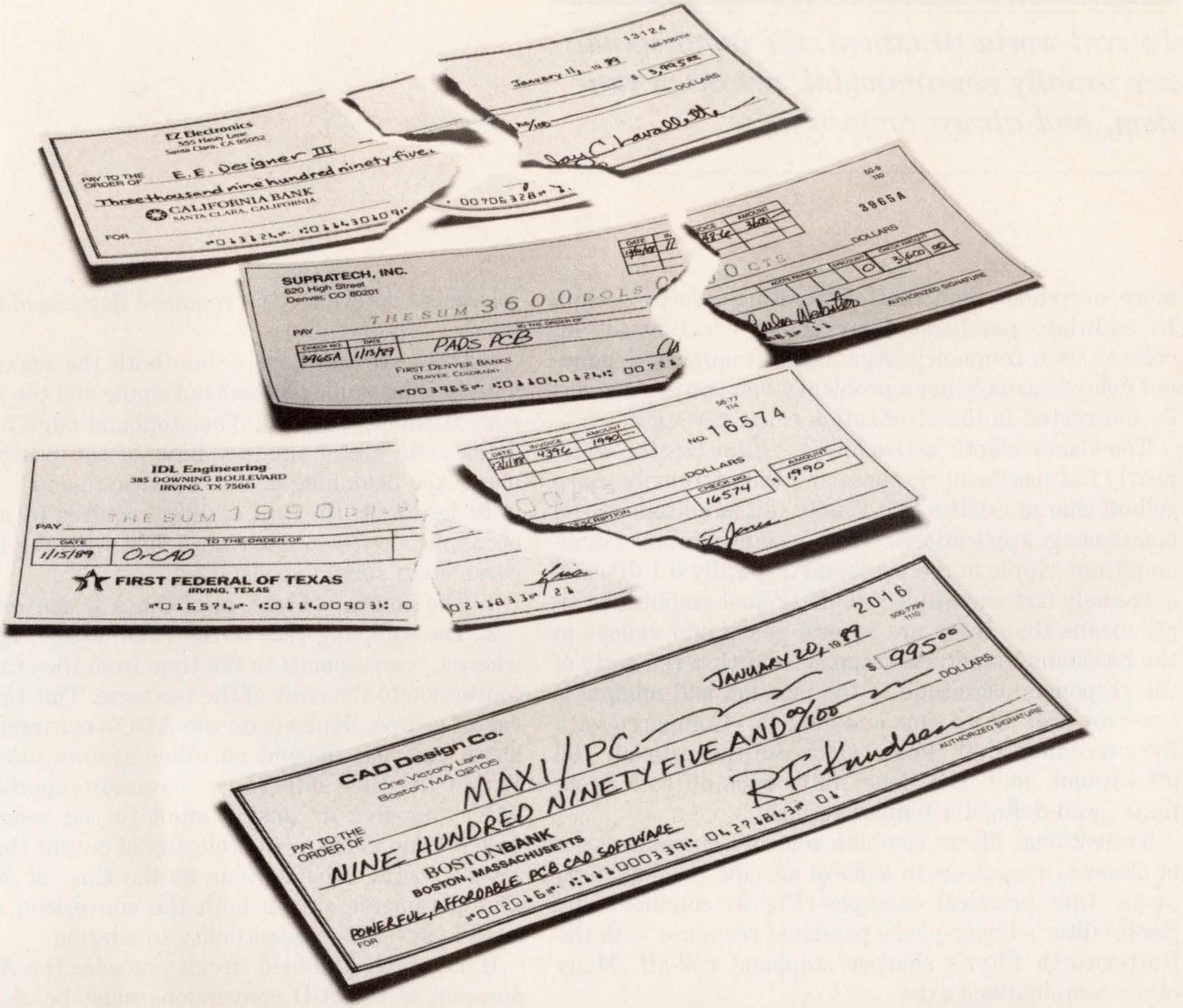
TABLE 3—COMPARISON OF TRANSITION BAND AND STOPBAND PERFORMANCE

CURVE	FILTER TYPE	SHAPE FACTOR Ω_S (f−80 dB/f−3 dB)	ROLL-OFF RATE	ROLL-OFF MONOTONIC
1	8-POLE BESSEL	6.068	SLOWEST	YES
2	8-POLE BUTTERWORTH	3.162	FASTER	YES
3	8-POLE, 0.1-dB CHEBYSHEV	2.183	NEXT TO FASTEST	YES
4	7-POLE, 6-ZERO, 0.1-dB CAUER	1.661	FASTEST	NO

Linear phase and overshoot-free step response come at the expense of passband flatness and slower roll-off in the region of the −3 dB corner frequency, f_c. The more gradual roll-off results in band limiting that is less sharp, or selective, than that of other types of filters. The roll-off of the linear-phase filter is, however, monotonic and approaches the slope of the Butterworth and Chebyshev designs: −6n dB/octave at higher frequencies. (In this case, n is the number of filter poles.)

The Butterworth filter, also known as a maximally flat-magnitude filter, exhibits a wider and flatter passband than does a Bessel design of the same order (the same number of poles). Continuing the comparison, the Butterworth filter rolls off monotonically, and much more sharply at the −3-dB corner frequency, f_c, than does the Bessel design. In exchange for sharper band-limiting, the Butterworth filter's phase varies nonlinearly with frequency; the delay is no longer constant, and the step response exhibits a moderate amount of overshoot. These characteristics present no problems for amplitude-based applications.

The Chebyshev filter exchanges the flat, ripple-free passband characteristic of the Butterworth filter for an even sharper roll-off rate at the stopband-edge frequency, f_r. This design exhibits equal-amplitude ripple across the passband and a step response with even



ARE YOU ABOUT TO WRITE A BAD CHECK?

TEAR IT UP AND CHECK OUT MAXI/PC INSTEAD...JUST $995!

"We almost wrote a $3,500 check for PCB CAD software that couldn't compare with MAXI/PC."

BOB TILDEN, SENIOR ELECTRONIC DESIGNER
PHYSICS RESEARCH GROUP,
NORTHWESTERN UNIVERSITY

Capabilities	EE Designer III*	PADS-PCB*	OrCAD*	MAXI/PC
Hierarchical Design			✓	✓
Back Annotation	✓	✓		✓
Automatic Placement	✓	✓		✓
Automatic Gate & Pin Swap		✓		✓
Automatic Component Rename				✓
Data Migration				✓
Price	$3,995	$3,600	$1,990	$995

Prices and features are those available at time of publication, 1/89.
*Trademark

How can the world's largest PCB CAD vendor offer you so many advanced capabilities for such an affordable price...MAXI/PC $995? It's simple. We took proven software from our high-end workstation systems and designed it to run on the PC.

MAXI/ PC is schematic capture/PCB layout software offering interactive and automatic capabilities such as automatic gate and pin swapping, automatic component rename, and back annotation to name a few. With features like these, you'll be able to tackle the toughest boards...dual in-line and multilayer designs, as well as double-sided and surface-mount designs.

And MAXI/PC is software you can grow with. Data can be migrated upward to our mid-range PC-based CADSTAR™ system and from there to our engineering workstation-based Visula™ system.

So, before you make out a bad check, check out MAXI/PC's impressive features and unbelievable price. We don't offer demo disks. We do one better. Order MAXI/PC today and you get a full 30-day money-back guarantee if you're not satisfied.

1-508-692-4900

MAXI/PC
PCB CAD SOFTWARE

RACAL-REDAC
238 Littleton Road, P.O. Box 365
Westford, MA 01886-9984

We accept check/money order, Visa and MasterCard.

In real-world situations, the input signals are usually nonsinusoidal, are often random, and always contain noise.

more overshoot than that of the Butterworth design. In addition, passband delay is not constant—it increases with frequency. Again, the frequency-dependent delay is usually not a problem when you are primarily interested in the attenuation characteristics.

The Cauer elliptic active lowpass filter has the wide, nearly flat passband response and the extremely sharp roll-off characteristics that ideally suit amplitude-based antialiasing applications. This design exhibits equal-amplitude ripple in the passband (typically 0.1 dB) and extremely fast amplitude roll-off. (Equal-amplitude ripple means that there are several peaks and valleys in the passband amplitude response and that the ratio of the response magnitude at the maxima and minima is constant over all maxima and minima.) Compared with the preceding filter types, which can theoretically roll off without limit, the Cauer filter rolls off to a deep, finite, well-defined attenuation floor.

Transitional filters combine selected characteristics of classical responses to achieve specific band-shaping tasks. One practical example **(Fig 5)** combines the Bessel filter's linear-phase passband response with the Butterworth filter's sharper stopband roll-off. Many other combinations exist.

Without violating other system performance criteria, the correct antialiasing filter provides the passband, transition-band, and attenuation-floor characteristics required to adequately prefilter the signals supplied to an n-bit ADC. Alias prevention defines the transition-band and attenuation-floor requirements; system tolerances determine the required flatness of the passband.

System specifications define both the maximum allowable magnitude of passband ripple and the stopband edge frequency, f_c or f_r. The stopband edge frequency defines the high-frequency limit of the passband and marks the beginning of the transition band.

To determine the type of filter required by a particular application, you must next deal with the following parameters simultaneously:

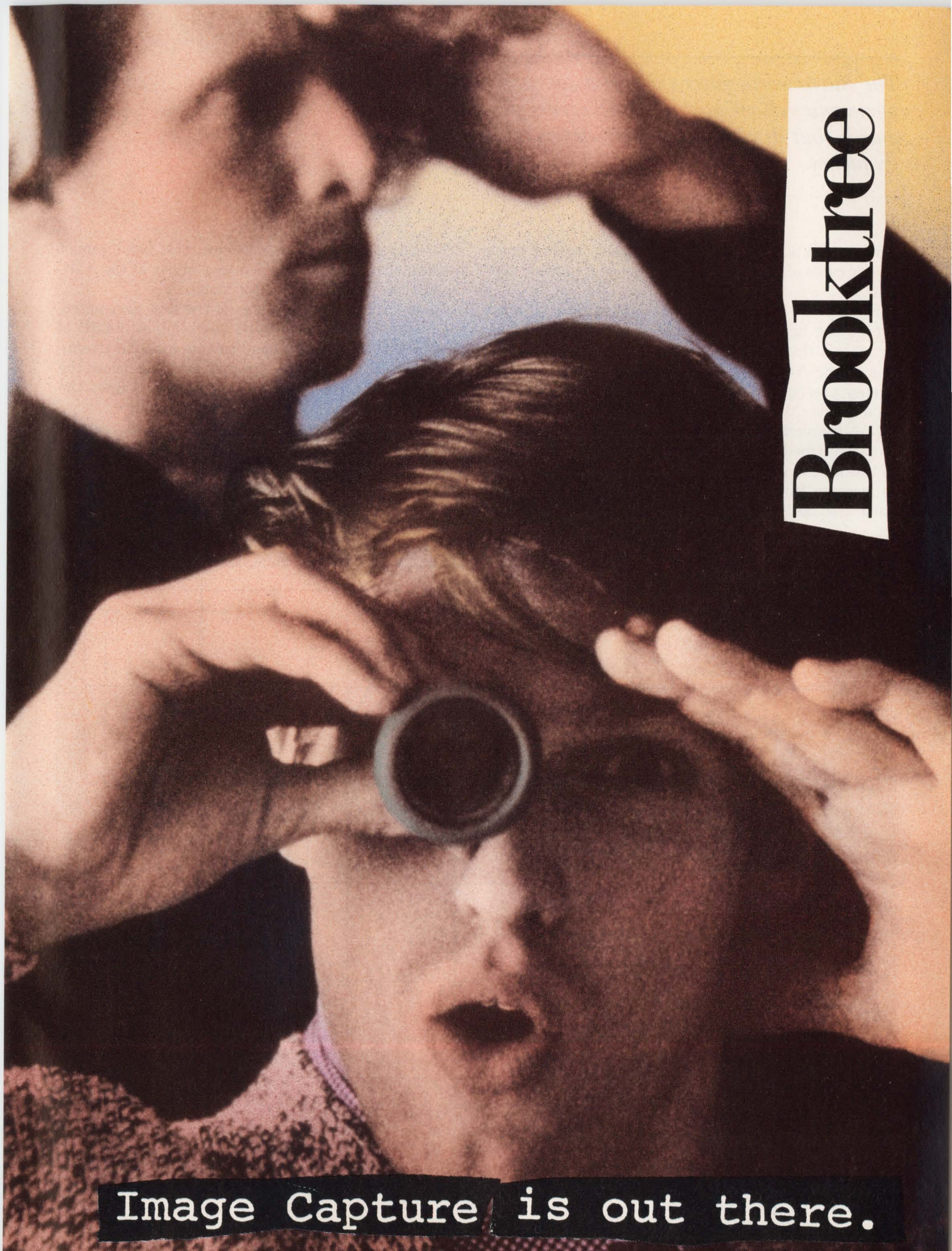
1. The number of bits, n, of the A/D converter.

2. The sampling rate of the A/D system, $f_{sr} = (1/t_{sr})$, where t_{sr} corresponds to the time from the start of one conversion to the start of the next one. This time interval, of course, depends on the ADC's conversion time, but it can also depend on other system parameters. Within the time interval, a successive-approximation ADC compares its analog input to the weighting of each bit and delivers an n-bit digital output that corresponds to the input's value at the time of sampling. This parameter affects both the conversion accuracy and the system's susceptibility to aliasing.

If no sample-and-hold circuit precedes the ADC, the duration of the A/D conversions must be short compared with the time required for the input signal to change by ½ LSB. In essence, when there is no S/H circuit, the sampling "window" of a successive-approximation converter is the same as the duration of a conversion. With a given value of f_{sr}, an S/H circuit at the ADC input dramatically shortens the sampling

TABLE 4—COMPARISON OF THE PASSBAND AND ATTENUATION-FLOOR SHAPE OF THE FILTERS

RESPONSE CURVES		STOPBAND EDGE (SE) AT −0.1 AND −3 dB	STOPBAND EDGE (SE) RATIO CAUER SE TO OTHER CURVES	PASSBAND/ ATTENUATION FLOOR
		f_r (=f_S/Ω_S) AT −0.1 dB, f_S=1	CAUER/CURVES 1, 2, 3 (f_{r4}/f_{rn})	
CURVE	RESPONSE TYPE	f_c (=f_S/Ω_S) AT −3 dB, f_S=1	CAUER/CURVES 1, 2, 3 (f_{c4}/f_{cn})	COMMENTS
1	BESSEL 8-POLE	f_{r1}=0.0506	11.9 AT −0.1 dB	NARROWEST/ THEORETICALLY UNLIMITED
		f_{c1}=0.1648	3.9 AT −3 dB	
2	BUTTERWORTH 8-POLE	f_{r2}=0.1283	4.7 AT −0.1 dB	WIDER/ THEORETICALLY UNLIMITED
		f_{c2}=0.3163	2.0 AT −3 dB	
3	0.1-dB RIPPLE CHEBYSHEV 8-POLE	f_{r3}=0.430	1.4 AT −0.1 dB	NEXT WIDEST/ THEORETICALLY UNLIMITED
		f_{c3}=0.4581	1.4 AT −3 dB	
4	0.1-dB RIPPLE CAUER ELLIPTIC 7-POLE, 6-ZERO	f_{r4}=0.6020	1.0 AT −0.1 dB	WIDEST/CUSP-LIKE WITH FIXED MINIMUM VALUE
		f_{c4}=0.6339	1.0 AT −3 dB	


Brooktree
Image Capture is out there.

The Butterworth filter exhibits a sharp, monotonic roll-off at the −3 dB corner frequency, but its phase varies nonlinearly with frequency.

window and allows conversion of signals having much higher rates of change and much higher frequency content.

For alias-free conversion, the sampling rate, f_{sr}, must exceed the highest in-band (passband) frequency, f_m, by no less than a factor of two: $f_{sr} \geq 2f_m$. This equation relates the ADC's sampling rate to the maximum frequency present in the ADC's input signal at an amplitude greater than or equal to ½ LSB.

3. A frequency span closely related to the transition band described earlier. The frequency band of interest in this case is that required for the filter's attenuation to increase from the value at the stopband edge to a value that attenuates signals above f_m to less than ½ LSB. Signals at frequencies above this band cannot produce aliases because, when they arrive at the ADC input, their amplitudes are too small.

Table 1 furnishes the values of the first parameter, the fractional and decibel (dB) weighting of ½ LSB of an n-bit ADC. The right-hand column lists the attenuation required to reduce a signal at f_m to below the ADC's threshold and, at the same time, defines the high-frequency bound of the transition band.

The value of the maximum frequency of interest, f_m, influences the value of the second parameter, t_{sr} and its frequency equivalent, f_{sr}. When selecting f_{sr}, you may discover that you must choose between using a faster ADC and a prefilter—and you may actually need

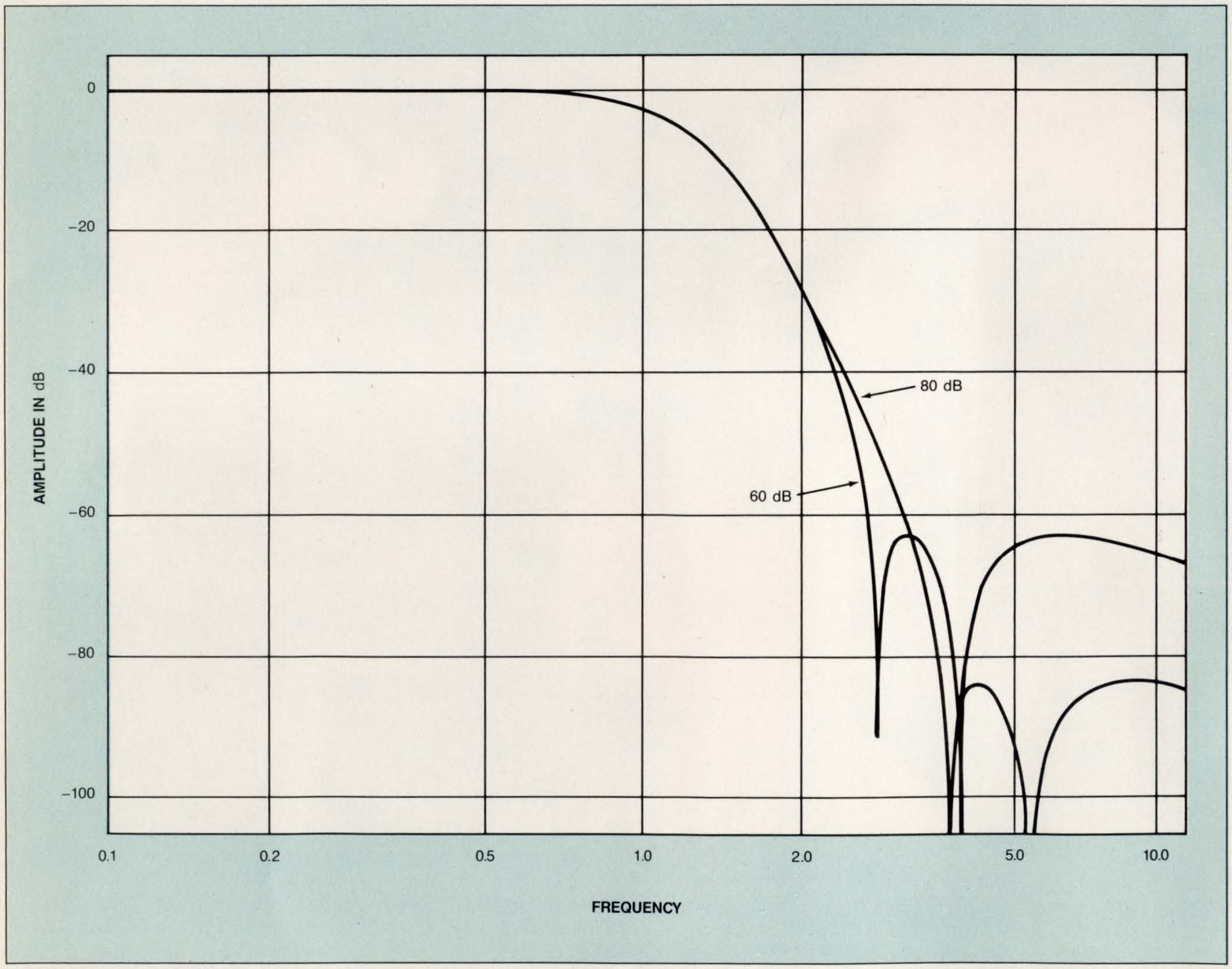


***Fig 5—This transitional filter** approximates the linear phase (constant delay) of the Bessel response in the passband, combined with the sharper roll-off of the Butterworth filter beyond the passband.*

CIRCLE NO 51

The Cauer elliptic filter has a flat passband and extremely sharp roll-off characteristics that suit amplitude-based, antialiasing applications.

both. If you add a prefilter, you may find that it slows the system response significantly; the system's response can become essentially the same as that of the prefilter. To make an intelligent selection of a conversion rate and a prefilter response, you must determine the highest signal frequency that's important to the system's operation. The ADC must sample at a rate equivalent to at least twice this frequency. You must also determine the amplitude of unwanted and potentially alias-producing artifacts (both signal components and noise) present in the system, and you must select a filter that attenuates the artifacts to a value no greater than one-half that of the ADC's LSB.

The third parameter is, in effect, the shape factor Ω_s. Ω_s is equal to the attenuation-floor frequency divided by the stopband-edge frequency. For the curves of **Fig 3**, the equation you use to obtain the shape factor is: $\Omega_s = f_{-80}/f_{-3}$. **Table 3** lists Ω_s for the actual filter realizations discussed.

You can now select a filter type. Selection begins by comparing your requirements with the transition-band response of the devices listed in this table. Obviously, the linear-phase, 8-pole Bessel filter exhibits the slowest roll-off rate and is best suited to applications requiring faithful pulse reproduction. Knowing the transition band and the tolerance on passband flatness, you can now select the filter type that best meets the system requirements.

Note that the 7-pole, 6-zero Cauer elliptic filter rolls off faster than its 8-pole cousins and yields the widest

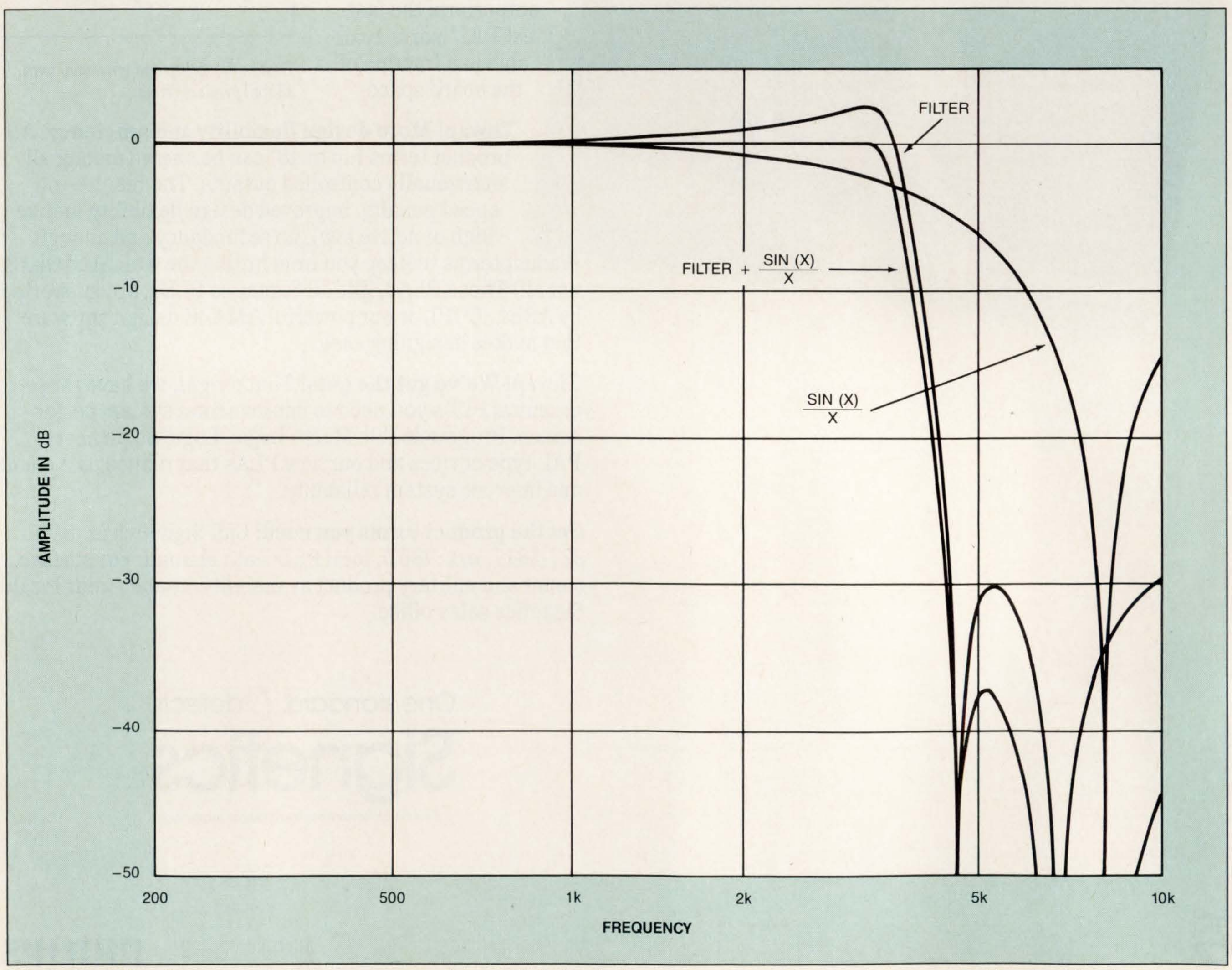
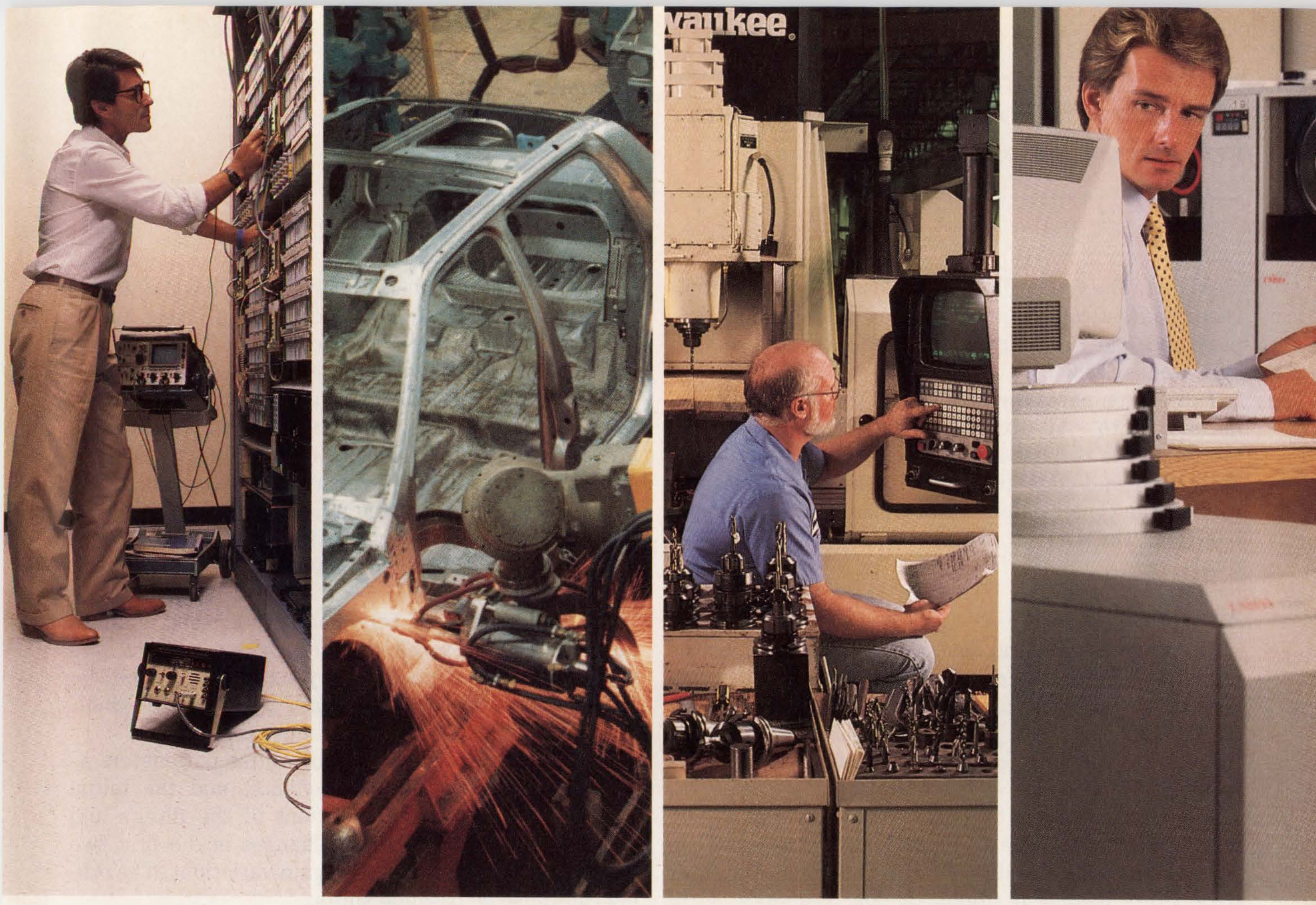


Fig 6—Sampling imposes a sin(x)/x response *on the sampled signal. Accurate reconstruction requires compensation for this effect.*



There's no one bigger in aluminum electrolytic caps...or smaller!

