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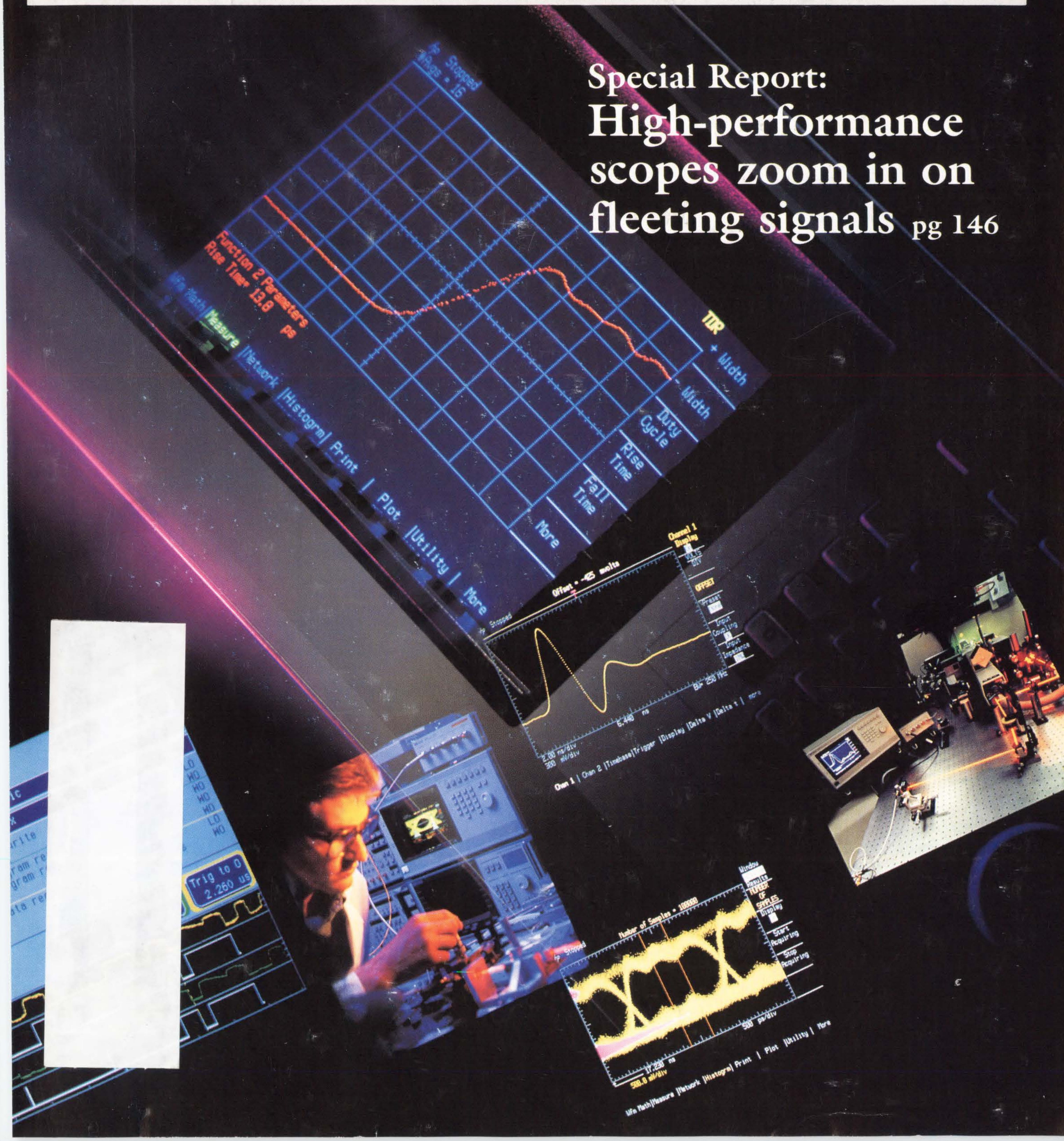
EDN®

TEST & MEASUREMENT SPECIAL ISSUE

ELECTRONIC TECHNOLOGY FOR ENGINEERS AND ENGINEERING MANAGERS

Special Report: High-performance scopes zoom in on fleeting signals pg 146



HMI development systems do it all!

HMI provides complete development systems—in-circuit emulator, window driven source level debugger and software performance analyzer—that address all aspects of the microprocessor system design cycle, from prototype to production:

HMI Emulators Feature:

- Run at real-time with no wait states.
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- Logic analyzer capabilities built into the emulator.
- 16 External Trace bits.
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SOFTWARE

HMI's SourceGate ties it all together, so emulator features aren't sacrificed to gain source-level debugging.

HMI SourceGate® Features:

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Add our Performance Analysis Card to complete your development package.