Mepco/Centralab makes the broadest range of aluminum electrolytic capacitors in the industry, from the smallest to the largest, with capacitance ratings from 0.1 μF to 1 million μF!

You can select true chip-size SMD® units that give your hybrids higher density. Or large, high-voltage units to 450 vdc.

We make a lot of sizes and ratings in between for your heavy-duty capacitor requirements — such as mainframe and uninterruptible power supplies, telecommunications switchgear, industrial motor control or robotic welding equipment.

Unique manufacturing...customizing, too!

Our expanding R&D operations are continually uncovering new ways to put our technological expertise to work for you. So if you don't find the exact aluminum electrolytic cap you need, we'll make it for you — with prompt turnaround on custom prototypes.

Since we're the nation's largest manufacturer of formed and etched electrical-grade aluminum foil, our aluminum electrolytic caps are readily available, with assured delivery to meet your JIT and dock-to-stock programs. And, because our total production is vertically integrated under strict quality control, our high-yield caps are bound to be more cost-effective.

For standard or custom solutions to your aluminum electrolytic capacitor needs, start with our catalogs. Just write to Mepco/Centralab — the active leader in passive components.

Mail to: Mepco/Centralab
Attn: Corp. Advertising
2001 W. Blue Heron Blvd.
P.O. Box 10330
Riviera Beach, FL 33404

Please send me the following:

☐ Surface Mount Device Catalog
☐ Leaded Resistor/Capacitor Data Book
☐ Please have a sales representative call

Name/Title ____________________

Firm/Dept./Div. ____________________

Address/MS ____________________

City/State/Zip ____________________ Phone ( ) ____________________

EDN 03/30/89

MEPCO/CENTRALAB
A DIVISION OF NORTH AMERICAN PHILIPS CORPORATION

PHILIPS

CIRCLE NO 53

®SMD is a service mark of North American Philips Corporation.

The Cauer filter rolls off to a deep, finite, well-defined attenuation floor.

passband. The Cauer filter's response suits applications requiring fast roll-off and the widest possible alias-free passband. The need for this type of filter grows as f_{sr}/f_m approaches two.

Table 4 compares the passband of the four responses, normalized to −80 dB, and provides a figure of merit for amplitude response. With reference to the 0.1- and 3-dB stopband-edge frequencies, this table lists the ratio of the Cauer elliptic filter's passband to the passbands of the Bessel, Butterworth, and Chebyshev filters.

An example is useful

To illustrate a typical design approach, consider the definition of a prefilter for use with a 12-bit A/D conversion system that must digitize signals to 20 kHz without aliasing. The passband must extend from dc to 10 kHz and must exhibit no more than 0.1 dB of ripple.

Alias-free operation requires the attenuation of signals at and above the f_m of 20 kHz by no less than $6(n+1)$ dB $=6(12+1)$ dB $=78$ dB. The applicable filter parameters include a stopband-edge frequency, f_r, of 10 kHz, a passband ripple of 0.1 dB max, and a minimum attenuation floor of 78 dB at $f_s=20$ kHz. The resulting shape factor is $\Omega_s=f_{-78}/f_{-0.1}=$ 20 kHz/10 kHz=2. The 7-pole, 6-zero Cauer filter easily meets these requirements.

The A/D converter must be able to sample at a minimum rate of $2f_m$, or 40 kHz. This rate corresponds to a maximum A/D conversion time of 25 μsec, and a sampling window on the order of 10 nsec for 12-bit accuracy.

Other considerations

You should consider data reconstruction in the early phases of system design. Reconstruction is often necessary because the sampling rate and window modify a signal of frequency f in the same way as does a lowpass filter with the sin(x)/x response shown in **Fig 6**. With $x=\pi f/f_{sr}$, and nulls occurring at f_{sr} and its harmonics, the attenuation is equal to

$$20\log(\sin(\pi f/f_{sr}))/(\pi f/f_{sr}).$$

Thus, at $f_{sr}=4f$, the attenuation is

$$20\log(\sin(\pi/4)/(\pi/4))=0.9 \text{ dB}.$$

Accurate reconstruction requires compensation for the losses caused by this effect. There are many recovery mechanisms, including the zero-order hold (a clocked digital-to-analog converter) and lowpass filters of various orders and complexity. All of these filters have the task of filling in the steps of the sampled waveform to smoothly replicate the original.

Certain filter parameters warrant attention. First, you must take care to ensure that the prefilter exhibits low distortion. The harmonics generated by a filter suffering from amplitude or rate limiting are likely sources of alias errors. You must therefore observe all of your chosen filter's specified restrictions on output loading and such signal characteristics as peak voltage and slew rate.

Then, because noise contributes to aliasing and also degrades system sensitivity and dynamic range, you need to know how much noise your filter can produce. Fortunately, present-day lowpass active filters exhibit noise performance suitable for most applications.

Next, you should consider such filter parameters as input impedance, output impedance, and the initial value and temperature coefficient of the filter's and ADC's input offset voltages. Changes in the first two quantities can produce system gain variations. The others can cause dc baseline shifts.

A final consideration concerns the reproducibility of your product. You should know or determine how closely you or the filter vendor can match the characteristics of supposedly identical filters. With this knowledge, you can ensure compliance with system specifications in both single and multichannel configurations. **EDN**

Reference

Vandoren, A, *Data Acquisition Systems*, 1982, Prentice-Hall, Englewood Cliffs, NJ, pgs 27 and 29. Figs A, B, and C(a) reprinted with permission of Prentice-Hall.

Author's biography

Bob Steer is president and treasurer of Frequency Devices Inc in Haverhill MA—but those are only his official titles. In his 20 years at the company, he has always been active as a design engineer. He holds a BSEE from Merrimac College and MS and ScD degrees from MIT. Prior to founding Frequency Devices, he held positions in academia as an associate professor and as chairman of an EE department. Bob's hobbies include boating and cycling.

SAFT BATTERIES. ONE FOR ALL. ALL FROM ONE.

Powering the portable electronics of the 80's has been a major problem for product design engineers. And the 90's will be even more challenging. But there is a one source supplier who can meet almost any portable power design challenge. With the industry's broadest line of Nicad® batteries and a variety of lithium chemistries, SAFT allows today's design engineer to design portability into a broad spectrum of electronics, from simple toys to sophisticated computers. And, best of all, this full range of portable power is available from a single source–one order, one shipment, one invoice.

For more information on our complete line of Nicad batteries, contact SAFT America Inc., Portable Battery Division, 711 Industrial Boulevard, Valdosta, Georgia 31601, or call (912) 247-2331. For information on our variety of lithium chemistries, contact SAFT America Inc., Advanced Battery Systems Division, 107 Beaver Court, Cockeysville, Maryland 21030, or call (301) 771-3200.

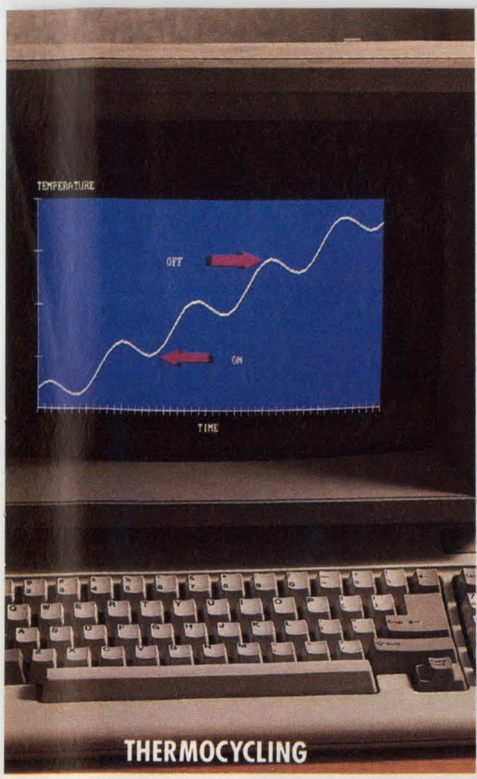
GROUPE CGE

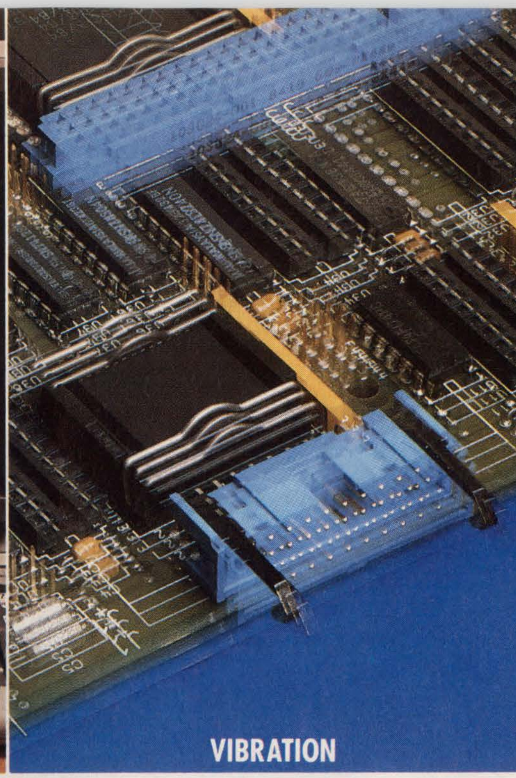
SAFT

CIRCLE NO 55

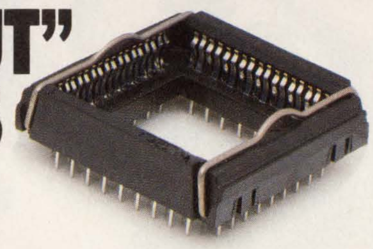

EPSON
IC MEMORY CARDS
2.4 mm thin + Epson quality
BUILT TO LAST
Epson IC Memory Cards are engineered like no others . . . they are the fastest, thinnest, toughest, most reliable cards made, and have the highest industry ratings for suppression of EMI plus protection from ESD and contaminants.
Durable stainless steel outer panels cover a high-impact resistant core. Unique package provides 25,000 volts ESD protection and EMI noise suppression. The card connector's grounding system adds to the cards ESD and EMI noise protection for overall system isolation.
Epson offers IC Memory Cards from stock, plus Mask ROM and other customs made to your order. All Epson IC-Memory Cards of the same pin type are interchangeable . . . ideal wherever small, rugged and portable memories are required.
EPSON
MEMORY CARD
EEPROM 32KB
SEIKO EPSON CORPORATION
EPSON
MEMORY CARD
RAM 512KB
User replaceable battery for SRAM cards . . . plus write protect switch.
2.4 mm thin cards fit standard connectors for 8-bit (34/40-pin) or 16-bit (50-pin) bus applications.
SRAM Card has 150 ns access time . . . the best available by far!
EEPROM Card Series 8K to 32K Bytes
EPROM Card Series 32K to 1024K Bytes
Mask ROM Card Series 32K to 2048K Bytes
SRAM Series 8K to 512K Bytes
EPSON
MEMORY CARD
M-ROM 2MB
EPSON
MEMORY CARD
RAM 512KB
EPSON
MEMORY CARD
EEPROM 32KB
EPSON
MEMORY CARD
EPROM 1MB
Contacts are covered by a unique protective shutter that slides open as card is inserted into the connector.
Long-life contacts permit cards to be inserted and removed a minimum of 10,000 times. Inquire about Z.I.F. type connector for 100,000 cycle applications.
Call or write for complete information
EPSON
Epson America, Inc.
Component Sales Department
3415 Kashiwa Street, Torrance, CA 90505
Telephone (213) 534-4500 • Telex 664277 • FAX (213) 539-6423
CIRCLE NO 17


Aerospace Switches



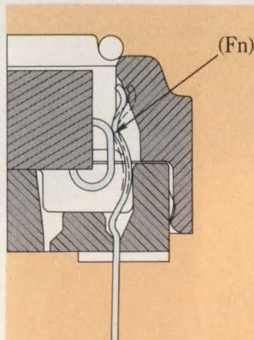


OUR PCC SOCKET WON'T "WALK-OUT" WHEN CONDITIONS GET ROUGH.



The Ansley® Plastic Chip Carrier (PCC) Socket is the only one that's tough enough to withstand the punishment of thermocycling, vibration and mechanical shock, and still stay on the job. Our unique cam-actuated socket contact design provides a positive gas-tight connection, producing 200g's normal force.

The contacts are cammed both inward and downward against the knee of the "J" lead, by means of a cam profile in the cover. This cam action assures that the IC won't walk out of the socket no matter how rough the environment. So when your designs call for durability and high reliability, Thomas & Betts is the way to go.



Components of the normal force drive IC into the socket.

High retention force is just one of the benefits you get with the new Ansley® PCC Socket. Our cam-actuated design also provides a low insertion/extraction force –50g/contact maximum–perfect for VLSI and high density applications. A polarizing feature assures positive chip carrier orientation, and the socket installs on the board without special tooling. The device is available in four sizes: 44, 52, 68 and 84 positions. Trouble-free removal of the IC package is accomplished with a simple extraction tool.

All these Thomas & Betts benefits add up to one thing–a better PCC socket. *For more information, write or call* Thomas & Betts Corporation, Electronics Division, 1001 Frontier Road, Bridgewater, NJ 08807, (201) 685-1600.

Other quality Electronics Division products include: *IDC Cable and Connector Systems, DIP and VLSI Sockets, Fiber Optic Systems, Flexible Interconnects, and Two-Piece Connectors.*

To get literature immediately call:

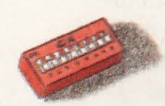
1-800-344-4744

Thomas&Betts

We Wrote The Book On Switches!

Update your switch source file with C&K's new free catalogs. The Newton Division Products Catalog #8709 includes miniature instrument grade toggle, rocker, slide, DIP, pushbutton, rotary and thumbwheel switches. The Clayton Division Products Catalog #C8803 includes switchlocks and low cost slide, rotary, rocker and pushbutton switches.

Send for our new free catalogs and see how we wrote the book! To receive a free sample, call (617) 964-6400. FAX (617) 527-3062



C&K®

C&K Components, Inc.
15 Riverdale Avenue
Newton, MA 02158-1082

The Primary Source Worldwide®...

SEE US AT NEPCON WEST, BOOTH #2148 & SOUTHCON BOOTH #1536-1538

A PUBLICATION APRIL 1, 1989

END

ELECTRONIC NONSENSE FOR ENGINEERS AND ENGINEERING MANAGERS

INSIDE THIS ISSUE

Blurry scope photos

Proper EE etiquette

Designer's guide to boring applications

Gausser/degausser causes cancer

Computer-aided production makes EEs smaller, faster

Etiquette for Engineers

It's a sad fact that engineering schools give short shrift to the social graces. Yet, in your career, you're faced with the necessity of dealing with people, many of them highfalutin. This column, therefore, will give you the rudiments of etiquette, both to spare you embarrassment and to increase the likelihood of your keeping your job. This month, we'll explore how to act in a fancy restaurant.

1. Upon entering, show no signs of being impressed. Statements like, "Gosh, this is a beautiful, fancy place" are a no-no. Just raise your eyelids slightly and say something like, "Hmm—looks as though my decorator's been here."

2. Always carry a flashlight and a pair of scissors with you. Americans think dark restaurants are classy, so it's likely you won't be able to read the menu by the light of the small candle on the table. Using the scissors, cut out the price column from the menu. That way, the person you're with won't think you're price conscious. And never ask for a translation of items printed in French. Nod your head knowingly and order at random.

3. When you taste the wine the sommelier (wine steward) brings, chew it a while, then spit it on the floor. Then, even though you have no idea how good or bad the wine is, say something like, "Hmm—an impish little wine" or "Hmm—it has an imposing character that stops just short of ostentation."

4. When you eat your meal, be ambidextrous. Switching the fork from hand to hand after cutting your meat reveals your roots.

5. Finally, if your waiter's name is Jacques or Pierre, impress him and your dining companion by using a little French. Here are three phrases that are sure to go over big.

★ Cette nourriture est abominable.
(set new-ree-tyur ett ah-bow-me-nah-bluh)
This food is delicious.

★ Je pense que je vais vomir.
(zhe ponss kuh zhe vay voh-meer)
I think that I will return.

★ Votre chef est un sacré imbécile.
(voe-truh chef ett unh sah-cray em-bay-seal)
Your chef is a real genius.

ENGINEERS

YOU HAVE DEFINITELY WON A **FREE** GIFT!!!

Gift Category A	Gift Category B	Gift Category C
The Taj Mahal	19″ Color TV	Tooth Brush
Yankee Stadium	Food Processor	HB Pencil
Fort Knox	Pasta Machine	Pocket Protector
47k, 1% Resistor	47k, 5% Resistor	47k, 20% Resistor

Inspect the three numbers below. If no numbers match, you've won a gift from Category C! If two numbers match, your gift is in Category B! If all three numbers match, you'll definitely receive one of the gifts in Category A!!!

6347 **6347** **6347**

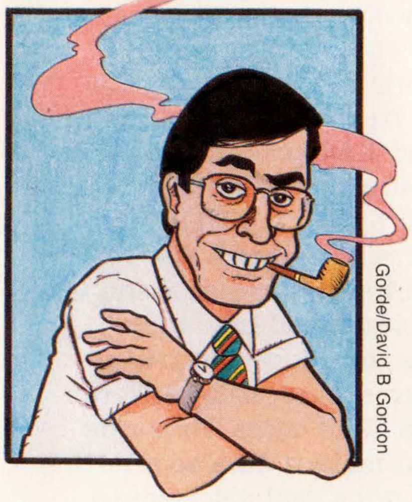
To claim your gift, all you have to do is visit our engineers' vacation resort in beautiful Sleazonia, West Virginia! You'll receive a presentation (whether you want it or not) on the benefits of purchasing a lifetime privilege to spend your vacations in our luxurious 4×6-ft mobile dwellings, which feature convenient outdoor toilet facilities and a test lab nearby.

Before setting up an appointment, simply find the gold star somewhere in this magazine and paste it on the entry certificate found somewhere else in the magazine. Then find the blue dot somewhere, and paste it on the gold star. To be eligible for the grand prizes, find the symbols of the Taj Mahal, Yankee Stadium, and Fort Knox somewhere in the magazine, and paste the symbol of your choice on the Grand Prize form found somewhere else. Then, stand on your head for 30 seconds while reciting "Beautiful Sleazonia." Finally, send proof that you're married with a combined income exceeding $80,000 and a copy of your mortgage, including all liens attached thereto, to

Sleazonia Vacation Resorts Inc
1500 Sucker Lane
Sleazonia, WV 55555

Drawing for Grand Prizes will take place June 6, 1989. Drawing will be supervised by Joe. Odds of winning: Taj Mahal, Yankee Stadium, Fort Knox: 1 in 1 googolplex. 19″ Color TV, Food Processor, Pasta Machine: 1 in 1 googol. Tooth Brush, HB Pencil, Vinyl Pocket Protector: who cares?

Tax the watt guzzlers and bit polluters



Gorde/David B Gordon

President Bush has inherited the excruciatingly difficult task of reducing our country's $17 zillion deficit. His "1000 points of light" can only increase the debt—how much depends on the wattage of the lights. A plausible way to cut the deficit is to tax electronics end users who use circuits and systems that consume too much power, operate too fast, or use too many bits.

It's inarguable that our deficit is linked closely to our consumption of energy. Because we have 432 ready-to-go nuclear plants whose startups are blocked by picketers who yearn for a return to kerosene lamps, we must use fossil fuels to produce electricity, Ovshinsky notwithstanding. And because OPEC is poised to inflict another '70s-type punishment on us, we simply must reduce the power we consume. Some will say, "What's the problem? Now we have CMOS, so power consumption is going down." True. But what most people don't realize is that our supply of C is dwindling rapidly. There's still plenty of N in the hills, but NMOS has fallen out of favor. So we must import a high percentage of the C we use in making CMOS ICs—hardly a way to reduce the deficit.

The ever-increasing speed of modern systems is inextricably tied to the rising consumption of power. What's needed, then, is a tax system that penalizes excessive power consumption and its bosom buddy, high speed. I propose that President Bush issue guidelines on IC speed. For example, he could impose a limit on A/D-converter speed in the form of a maximum resolution-frequency product. In my opinion, 315 CM (codes × MHz) is a reasonable figure. A 12-bit A/D converter, for instance, has 4096 codes. The 315-CM limit would restrict the converter's speed to 0.077 MHz, corresponding to a conversion time of 13 μsec.

Another factor tied to power consumption is bit count. The evolution of computer systems from 8 to 16 to 32 bits has been accompanied by significant increases in power consumption. The same is true for the ever-increasing RAM capacities in modern computers. A side effect of this insatiable demand for more and more bits is bit pollution. A large portion of these zillions of bits goes unused, and so we have the problem of bit disposal and its resulting pollution. Land bitfills are becoming exhausted; bit incinerators use fossil fuels and pollute the atmosphere.

A presidential commission could determine a reasonable progressive tax on the number of bits in a system. Another source of revenue would be a tax on bit disposal. This disincentive would provide an impetus for developing trinary (base-3), quadrary (base-4) and quinary (Schweppes) computers, which use fewer bits to process a given amount of data. Some other ways to reduce the deficit:

- Sell Silicon Valley to the highest bidder
- Raise engineers' income taxes to 90% of gross income
- Eliminate all taxes on management personnel. Management deserves the credit for the healthy state of American electronics, despite engineers' blunders; eliminating taxes on these business geniuses will provide incentive for making companies healthier yet.
- Impose an application fee of $1,000,000 per patent
- Restrict defense contractors' illegal overcharging to 20% of a contract's face value (unless the illegal overcharging is proven to be justified).

WJ Travis

Bill Travis
Contributing Editor

NEWS BREAKS

COMPANY MARKETS DATA-DEGRADATION SYSTEM

A new data-acquisition board, dubbed "BarfData," is available from Data Distortion Inc (Chesterfield, MA), a company that specializes in PC-based analog-signal degradation. The board features 16 poorly multiplexed analog-input channels, a signal-degrading instrumentation amplifier, a track-and-hold distorting amplifier, and a 12-bit, nonlinear A/D converter. The input multiplexers are from the bottom of the barrel, and offer only 20-dB channel-to-channel isolation and 1 MΩ each of on- and off-resistance. By the time a signal reaches the instrumentation amp, it's tainted by pollution from adjacent channels and severely attenuated by the multiplexers' high on-resistance. The instrumentation amp's specs are as repugnant as the multiplexers'; for example, gain accuracy is ±48% and total harmonic distortion is −15 dB. The almost unrecognizable signal then goes to the track-and-hold amp, whose abominable pedestal, accuracy, and droop parameters introduce additional errors in the signal. Finally, the output A/D converter features nauseating differential and integral nonlinearity and misses at least 2011 of its 4096 codes. Explains Joe Signalicide, president of Data Distortion, "Any wimp can make a data-acquisition system whose output accurately represents the input codes; it's a real art form to take a perfectly pure input and turn it into a stench in the nostrils of the signal-processing community."—Bill Travis

EVERYBODY ACQUIRES EVERYBODY

In a startling press conference on April 1, a spokesman from Insiders Inc, a Wall Street illegal-insider-information trader, announced that every electronics firm in the US has concluded a leveraged buyout of every other firm. According to Insiders' Boesan Ivesky, top-secret negotiations for the buyouts have been going on for the past three years. The ramifications of the buyouts are unclear at this moment; what's certain, however, is that every firm plans to fire every other firm's management team. The implications for design engineers in the acquir(ed)(ing) companies are equally unclear. Ivesky revealed, however, that the industry plans to adopt a free-agent system similar to the one used in professional sports.—Bill Travis

IBM ANNOUNCES PS/1,000,000 SERIES

Big Blue set the computer industry on its ear on April 1, when the firm announced its new, PS/1,000,000 Series of personal computers. Designed to prevent cloning, the family uses a bus architecture called TeraChannel—a 128-bit bus structure that's covered by 967 patents, 401 copyrights, and two Emmy awards. Additional clone-thwarting measures include explosive cabinet bolts, an automatic videotape record of users, and a 1-time user oath (with Bible) administered by the firm's authorized value-depleted resellers (VDRs). According to Mr Large Blue of IBM, Microhard is developing a PS/1,000,000-compatible operating system called OS/1,000,000. Immediately after IBM announced the series, a consortium of personal-computer manufacturers (led by Compaq) revealed plans for a counterattack. The firms plan to introduce a 256-bit, open-architecture system that uses Intel's new 8,000,986 microprocessor, a 250-GHz IC that addresses 9,999,999,999,999,999 Tbytes of memory.
—Bill Travis

Avoid burned-out ICs . . . also, how much for trade secrets?

Dear **Abbott:**

I have this problem with CMOS logic ICs. Every time I wire up a breadboard, I end up with one or more burned-out ICs. I've tried fusing the power supply and bringing the voltage up gradually, but nothing seems to help. Do you have any idea what I'm doing wrong?
Worried, Santa Clara, CA

Dear **Santa:**

Sure—you're not seasoning the CMOS ICs properly. It's a little-known fact that these circuits require some "stroking" before you can use them in an application. The procedure is simple: Wear shoes with leather soles and scuff them about 20 times on a nylon rug. Then run a nylon comb through your hair about 10 times. Now you're ready to season the ICs. Just hold one row of pins against a ground plane and touch the other row (the row with the input pins) with your index finger. You should have no more problems.

Dear **Abbott:**

I'm bewildered. First, we had the 150V supplies for powering vacuum-tube circuits. Then ±15V came along, and it seemed to be the ultimate solution. Now we have ICs that are powered from single 5V supplies, and some say the voltage will drop even further, say to 3.3V. What's your opinion about all these changes? **Concerned in New Jersey**

Dear **New:**

Well, let's look at it from the standpoint of numerology. Consider the ratios of the successive power-supply voltage-span reductions—150V to 30V, a ratio of 5; 30V to 5V, a ratio of 6. Now hold on to your hat. What's startling is that the ratio of 5V to 3.3V is 1.5151515 . . . , a never-ending number. Are you sitting down? There's more—it so happens that Ramus II, the father of astrological proctology, was born on May 6, 1515. If I were you, I'd run right out and play 5615 in the daily-numbers lottery.

Dear **Abbott:**

My boss and I have this argument going. We have an application for a large number of extremely fast flip-flops. I want to use an ECL gate array, and my boss is set on using a GaAs array. Who do you think is right? **ECL Advocate, High Power, CA**

Dear **ECL:**

You're both wrong. The 6SN7 dual triode makes the best flip-flop in the world. You and your boss have the same problem: You're hung up on the latest, trendiest technology, and you've lost sight of tried-and-proven techniques. Get off the fad bandwagon and take some time to smell the filaments.

Dear **Abbott:**

I'm a circuit-design engineer in a defense-electronics firm, and I don't make enough money to make ends meet. The problem is, my wife likes Porsches, Perrier water, and expensive yuppie restaurants. So, I've begun selling some of our company's schematics to a bearded man named Boris. My question is, how do I determine how much to charge? **Entrepreneur, Profit Motive, CA**

Dear **Entrepreneur:**

First, let's determine my share for not turning you in. I think 40% is equitable. The best way to set a price for stolen trade secrets is to charge by the IC count. That way, you'll have an incentive to maximize the number of ICs in the circuits you design. I feel $1000 per IC package ($10,000 for gate arrays) is fair. You'll receive the number for my Swiss bank account in the mail.

Dear Abbott is pleased to answer questions from engineers who are either too dumb or too lazy to solve their own problems. Send self-addressed stamped envelope and a blank, signed check.

Use a negative capacitor for useful, banal applications

Bill Travis, *Contributing Editor*

It's been 21 years since this editor, employed as a bizarre-product development engineer at Sprague Electric Co (North Adams, MA), serendipitously invented the MinusCap (**Ref 1**). This component resembles an ordinary capacitor in every way, except that its value is negative (for example, $-1\ \mu F$). **Fig 1** shows the startling results of applying a step signal to a series-RC integrator incorporating the MinusCap. Note that the output waveform has a negative time constant. This phenomenon is easy to explain—to preserve the negative exponent of e in the expression $V_{out} = V_{in}(1 - e^{-t/RC})$, the time t assumes a negative value.

An interesting aspect of the output waveform in **Fig 1** is the fact that two output voltages exist simultaneously. A useful, albeit banal, application comes to mind. If you connect a lowpass and highpass dc-voltage filter to the output and buffer the outputs of the filters, you obtain a dual-voltage power supply. For example, assume the lower output voltage in **Fig 1** is 5V and the upper one is 15V. A 5V lowpass dc filter with reasonably steep skirts will, for all intents and purposes, completely attenuate the 15V signal and pass the 5V level. And vice-versa for the 15V highpass dc filter.

Some applications suggested in **Ref 1** include predictions of future noise spikes, scope probes with zero shunt capacitance (made by connecting an equal-value MinusCap in parallel with the probe's positive capacitance), and observations of future failures. The promise of a rosy future for the component, however, never bore fruit. The Department of Defense (DoD) seized all lab samples and notes, and put the material in the same storage facility that's housed the Lost Ark (**Ref 2**) since 1939.

Because of the USSR's development this year of the negative inductor and the imaginary resistor, the DoD

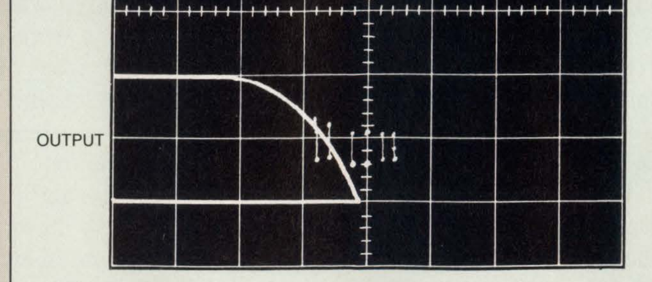


***Fig 1—This scope photo** depicts the input and output waveforms of the -1-μF MinusCap; pay no attention to the phospher burn marks.*

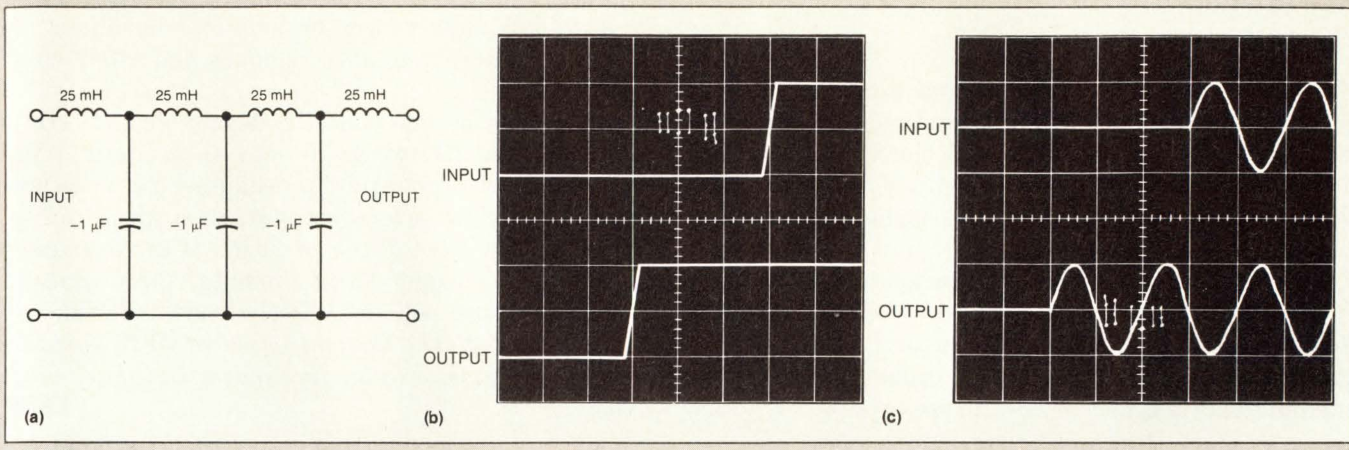


***Fig 2—It's up to you** to figure out any useful applications for the MinusCap.*

no longer considers the MinusCap to be a threat to national security. Development of paper, ceramic, and electrolytic negative capacitors is now underway at several manufacturers' facilities. At the mammoth EDN test lab, for example, this editor recently constructed some units that exhibit a -1-μF value and effective series resistance of -0.1Ω.

Fig 2a shows a delay line constructed with 25-mH positive inductors and the -1-μF MinusCaps. In **Fig 2b,** you see the results of applying a 10V step to the input of the line. The output step appears 3 msec before the application of the input. As seen in **Fig 2c,** the same results accrue when you apply a sinusoidal input to the input of the delay line (actually, the anticipation line)—the sinusoidal output appears at the output 3 msec before the application of the input. It's up to you to determine useful applications for such anticipation lines. One possibility is to detect changes in system logic states before they occur.

One final application possibility, one the DoD is studying very carefully, is in imaginary-frequency transmitters. The expression

$$f = \frac{1}{2\pi\sqrt{LC}}$$

gives the frequency determined by an LC tank in an oscillator. If the value of C in the expression is negative, then the resulting frequency is, naturally,

$$f = -j\frac{1}{2\pi\sqrt{L|C|}}.$$

The reason for the DoD's interest in such imaginary-frequency transmitters is the fact that their signals are detectable only by imaginary receivers, such as those the DoD often receives under defense contracts. EDN

References

1. Travis, W J, "The negative capacitor: A challenging new component," *EEE*, September 1968.

2. Jones, Indiana, "Discovery of the Lost Ark of the Covenant," Journal of Mythical Artifacts, July 1939.

CAREER OPPORTUNITY: ENGINEERING PROFESSORS NEEDED

If you're experienced in electronic engineering but you feel you're at a dead end in your job, consider making a career change. At Real-World Engineering Institute, we have openings for professors who can teach practical courses not offered at most engineering schools. Some examples:

- **Buck-Passing I and II. The fundamentals of how to avoid taking the blame for project catastrophes. Includes such categories as The Power-Outage Ploy, Copy-Protection Crash, and Joe Did It.**
- **Advanced Rationalization. The course material gives students hundreds of ways to explain away undesirable results in their designs. Some topics: We Need a Class-(1000/100/10/1) Clean Room, We're Getting Lousy Wafers from Our Supplier, and The Coprocessor Made a Math Error.**
- **Climbing the Ladder. How designers can stab their bosses in the back and get ahead. Examples: Anonymous Notes to the President, Anonymous Notes to the Boss's Wife, and The Perfect Murder.**

Back-stabbing, scapegoating, and buck-passing experience is preferred. Send your resume in complete confidence to:

Real-World Engineering Institute
Opportunism, CA

An equal-opportunity employer.

ABERRANT DESIGN IDEAS

Gausser/degausser brightens color monitors

Ted Burton
Signetics

A small permanent magnet (the gausser), held in close proximity to the face of an operating color monitor, will produce a striking display of colorful patterns (**Fig 1**). Much to the chagrin of the gausser user, though, the colorful patterns turn into permanent color clouds when the gausser is removed.

Luckily for the gausser user, whose job might now be in jeopardy, it's easy to build a degausser from a 1000-ft roll of 30-gauge wire-wrapped wire. This degausser is not UL approved, it erases any magnetic medium within a foot or two, it uses potentially lethal voltages, it interferes with pacemaker operation, and it probably causes cancer or hair loss in laboratory rodents. However, it also removes the cited color clouds.

Fig 2 shows how to build the degausser and turn it on by sticking its two leads into an ac outlet. You should sweep the powered-up degausser past the face of the monitor for several seconds, then turn it off by pulling the leads out of the ac outlet. If the degausser is left running longer than a minute, the degausser and its operator will most likely start to smoke or burn. (Ed Note: *The thought occurred to this editor: Why use the gausser in the first place? But that's picayune.*) EDN

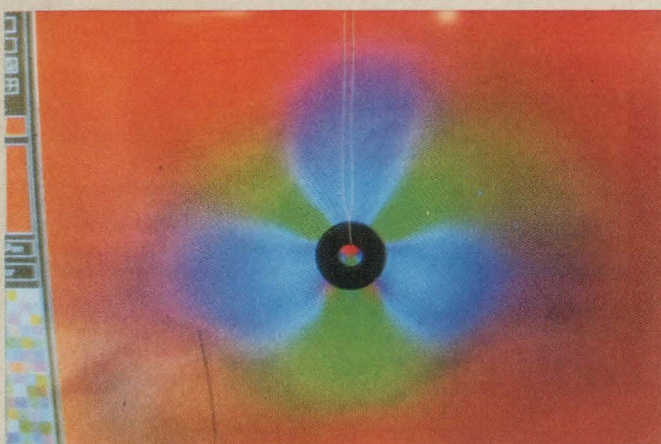


Fig 1—A simple magnet *can really liven up your color monitor.*

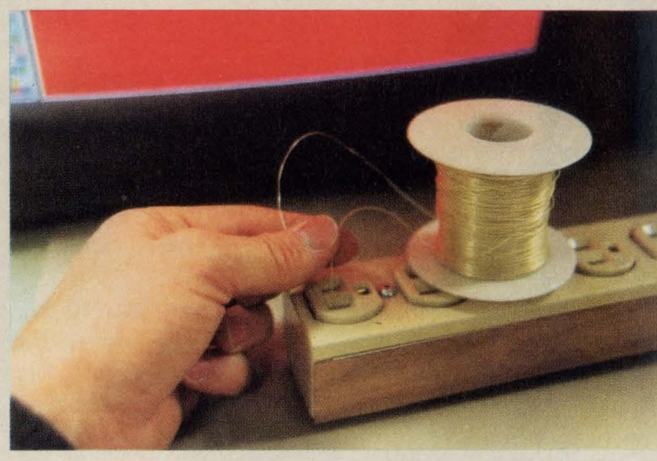


Fig 2—In addition to killing innocent lab animals, *this degausser gets rid of the colorful patterns on your monitor.*

Exploit Z80's hidden logarithmic mode

Jim Williams
Linear Technology Corp

The popular Z80 microprocessor contains a very powerful embedded routine dedicated to high-speed logarithmic functions. Because it operates in real time, it is significantly faster than lookup tables or computational approaches. Furthermore, it's directly addressable in analog format. All Z80 chips have this capability, although manufacturers do not supply the necessary data to exploit it.

The circuit in **Fig 1** is a complete, real-time logarithmic ratio computer that uses fully parallel, coprocessing Z80s in the embedded logarithmic mode. Connecting an analyzer between the Z80's ground pin (pin 29) and the D_1 data bus (pin 15) reveals the internal logarithmic instruction set. **Figs 2a, 2b, 2c,** and **2d** show that the best performance occurs in the 300-nA to 750-μA range.

This designer (Ed Note: *We must avoid writing in the first person at all costs*), discoverer of the Z80's logarithmic mode, is ebullient. Everyone always told this designer that analog circuits were nowhere. Now this designer believes it. Microcomputers are great. You can do anything with them. Can you imagine what's possible with one of those 32-bit babies? This designer will bet that you can get another decade with

that 386 thing. After lunch, this designer is going to go over to Intel and apply for a job. This designer is also going to trade in his Tektronix 547 and 556 for a development system. But it's going to to be tough to find one with those funny little dots on the CRT.

EDN

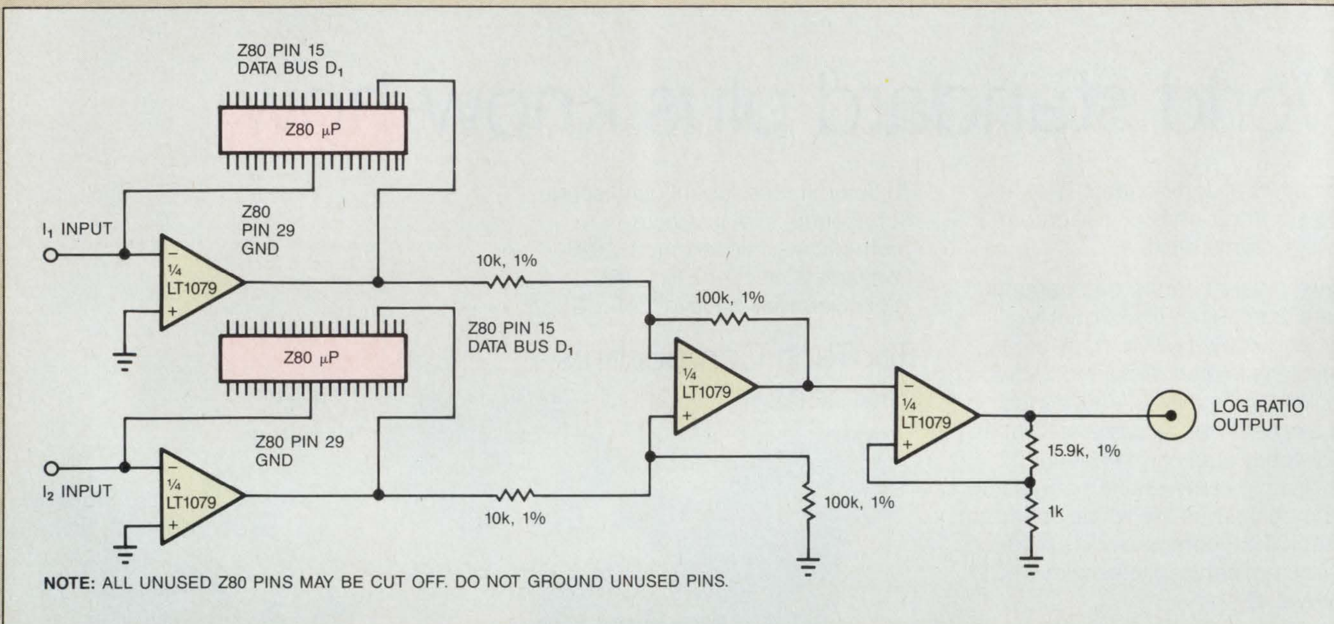


Fig 1—A couple of Z80s, *configured as full parallel coprocessors, perform real-time logarithmic ratio computations.*

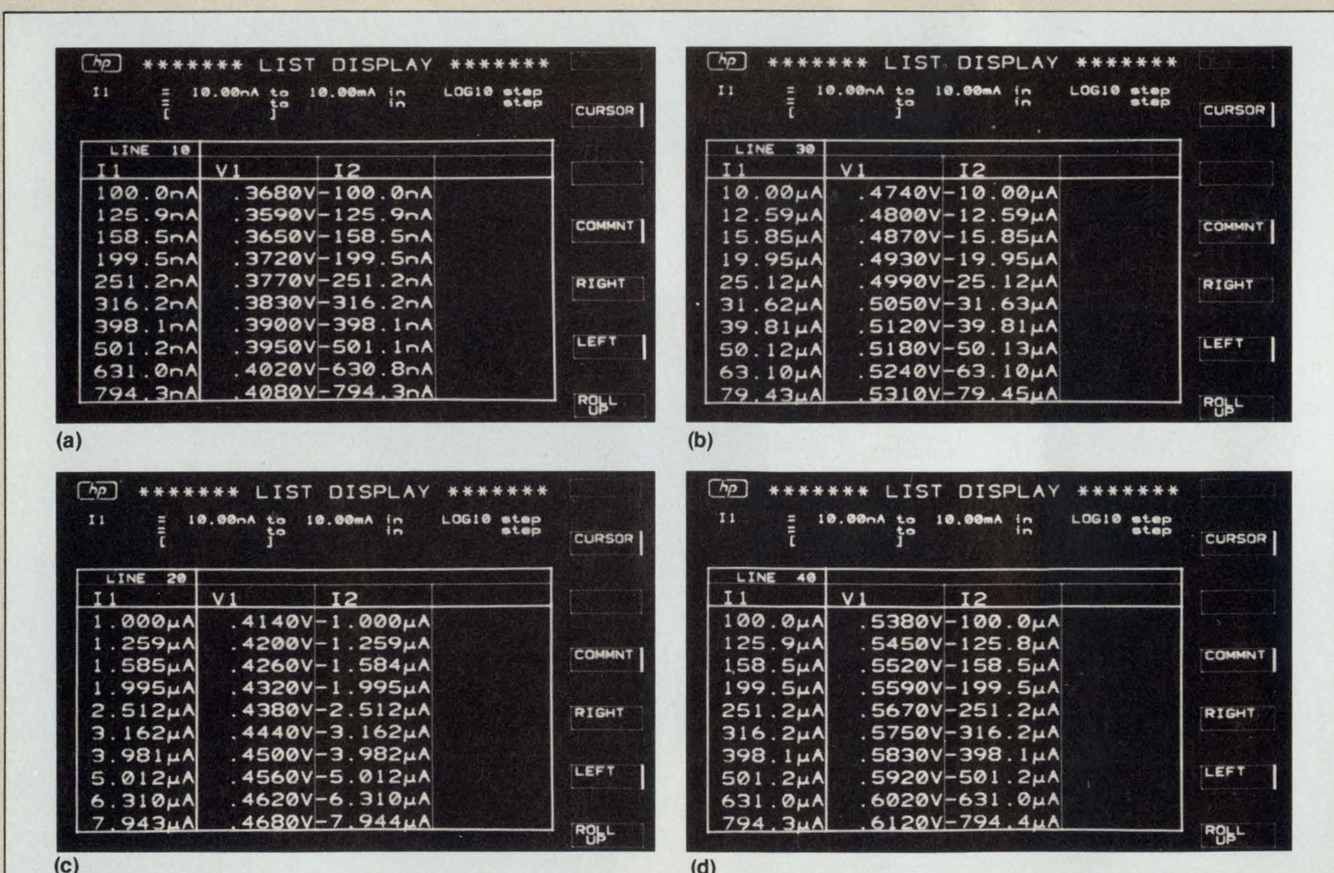
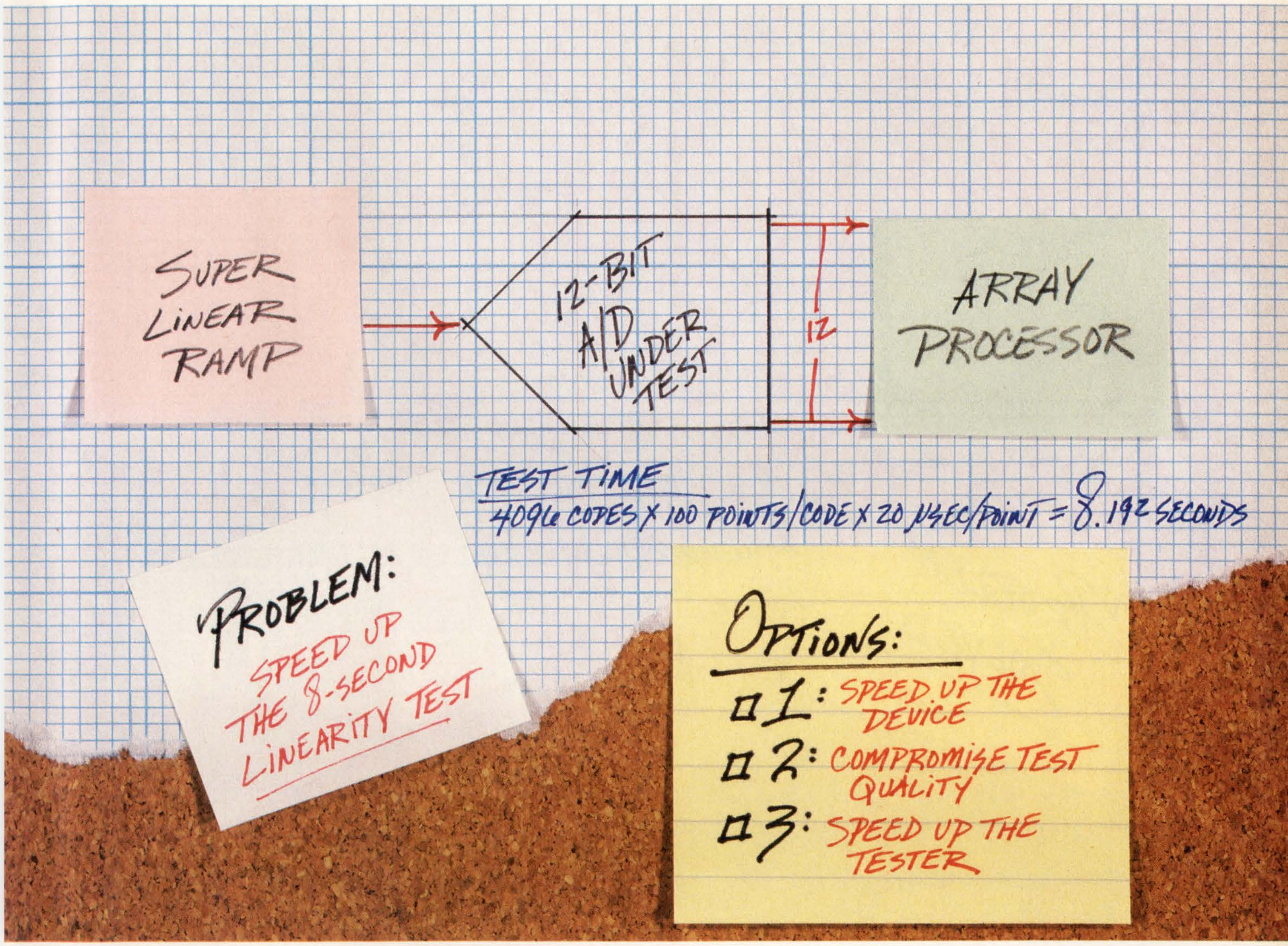


Fig 2—After viewing these displays, *this author now believes "microcomputers are great."*

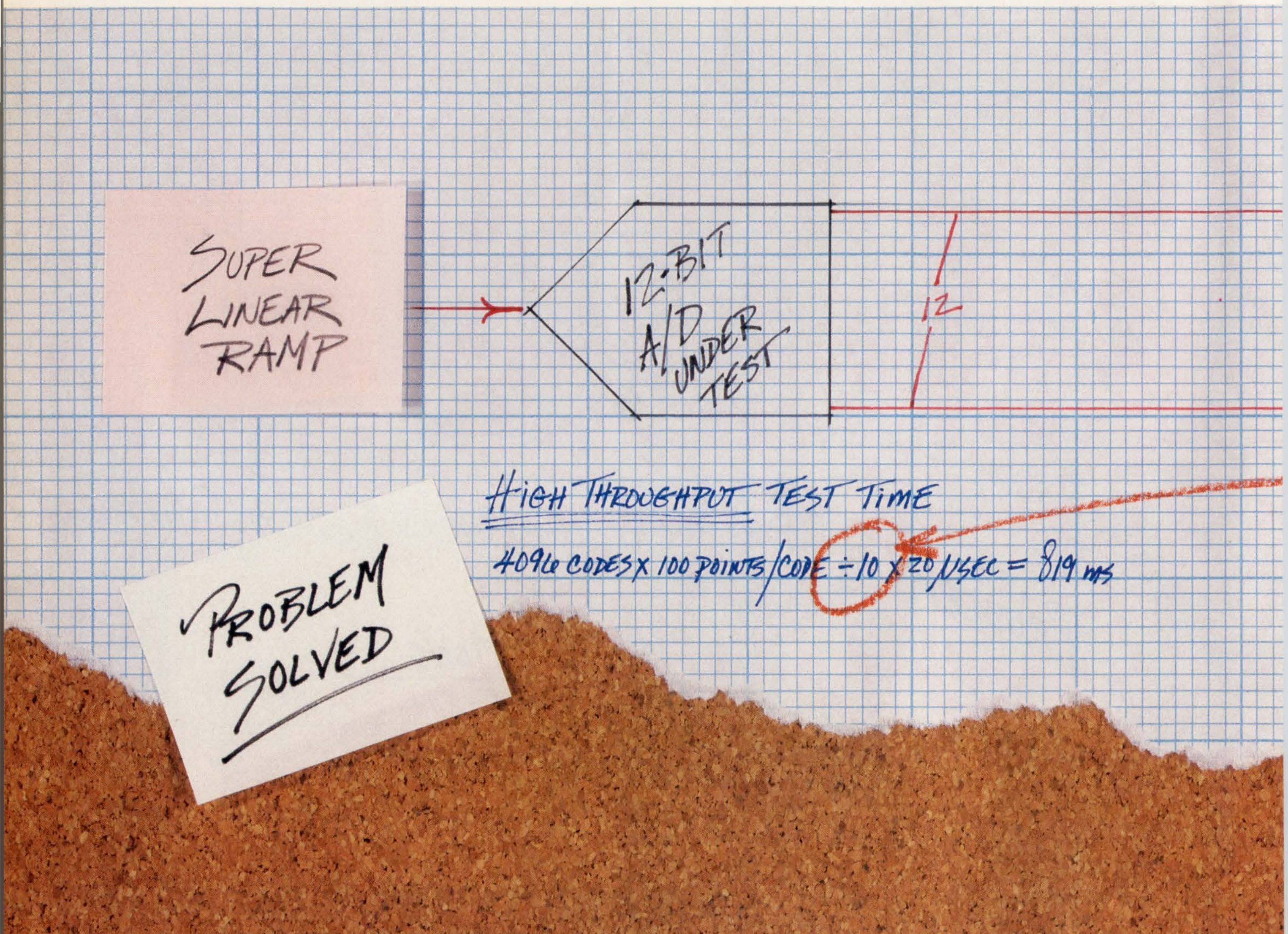
1 is impossible. 2 is undesirable. 3 is...