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If you are looking for one development system that does it all, call (205) 881-6005, or write to Huntsville Microsystems Inc., 3322 South Memorial Parkway, Huntsville, AL 35801.

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68008	68331/332	8051 Family
68010	68340	DS5000
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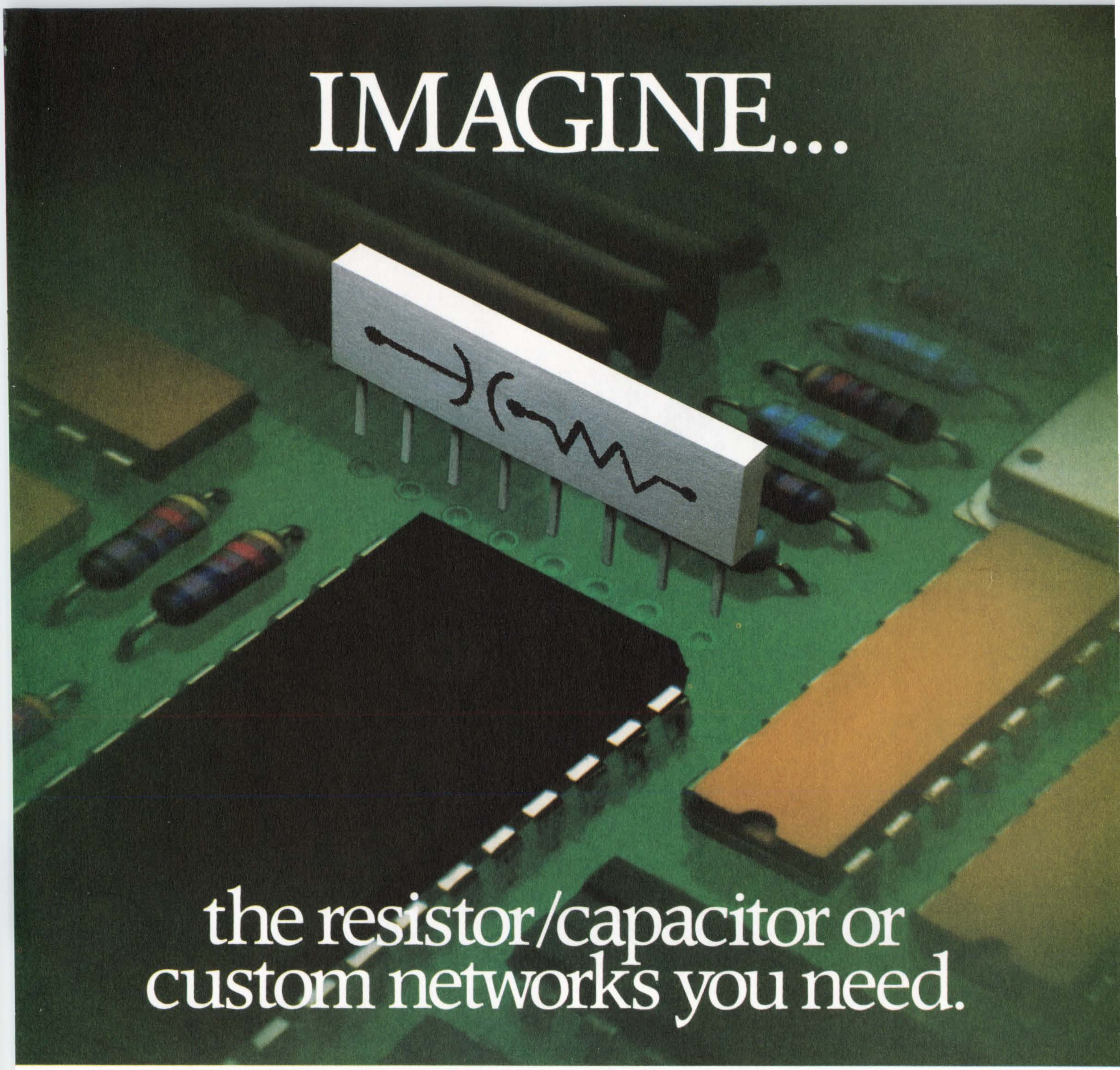
68030	68EC020	8085
68302	68EC030	64180/Z180
68301/303	68HC11 including F1 and D3	Z80

HMI

IBM is reg. T.M. International Business Machines, Inc. UNIX is reg. T.M., Bell Laboratories, Inc.

CIRCLE NO. 3



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Imagine the exact circuit you need. Then call Dale® and get dozens of ways to package resistors, capacitors and other components. Reliably. Faster. And in less space.

We're ready to deliver all types of general purpose R/C networks in molded DIP and conformal-coated SIP styles for ECL, line and Thevenin equivalent termination. In addition, we're an established producer of custom circuits which combine a variety of active and passive components in DIP, SIP or special packages.

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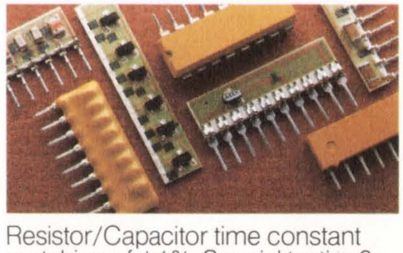

Resistor/Capacitor time constant matching of ±1%. Special testing? Our capabilities include temperature cycling from −55°C to +125°C and power conditioning at room temperature, 70°C and 125°C.

Imagine how Dale networks can help you do a better job. Then call (402) 371-0080 for immediate assistance or write: Dale Electronics, Inc., 2300 Riverside Blvd., Norfolk, NE 68701-2242.

Remember, when it comes to delivering the networks you need — Dale Can.

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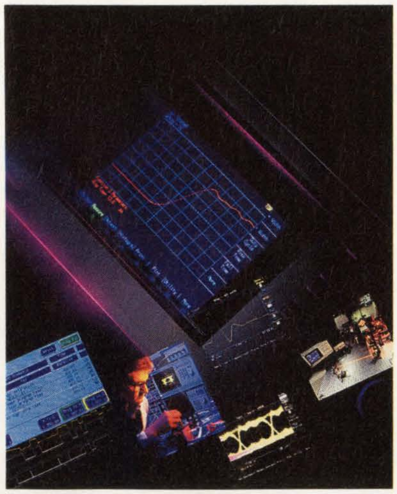
EDN Magazine Edition®

Volume 36, Number 21

October 10, 1991

ELECTRONIC TECHNOLOGY FOR ENGINEERS AND ENGINEERING MANAGERS



On the cover: *By carefully examining your application's requirements, you can select a high-performance oscilloscope that best suits the case and, ultimately, saves you time, money, and frustration. See our Special Report on pg 146. (Photo courtesy Hewlett-Packard Co)*

TEST AND MEASUREMENT SPECIAL ISSUE

SPECIAL REPORT

DESIGN FEATURES

TECHNOLOGY UPDATES

Continued on page 7

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Check Out What Hamilton/Avnet Has in Storage for You.

Hamilton/Avnet now has, in stock, the industry's first 1 megabyte and 4 megabyte, PCMCIA-compatible flash memory cards to help you achieve higher functionality in portable and dedicated applications.
In fact, when it comes to data acquisition and firmware updates, Hamilton/Avnet has the knowledge and expertise to help you design-in flash memory cards...today!

And for applications incorporating DOS, Intel offers a flash system developer's kit that enables you to check out how easy it is to design-in flash memory cards.

To order your flash system developer's kit, a $499.95 value, simply call Hamilton/Avnet. For the branch nearest you, call toll free, 1 (800) 888-9236. Or, for further details, simply send in the coupon below.

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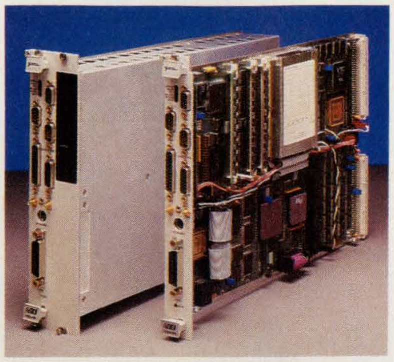


***Those who take the time** to learn about VXI (VME extensions for instrumentation) will be surprised and rewarded with the bus's cost savings, size, and fast operation. EDN's source guide presents VXI products from about 50 vendors (pg 73).*

TECHNOLOGY UPDATES *(CONTINUED)*

Picking the VXIbus for a test system might seem like making a conscious choice to start your project $10,000 in the hole. But a closer look reveals a different picture.—*Dan Strassberg, Associate Editor*

COMDEX TRENDS

This time of year computer and electronic sleuths worldwide turn their attention to the Fall Comdex trade show, which produces the most important computer-related product announcements. As a prelude to the show, EDN examines industry trends in the areas of mass storage and graphics products and provides hints of some of the hottest new products.