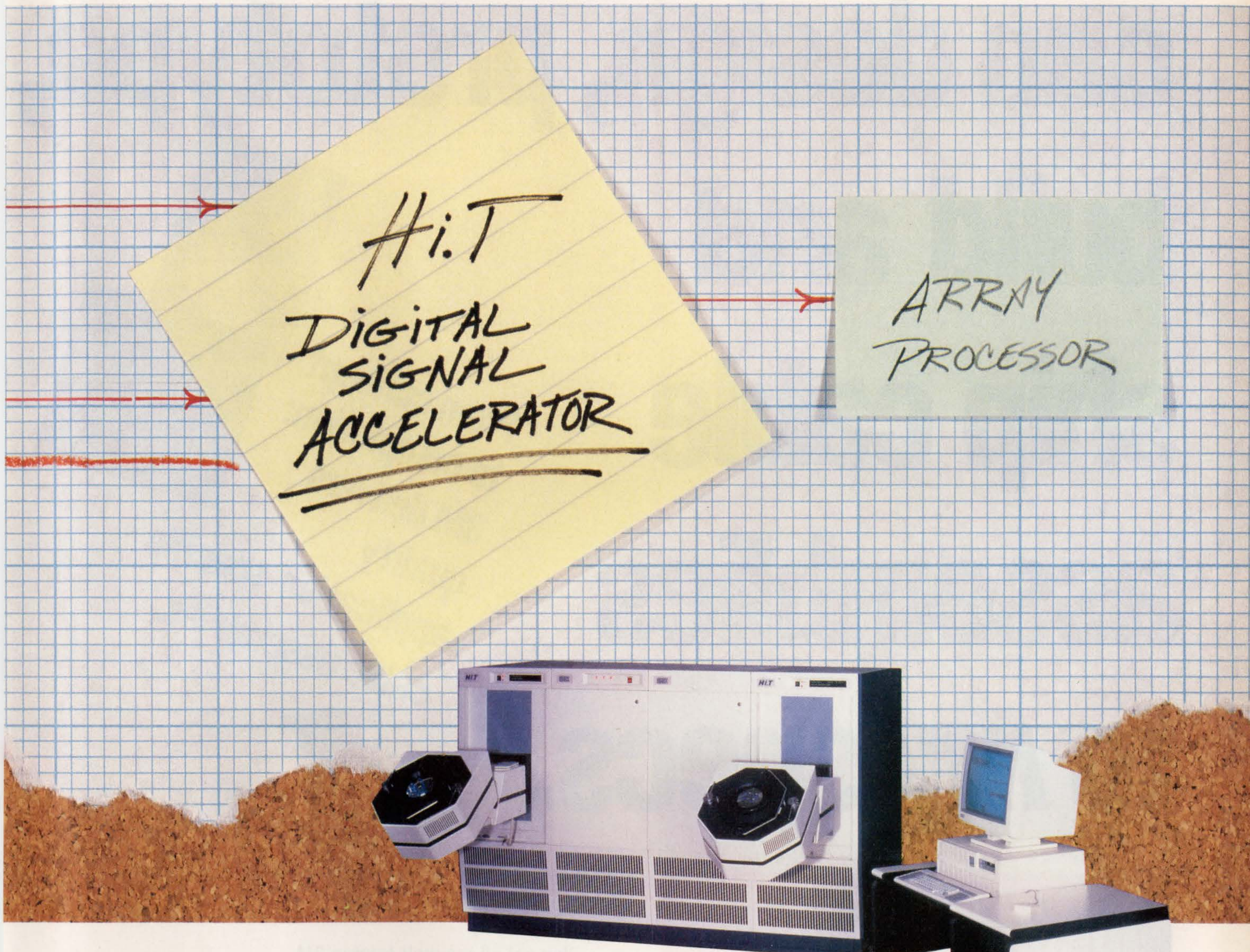
The choices don't appear to be very attractive, but the problem must be solved. An eight-second test time for all-code differential and integral non-linearity testing is out of the question for production testing. And it gets worse geometrically for higher-order converters: A 16-bit device would take 128 seconds.

What about your options? The A/D already spits out numbers ten times as fast as most testers can process them — especially with the single, general-purpose array processor typically used for this test. Testing less codes or reducing the amount of averaging would seriously diminish test quality.

Which leaves you with speeding up the tester. An option LTX has considered...


SUPER LINEAR RAMP
12-BIT A/D UNDER TEST
12
HIGH THROUGHPUT TEST TIME
4096 CODES X 100 POINTS/CODE ÷ 10 X 20 µSEC = 819 ms
PROBLEM SOLVED

...unbeatable. As long as it's Hi.T.



Hi.T. High-throughput linear testing from LTX.

As a result, the Hi.T system brings all-code test time down to just 800 milliseconds. So you no longer have to compromise full testing to meet production demands on A/Ds and other sophisticated mixed-technology devices.

The Digital Signal Accelerator system is just one of the many local computers Hi.T uses to remove testing bottlenecks. Local processing helps Hi.T's parallel analog resources perform instant DC measurements. And local processing throughout the system cuts down the time it takes instruments to set up between tests.

The result: Hi.T, as you would expect, approaches testing speed limited only by the response time of the device itself. When you're looking for speed — in multiples — Hi.T is the obvious choice.

Get "Beat the Clock," our White Paper with the details on Hi.T's Digital Signal Accelerator. Circle the number or call Carol Everett at (617) 461-1000.

LTX Responds.

CIRCLE NO 60

"I need a supplier who can design, prototype, build and ship cable assemblies to *my* specs."

Tough customers turn to 3M.

Turn to 3M for cable assemblies created for your specific application.

We'll help you right up front with design assistance to quickly turn your interconnect idea into a prototype. Manufacture as many finished assemblies as you need, to your most demanding specs. Then deliver everything you need–from pressed and molded to high-speed transmission line and fiber optic cable assemblies–to meet your most ambitious production schedule.

You get all the well-known 3M quality in assemblies that meet your demanding criteria. Without having to cope with rejects or in-house modifications. You get the reliability you need to help eliminate wasted time or field failures. And the just-in-time delivery programs that reduce inventory and materials handling costs.

There's only one place tough customers turn to no matter what their specs. 3M. For information, dial 1-800-CALL-EPD. Or call from your modem 1-800-444-8080 (300-2400 baud, 8 bit, no parity 1 stop bit) and enter the access code 3MEPD4 when prompted. Or write 3M Electronic Products Division, Department F, P.O. Box 2963, Austin, TX 78769-2963.

3M

CIRCLE NO 61

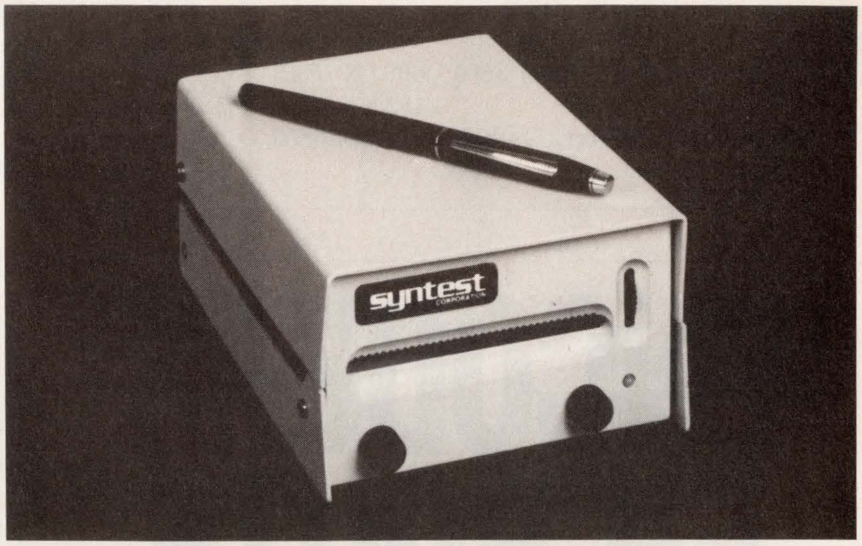
NEW PRODUCTS

COMPUTERS & PERIPHERALS

THERMAL PRINTER

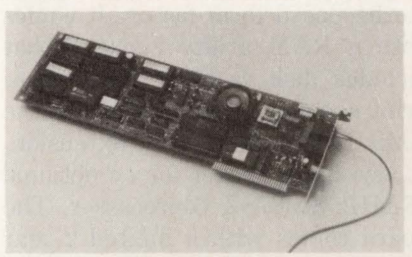
- *Contains NiCd battery pack for handheld applications*
- *Unit measures 4.5 × 2.6 × 6.2-in. and weighs 2.25 lbs*

The SP-400B is a battery-powered handheld thermal printer useful in field applications requiring a portable data logger. The unit has a 40-column thermal printhead, an enclosed paper supply, and a replaceable NiCd battery pack. It can print as many as 3000 lines of text between battery charges and contains a multinational character set with graphics capability. The unit provides three input interfaces: an RS232C serial port, a 20-mA current loop, and a Centronics parallel port. The printer comes in an aluminum case measuring 4.5 × 2.6 × 6.2-in. and weighs only 2.25 lbs. A flip-open cover permits easy access to the paper supply and battery pack. $435. Delivery, four to six weeks ARO.



Syntest Corp, 40 Locke Dr, Marlboro, MA 01752. Phone (617) 481-7827. FAX 617-481-5769.

Circle No 370



SNA COMM BOARD

- *Conforms to CCITT V.32*
- *Combines three communications protocols on one plug-in board*

The AdaptModem V.32 is a multiprotocol communications board for the IBM PC, PC/XT, PC/AT, PS/2 models 25 and 30, and compatible computers. Because the board is designed for IBM's Systems Network Architecture (SNA), it implements three communications protocols on one plug-in board: a full-duplex asynchronous modem and a synchronous modem, which conform to the CCITT V.32 standard, and a Synchronous Data-Link Control adapter. The board also supports 9600-bps communications for a variety of available AdaptSNA software packages for SNA communications protocols, including interactive 3270, batch 3770/RJE, cooperative processing LU6.2/APPC, and program-to-program LU0. Plug-in board, $1295; AdaptSNA software packages, $245 to $785.

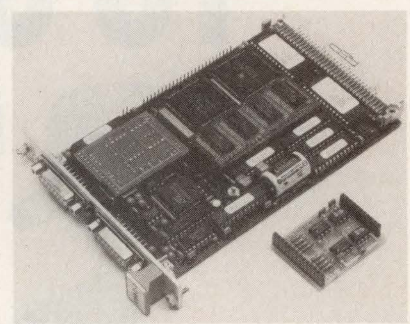
Network Software Associates Inc, 22982 Mill Creek, Laguna Hills, CA 92653. Phone (714) 768-4013.

Circle No 371

BOARD COMPUTER

- *Has a CMOS μP and peripheral devices*
- *Is housed on a single-height VME bus board*

Implemented with CMOS devices, the VSBC-1 single-board computer for VME bus systems consumes only 3W of power. The single-height board has a 68HC000 μP that runs at a clock speed of 12.5 or 16.7 MHz, and a memory capacity of 1M bytes of zero-wait-state



CMOS static RAM and as much as 512k bytes of 1-wait-state EPROM. I/O facilities include two serial ports that you can configure with piggyback modules to operate at RS-232C, -422, -485 levels or in a 20-mA current loop mode, and a 16-bit parallel port with additional handshaking lines. You can optionally have a SCSI bus interface that is controlled by an NCR53C90 SCSI bus controller. Other onboard peripherals include 16- and 24-bit timer/counters, a real-time clock, and a watchdog timer. An onboard lithium cell provides battery backup for the real-time clock and static RAM.

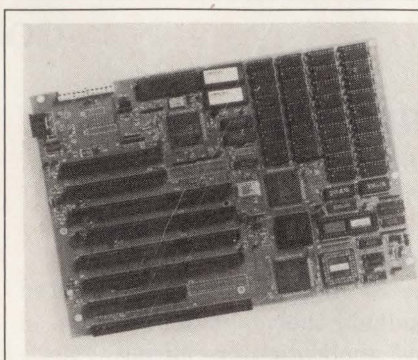
The board's VME bus interface includes a 7-level interrupt handler and a single-level bus arbiter. Software support includes the OS-9 and PDOS operating systems, and debug monitor firmware. From $590 in OEM quantities.

Pep Modular Computers GmbH, Am Klosterwald 4, 8950 Kaufbeuren, West Germany. Phone (08341) 81001. TLX 541233. FAX 08341-40422.

Circle No 372

Pep Modular Computers Inc, 600 N Bell Ave, Carnegie, PA 15106. Phone (412) 279-6661. FAX 412-279-6860.

Circle No 373



386SX MOTHERBOARD

- *Contains as much as 4M bytes of zero-wait-state RAM*
- *Comes with RAM utilities that include disk caching*

The Bullet-386SX motherboard features a 16-MHz 80386SX μP and is available with 512k, 1024k, or 4096k bytes of dynamic RAM running with zero-wait-states. It also contains five IBM PC/AT compatible expansion slots as well as three IBM PC/XT compatible expansion slots. The motherboard's dimensions conform to the IBM PC/XT motherboard form factor. It comes with a RAM utility package that includes disk caching, RAM disk, print spooling, and support for the EMS LIM 4.0 memory extension. It also has a socket for an optional 16-MHz 80387SX coprocessor. The board comes with a limited 2-year warranty. A motherboard with 512k bytes of DRAM and a 4-utility package costs $823, which includes a 50% discount for resellers on the first unit.

Wave Mate Inc, 2341 205th St, Suite 110, Torrance, CA 90501. Phone (213) 533-8190. FAX 213-533-5940.

Circle No 374

PGA VERIFIER

- *Tests LCA designs for the IBM PC/AT*
- *Consists of a plug-in card, a pod, and a target-system probe*

The Mesa I in-circuit PGA development tool for Xilinx's Logic Cell Arrays (LCA) consists of an IBM PC/

Text continued on pg 212

AT-compatible plug-in card, a pod with 12 LCAs, and a probe with an LCA connector and socket for the target system. The tool lets you verify host-downloaded data, observe the register states in the target LCA, isolate signals from the target system and create states to isolate problems, and alter real-time designs. In addition, the unit serves as a breadboard for developing LCA designs. A shadow LCA acts as a mirror for the states in the target LCA. The company and Tektronix jointly developed a flex-circuit cable that connects the pod to the probe. The probe connector plugs into a PLCC socket on the target system. The Mesa I software, which runs under Windows, is compatible with Xilinx's design software, allowing it to extract symbolic information from XACT files. $9390. Delivery, eight weeks ARO.

Data I/O Corp, Box 97046, Redmond, WA 98073. Phone (206) 881-6444. TLX 152167. FAX 206-882-1043.

Circle No 375

STD I/O CARDS

- *Provide 16 optoisolated inputs and outputs*
- *Each output can switch 50V with 400-mA max load current*

The 242-1 and the 342C-1 dual-port optoisolated I/O cards for the STD Bus provide 16 input and 16 output circuits arranged as two 8-bit ports. The 242-1 is compatible with the STD TTL Bus, and the 342C-1 is compatible with the STD CMOS Bus. You can configure the inputs to handle standard TTL inputs by setting an input threshold voltage to 1.4V. In addition, the inputs can handle industrial voltage swings by setting the threshold to 6.4V above industrial ground. The input circuits can withstand input voltages between −50 to +50V. The output circuits have Darlington open-collector arrangements with provisions to install pullup resistors. Each output can switch 50V at 400 mA max. Each of the two input and two output ports has its own power supply on board, which requires only a 5V signal from the bus. 242-1, $438; 342C-1, $486 (10).

Enlode Inc, 1726 Kingsley Ave, Orange Park, FL 32073. Phone (800) 874-7729; in FL, (904) 264-4405. FAX 904-264-0765. TLX 466036.

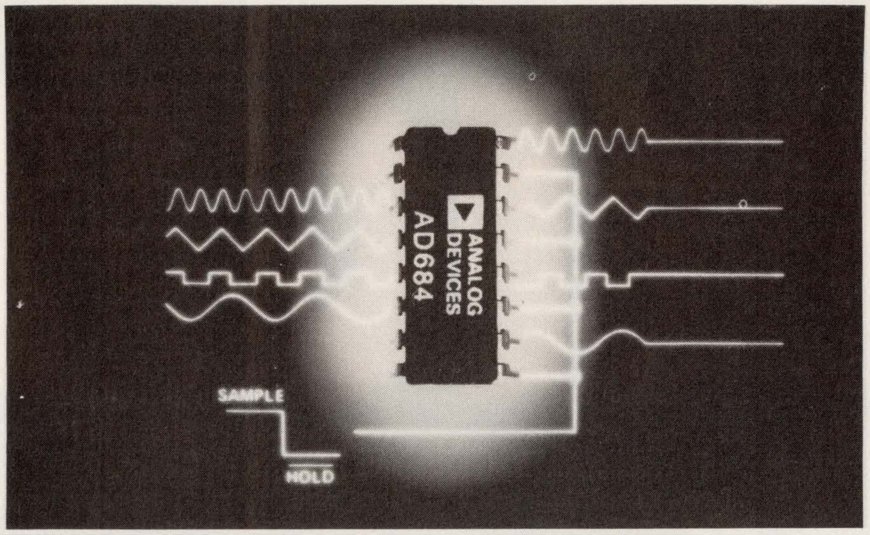
Circle No 376

R

INTEGRATED CIRCUITS

QUAD S/H AMPLIFIER

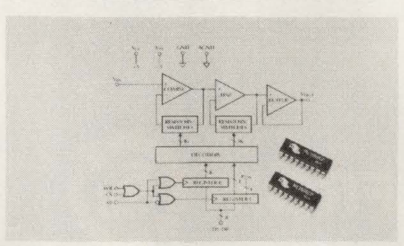
- *Has 12-bit accuracy*
- *Acquisition time is 600 nsec*



The AD684 quad S/H amplifier features 12-bit accuracy and a sampling rate to 100k samples/sec. Each channel of the AD684 has a guaranteed maximum acquisition time of 600 nsec to within 0.1%, and 1 μsec to within 0.01% for a 10V step. For simultaneous sampling, the AD684's entire error budget is completely encompassed in a 300-psec max aperture offset between channels. A proprietary error-correcting architecture compensates for hold-mode errors and ensures 12-bit accuracy and repeatability. The AD684 has a maximum full-scale nonlinearity of 0.005%, and its hold characteristics include a 500-nsec maximum settling time, 200-psec aperture uncertainty, and a 10-nsec aperture delay. The IC operates from ±12V supplies and dissipates 530 mW max. Three temperature grades are available. From $23.50 (100).

Analog Devices, Literature Center, 70 Shawmut Rd, Canton, MA 02021. Phone (508) 935-5565

Circle No 351



LOG GAIN/ATTENUATORS

- *Provide control from −24 to 24 dB*
- *Interface with 8- and 16-bit buses*

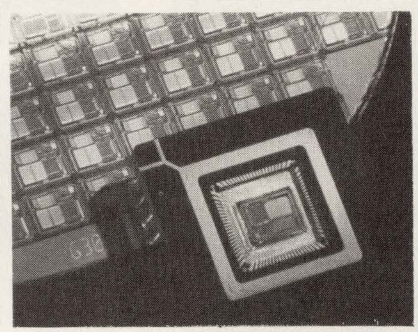
The ML2008 and ML2009 amplify or attenuate analog signals to ±3V under μP control and are noise-rated at 900 nV/$\sqrt{\text{Hz}}$ at 1 kHz. The devices provide automatic signal-level control from −24 to 24 dB in 0.1 dB steps. The ML2008 interfaces to an 8-bit μP bus, using two write operations to store nine gain-setting bits and a power-down bit. The ML2009 has a single 9-bit data register, which you can program with one write operation when using a 16-bit data bus. Both devices operate from ±5V supplies. 18-pin DIP or 20-pin plastic chip carrier, $5.50 (100).

Micro Linear Corp, 2092 Concourse Dr, San Jose, CA 95131. Phone (408) 433-5200.

Circle No 352

VIDEO CONTROLLER

- *Features video rates to 120 MHz*
- *Supports high-resolution graphics*



The IMS-G300 video controller supports high-resolution color graphics applications with resolutions of 640×480 (VGA), 1024×768, and 1280×1024 pixels. The highly integrated chip contains a 256×24-bit color look-up table, a programmable video-timing generator, a 32-bit multiplexed pixel port, a triple video DAC with 8-bit resolution, and an on-chip, phase-locked loop. The -G300 can handle video rates to 120 MHz and interlaced or noninterlaced video. The chip has four 8-bit pixel ports, which accept data directly from the video RAM array at 25% of the video rate. The pixel port has two software-selectable operating modes. Mode 1 sends the data via the 24-bit color look-up table, permitting the selection of 256 colors from a choice of over 16 million. Mode 2 sends the 24-bit data directly to the 8-bit video DACs, allowing the diplay of 16 million colors at any one time. The devices come in 84-pin PGA or LCCC packages. An 85-MHz part, $100 (1000).

Inmos Corp, Box 16000, Colorado Springs, CO 80935. Phone (719) 630-4215.

Circle No 353

THE

SMALL

AND THE

MIGHTY

HIGH POWER SWITCHERS...FROM

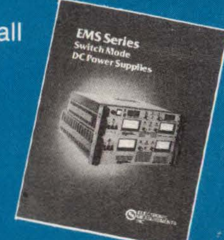
Lighter...Smaller...More Powerful...

for single and three phase applications where high efficiency, precise regulation and a high degree of packaging density are required.

The EMS Series incorporates the best of customer tested and application proven features:

- 1kW, 1Ø; 2.5kW, 1Ø and 3Ø in one unit; 5kW, 3Ø
- Highest power per cubic inch for wide range, rack mount, CV/CC power supplies in the industry
- Common programming with TCR, EMHP, ATR and HCR Series
- 650 microsecond transient response time
- Built in OVP and thermal protections ...and much, much more

Want all the details on the small and the mighty? Write or call for the latest Tech Bulletin on the EMS Series of DC Power Supplies.



ELECTRONIC MEASUREMENTS INC.

405 Essex Road, Neptune, NJ 07753

CALL **TOLL FREE 800-631-4298*** • Telex: 132-424 • Fax (201) 922-9334

*Except in New Jersey, Alaska, Hawaii and Canada call (201) 922-9300.

CIRCLE NO 43

See Us at ELECTRO Booth #1810

DUAL AUDIO DAC

- *Features 20-bit resolution*
- *Has two independent channels*

The D20200 is a complete, dual, 20-bit, D/A-converter subsystem. The module includes two 20-bit DACs, a stable bipolar reference, a serial CMOS/TTL-compatible digital interface, and two distortion-suppressing output deglitchers/amplifiers. It needs no external components or trimming to meet its specifications; you only need to connect ±15 and 5V power supplies, a serial data source, and appropriate timing signals. The D20200 handles output signal amplitudes from 0 to −60 dB. Total harmonic distortion and noise is typically −90 dB at −20-dB output and −52 dB at −60-dB output. Differential nonlinearity is typically ±0.0002% of FSR. The D20200's serial interface accepts digital word lengths from 16 to 32 bits, and it accepts simultaneous or multiplexed data at a 15-MHz maximum clock rate. It converts at rates from dc to 200 kHz per channel and accepts digital coding formats of two's-complement, offset binary, or complementary offset binary. $199 (100).

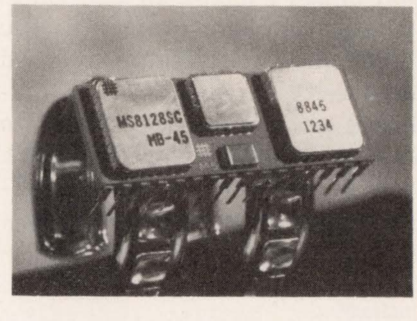
UltraAnalog Inc, Box 14164, Fremont, CA 94539. Phone (415) 657-2227.