The emergence of Windows 3.0 as a de facto industry standard for PCs means that standard graphics hardware doesn't matter as much as it used to.—*Margery Conner, Contributing Editor*

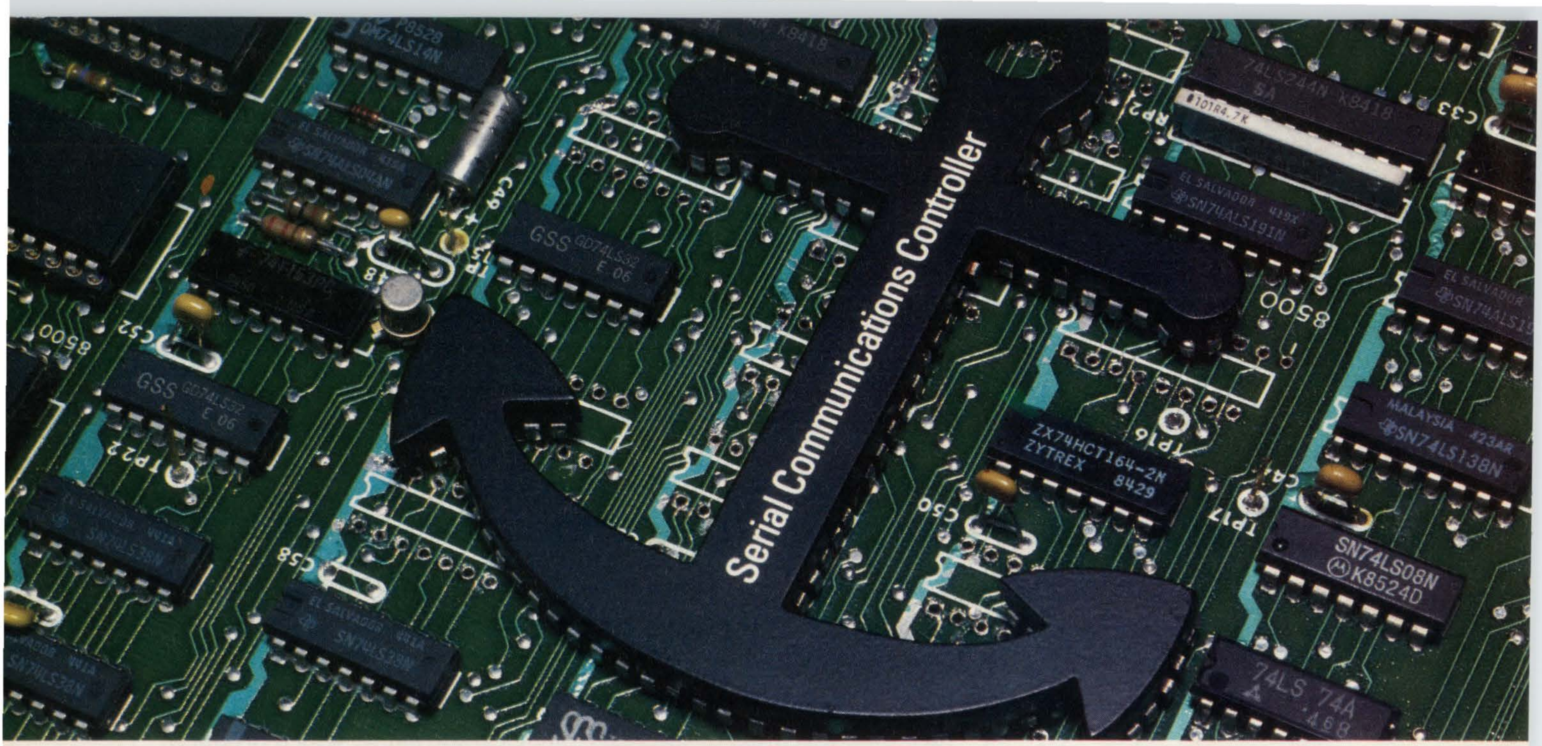
Every year manufacturers offer smaller mass-storage devices. The move toward smaller peripherals, however, has never been as dramatic as now—1.8-in. hard-disk drives are emerging, and some 3½-in. units can store 1 Gbyte.—*Maury Wright, Regional Editor*

EDITORS' CHOICE

PRODUCT UPDATES

Continued on page 9

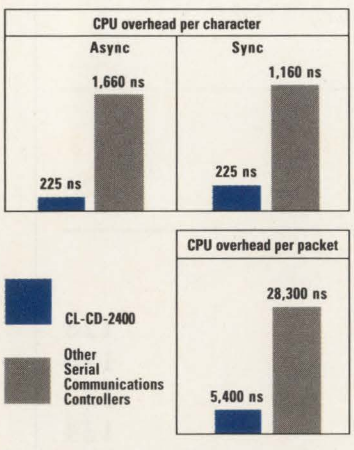
Cahners Publishing Company, A Division of Reed Publishing USA □ Specialized Business Magazines for Building & Construction □ Research □ Technology □ Electronics □ Computing □ Printing □ Publishing □ Health Care □ Foodservice □ Packaging □ Environmental Engineering □ Manufacturing □ Entertainment □ Media □ Home Furnishings □ Interior Design □ and Lodging. Specialized Consumer Magazines for Child Care □ Boating □ and Wedding Planning.



What other companies' datacom controllers look like to your CPU.

The CPU overhead imposed by standard datacom controllers can be a drag on your system performance, and on your development efforts.

Now there's a more intelligent solution. The Cirrus Logic CL-CD2400 single-chip datacom controller can send and receive complete packets with no host supervision. This gives you up to seven times more system performance than other serial communications controllers.

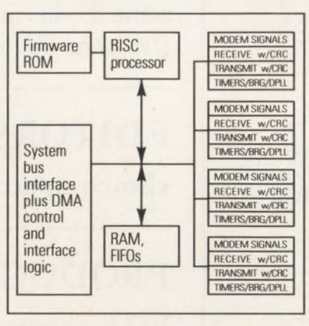


The CL-CD2400 has more intelligence for sophisticated error checking, special character matching, address recognition and automatic DMA management — with 1/7th the overhead.*

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

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

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



The next generation datacom controllers: An on-chip RISC processor gives you the intelligence to achieve more performance. Four multi-protocol channels let you choose from all asynchronous and synchronous protocols. An integrated 32-bit-address DMA controller, integrated interrupt controller and on-chip FIFOs for each channel give fast I/O. Sophisticated character- and frame-processing features make this the most efficient controller on the market.

For free product information and technical comparison

Call 1-800-952-6300.

Ask for dept. LD26.

CIRRUS LOGIC

Continued from page 7

EDN Magazine Edition®

October 10, 1991

DESIGN IDEAS

EDITORIAL

NEW PRODUCTS

DEPARTMENTS

EDN BBS Update

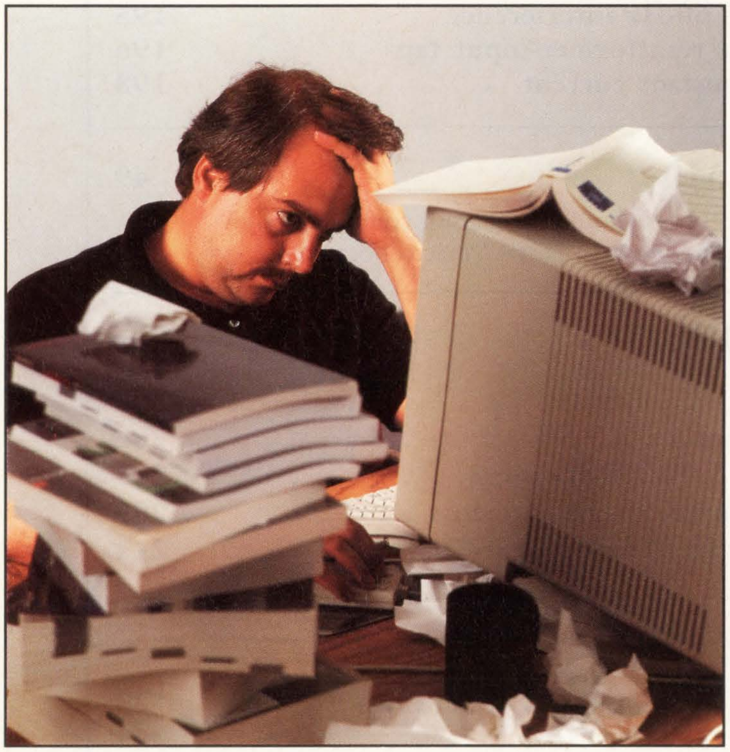
EDN continues to upgrade the Bulletin Board System (BBS) to make it easier for you to access the information you need, when you need it. The BBS ((617) 558-4241) now offers more than 1000 posted programs. Several readers are generously contributing their time and resources to make more programs available in the near future. You, too, can join reader-supported projects

- To develop a library of simple fuzzy-logic routines for ordinary microprocessors: /rsp_fuzz Special Interest Group.

- To develop a library of digital-signal-processing routines for ordinary microprocessors: /rsp_dsp Special Interest Group.

- To optimize Desqview, Windows3.0, and DOS5.0 as engineering environments on the PC. A massive documentation library for these operating environments is now available on EDN BBS: /eng_env Special Interest Group.

At $60,000 each, only two of t



Option A Available from most EDA suppliers

The Conventional Workstation Package

There used to be only limited choices. For $60,000 or so, you could get overpriced EDA software and a single PCB design environment. It also came with free, virtually endless levels of frustration, because these systems are hard to use and even more difficult to learn. Which made productivity look something like an inverted bell curve.

Option B Available only from OrCAD

The OrCAD Sun Productivity Package

Now, OrCAD brings you better options — OrCAD EDA tools and a high-performance UNIX® environment on the Sun SPARCstation™. Put OrCAD tools in the hands of an entire PCB design team for the same $60,000 or so. Get four times as many workstations. And with OrCAD's intuitive, easy-to-learn tools, your designers will set a new precedent for productivity.