Circle No 354

STATIC RAM

- *Features access time as low as 55 nsec*
- *Operates over the military temperature range*

Targeted for use in military and aerospace applications, the MS-8128SC 128k × 8-bit high-speed static RAM has an operating temperature range of −55 to +125°C and can be screened to MIL-STD-883C requirements. It is available with access times of 55, 70, 85, 100, 120, or 150 nsec and has TTL-compatible inputs and outputs. The device is manufactured from four 32k × 8-bit RAMs packaged in ce-



ramic leadless chip carriers that are bonded to a single 32-pin ceramic DIP substrate that also carries chip-select decoding logic and power-supply decoupling capacitors. Operating at a clock frequency of 1 MHz it consumes 150 mW of power from one 5V supply; in standby mode, it consumes 2 mW. A low-power version, which consumes only 40 μW in standby mode, is available for applications that use battery backup. From £145 to £290 (100).

Hybrid Memory Products Ltd, Elm Rd, W Chirton Industrial Estate, N Shields, Tyne and Wear NE29 8SE, UK. Phone 091-258-0690. TLX 53206. FAX 091-259-0997.

Circle No 355

Mosaic Semiconductor Inc, 7420 Carroll Rd, Suite 200, San Diego, CA 92121. Phone (619) 271-4565. FAX 619-271-6058.

Circle No 356

ANALOG MULTIPLEXERS

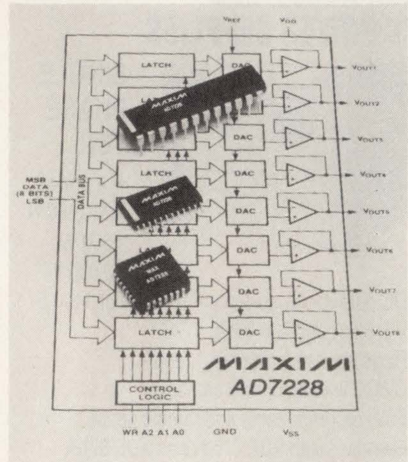
- *100Ω on-resistance*
- *250 nsec switching times*

Pin compatible with the industry-standard DG508A and DG509A, the DG408 and DG409 analog multiplexers offer improved specifications compared to earlier types. The on-resistance of the DG408/409 is only 100Ω, leakage current is less than 0.5 nA, switching time is 250 nsec, and power dissipation is only 2.5 mW. The DG408 is an 8-channel, single-ended device with a 3-bit binary address. The DG409 is a 4-channel, differential device with a

2-bit binary address. In addition to specification improvements, the DG408 and DG409 feature reduced sensitivity to electrostatic discharge (ESD) and the ability to withstand ±400V on all pins (with respect to ground). Both TTL-compatible multiplexers conduct current equally well in both directions and allow operation with supply voltages to ±15V or with 12 and 0V unipolar supplies. 16-pin DIP and small-outline packages, $4.68 to $15.92 (100).

Siliconix Inc, 2201 Laurelwood Rd, Santa Clara, CA 95054. Phone (408) 988-8000.

Circle No 357



OCTAL 8-BIT DAC

- *Includes output buffers*
- *Has μP interface logic*

The AD7228 CMOS IC features eight fully independent 8-bit, voltage-output D/A converters with output buffer amplifiers in a 24-pin DIP, SO package, or plastic leaded-chip carrier. The AD7228 requires no external trims or components to achieve full specified performance and guaranteed monotonicity with any of the standard 5, 12, or 15V supplies. Each of the eight DACs has an individual latch that accepts and holds data written by the system μP, similar to an address in system memory. Because the AD7228 works with a write-pulse width of 95 nsec, it is compatible with most μPs. Each DAC can provide an output to 10V for a 2-kΩ and 100-pF load at a slew rate of 2 V/μsec and a settling time of 5 μsec. The AD7228 is available in grades of ±1 LSB and ±2 LSB, and in three temperature ranges. $32 to $37.50 (100).

Maxim Integrated Products, 120 San Gabriel Dr, Sunnyvale, CA 94086. Phone (408) 737-7600.

Circle No 358

SUPER FAST SRAM

Available Now 256K 25ns/64K 15ns

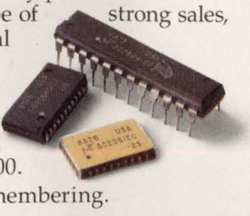
Micron just broke the SRAM speed barrier with our family of leading edge, super high speed CMOS SRAMs.

We've applied the same state-of-the-art design and process technology used for our high quality DRAMs in development of our fast static RAMs — with some amazing results.

At an incredible 25ns for 256K and 15ns for 64K, our SRAMs are breaking speed records. And we're not just sampling product, we're shipping production volumes.

Choose from a wide variety of components in DIP, SOJ and LCC packages, with densities from 16K to 256K and organizations of x1, x4 and x8.

And like all Micron memory products, our SRAMs are backed by the type of strong sales, customer service and technical support that keeps you on the leading edge.



For additional information on how you can break the SRAM speed barrier, call 208-386-3900.

Micron, it's a name worth remembering.

Part #	Organization	Speed*	Packages
MT5C2561	256K X 1	25ns	PDIP, CDIP, SOJ, LCC
MT5C2564	64K X 4	25ns	PDIP, CDIP, SOJ, LCC
MT5C2565	64K X 4 $\overline{OE}$	25ns	PDIP, CDIP, SOJ, LCC
MT5C2568	32K X 8	25ns	PDIP, CDIP, SOJ, LCC
MT5C6401	64K X 1	15ns	PDIP, CDIP, SOJ
MT5C6404	16K X 4	15ns	PDIP, CDIP, SOJ
MT5C6405	16K X 4 $\overline{OE}$	15ns	PDIP, CDIP, SOJ
MT5C6406/7	16K X 4 S.I/O	15ns	PDIP, CDIP, SOJ
MT5C6408	8K X 8	15ns	PDIP, CDIP, SOJ, LCC
MT5C1601	16K X 1	15ns	PDIP, CDIP, SOJ
MT5C1604	4K X 4	15ns	PDIP, CDIP, SOJ
MT5C1605	4K X 4 $\overline{OE}$	15ns	PDIP, CDIP, SOJ
MT5C1606/7	4K X 4 S.I/O	15ns	PDIP, CDIP, SOJ
MT5C1608	2K X 8	15ns	PDIP, CDIP, SOJ

*Slower speeds also available.

MICRON
TECHNOLOGY, INC.

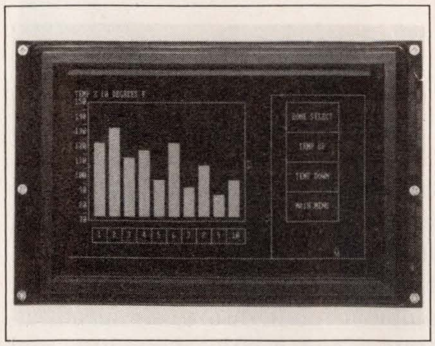
European Office: Trafalgar House, Grenville Place, Mill Hill, London W7 3SA Phone: 01-959-3611, FAX: 01-959-6168

UNITED KINGDOM Micro Call Ltd. Phone: (084 421) 5405; Abacus Electronics PLC Phone: (0635) 30680
FRANCE Rep'Tronic, SA Phone: (1) 69288700; A2M Phone: (1) 39549113; RTF Diffusion Phone: (1) 47460113
BELGIUM MCA-Tronix SPRL Phone: (041) 674208
DENMARK Henckel Elektronik Phone: (03) 906333
FINLAND Turion Oy Phone: (0) 372144
NETHERLANDS AKAM Phone: (079) 443200
ITALY Moxel S.r.L. Phone: (02) 61290521
SPAIN ATD Electronica, S.A. Phone: (1) 2344000 (1) 2344009
ISRAEL Rapac Electronic, Ltd. Phone: (3) 477115
NORWAY BIT Elektronikk A.S. Phone: (03) 847099
SWEDEN IEK AB Phone: (08) 804685

CIRCLE NO 41

NEW PRODUCTS

COMPONENTS & POWER SUPPLIES



DISPLAY MODULE

- *Features VT320 emulation*
- *Includes touch-input system*

The M320ST electroluminescent display module provides graphics capability and VT320 emulation with standard 80-character × 25-line text. It also features an infrared touch-input system, SealTouch, that provides a resolution of 2000 touch points. SealTouch firmware allows you to program button sizes, positions, and response. You can have as many as 120 pages with a maximum of 120 buttons/pg. You can define buttons as pop-up menus, multistate responses, or program them for touch sensitivity for applications requiring fail-safe operation. Complete terminal setup parameters are accessible on screen. The module includes an RS-232C, RS-422, or RS-485 serial communications port (or optional 4- to 20-mA operation), a serial printer port, and an ASCII keyboard port. $3195.

Digital Electronics Corp, 31047 Genstar Rd, Hayward, CA 94544. Phone (415) 471-4700. TLX 172073.

Circle No 360

FIBER-OPTIC LINK

- *Operates over 2 km*
- *Offers user-selectable inputs*

This fiber-optic link provides an RFI/EMI-secure circuit for Electrospace Systems' MLP-1 phone and its associated PBX. The link consists of the F9765 and the F9766 and has a transmission capability of 2 km min. The F9765 is designed for use at the PBX end of the circuit and includes a male 25-pin connector. The F9766 is located at the phone and features a female 25-position connector. The link has a 0.3- to 3.5-kHz bandwidth and outputs 0 dBm into a balanced 600Ω load. Each unit consists of two pc boards. The first board holds the power supply and the digitizing and multiplexing circuitry, and the second holds the interface circuitry. A slide switch allows you to select link inputs of 115 or 230V ac, 47 to 63 Hz. The link operates over 0 to 50°C and consumes 6W. \$1960 per pair.

Versitron, 9005-8 Junction Dr, Annapolis Junction, MD 20701. Phone (301) 497-8600.

Circle No 361

COOLING SWITCH

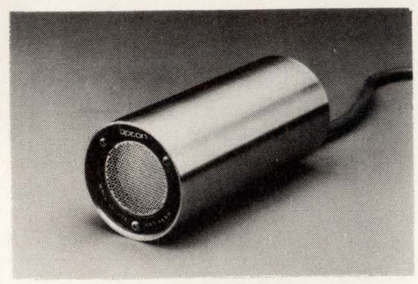
- *Operates on logic-level inputs*
- *Can operate to 70°C*

The Series 305 cooling-failure switch operates on 5V dc input signals and responds to any change in temperature in 1 to 3 sec. The switch can generate a false signal when its own temperature exceeds

a factory preset limit. Operating over a 5 to 70°C range, the switch features a self-heated glass-bead thermister, which compensates for ambient temperature, air speed, altitude, and relative humidity, and can sense a reversal in air flow. The switch is cooled by the same air stream that cools the host equipment, and measures 3×0.5 in. From \$15.

Cambridge Aeroflo Inc, 900 Mt Laurel Circle, Shirley, MA 01464. Phone (508) 425-2346.

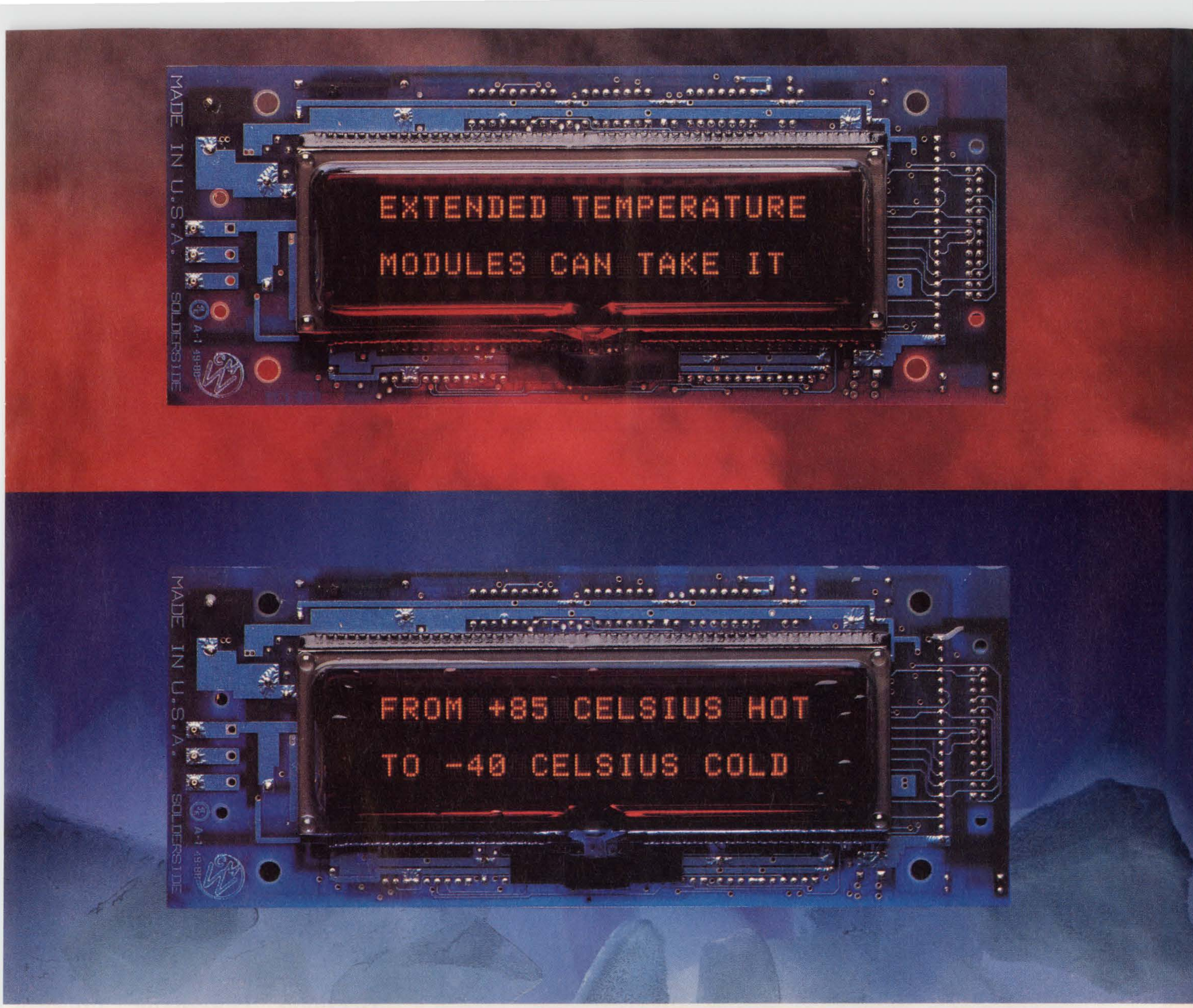
Circle No 362



ULTRASONIC SENSORS

- *Feature noncontact operation*
- *Withstand harsh environments*

UC60 Series ultrasonic sensors offer a noncontact distance-sensing capability. The series is made up of the UC60-LN1A analog output-level sensor and the UC60-ZD1A switched-output zone-detection sensor. Both include adjustable sensing-zone features, built-in temperature compensation, short-circuit/transient-protected outputs, and 10 to 30V dc operation. The LN1A outputs distance measurements as an analog voltage or current. The ZD1A produces a switched output when an object enters a preset zone. Both units are built to with-



THE VF MODULES TO USE IF HELL FREEZES OVER.

If that day arrives and you need a clear readout, DeeCO's XT and XTB extended temperature display modules won't let you down.

From −40°C to +85°C, through 40g shock and 2g rms vibration, XT series modules can take the heat. And the cold. And whatever else you or the forces of evil throw at them.

And when you need clear sunlight readability, our XTB1x40 high brightness extended temperature module delivers more than 600 fl of brilliant performance.

XT and XTB features include selectable baud rates, 15 microsecond-per-character burst mode for high-speed display changes, steady or flashing characters, and brightness control.

If you'd like further proof of how well we go to extremes, we'd be happy to send you test results from an independent testing lab. For more information about XT and XTB extended modules, or our full line of VF and EL display products, write or call (415) 471-4700.

DeeCO®

Digital Electronics Corporation, 31047 Genstar Road, Hayward, CA 94544-7831 (415) 471-4700. DeeCO is a registered trademark of Digital Electronics Corporation © 1989.

CIRCLE NO 37

stand harsh environments and are encapsulated in stainless-steel cases that carry a NEMA 1, 2, 12, and 13 rating. UC60-LN1A, \$695; UC60ZD1A, \$595.

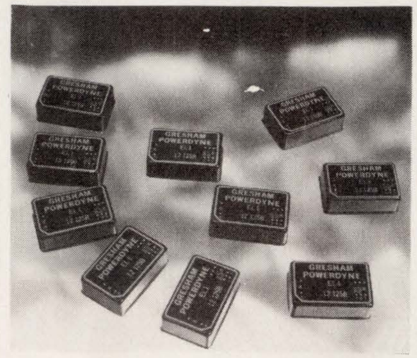
Opcon Inc, 720 80th St SW, Everett, WA 98203. Phone (206) 353-0900.

Circle No 363

DC/DC CONVERTERS

- *Provide 1.5W single- or split-rail outputs*
- *Have 500V input-to-output isolation*

EL1 isolated dc/dc converters have an output power rating of 1.5W and are available in single- or dual-output versions. Single-output versions have an output voltage of 5, 12, or 15V, and dual-output versions have split-rail ±5, ±12, or ±15V outputs. They are available with nominal input-voltage ratings of 5, 12 or 24V. Their input-to-output isolation voltage capability is 500V dc, and they have an isolation resistance of 10 GΩ. Line regulation is more than ±0.3% for a ±10% input voltage change, and zero- to full-load output regulation is more than ±0.5%. All versions have a Pi filter on the input to minimize input and output noise. The converters are housed in standard DIP packages that measure 32×20×10.5 mm and weigh 17g. They have a −25 to +71°C operating temperature range. £18.



Gresham Powerdyne Ltd, Gresham House, Telford Rd, Salisbury, Wiltshire SP2 7PH, UK. Phone (0722) 413080. TLX 477576. FAX 0722-336263.

Circle No 364

Dowty Electronics Corp, Box 250, Prospect St, Brandon, VT 05733. Phone (802) 247-6811.

Circle No 365

CONNECTORS

- *Have 15 contacts in a 9-contact shell*
- *Feature gold-plated contacts*

Sigma-D crimp-insertable D-subminiature connectors provide 15 contacts in a 9-contact shell. You can install the contacts by hand or with a machine. The brass contact pins and phosphor bronze sockets have gold over nickel plating as standard. Other finishes are available as an option. The contacts have a 5A/500V dc rating. The connectors can accept #26 or 28 AWG wire sizes. Contacts are available in reels or in loose pieces for hand crimping. Male connectors, $1.31 (500); 10,000-pin reel of contacts, $70.

Vernitron Corp, Beau Products Div, Box 10, Laconia, NH 03247. Phone (603) 524-5101. FAX 603-524-1627.

Circle No 366

SELECTOR SWITCHES

- *Available in top- or side-adjust versions*
- *Sealed to withstand assembly processes*

SS-10 rotary DIP selector switches are available in top- or side-adjust versions. Single- and dual-pole models are available with four or six contacts and three contact configurations, respectively. All surfaces are permanently sealed to withstand standard soldering and washing processes. The self-cleaning, gold-plated contacts have a 5V/100 mA resistive switching rating. Contact resistance equals 100 mΩ max. The switches can carry 50V dc at 100 mA. The rotational life equals 500 cycles min and the operating range spans −10 to +60°C. $1.70 (100).

Mepcopal Co, 11468 Sorrento Valley Rd, San Diego, CA 92121. Phone (619) 453-0332. FAX 619-481-1123.

Circle No 367

FAN SYSTEM

- *Offers 12- and 15-fan capacity*
- *Design isolates vibration*

The Airmatic 300 Fan Tray system features models with either a 12-or 15-fan capacity. The tray is configured from two structural foam halves, which include individual fan compartments to isolate noise and vibration. Rubber standoffs mounted to 8 points on the fan further isolate noise and vibration. Each fan compartment is prewired, and each fan is terminated with a plug to ease fan replacement or additions in the field. Empty fan positions come with foam and a metal insert. All trays feature a brushed and anodized front panel, which includes easy-access handles. You can order the trays with any number of fans from one to each tray's maximum capacity. 12-position tray with one fan, $302.47.

Dacobas Inc, 1890 N Voyager Ave, Simi Valley, CA 93063. Phone (805) 526-7733. FAX 805-584-8371.

Circle No 368

NEW PRODUCTS

TEST & MEASUREMENT INSTRUMENTS

CALCULATOR

- *Performs 254 functions*
- *Works with simultaneous equations and complex numbers*

The TI-68 advanced scientific calculator performs 254 functions and handles complex numbers as easily as it handles real ones. It can simultaneously display the real and imaginary parts of a complex quantity. The $6\times3\times0.6$-in. unit sports a 12-character alphanumeric LCD that scrolls horizontally to display equations having as many as 80 characters. The calculator can solve five simultaneous equations; a plain-English prompting scheme guides you through equation entry. You can recall and replay the last equation entered, and you can edit equations after you've entered them. The calculator allows you access to as many as 36 registers and lets you assign names to the registers. You can enter as many as 12 formulas; the formulas remain in memory even when the calculator is off. The unit also determines the real and complex roots of quadratic, cubic, and quartic equations. $65.

Texas Instruments Inc, Box 53, Lubbock, TX 79408. Phone (806) 747-1882.

Circle No 380

AUDIO TEST SET

- *Generates 8-ppm distortion sine waves from 1 Hz to 102.39 kHz*
- *Provides 0.03%-inaccurate crystal-controlled frequencies*

The 3100B generator and 3200B autoranging analyzer form an audio test set that measures amplitude and phase vs frequency and intermodulation (IM) and total harmonic distortion (THD) vs frequency or amplitude. The analyzer measures phase from −180 to +180° with 0.1° resolution to 40 kHz and ac voltages from 4 μV to 100V with residual THD and IM of 20 ppm. The generator stores 91 front-panel setups and can produce sine waves from 1 Hz to 102.39 kHz with 8-ppm distortion and square waves from 1 Hz to 50 kHz with a rise time of <1 μsec. As the frequency is crystal controlled, errors are less than 0.03% at fixed frequencies and on some sweeps. Generator, $4250; analyzer, $5495.

Sound Technology, 1400 Dell Ave, Campbell, CA 95008. Phone (408) 378-6540. TLX 357445.

Circle No 381

Text continued on pg 230

RISC DEVELOPER

- *Supports 88000 RISC chips*
- *Traces system activity in real time to 50 MHz*

The DS5000 development system provides in-circuit support for the 88100 RISC processor and the 88200 cache/memory management unit. The development system can perform 256-channel logic analysis and provides 16 levels of unrestricted triggering. It traces all target-system activity in real time to 50 MHz and captures trace data in 4k- or 16k-frame buffers. You can define trigger conditions for the cache, program memory, data memory, instruction memory, or combinations of all of them. By using a pair of buffers and filling one while routing the other's contents via DMA to the host processor's RAM, the development system can acquire data continuously. The development system works with MS-DOS-based hosts, including some Sun Microsystems units. $28,000 to $40,000. Delivery, six weeks ARO.

Hilevel Technology Inc, 31 Technology Dr, Irvine, CA 92718. Phone (800) 445-3835; in CA, (800) 541-2742. TLX 655316.

Circle No 382

TEST TRANSLATOR

- *Tranlates PLD test vectors*
- *Creates source files for GenRad testers*

The JED2DTS software utility runs on DEC VAXs under VMS and on IBM PCs, PC/XTs, PC/ATs, and compatible computers. The utility translates PLD test vectors created with the vendor's ATG (automatic test generator) software into DTS (digital test source) files for GenRad 227x and 2282 in-circuit pc-board test systems. The DTS files include head, inhibit, disable, force, and main sections. If the number of vectors exceeds a user-defined limit, the utility creates multiple pattern bursts. PLD definition files let you customize the translation process. $1695 including communication software for error-free file transmission to the tester.

Anvil Software Inc, 427-3 Amherst St, Suite 341, Nashua, NH 03063. Phone (603) 891-1995. FAX 603-891-1999.

Circle No 383

DMM/THERMOMETER

- *Offered with °C and °F readouts*
- *Measures ac current with clamp-on transformer*

The ACA Series of multimeters includes three models, two of which measure temperature—one in °F, the other in °C. All three units incorporate a peak-hold function; the two that measure temperature also include data-hold and diode-check functions. All three models measure ac current via integral clamp-on

transformers on full-scale ranges of 200 and 400A. The unit that doesn't measure temperature also includes a 20A ac current range. AC-current-measuring accuracy on all units is 1% to 100A. All units measure ac and dc voltage and resistance and have four dc-voltage ranges. The unit that doesn't measure temperature has four resistance and two ac-voltage ranges. The other units have two resistance ranges and one ac-voltage range. $119; $109 without temperature measurement.

Extech Instruments Corp, 150 Bear Hill Rd, Waltham, MA 02154. Phone (617) 890-7440. TLX 940913.

Circle No 384

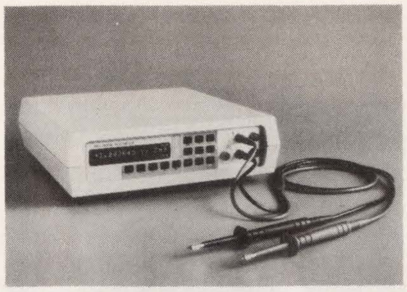
BOARD TEST SOFTWARE

- *Adds enhancements to 1800-Series testers*
- *Automatic test-program backup prevents program loss*

A software update to the vendor's 1800-Series board testers incorporates five features that expand test coverage and increase programming flexibility. These features include dual threshold measurements, which let you define both high- and low-voltage regions; HiCheck, which produces a 4-digit hexadecimal signature for all high-region measurements; digital filtering, which increases stability in a voltage measurement by averaging multiple sample readings; HiGuard, which improves guarded measurement accuracy by eliminating the thermal EMF of relay contacts; and differential measurements, which let you make voltage measurements that aren't referenced to system ground. The addition of program flow control and branching capabilities increases programming flexibility. $500.

Zehntel Inc, 2625 Shadelands Dr, Walnut Creek, CA 94598. Phone (415) 932-6900. TWX 910-385-6300.

Circle No 385



DIGITAL MULTIMETERS

- *Have a 1-year dc voltage accuracy of 20 ppm*
- *Include an IEEE-488 interface and digital recalibration*

The Model 5001 and Model 6001 are 6½-digit instruments that have a 24-hour dc voltage stability of ±(4 ppm of reading + 2 ppm of full scale) and a 1-year dc voltage accuracy of ±20 ppm. The Model 5001 provides dc and true-rms ac voltage, dc and true-rms ac current, and 2-wire resistance measurement functions. The Model 6001 has the same basic specification as the 5001, and also provides both temperature measurement using a 100-Ω platinum resistance thermometer probe, and 4-wire resistance measurement. Both instruments have dc voltage measurement ranges from 0.2 to 1000V, ac voltage measurement ranges from 2 to 700V rms, dc and ac current ranges of 2 mA and 2A, and resistance measurement ranges of 200Ω to 12 MΩ. The instruments provide measurement periods selectable between 50 msec and 10 sec and feature math functions, an IEEE-488 interface, and digital recalibration facilities. A 10-channel input scanner option is available for both instruments. Model 5001, \$1495; Model 6001, \$1695.