OrCAD®

hese EDA options make sense

Option C Available only from OrCAD
The OrCAD Sun Vacation Package

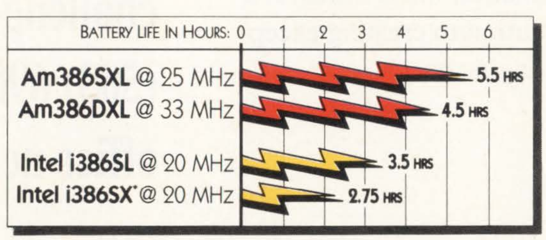
Or with the same budget, you can set up one PCB designer with a truly inspiring, high-performance environment, including a hot car, a fast boat, and a view!
With OrCAD EDA tools and a Sun SPARCstation, you'll have enough cash left over to requisition these extras. It's outrageous. But it is a feasible solution to creating exceptionally happy, motivated design engineers.

To find out how OrCAD can solve your PCB design challenges, call us today at (503) 690-9881 for the sales office nearest you.

More Designs From More Designers Than Anyone in the World

This Is H
Am386™ CP
Batter

Some might call it sleeping on the job. We call it true static operation—and that's how the low power Am386 microprocessors use a full 35% less power than the other so-called low power 386 at any sustained clock speed.



They're not only the most efficient 386s on the planet, they're also the fastest. Our Am386SXL-25 CPU clocks in at 25MHz, 25% faster than the i386SX-20, while our Am386DXL-40 CPU boasts a 40MHz clock speed.

Because Am386 microprocessors are truly static, you can configure your system to literally stop the clock and save power when the processor is idle. Even between keystrokes.

Which means you get maximum battery life, with no performance compromise. Up to 2

ow The
U Extends
y Life.

hours and 45 minutes (100%) longer battery life than the i386SX-20. Or 2 hours (57%) longer than the i386SL-20.

The Am386SXL-25 and Am386DXL-33 microprocessors are available now in PQFP packages for the most compact notebook and palmtop designs ever. Our Am386DXL-40 CPU is available in standard PGA. Better still, they're now shipping in quantity.

So if you want longer battery life from your next design, it's time to retire that old 386.

Call **1-800-222-9323.** And rest easy with a low power Am386 microprocessor.

Advanced Micro Devices

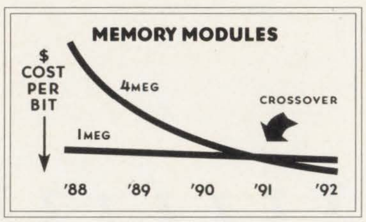
"We're Not Your Competition."

SAMSUNG NOW

IN MEMORY MOD CROSSOVER HAS J

You've heard the old saying, "we'll cross that bridge when we come to it." Well, we have.

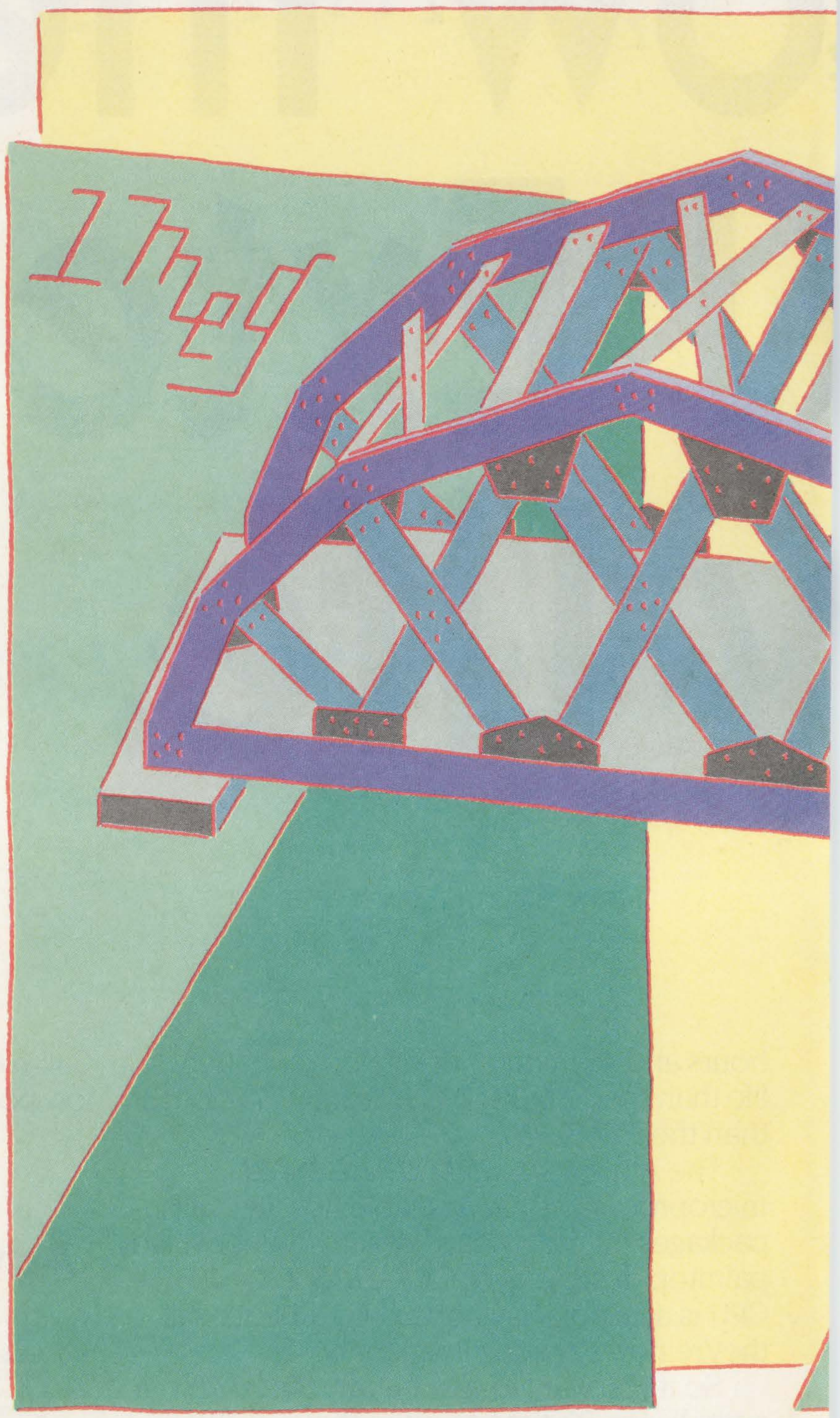
Cost crossover today makes 4-meg DRAMs more economical per bit than 1-meg DRAMs. And given all the benefits in reliability and board real estate, that's good news.



People are lining up to take advantage of it.

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

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



ULES, COST-PER-BIT UST BEEN COMPLETED.

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

SAMSUNG MEMORY MODULES BASED ON 4-MEG DRAMs

Megabytes	*Part Number*	*Organization*
1	KMM581000AN	1M x 8
1	KMM591000AN	1M x 9
4	KMM584000A	4M x 8
4	KMM594000A	4M x 9
4	KMM5321000A	1M x 32
4	KMM5331000A	1M x 33
4	KMM5361000A	1M x 36
8	KMM5322000A	2M x 32
8	KMM5332000A	2M x 33
8	KMM5362000A	2M x 36