Prema GmbH, Robert-Koch-Strasse 10, 6500 Mainz 42, West Germany. Phone (06131) 50620. TLX 4187666. FAX 06131-506222.

Circle No 386

Prema Precision Electronics Inc, 4650 Arrow Highway, Suite E5, Montclair, CA 91763. Phone (714) 621-7292. FAX 714-625-2098.

Circle No 387

CABLE CUTTER

- *Cuts round cables*
- *Handles 300-pair cable*

The PA 1818 portable cable cutter is 12 in. long. It cuts round multiconductor cables containing as many as 300 signal pairs. It also cuts copper cables to 750 MCM (thousands of circular mils) and aluminum cables to 1000 MCM. The unit includes a folding safety latch and a release mechanism that enables you to move the tool to a different location. \$239.

Paladin Corp, 3543 Old Conejo Rd, Suite 102, Newbury Park, CA 91320. Phone (805) 499-0138.

Circle No 388

NEW PRODUCTS

CAE & SOFTWARE DEVELOPMENT TOOLS

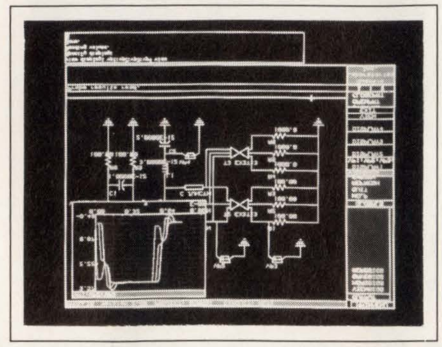
REAL-TIME KERNEL

- *Runs in the 32-bit, protected mode of the 80386*
- *Allows a combination of local and global tasks*

MTOS-UX/386 is a multiprocessing, multitasking, real-time operating system for 80386-based computers. This OS normally runs in the 32-bit, protected mode of the 80386, and protects system resources such as block and memory pools, message buffers, controlled shared variables, and task resources. Also available is a version that uses the multisegmented memory model to run MS-DOS software. This model protects the kernel and the system resources by means of task privilege levels. You can increase the computing power of the system merely by adding up to 16 CPUs; changing the number of CPUs does not require any change to the applications programs. The development kit includes test facilities, debugging tools, validation programs, configuration programs, a RAM-disk driver, a Unix interface, and a C-portable library. The symbolic debugger provides task-level debugging facilities. Because all versions of MTOS-UX have the same programmer interface, programs written in a high-level language will run under any version of MTOS-UX, regardless of the processor type. Development kit prices start at $5000.

Industrial Programming Inc, 100 Jericho Quadrangle, Jericho, NY 11753. Phone (516) 938-6600. TLX 429808. FAX (516) 938-6609.

Circle No 389



CAE TOOL

- *Handles double-sided SMT designs*
- *Handles multiple power planes and as many as 16 signal layers*

The MAXI/PC schematic-capture and pc-board layout package can execute double-sided, surface-mount designs with as many as 16 signal layers; it also handles multiple power and ground planes having a resolution of 1/1000 in. High-speed automatic features include placement, gate- and pin-swapping, component renaming, back-annotation, and routing. The package runs on IBM PCs and compatibles. $995.

Racal-Redac Inc, 238 Littleton Rd, Westford, MA 01886. Phone (508) 692-4900.

Circle No 390

STABILITY ANALYZER

- *Simplifies setup and operation of a network analyzer*
- *Includes modeling and synthesis package for loop analysis*

The S350/3577 stability software package allows you to integrate your HP3577A Network Analyzer from Hewlett-Packard (Palo Alto, CA) with an IBM PC or compatible, a printer, and a plotter, to form a complete stability-analysis workstation. The menu-driven software simplifies the setup and operation of the HP3577A, so that you can quickly obtain Bode plots or Nyquist diagrams of control-loop circuits. You can store the data on disk for later analysis and circuit optimization. The software includes the vendor's proprietary K-factor modeling and synthesis package for loop optimization; the software also works with PC-MATLAB for matrix computations, and with ECA-2 for circuit modeling and analysis. From $5995.

Venable Industries Inc, 3555 Lomita Blvd, Torrance, CA 90505. Phone (213) 539-2522. FAX 213-539-4139.

Circle No 391

SIMULATION MODELS

- *Library contains models for more than 4000 LSI/VLSI devices*
- *Models allow fault simulation at the board or system level*

SmartModels is a library of behavioral models for more than 4000 LSI/VLSI devices. Previously available for logic simulation, the vendor has now adapted all the models for use on Mentor Graphics' (Beaverton, OR) QuickFault fault simulator. The vendor plans to support other simulators that have a behavioral interface. Behavioral models are easier to write and faster to load than gate-level models; they also run faster and allow you to simulate larger designs without increasing the memory requirements. SmartModels allow concurrent fault simulation; that is, you can divide the design into several parts and run each part on a different node of a network, or on parallel processors of a multiprocessor system. The original subscription serv-

The word is out!

You need microprocessor control for your new product. You want to beat the competition to market. But microprocessor designs take time.

Cubit's STD Bus board level computers get the job done fast. You save hardware design time, prototyping time and debugging time. And we include software tools to get the job done fast.

STD Bus is simple, compact and inexpensive. It is also rugged and rich in industrial I/O functions that other busses neglect.

Read all about it!..

CuBIT has a full line of STD Bus boards. Fill out the order below or call us at CuBIT, and we'll send you our new STD Bus Catalog.

Name

Company

Address

City

State Zip

Phone

CuBIT DIVISION OF PROTEUS INDUSTRIES

340 Pioneer Way, Mountain View, CA 94041-1577 • (415) 962-8237 • FAX: (415) 965-9355

CIRCLE NO 26

ice to SmartModels for fault simulation costs $7900; the FLEX-Node service, which allows you to move licenses around a network, costs $9900 (minumum, 3 FLEX-Node subscriptions).

Logic Automation, 19500 NW Gibbs Dr, Beaverton, OR 97006. Phone (503) 690-6900.

Circle No 392

C LIBRARY

- *Lets you build resident shared libraries*
- *Allows you to convert existing programs to TSR versions*

/*resident_C*/ is a library of C routines for building terminate-and-stay-resident (TSR) programs. The C routines let you build interrupt-service routines, such as timers that schedule a program to run at a particular time. You can also build resident shared libraries that can be accessed by any number of programs. The library also allows you to convert existing C programs to TSR status by adding a few function calls. Other routines included in the library let you save screens or windows so your TSR program won't disrupt the program that it interrupts. Versions of the library are available for the Microsoft (QuickC and C 5.0), Borland (Turbo C), and Lattice C compilers that run on IBM PCs and compatibles. The distribution disk includes demonstration programs that show you how to use the library and how to build shared libraries. Binary version, $99; binary and source code, $198.

Essential Software Inc, 76 S Orange Ave, Suite 3, S Orange, NJ 07079. Phone (201) 762-6965.

Circle No 393

NET-LIST GENERATOR

- *Allows you to reverse-engineer pc boards*
- *Copes with boards that contain high pin-count devices*

The Net-Learn utility software for the company's SI635 diagnostic test system lets you reverse-engineer pc boards by generating a connectivity net list for the board's components. You can then use the net list to construct a schematic diagram. The menu-driven software uses the system's in-circuit test capabilities to learn the pin-to-pin interconnections between all the devices on the pc board. Net-Learn combines as many as 128 test channels to cope with high pin-count devices. The utility employs a 2-pass test strategy to generate the net list. During the first pass, the pc board under test is powered up, and the tester locates all pins that are connected to power or ground lines. The pc board is turned off during the second pass, and the utility determines the interconnections between devices. The system eliminates faulty net-list generation by checking for good probe contact before the learning process begins. To cope with board modifications or updates, the software can perform a partial learn operation. You can use the ouptut files from Net-Learn to generate schematic diagrams for the pc under test. Around £2100.

Schlumberger Technologies, Instruments Div, Victoria Rd, Farnborough, Hampshire GU14 7PW, UK. Phone (0252) 544433. TLX 858245. FAX 0252-543854.

Circle No 394

Schlumberger Technologies, Instruments Div, 20 N Ave, Burlington, MA 01803. Phone (617) 229-4825. TLX 910-250-745. FAX 617-229-4885.

Circle No 395

SIMULATOR

- *Provides a single-screen display of analog and digital signals*
- *Works with the vendor's ASIC-design tool set and cell libraries*

DesignSim A&D lets you simulate both analog and digital circuits concurrently, and provides a single-screen display of analog and digital signals that are synchronized in time and use the same time scale. You can run simulations of electronic devices at the system, cell, or transistor level with the accuracy of Spice. You can also model electromechanical interfaces. DesignSim A (the analog portion) is based on Analogy Inc's (Beaverton, OR) Saber simulator; DesignSim D (the digital portion) is based on HHB Systems Inc's (Mahwah, NJ) Cadat simulator. DesignSim supplements, and is accessible from, the vendor's Product Design Series I (PDS I) ASIC-design tool set, and is fully integrated into the newer PDS II tool set. When you run a mixed-signal simulation, each simulator schedules its own time steps for optimal execution speed, and both simulators analyze information simultaneously so that feedback is propagated through the analog and digital simulators as required. The simulation and analytical algorithms maintain a high level of accuracy and result in a decrease of simulation time. Pricing for PDS II with DesignSim A&D for a single user, from $64,000.

NCR Corp, 2001 Danfield Ct, Fort Collins, CO 80525. Phone (303) 226-9500.

Circle No 396

When you need volume and demand quality, Elec & Eltek is *the* Source.

We effectively use all of our technological, manufacturing and human resources to provide the best business solution for you. With more than 400,000 square feet of manufacturing in Hong Kong, Thailand, and mainland China, Elec & Eltek can supply volume production from basic PC board to turnkey electronic assembly.

Printed Circuit Boards

See us for competitive prices. Our Printed Circuit Board division currently processes 600,000 square feet of boards per month. With this volume we can easily pass savings on to you.

Power Supplies

We are proud of our highly trained and experienced engineering staff. Our full range of 40- to 500-watt power supplies has been designed to meet even the strictest standards.

OEM Services

Our international base of customers relies on us for manufacturing services which include our standard products and OEM designs for telecommunications devices, mixed technology boards, computer peripherals and electronic subsystems.

You can rely on our 16 years of quality service and advanced automation for your next off-shore manufacturing project. Join us to build a partnership for your total manufacturing solutions.

HEADQUARTERS
18/F., Luk Hop Ind. Bldg.,
8 Luk Hop Street,
San Po Kong
Hong Kong
TEL: 3-7269211, 3-7269333
FAX: (852) 3-3524625

OR CARE OF:
U.S.A. MARKETING OFFICE
1230 Oakmead Parkway
Suite 310
Sunnyvale, California 94086
TEL: (408) 732-1181
FAX: (408) 732-8010

FOR FURTHER INQUIRIES, PLEASE WRITE TO:

Elec & Eltek
COMPANY, LTD.

Winner Of Wescon's New Products And Technology Achievement Award.

Toshiba M-ST LCD modules are available in two sizes: the 640 × 400 dot TLX-1501-C3M and the 640 ×480 dot TLX-1551-C3M.

At Wescon/88, our remarkable new Monochrome ST (M-ST) Liquid Crystal Display modules earned a New Products and Technology Achievement Award.

Toshiba's M-ST modules offer significantly improved black-and-white contrast for better visibility, with a unique single-layer design that makes them 25% lighter and 15% thinner than double-layer panels.

Toshiba's thin, light, high-contrast M-ST Liquid Crystal Display modules — the new industry standard in LCD performance.

In Touch with Tomorrow

TOSHIBA

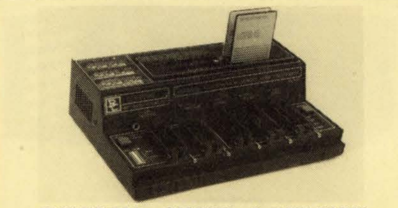
Toshiba America, Inc., Electronic Components Business Sector, Chicago Office: One Parkway North, Suite 500, Deerfield, IL 60015-2547 Tel: 312-945-1500 **Western Area Office:** 2021 The Alameda, Suite 220, San Jose, CA 95126 Tel: 408-244-4070 **Eastern Area Office:** 25 Mall Road, 5th Floor, Burlington, MA 01803 Tel: 617-272-4352

CIRCLE NO 20

EDN
PRODUCT MART

This advertising is for new and current products.

Please circle Reader Service number for additional information from manufacturers.



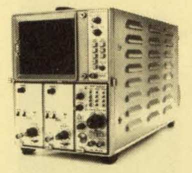
E(E)PROM, MICRO & MEMORY CARD PROGRAMMER..... $345 - $595

- No personality modules for E(E)Proms & Intel Micros.
- All 24/28/32 pin EProms/EEProms to 4 MBit (upgr. to 32MB).
- Flash Eproms; Micros: 8741,-2,-8,-8H,-9,-9H,-51,-C51,-52,-55 ...
- Memory Cards: Seiko/Epson, Mitsubishi, GI. Modular design.
- ON-BOARD Programming capability. Easy F/W upgrades.
- Stand-alone E(E)Prom & Memory Card Duplication / Verify.
- User friendly menu - driven driver for IBM-PC & Macintosh.
- Autobaud RS232 to any computer. Hex/Binary/Intel/Motorola.
- Built-in Eraser/Timer option ($50). Gang-Module ready.
- Open board units starting from $245. (OEM discounts available)
- Direct technical support. Dedicated BBS. Full 1 year warranty.

MC/VISA/AMEX *Call today for datasheets!*

B&C MICROSYSTEMS INC.
355 WEST OLIVE AVE. SUNNYVALE, CA 94086
TEL: (408)730-5511 FAX: (408) 730-5521

CIRCLE NO 340



Davilyn CORP.
13406 Saticoy Street
No. Hollywood, CA 91605-3475

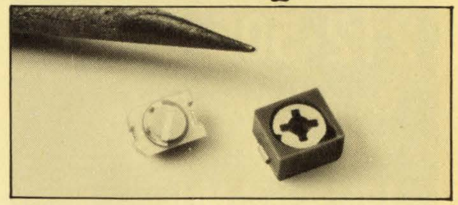
TEK 7603N
(AN/USM-281C)

$595.00

TEKTRONIX 7603N
(Mil Spec AN/USM-281C)
8 x 10 CM Display
100 MHZ Response which accepts Standard 7000 Series Plug-Ins.
Vertical Plug-In 2 ea. 7A15 (AM-6565)
Frequency BW 75 MHZ
Maximum Sensitivity 5mV/DIV
Horizontal Plug-In 1 ea. 7B53 (TD-1085)
Triggering to 100 MHZ
Minimum Sweeptime 50 NS/DIV
Has delayed sweep capacity
Includes Manual and Cover • 90 Day Unconditional Warranty
1-800-235-6222 (outside Calif.) / **1-818-787-3334**
CALL FOR FREE CATALOG

CIRCLE NO 341

Sprague-Goodman Surftrim® Surface Mounted Trimmer Capacitors

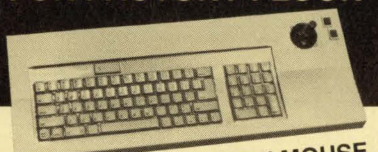


- Wide range of unsealed and sealed models.
- Designed for vapor phase reflow soldering.
- Available in carrier and reel packaging.
- Sizes: unsealed—3.2 × 4.5 × 1.6mm; sealed—4 × 4.5 × 2.8 mm.

SPRAGUE GOODMAN **Sprague-Goodman Electronics Inc.**
The First and Last Name in Trimmer Capacitors
134 Fulton Avenue, Garden City Park, NY 11040-5395
516-746-1385/TWX: 510-600-2415/TLX: 14-4533

CIRCLE NO 342

RUGGED JOYSTICK/KEYBOARD FOR FACTORY FLOOR



REPLACES THE MAC II MOUSE

- **Noncontacting inductive joystick** no moving electrical parts
- **Sealed keyboard enclosure** for harsh environments

PATENTS PENDING

CTI
CTI ELECTRONICS CORP.
200 Benton Street, Stratford, CT 06497
TEL: 203/386-9779 FAX: 203/378-4986

MAC II IS A REGISTERED TRADEMARK OF APPLE.

CIRCLE NO 343

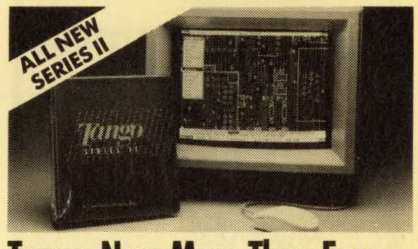
DIGITAL AUDIO

The Desktop Recording™ board plugs into an AT and allows the recording and playback of professional quality digital audio. Audio data is stored to the AT's hard disk. The record channels feature 2x oversampling, digital filter, and linear-phase antialiasing filters. Playback features digital filter, 8x oversampling, and dual 18-bit DACs. Sampling rate is software selectable at 48kHz, 44.1kHz, and 32kHz. The price is $1295, $795 in 100's.

Digital Audio Labs

2570 Abbey Hill Dr.
Minnetonka, MN 55343
(612) 559-6104

CIRCLE NO 344



Tango. Now More Than Ever, The Best Value in PCB Design.

Take a look at the all new Tango Series II. Our pop-up menu interface sets a new standard for ease-of-use and productivity. Lay out simple prototypes or complex, multi-layer, SMT designs with over 100 new features including user-definable tracks, pads, and grids.

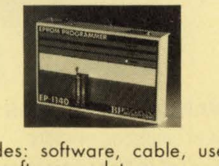
For IBM-PCs and compatibles, Tango-PCB Series II, just $595. Tango-Route Series II autorouter, just $495. Both include one year's updates, free tech support, 30-day money-back guarantee. Call today.

FREE EVALUATION PACKAGE
800-433-7801 619-695-2000
ACCEL Technologies, 7358 Trade Street, San Diego, CA 92121

CIRCLE NO 345

E/EPROM & MICRO PROGRAMMER

$895



- EP-1140 includes: software, cable, user's manual, 2 free software update coupons, toll-free technical support, one-year warranty & a unconditional 30-day money back guarantee
- Programs 24-, 28-, 32- & 40-pin E/EPROMs
- Supports 874X & 875X series microcontrollers
- Connects to a standard parallel port
- Hardware to support future parts to 8 Megabit
- Software updates on floppy disk
- 32-pin model, EP-1132, available for $695

The Engineer's Programmer™

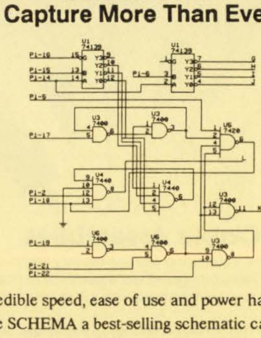
CALL TODAY 800-225-2102

BP MICROSYSTEMS
10681 Haddington, #190, Houston, TX 77043
713/461-9430 FAX 713/461-7413
Electro Booth #374

CIRCLE NO 346

FREE SCHEMATIC CAPTURE DEMO DISK

SCHEMA II+:
Capture More Than Ever



Incredible speed, ease of use and power have made SCHEMA a best-selling schematic capture program for engineering professionals the world over. Now, SCHEMA II+ sells for **$495** and supports most common IBM PC/XT/AT/PS2 configurations.

OMATION
In Texas Call (214) 231-5167
FREE Demo Disk: **1-800-553-9119**

CIRCLE NO 347

Cut the Time and Cost to Get Agency Approval for Your Product

LCAD

A leader in product safety and regulatory compliance engineering, L-CAD provides:

• Design Review	• Construction Review
• Product Testing	• Consulting
• Agency Submittal	• Document Support
• Factory Follow-up	• Seminars

UL DVE TÜV SP FCC

Call or write today for free estimate or catalog
508-683-6274
L-CAD, Inc.
1755 Osgood Street, N. Andover, MA. 01845

CIRCLE NO 348

To advertise in Product Mart, call Joanne Dorian, 212/463-6415

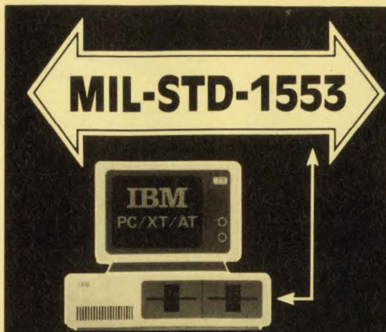
Quartz Crystals Oscillators

212-505-5340

- World's Smallest
- SMT & Thru-hole
- 10kHz – 35 MHz
- Ceramic & Metal Pkgs
- Free Catalog

Micro Crystal Division/SMH

CIRCLE NO 349



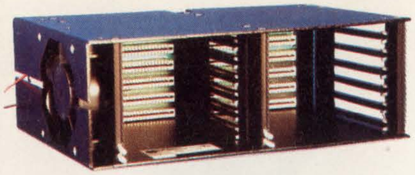
MIL-STD-1553 Interface Board For IBM-PC/XT/AT or Compatibles

Dual redundant bus controller, remote terminal and monitor with powerful easy-to-use software. **From only $2095**

Call now for free data & demo disc

Ballard Technology 1216 N.W. 75th St., Seattle, WA 98117 (206) 782-8704

CIRCLE NO 350



STDbus

12-SLOT CARD CAGE/BACKPLANE ASSEMBLY

- OFFERS MORE FUNCTION CAPABILITY IN LESS SPACE
- INEXPENSIVE ALTERNATIVE TO MULTIBUS I
- WITH SIMILAR FORM FACTOR
- IDEAL FOR PC BUS EMULATION APPLICATIONS
- CAN BE USED FOR 8 TO 16 BIT APPLICATIONS
- BUILT-IN COOLING SYSTEM

Hybricon

12 Willow Road, Ayer, MA 01432

Factory 508-772-5422

Western Operations 602-921-1824

CIRCLE NO 751

DATA ACQUISITION

PC-BASED

MODULES:

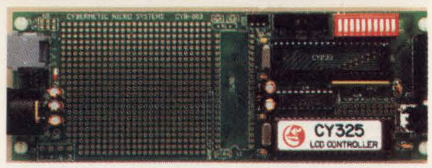
- 12 BIT A/D and D/A
- 8 BIT A/D and D/A
- 72 Line Digital I/O
- Counter/Timer

1-800-553-1170

QUA TECH INCORPORATED

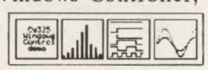
478 E. Exchange St., Akron, OH 44304
TEL: (216) 434-3154 FAX: (216) 434-1409
TLX: 5101012726

CIRCLE NO 752



CYB-003 LCD Windows Controller Board

Quickly prototype new LCD applications. Built around CY325 LCD Windows Controller, board provides LCD with 256 built-in windows, window relative scroll/wrap/clip, plots, bargraphs, waveforms, text, etc. Independent write, erase, & overlay for text and graphics. Also provides circuitry for CY233 network chip, parallel or serial interface, and wirewrap for an 8051 host. Mounts directly on Toshiba/Optrex 64x240 dot matrix LCDs, or via ribbon cable to LCDs of up to 128x240 pixels. Several versions, starting at $170 kit form.



Cybernetic Micro Systems
Box 3000, San Gregorio CA 94074
(415) 726-3000 Tlx: 910-350-5842

CIRCLE NO 753

CDC HIGH PERFORMANCE DRIVES

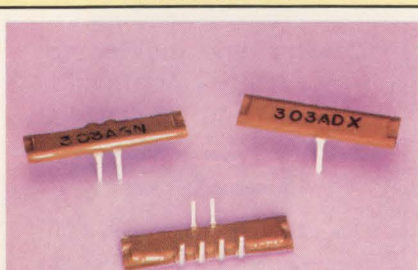
LAN KITS for PC's, Work stations & DEC computers

106MB	5¼"	18ms	40,000MTBF	$995
182MB	5¼"	16.5ms	40,000MTBF	$1295
228MB	5¼"	18ms	40,000MTBF	$1595
383MB	5¼"	14.5ms	40,000MTBF	$2195
385MB	5¼"	10.7ms	40,000MTBF	Call
766MB	5¼"	14.5ms	40,000MTBF	$3295
1.2GB	5¼"	16.5ms	40,000MTBF	Call
1.154GB	8"	16ms	50,000MTBF	Call
1.123GB	8"	16ms	50,000MTBF	Call

- ❑ Complete LAN KITS, CD ROM NETS, WORM NETS, ERASABLE OPTICAL DRIVES. Custom configurations available.
- ❑ High performance drives from Maxtor, Priam and other reputed manufacturers available
- ❑ Let us configure and custom package storage to your specifications. Call us today for a fast quotation
- ❑ We accept International orders

EDS (714) 938-1635

CIRCLE NO 754



SOLVE EMI/RFI PROBLEMS

MICRO/Q 1000® capacitors with special pinout configurations give superior noise suppression, design ease. Solve special decoupling and routing problems for various microprocessors, and other devices where power and ground are not at conventional positions. **Rogers Corp.** 2400 S. Roosevelt St., Tempe, AZ. 85282. 602/967-0624

CIRCLE NO 755

Cable Assemblies

OFTI exceeds in supplying you with the very best in cable assemblies. All factory tested, our assemblies are low loss, skillfully prepared and available with a wide range of connector options.

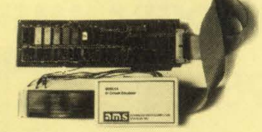
Count on OFTI to exceed in solving your fiber optic application problem with high performance cable assemblies, connectors and termination equipment.

Pictured above are cables terminated with OFTI singlemode Biconic, SMA, NTT PC, STC and multimode Biconic connectors.

ofti® *Your Fiber Optic Connection*
Optical Fiber Technologies, Inc.
5 Fortune Drive Billerica, MA 01821
Tel.: (617)663-6629

CIRCLE NO 756

803X/805X In Circuit Emulator For $495



ADVANCED FEATURES:

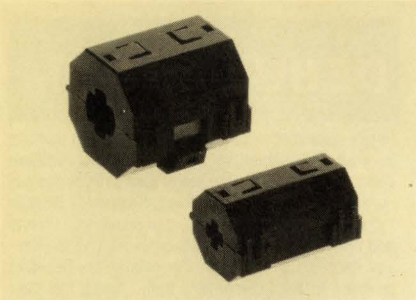
- 64K of emulation memory
- 64K break points
- 1.5K trace buffer with 7 user test probes
- POD for emulating 8031, 8051*, 8032, 8052*, and 8053* microcontrollers
- 12 Mhz local microcontroller clock source
- Emulator to PC interface and support software on a 5¼" Floppy disk
- User manual
- 30 days money back guarantee

ADVANCED MICROCOMPUTER SYSTEMS, INC.
1321 N.W. 65th Place • Ft. Lauderdale, Florida 33309
Phone (305) 975-9515

ams *CALL TOLL FREE 1-800-9PC-FREE*

CIRCLE NO 757

To advertise in Product Mart, call Joanne Dorian, 212/463-6415



ESD-QR SERIES
DATA LINE CLIP-ON FILTERS

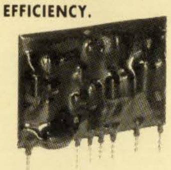
Convenient hinged clamp construction provides high frequency filtering for existing signal or data lines. The high grade ferrite material is available with a variety of ID's to accommodate most common cable sizes. The ESD-QR series is effective over the frequency range from 10 to 1000 MHz to help reduce radiated noise emission. This product can be a life saver when your finished product fails to meet FCC regulations.

Tokin America,
155 Nicholson Lane, San Jose, CA 95134
408-432-8020

CIRCLE NO 767

AC TO DC POWER CONVERTOR

WIDE RANGE I/P 90 ~ 265V AC
O/P LOAD REGULATION 5%.
HIGH EFFICIENCY.



NEW!

PATENTED: U.S.A.
TAIWAN

FEATURES
* WIDE AC INPUT VOLTAGE RANGE 90-265V AC
* O/P DC VOLTAGE: 24-200V DC
* O/P MAX. WATTES: 200W.
* HIGH OUTPUT CURRENT TO 1A DC.
* OUTPUT VOLTAGE REGULATED TO 5%.
* HIGH EFFICIENCY TO 90%.
* TURN ON SURGE CURRENT LIMITING NOT NEEDED.
* POWER RESISTORS NOT USED.
* MINI. EXTERNAL PART COUNT.

POWER-M
division of Mobiltron Electronics Co., Ltd.
USA: Power-M
47 Edgewood RD. Westwood, Ma. 02090
Tel: (617) 769-8795 Attn: Fred Mirow
Taiwan: Mobiletron
P.O.Box 54, Taya, Taichung Hsien, Taiwan, R.O.C.
Tel: 045-668526/668926 Fax: 045-669925 Tlx: 57568 Mobiletn

CIRCLE NO 768

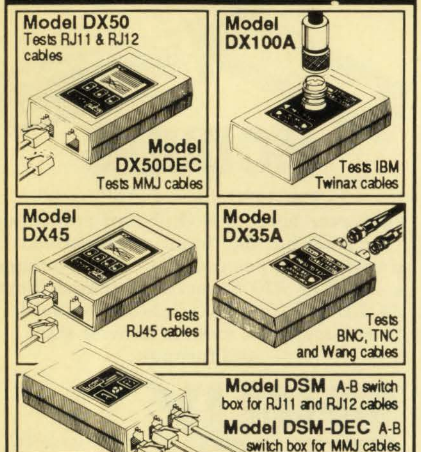
NEW. TOUGHER SPECS FOR FILTER MODULES.

Compare. 130 or 80 dB/octave. Up to 204 kHz. 1024 cutoff settings. HP, LP, TD. Phase match: ±1° max., ±0.25° typical. Amplitude match: ±0.1 dB max., ±0.03 dB typical. Programmable. You get Precision filter system performance in circuit modules, 2.7" x 4.2" x 0.54". Call or write.

PRECISION FILTERS, INC.
240 Cherry Street, Ithaca, New York 14850.
607-277-3550. Fax 607-277-4466.

CIRCLE NO 769

CABLE TESTERS



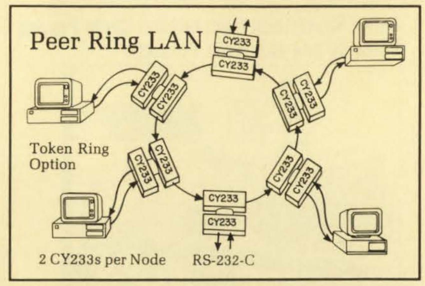
L-com
1755 Osgood St, N. Andover, MA 01845
Orders 800 343-1455 • FAX 508 689-9484
Inquiries 508 682-6936

CIRCLE NO 770

smARTWORK® PCB Software. In a fraction of the time hand taping requires, you can create double-sided printed-circuit boards with smARTWORK and your IBM PC. The program's features include continual design-rule checking, automatic pad shaving, a silkscreen, and text for all three layers. **smARTWORK** with autorouting is $895 (without, $495) and comes with a 30-day money-back guarantee. Credit cards accepted. Write or call

Wintek Corporation
1801 South Street, Lafayette, IN 47904
(800) 742-6809 or (317) 742-8428

CIRCLE NO 771



CY233-LINC Network Control

Connect computers, intelligent peripherals, or remote sites. 5v CMOS 40-pin IC. Up to 57.6K baud. Many configs such as Peer LAN shown and Host LAN with opt token; Simpler Networks allow host to control up to 255 parallel devices; UART mode with Ser/Par conversion can connect parallel devices over serial interface and save wire. $75 ea ($30/100). Box 3000, San Gregorio CA 94074. 415/726-3000.

Cybernetic Micro Systems

CIRCLE NO 772

Telecom Design!

HIGH-PERFORMANCE
DTMF RECEIVERS

Designed for the most demanding on-line applications (voice message systems, noisy commercial environments).

- **M-927** is a 40-pin DIP, needs no external components except 3.579 MHz crystal. 12V.
- **M-937** is a PCB with speech immunity 3 times that of other DTMF receivers, superior signal-to-noise, 45 dBm dynamic range. Exceeds CEPT, CCITT, and USITA CO specifications. 12V.

For more info call: **1-800-426-3926**
(In Washington State: 206-827-9626)

TELTONE®
10801-120th Avenue NE, Kirkland, WA 98033

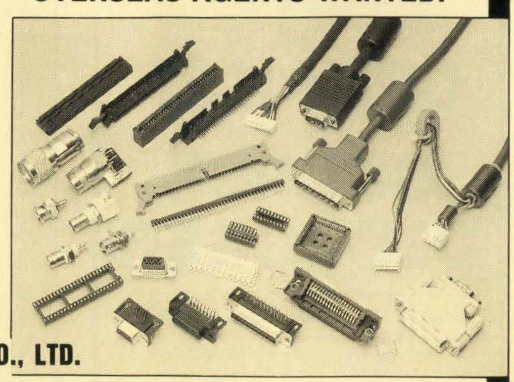
CIRCLE NO 773

CONNECTORS, CABLE ASSEMBLIES, PRECISION PARTS

"CPI" IS THE SOURCE YOU CAN TRUST

"CPI" Main Products:
* IC SOCKETS
* CARD EDGE CONNECTORS
* D-SUB CONNECTORS
* P.L.C.C.
* RF CONNECTORS: BNC, TNC, TWIN AX, etc.
* CABLE ASSEMBLIES: IBM DISK DRIVER CABLE, FLOPPY DISK DRIVER CABLE, HARD DISK DRIVER CABLE, PRINTER CABLE, RS232 CABLE, 256K CABLE, COAXIAL CABLE ASS'Y, I/O CABLE (With 3R15P high density connector) etc. SIGNAL CABLE ASS'Y

OVERSEAS AGENTS WANTED!



NEPCON WEST Booth No 7135

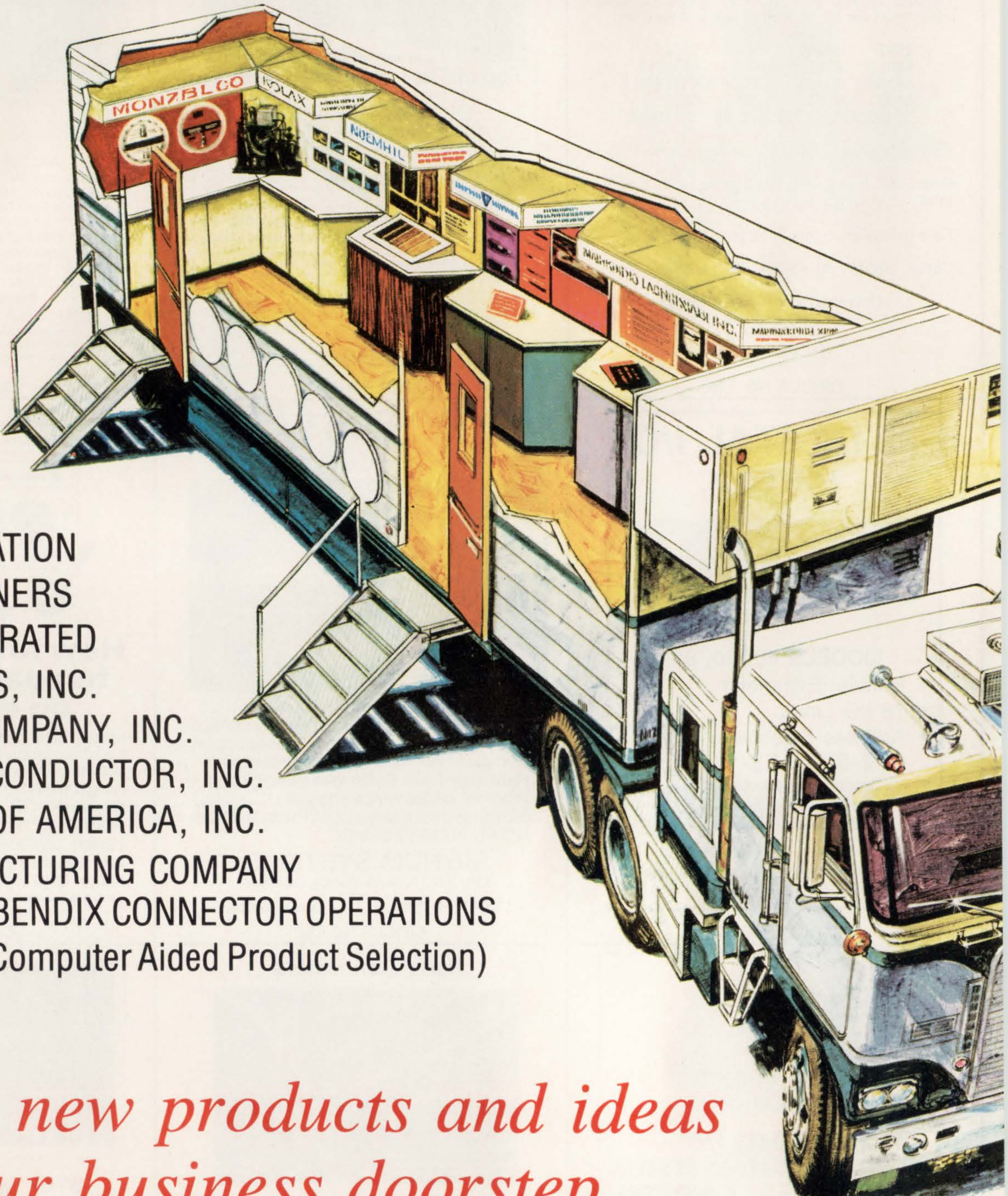
Manufacturer & Exporter:
CONNECTEK PRECISION IND. CO., LTD.
P.O. Box 12-29 Taipei, Taiwan. R.O.C.
Office: No. 104, Pao Chung Rd., Hsin Tien City, Taipei Hsien, Taiwan. R.O.C.
Tel: 886-2-918-4588 (REP) Fax: 886-2-912-8587 Tlx: 33237 CONTEK

CIRCLE NO 775

To advertise in Product Mart, call Joanne Dorian, 212/463-6415

Announcing the 1989 Western EDN Caravan

"The Electronic Show on Wheels"



MUPAC CORPORATION
SOUTHCO FASTENERS
T-BAR, INCORPORATED
SPEEDY CIRCUITS, INC.
CAROL CABLE COMPANY, INC.
SAMSUNG SEMICONDUCTOR, INC.
NKK SWITCHES OF AMERICA, INC.
OHMITE MANUFACTURING COMPANY
Amphenol Corp., BENDIX CONNECTOR OPERATIONS
CAHNERS CAPS (Computer Aided Product Selection)

Bringing new products and ideas to your business doorstep.

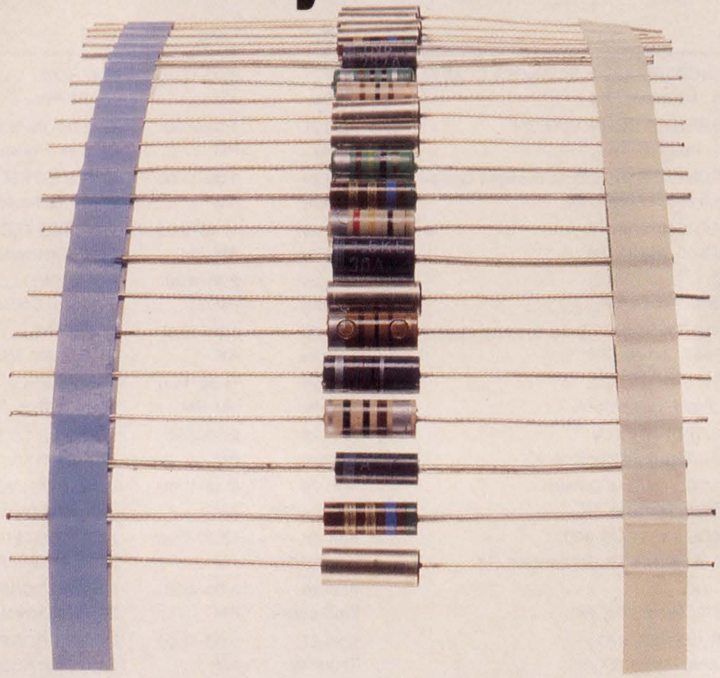
CHECK THE ITINERARY ON THE OPPOSITE PAGE FOR THE DATE WE VISIT YOUR COMPANY.




1989 WESTERN EDN CARAVAN TRAVELING ELECTRONIC SHOW
April 3 to May 5 (Central Edition)

DATE	TIME	SITE
April 3 Monday	9:00-12:00 AM	LOCKHEED ENGINEERING & SCIENCES COMPANY 2400 Nasa Rd., Houston, TX
April 3 Monday	1:30-4:00 PM	COMPAQ COMPUTER CORPORATION 20555 FM 149, Houston, TX
April 4 Tuesday	9:00-11:00 AM	TEXAS INSTRUMENTS INC., Data Systems Group 12501 Research Blvd., Austin, TX
April 4 Tuesday	1:00-3:30 PM	IBM CORPORATION 11400 Burnet Road, Austin, TX
April 5 Wednesday	8:30-11:00 AM	TRACOR, INC. 6500 Tracor Lane, Austin, TX
April 5 Wednesday	1:00-3:30 PM	TEXAS INSTRUMENTS INC., Data Systems Group 5701 Airport Road, Temple, TX
April 6 Thursday	8:30-10:30 AM	ROCKWELL INTERNATIONAL 1225 N. Alma Road, Richardson, TX
April 6 Thursday	11:30-1:00 AM-PM	ROCKWELL INTERNATIONAL Shiloh & Renner Road, Richardson, TX
April 6 Thursday	2:15-4:30 PM	E-SYSTEMS, INC., Garland Division 1200 Jupiter Road, Garland, TX
April 7 Friday	8:30-11:00 AM	ELECTROSPACE SYSTEMS INC. Greenville Ave. & Terrace Dr., Richardson, TX
April 7 Friday	1:30-3:30 PM	E-SYSTEMS, INC. Farm Road 1570, Greenville, TX
April 10 Monday	9:00-11:30 AM	TEXAS INSTRUMENTS, INC. 8505 Forest Lane, Dallas, TX
April 10 Monday	1:00-3:30 PM	TEXAS INSTRUMENTS INC. 13500 North Central Expressway, Dallas, TX
April 11 Tuesday	9:00-11:00 AM	LTV -Missiles & Electronics Group 1902 West Freeway, Grand Prarie, TX
April 11 Tuesday	2:00-4:00 PM	RELIANCE COMM/TEC 2100 Reliance Pkwy., Bedford, TX
April 12 Wednesday	9:00-12:00 AM	GENERAL DYNAMICS Grants Lane, Ft. Worth, TX
April 12 Wednesday	2:00-4:00 PM	RECOGNITION EQUIPMENT INC. 2701 Grauwyler Rd. Irving, TX
April 13 Thursday	8:30-11:00 AM	TEXAS INSTRUMENTS INC. Data Systems Group 2501 S. Highway 121, Lewisville, TX
April 13 Thursday	1:30-4:00 PM	BOEING ELECTRONICS 7801 S. Stemmons, Corinth, TX
April 14 Friday	9:00-11:30 AM	TEXAS INSTRUMENTS INC. 6500 Chase Oakes Blvd., Plano, TX
April 14 Friday	1:00-3:00 PM	TEXAS INSTRUMENTS INC. 2501 W. University, McKinney, TX
April 17 Monday	9:00-11:00 AM	IMPRIMIS TECHNOLOGY INC. 10323 West Reno Ave., Oklahoma City, OK
April 18 Tuesday	9:00-11:30 AM	NCR CORPORATION 3718 N. Rock Rd., Wichita, KS
April 18 Tuesday	1:30-4:00 PM	BOEING MILITARY AIRPLANE CO. 3801 South Oliver, Wichita, KS
April 19 Wednesday	9:00-11:30 AM	BENDIX KING 400 N. Rogers Road, Olathe, KS
April 19 Wednesday	1:30-3:30 PM	WILCOX ELECTRIC, INC. 2001 NE 46th St., Kansas City, MO
April 20 Thursday	9:00-12:00 AM	AT&T BELL LABORATORIES 777 North Blue Pkwy., Lees Summit, MO
April 21 Friday	9:00-11:30 AM	EMERSON ELECTRIC Evans Ave., St. Louis, MO
April 21 Friday	1:30-3:30 PM	EMERSON ELECTRIC, Electronics & Space Div. 8100 W. Florissant, St. Louis, MO
April 24 Monday	9:00-11:00 AM	MTS SYSTEM CORPORATION 14000 Technology Dr., Eden Prairie, MN
April 24 Monday	11:45-2:00 AM-PM	IMPRIMIS TECHNOLOGY INC. 5950 Clearwater Dr., Minnetonka, MN
April 24 Monday	2:45-4:30 PM	HONEYWELL, INC., Defense Systems 5901 So. County Road 18, Edina, MN
April 25 Tuesday	8:30-10:30 AM	HONEYWELL, INC. Military Avionics 6300 Olson Memorial Pkwy., Golden Valley, MN
April 25 Tuesday	11:30-1:30 AM-PM	HONEYWELL, INC., Military Avionics 1625 Zarthan Avenue, St. Louis Park, MN
April 25 Tuesday	2:30-4:30 PM	IMPRIMIS TECHNOLOGY INC. 7801 Computer Dr., Bloomington, MN
April 26 Wednesday	8:30-11:00 AM	CONTROL DATA CORPORATION 3101 East 80th St., Minneapolis, MN
April 26 Wednesday	12:30-2:30 PM	NCR COMTEN 2700 Snelling Ave., Roseville, MN
April 26 Wednesday	3:00-4:30 PM	UNISYS CORPORATION 2276 Highcrest Dr., Roseville, MN
April 27 Thursday	8:30-11:00 AM	UNISYS CORPORATION 3333 Pilot Knob Rd., St. Paul, MN
April 27 Thursday	1:00-4:00 PM	IBM CORPORATION Hwy. 52 & Northwest 37th St., Rochesteer, MN
April 28 Friday	8:30-11:00 AM	ALLEN-BRADLEY COMPANY 1201 So. 2nd St., Milwaukee, WI
April 28 Friday	12:00-1:30 PM	GENERAL ELECTRIC, Medical Systems 16800 W. Ryerson Rd., New Berlin, WI
April 28 Friday	2:30-4:30 PM	GENERAL ELECTRIC, Medical Systems 3000 N. Grandview Blvd., Waukesha, WI
May 1 Monday	9:00-11:30 AM	ROCKWELL INTERNATIONAL, Collins Avionics Div. 400 Collins Road NE, Cedar Rapids, IA
May 1 Monday	1:00-3:30 PM	ROCKWELL INTERNATIONAL, Communications Div. 855 35th St. N.E., Cedar Rapids, IA
May 2 Tuesday	9:00-11:00 AM	NORAND CORPORATION 550 Second St. S.E., Cedar Rapids, IA
May 2 Tuesday	1:00-3:00 PM	LITTON INDUSTRIES, Clifton Precision 2734 Hickory Grove Rd., Davenport, IA
May 3 Wednesday	8:30-11:00 AM	SUNDSTRAND CORPORTION, Data Control Group 4747 Harrison Ave., Rockford, IL
May 3 Wednesday	1:30-3:30 PM	MOTOROLA, INC. 1501 W. Shure Dr., Arlington Heights, IL
May 4 Thursday	8:30-10:30 AM	NORTHROP CORPORATION 600 Hicks Road, Rolling Meadows, IL
May 4 Thursday	11:30-1:00 AM-PM	NORTHROP CORPORATION 2525 Buffe Road, Elk Grove Village, IL
May 4 Thursday	2:00-4:00 PM	MOTOROLA, INC. 1301 E. Algonquin Rd., Schaumburg, IL
May 5 Friday	9:00-11:30 AM	AG COMMUNICATION SYSTEMS 2500 N. Wolf Road, Northlake, IL
May 5 Friday	1:00-3:30 PM	ZENITH ELECTRONIC SYSTEMS 1000 Milwaukee Ave., Glenview, IL

Now your CMOS backup battery can be what you've always wanted it to be.



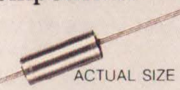
Just another component.

Forget those labor intensive methods normally required for printed circuit board mounting of batteries. Our new axial lead μPowerCells™ (Lithium Iodine 2.8V Solid CMOS Backup Cells) look like a resistor or capacitor. They're about the same size and they don't need special handling. You can put them on a sequenced tape reel for automatic printed circuit board insertion. And like most other components, μPowerCells™ can be wave soldered, cleaned and dried using normal procedures.

Once they're in place, μPowerCells™ are dependable. Their Lithium Iodine chemistry is the number one choice for powering cardiac pacemakers. And a performance study of over 1 million batteries in use shows that a useful life of more than 20 years can be predicted.

At 35 milliamp-hours, the axial lead μPowerCell™ will handle most CMOS backup problems. However, higher capacity versions to 1 amp hour are available in a new space-saving rectilinear package. The Catalyst Research line includes modules for sensing power loss and transferring to battery backup as well as clock modules with battery built in.

Best of all, Catalyst Research μPowerCells™ are priced like other components.



For more information, call us at 301-296-7000 ext. 304.

CATALYST RESEARCH
A DIVISION OF MINE SAFETY APPLIANCES COMPANY

1421 Clarkview Road Baltimore, MD 21209-9987, USA Telephone (301) 296-7000 ext 304 Telex 898095 CATALYST

CIRCLE NO 18

CAREER OPPORTUNITIES

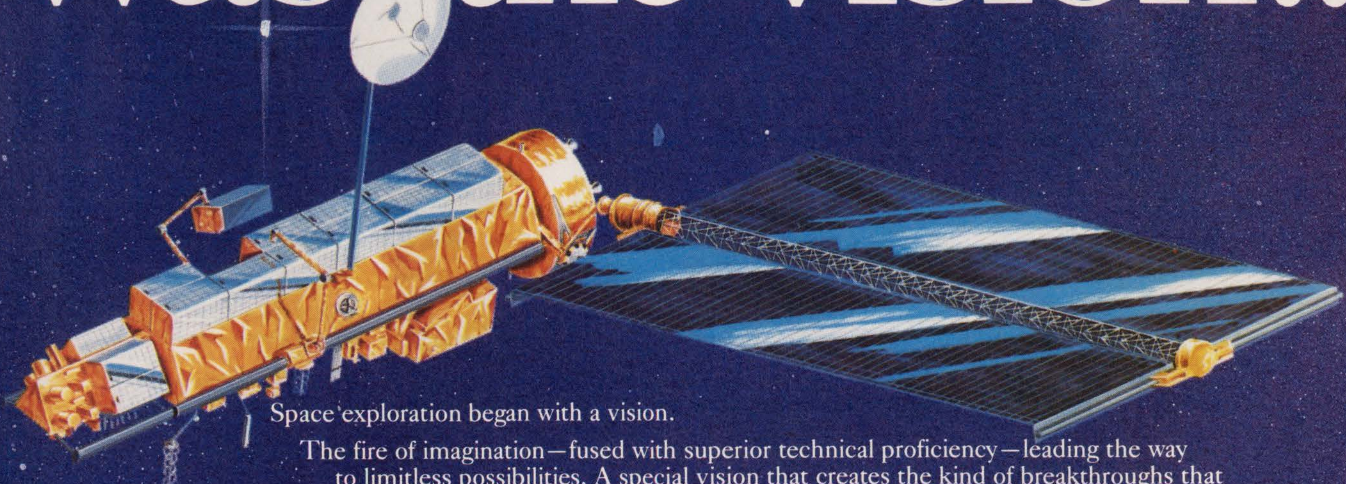
1989 Editorial Calendar and Planning Guide

Issue Date	Recruitment Deadline	EDN Editorial Emphasis	EDN News Edition
Apr. 27	Apr. 6	Communications Technology, Special Issue Communication ICs	Closing: Apr. 13 Mailing: May 4
May 11	Apr. 20	Analog Technology, Special Issue Computer Peripherals	Closing: Apr. 28 Mailing: May 18
May 25	May 4	Digital ICs, Computer Peripherals	Closing: May 25 Mailing: June 15
June 8	May 18	Components, Digital ICs	
June 22	June 1	Semicustom ICs, Computer Boards	Closing: June 9 Mailing: June 29
July 6	June 15	Product Showcase — Volume I, Power Supplies	Closing: June 22 Mailing: July 13
July 20	June 29	Product Showcase — Volume II, Components	Closing: July 21 Mailing: Aug. 10
Aug. 3	July 13	Integrated Circuits, Computer Boards	
Aug. 17	July 27	Military Electronics, Special Issue Military Software	Closing: Aug. 4 Mailing: Aug. 24
Sept. 1	Aug. 10	Test & Measurement, Integrated Circuits	Closing: Aug. 18 Mailing: Sept. 7
Sept. 14	Aug. 24	Industrial Product Showcase, Digital ICs	Closing: Aug. 30 Mailing: Sept. 21
Sept. 28	Sept. 7	Integrated Circuits, Computer Peripherals	Closing: Sept. 15 Mailing: Oct. 5
Oct. 12	Sept. 21	DSP Chip Directory, Integrated Circuits	Closing: Sept. 28 Mailing: Oct. 19
Oct. 26	Oct. 5	Test & Measurement, Special Issue, Computers & Peripherals	Closing: Oct. 27 Mailing: Nov. 16
Nov. 9	Oct. 19	CAE, Integrated Circuits	
Nov. 23	Nov. 2	16th Annual $\mu P/\mu C$ Directory, Integrated Circuits	Closing: Nov. 9 Mailing: Nov. 30
Dec. 7	Nov. 16	Product Showcase — Volume I, Power Supplies	Closing: Nov. 22 Mailing: Dec. 14
Dec. 21	Nov. 30	Product Showcase — Volume II, Components	

Call today for information:

East Coast: Janet O. Penn (201) 228-8610
West Coast: Mary Beth West (213) 820-3887
National: Roberta Renard (201) 228-8602

First, there was the vision...



Space exploration began with a vision.

The fire of imagination—fused with superior technical proficiency—leading the way to limitless possibilities. A special vision that creates the kind of breakthroughs that characterize GE Astro-Space.

Since the nation's first space communications adventure nearly 30 years ago, GE Astro-Space has been a world leader in the design and manufacture of satellites for government and commercial communications, meteorological, navigational and scientific use.

And, with over one hundred and fifty satellites currently circling the globe—and long-term, history-making projects such as the ***Mars Observer, Space Station and Landsat***—we can offer Engineers the kind of rare opportunities that few are destined to realize.

If you're the Engineer we're seeking, join us as we pave the way for a new generation of emerging space technology. Our mission requires the technical proficiency of Engineers **with a minimum of 3 years experience in one or more of the following:**

■ Mechanical Engineers
Antenna Design
RF Packaging Design
Robotics/Mechanism Design
Spacecraft Attitude Control

■ Systems Engineers
Spacecraft Power Systems
Mission Analysis

■ Electrical Engineers/ Hardware
Electronic Packaging
Harness Design
ATE/AGE Design
Power Supply/Analog Design
Video Design

■ Integration & Test Engineers

Our New Jersey location offers all the advantages of nearby Princeton—within easy access to New York City and Philadelphia. Additionally, selected positions are open in Valley Forge, PA. In either location, you'll experience a lifestyle that complements your career, providing unlimited opportunities for personal and professional growth. As the largest employer of engineers and scientists in the world, GE provides competitive salaries and exceptional benefits including tuition refund and continuing education programs—so your expertise is always current and expanding.

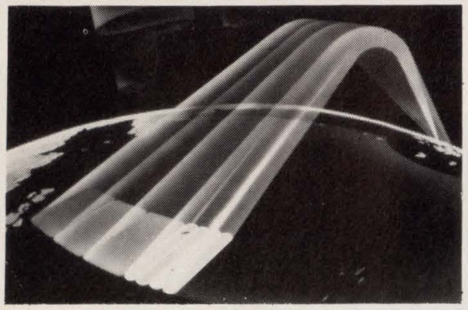
Rush your resume to: Employee Relations, Dept. EDNM, GE Astro-Space, P.O. Box 800, Princeton, New Jersey 08543-0800. An equal opportunity employer.

GE Aerospace
Astro-Space

Cross the engineering frontier.

A Tale of Two Cities With One Mission

Shape the Future - Join GE in Syracuse or Moorestown.



We make engineers like you part of the longest-term, most inherently dramatic "hide and seek" missions of our time.

GE Government Electronic Systems Division is prime contractor for a second generation, integrated system that will make Seawolf SSN subs effective defenders well into the 21st Century.

If your ambitions include developing big, fast signal processing capabilities and linkages to advanced ASW sensor systems and C+...or being part of more powerful, more discriminating radar, sonar and acoustical programs that enlarge ocean surveillance capabilities of surface ships...tell GE.

The more that company resources and reputation mean to you—and the more you want to accomplish in system and software architecture, hardware and circuit design, low frequency and broadband sonar, and signal and data processing—the sooner we should meet. Do what our customers do. Talk to key GE managers at our two locations.

Syracuse, NY

In an area with wide recreational, cultural and lifestyle options, you can be part of the most far-sighted signal processing programs. We have openings for engineers with at least 5 years experience as...

Systems Engineers/Managers

opportunities exist in:

- **Algorithm Development • Signal Processing • Human Factors**
- **Sensor System Design • Systems Analysis • ASW Systems**
- **Combat Systems Architecture • Reliability/Maintainability**
- **PIDS Through B level Specification Design**

Hardware/Circuit Design Engineers/Managers

help design the future by working in:

- **CMOS • Power Design • Gate Array Design**
- **Configuration Management • Cabinet Design**

Software Engineers/Programmers/Managers

opportunity to advance if you're experienced with:

- **Top Down Structured Design • MIL-STD 2167**
- **ADA Language Architecture and Programming**
- **Embedded Programmable Processors (68000 or similar)**

Software Quality Assurance Engineers

with experience in:

- **Metrics/Trend Analysis • ADA/Case tools helpful**
- **Strong organization/personal skills • MIL-STD 2167/2168**
- **Summarizing detailed data for management decisions**

Choice opportunities also exist in the following areas:

- **Advanced engineering design/development of future ASW systems**
- **Test and integration testing**
- **Quality assurance programs engineering**
- **Subcontracts management and financial analysis**
- **Field programs engineering (Naval systems)**

Moorestown, NJ

In an attractive suburb, 15 miles outside Philadelphia— near shore and mountains—engineers make exciting mental journeys. Should have BSEE or BSCS and at least 5 years experience as...

Senior Engineers, Combat Control

- **BSEE**
- **5+ years in Combat Control performance definition, design and test for real time Combat Control Systems.**
- **Knowledge of U.S. Navy systems, preferably submarine systems.**

Senior Digital Design Engineers

BSEE, with 5+ years experience in the digital/firmware design of digital sub-systems. Should also have experience in the design of special purpose digital processors with strength in current custom design and simulation techniques.

Senior Software Design Engineers

BSEE or BSCS with 5+ years direct experience in the design and development of large real time Command and Control Systems which utilize sensor data input. Experience with the following:

- **Fault location/fault detection with a plus for automatic configuration design experience.**
- **Real-time data base design experience with Ingress or Oracle.**
- **Motorola 68020 assembly language, and/or real time operating system experience.**

Senior Engineers, Command & Decision

BSEE with 5+ years in Command and Control performance definition, design and test for real time Command and Control Systems. Should have knowledge of U.S. Navy systems, preferably submarine systems.

Both locations provide competitive salaries, and the technical and management training and comprehensive benefits you'd expect from GE. To apply, please send your resume indicating position of interest, and salary history, to:

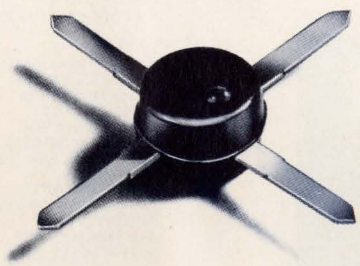
GE Professional Staffing, ADEDN, P.O. Box 4840, EP-1-106, Syracuse, NY 13221 or MTEDN, GESD,, Bldg. 127-101, Moorestown, NJ 08057.

U.S. Citizenship Required

GE Government Electronic Systems Division

An Equal Opportunity Employer

from 99¢



dc to 2000 MHz amplifier series

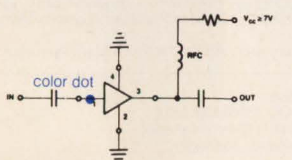
SPECIFICATIONS

MODEL	FREQ. MHz	GAIN, dB 100 MHz	1000 MHz	2000 MHz	Min. (note)	•MAX. PWR. dBm	NF dB	PRICE $ Ea.	Qty.
MAR-1	DC-1000	18.5	15.5	—	13.0	0	5.0	0.99	(100)
MAR-2	DC-2000	13	12.5	11	8.5	+3	6.5	1.50	(25)
MAR-3	DC-2000	13	12.5	10.5	8.0	+8□	6.0	1.70	(25)
MAR-4	DC-1000	8.2	8.0	—	7.0	+11	7.0	1.90	(25)
MAR-6	DC-2000	20	16	11	9	0	2.8	1.29	(25)
MAR-7	DC-2000	13.5	12.5	10.5	8.5	+3	5.0	1.90	(25)
MAR-8	DC-1000	33	23	—	19	+10	3.5	2.20	(25)

NOTE: Minimum gain at highest frequency point and over full temperature range.
• 1dB Gain Compression
□ +4dBm 1 to 2 GHz

designers amplifier kit, DAK-2

5 of each model, total 35 amplifiers
only $59.95



Unbelievable, until now...tiny monolithic wideband amplifiers for as low as 99 cents. These rugged 0.085 in.diam.,plastic-packaged units are 50ohm* input/output impedance, unconditionally stable regardless of load*, and easily cascadable. Models in the MAR-series offer up to 33 dB gain, 0 to +11dBm output, noise figure as low as 2.8dB, and up to DC-2000MHz bandwidth.

*MAR-8, Input/Output Impedance is not 50ohms, see data sheet. Stable for source/load impedance VSWR less than 3:1

Also, for your design convenience, Mini-Circuits offers chip coupling capacitors at 12 cents each.†

Size (mils)	Tolerance	Temperature Characteristic	Value
80 × 50	5%	NPO	10, 22, 47, 68, 100, 470, 680, 100 pf
80 × 50	10%	X7R	2200, 4700, 6800, 10,000 pf
120 × 60	10%	X7R	.022, .047. .068, .1μf

† Minimum Order 50 per Value

finding new ways...
setting higher standards

Mini-Circuits

A Division of Scientific Components Corporation
P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500
Fax (718) 332-4661 Domestic and International Telexes: 6852844 or 620156

C113-Rev. D

CIRCLE NO 52

BUSINESS/CORPORATE STAFF

Peter D Coley
VP/Publisher
Newton, MA 02158
(617) 964-3030; Telex 940573
Ora Dunbar, Assistant/Sales Coordinator

Mark J Holdreith
Advertising Sales Director
Newton, MA 02158
(617) 964-3030
Heather McElkenny, Assistant

Deborah Virtue
Business Director
Newton, MA 02158
(617) 964-3030

NEW ENGLAND
John Bartlett, Regional Manager
Chris Platt, Regional Manager
199 Wells Ave
Newton, MA 02159
(617) 964-3730

STAMFORD 06904
George Isbell, Regional Manager
8 Stamford Forum, Box 10277
(203) 328-2580

NEW YORK, NY 10011
Daniel J Rowland, Regional Manager
249 West 17th St
New York, NY 10011
(212) 463-6419

PHILADELPHIA AREA
Steve Farkas, Regional Manager
487 Devon Park Dr, Suite 206
Wayne, PA 19087
(215) 293-1212

CHICAGO AREA
Clayton Ryder, Regional Manager
Greg Anastos, Regional Manager
Jack Johnson, Regional Manager
Randolph D King, Regional Manager
Maris Listello, Telemarketing
Cahners Plaza
1350 E Touhy Ave, Box 5080
Des Plaines, IL 60017
(312) 635-8800

DENVER 80206
John Huff, Regional Manager
44 Cook St
(303) 388-4511

DALLAS 75243
Don Ward, Regional Manager
9330 LBJ Freeway, Suite 1060
(214) 644-3683

SAN JOSE 95128
Walt Patstone, Regional Manager
Bill Klanke, Regional Manager
Philip J Branon, Regional Manager
James W Graham, Regional Manager
3031 Tisch Way, Suite 100
(408) 243-8838

LOS ANGELES 90064
Charles J Stillman, Jr
Regional Manager
12233 W Olympic Blvd
(213) 826-5818

ORANGE COUNTY/SAN DIEGO 92715
Jim McErlean, Regional Manager
18818 Teller Ave, Suite 170
Irvine, CA
(714) 851-9422

PORTLAND, OREGON 97221
Pat Dakin, Regional Manager
Walt Patstone, Regional Manager
1750 SW Skyline Blvd, Box 6
(503) 297-3382

UNITED KINGDOM/BENELUX
Jan Dawson, Regional Manager
27 Paul St
London EC2A 4JU UK
44 01-628 7030
Telex: 914911; FAX: 01-628 5984

SCANDINAVIA
Stuart Smith
27 Paul St
London EC2A 4JU UK
01-628 7030
Telex: 914911; FAX: 01-628 5984

FRANCE/ITALY/SPAIN
Alasdair Melville
27 Paul St
London EC2A 4JU UK
01-628 7030
Telex: 914911; FAX: 01-628 5984

WEST GERMANY/SWITZERLAND/AUSTRIA
Wolfgang Richter
Sudring 53
7240 Horb/Neckar
West Germany
49-7451-7828; Telex: 765450

EASTERN BLOC
Uwe Kretzschmar
27 Paul St
London EC2A 4JU UK
01-628 7030
Telex: 914911; FAX: 01-628 5984

FAR EAST
Ed Schrader, General Manager
18818 Teller Ave, Suite 170
Irvine, CA 92715
(714) 851-9422; Telex: 183653

HONG KONG
John Byrne & Associates Ltd
1613 Hutchison House
10 HGarcourt Road
Central Hong Kong
Tel: 5-265474
Tlx: 61708 WEDIN HX
Fax: 5-8106781

JAPAN
Kaoru Hara
Dynaco International Inc
Suite 1003, Sun-Palace Shinjuku
8-12-1 Nishishinjuku, Shinjuku-ku
Tokyo 160, Japan
Tel: (03) 366-8301
Telex: J2322609 DYNACO

KOREA
Kim Kyong-Hae, BK International
Won Chang Bldg, 3rd Floor 26-3
Yoido-dong, Youngdungpo-ku
Seoul 150, Korea
Tel: 785-6665; FAX: 784-1915
Telex: K32487 BIZKOR

SINGAPORE/MALAYSIA/INDONESIA/THAILAND/ THE PHILIPPINES/AUSTRALIA/NEW ZEALAND
Asia Pacific Media House PTE Ltd
Peter Cheong
100 Beach Rd
#24-03 Shaw Tower
Singapore 0718
Tel: 2915354; Telex: RS 50026 MESPLY

TAIWAN
Acteam International Marketing Corp
6F, No 43, Lane 13
Kwang Fu South Rd
Mailing Box 18-91
Taipei, Taiwan ROC
760-6209 or 760-6210
Telex: 29809; FAX: (02) 7604784

PRODUCT MART
Joanne Dorian, Manager
249 West 17th St
New York, NY 10011
(212) 463-6415

INFO CARDS
Donna Pono
Newton, MA 02158
(617) 558-4282

CAREER OPPORTUNITIES/CAREER NEWS
Roberta Renard, National Sales Manager
(201) 228-8602

Janet O Penn, Eastern Sales Manager
(201) 228-8610
103 Eisenhower Parkway
Roseland, NJ 07068

Mary Beth West, Western Sales Manager
12233 West Olympic Blvd
Los Angeles, CA 90064
(213) 826-5818

Staci Comstock, Sales Assistant
(201) 228-8608
FAX: 201-228-4622

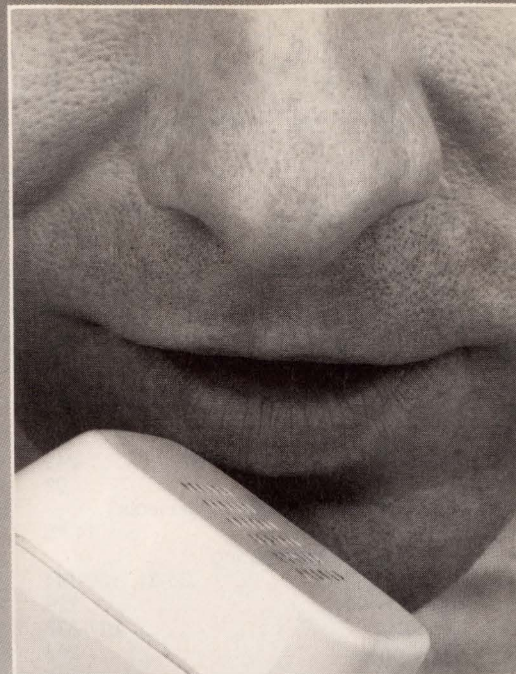
Wendy A Casella, *Advertising/Contracts Coordinator*
Nan E Coulter, *Advertising/Contracts Coordinator*
Aileen B Turner, *Advertising/Contracts Coordinator*
(617) 964-3030

William Platt, Senior Vice President, Reed Publishing USA

Cahners Magazine Division
Terry McDermott, President, Cahners Publishing Co
Frank Sibley, Senior Vice President/General Manager, Boston Division
Tom Dellamaria, VP/Production & Manufacturing

Circulation
Denver, CO: (303) 388-4511
Sherri Gronli, Group Manager
Eric Schmierer, Manager

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 Joanne R Westphal, Cahners Reprint Service, Cahners Plaza, 1350 E Touhy Ave, Box 5080, Des Plaines, IL 60018. Phone (312) 635-8800.



Your VME Synchro/Resolver I/O solution may be just under your nose.

It may even be just a phone call away.

To VMIC.

When it comes to VME Synchro/Resolver I/O boards and backplanes, VMIC has six high performance, board level solutions with over 100 options available to meet your needs today. Off-the-shelf.

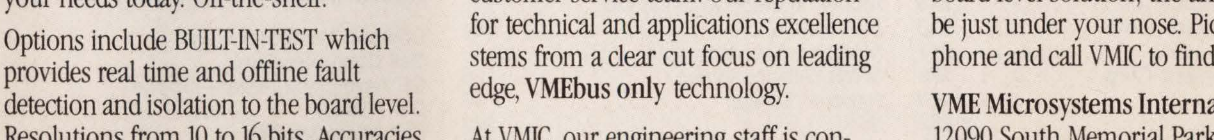
Options include BUILT-IN-TEST which provides real time and offline fault detection and isolation to the board level. Resolutions from 10 to 16 bits. Accuracies from ±2.3 to ±4 arc minutes. References of 60 to 6000 Hz. Single, dual, or quad channel configurations. And so much more.

In addition, **all VMIC Products are backed by a full two year warranty;** and are supported by the industry's most responsive and knowledgeable 24-hour customer service team. Our reputation for technical and applications excellence stems from a clear cut focus on leading edge, **VMEbus only** technology.

At VMIC, our engineering staff is continually driven toward VMEbus product refinement and innovation. The proof is evident in several VMEbus solutions we offer for Host Computer Interfaces, VME-to-VME links and Repeaters, Digital I/O, Analog I/O and Serial I/O, Intelligent I/O controllers and more.

So, when you are searching for your Synchro/Resolver, or any other VMEbus board level solution, the answer could be just under your nose. Pick up the phone and call VMIC to find out—today.

VME Microsystems International Corp.
12090 South Memorial Parkway
Huntsville, Alabama 35803
205/880-0444 Ext. 189, Fax 205/882-0859
1-800-322-3616



VMIC VME ™

CIRCLE NO 58

ADVERTISERS INDEX

Recruitment Advertising 251-256

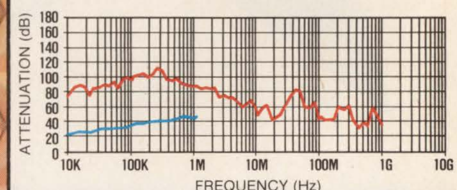
*Advertiser in US edition
**Advertiser in International edition

When your specs call for emission control,

call for Emcor's EMI/RFI series

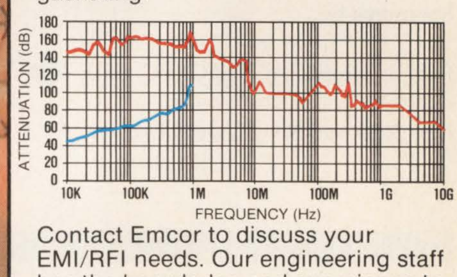
FCC Level

Emcor offers shielding solutions. Shown at left is an Emcor EMI/RFI enclosure —designed for commercial applications and tested to MIL STD 285. Fabricated with 14-gauge cold-rolled steel, these enclosures have the rigidity to maintain shielding continuity. They are also fully zinc-plated — both frame and external components — and come with a full complement of accessories.



Tempest Style

To meet the most demanding levels of shielding often required by the military, Emcor offers its Tempest style line of enclosures as shown in the top photo. Also tested to MIL STD 285, this line combines high strength with modular options and attractive esthetics. Features include a rigid, 12-gauge frame plus a unique latching system and door design (patent pending). These enclosures are nickel-plated with copper finger stock gasketing.



Contact Emcor to discuss your EMI/RFI needs. Our engineering staff has the knowledge and experience to help solve your shielding problems. We can also design modified and custom products.

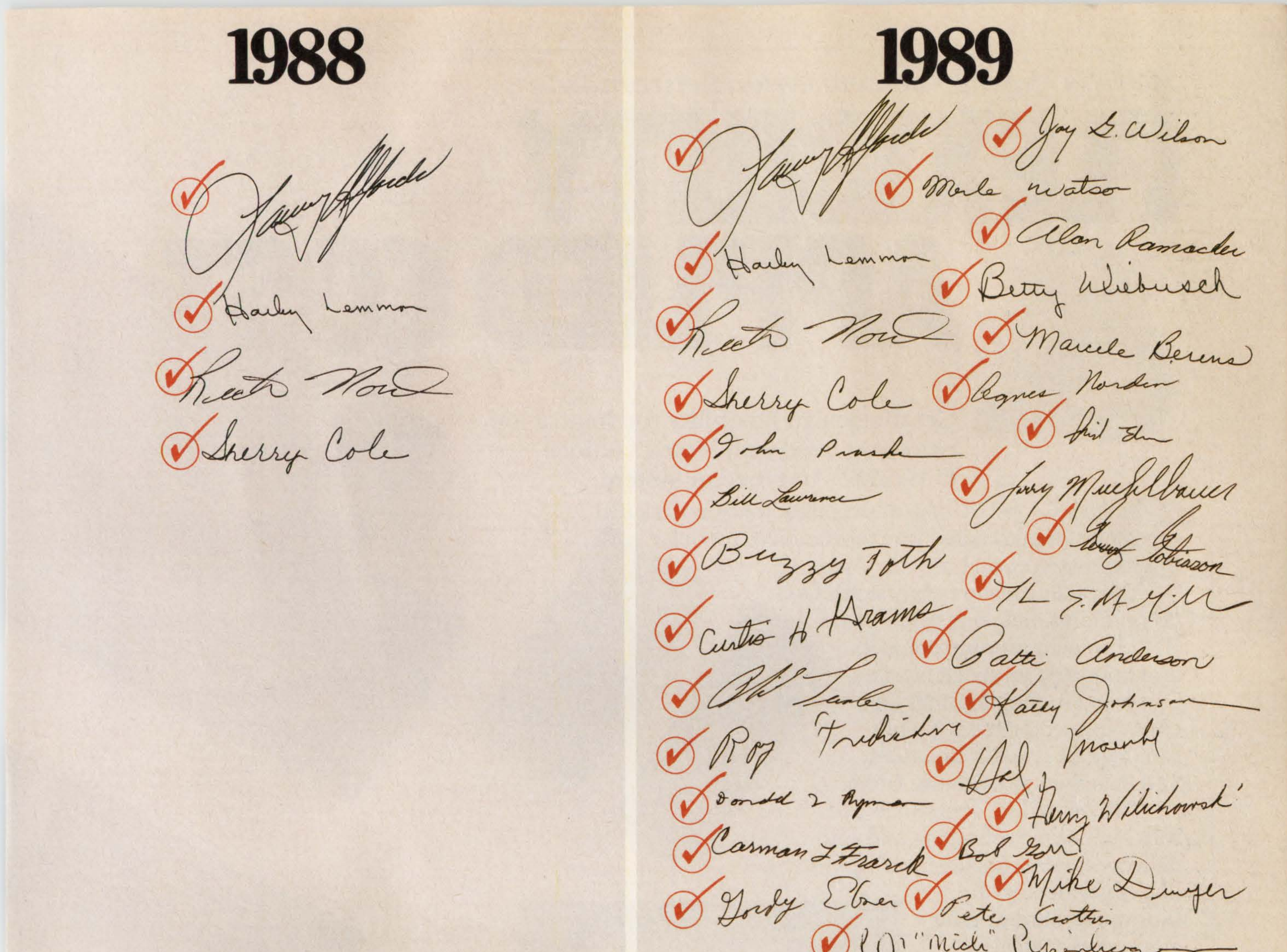
Crenlo, Inc.

1600 - 4th Ave. N.W.
Rochester, MN 55901
Phone 507-289-3371
FAX #507-287-3405

EMCOR®

See us at the Electro Show, Booth #1835.

CIRCLE NO 14



Recently we added 1,424 quality control inspectors.

Every single Hoffman employee is now a quality control inspector. It's part of our ongoing "Total Quality" program. It makes doubly sure that every single piece of Hoffman equipment will do precisely what you need it to do. And more. We've made some other innovations, too. They're in our new brochure. For your copy and brief product information, just drop us a line.

Hoffman®
ENGINEERING COMPANY
900 Ehlen Drive, Anoka, MN 55303
Phone: 612-421-2240

CIRCLE NO 13

Molex Is Making The Connection Between...

FLEXIBILITY & APPLIED COST

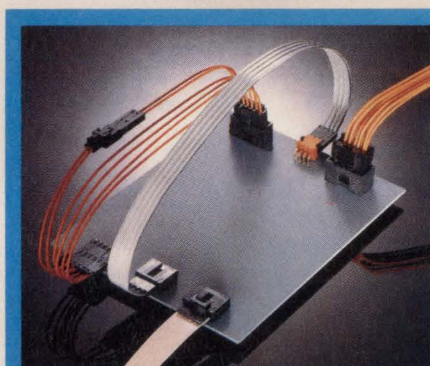
Get the design flexibility you want at the price you need with Molex's unique C-Grid SL™ connector system.

Molex's C-Grid SL system of connectors was designed especially for automated wire termination, modular interconnection, and robotic placement.

The SL line features fully stackable components including single piece IDT connectors, crimp contacts and housings, shrouded headers, and panel mount housings and clips. Connector styles include modular, low profile, polarized, and polarized with positive latching.

This broad line of products combined with our unique packaging and automated delivery systems make Molex's C-Grid SL line of connectors an innovative, hard-working answer for engineers looking to achieve their designs at the optimum cost.

For your free samples and our full-line catalog, contact us today.



There's a C-Grid SL connector for all your wire-to-wire, board-to-board, and ribbon cable-to-board needs.

The dual row IDT connector... the only coverless dual row connector available today.

molex®

Service To The Customer... Worldwide

***Corporate Headquarters:** 2222 Wellington Ct., Lisle, IL, 60532 USA, 312-969-4550 • **European Headquarters:** Munich, West Germany, 49-89-496093*
***Northern Asia Headquarters:** Tokyo, Japan, 03-487-8333 • **Southeast Asia Headquarters:** Jurong Town, Singapore, 65-265-4755*

CIRCLE NO 11