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

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

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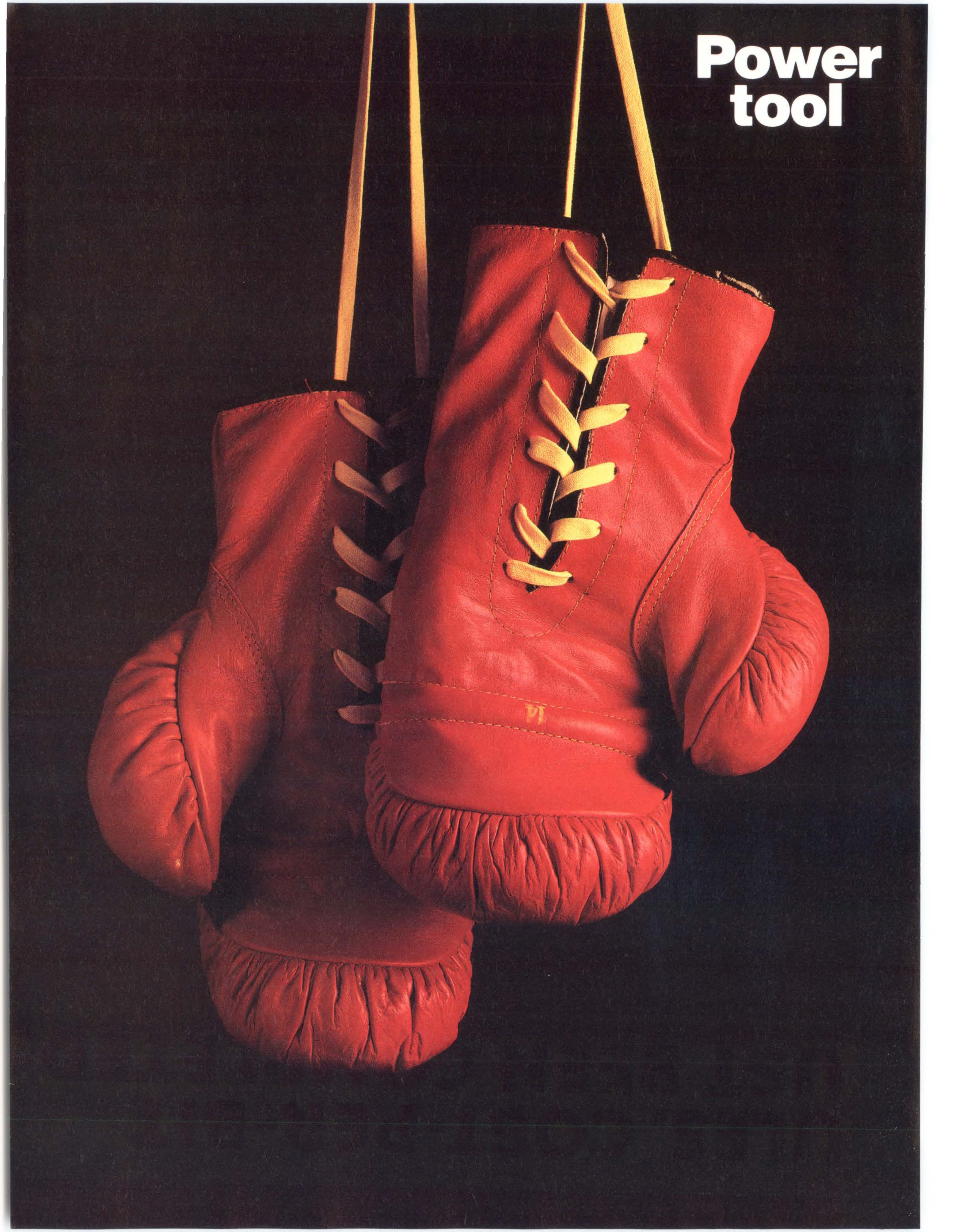

Power
tool

Power tools

KEPCO TEST/BENCHTOP POWER SUPPLIES

The correct tool makes any job easier. Kepco's Power Supplies for workbench, for burn-in, and float-charging batteries are just some of the tools at your disposal.

For your workbench choose a multi-out array that you configure for the application by plugging-in modules with adjustable outputs. You can combine one, two or three modules in convenient bench-top housings or put six of them together in a rack. Other experimentalist power includes a nice selection of 100W single output instruments (MSK), a triple output logic-analog model (MPS), and burn-in/float chargers (TBC) that range from 300 to 3000 Watts in all the popular voltages.

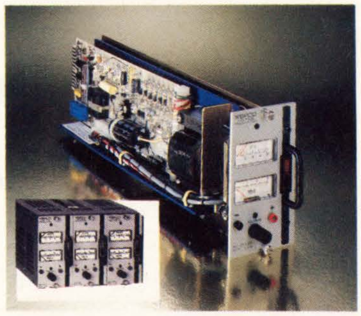
Custom power assemblies allow you to create your own toolkit with just the selection of voltage and power to fit your need.

Other power tools from Kepco include: *ac power* to 18KVA, precision *programmable dc* for test applications, *high voltage* models and four-quadrant *bipolar power.* For these, and our broad selection of *switching power* models, including *d-c to d-c converters,* please ask for one of the three catalogs illustrated below.

SEE OUR PAGES IN VOLUME D eem 91 92

Instrumentation and Bench — a-c power and d-c bipolar — Switching a-c to d-c and d-c to d-c

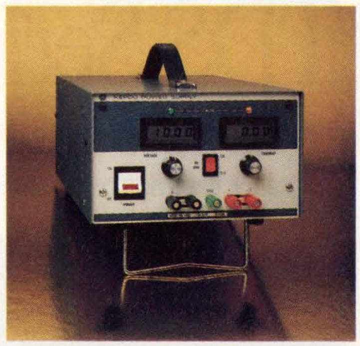
146-1716 — 146-1704 — 146-1692



Plug-in power

- ☐ 20 Watt modules, either voltage stabilizers (series PCX-MAT) or current stabilizers (series CC).
- ☐ Sized to plug-in six abreast in a 19″ rack or in bench-top housings for 1, 2 or 3 units.
- ☐ Mix or match.
- ☐ Select from six voltage ranges up to 100V.

Kepco Group PCX-MAT and CC Power Supplies



100 Watts of precision benchtop power.

- ☐ LCD meters to set the level accurately, a preview feature to check your setting before applying power to your load.
- ☐ Linear design for low-noise high stability.
- ☐ Ten-turn controls for good resolution.
- ☐ Five models offer outputs up to 125 Volts.

Kepco Group MSK Power Supplies

A triple output design for maximum convenience.

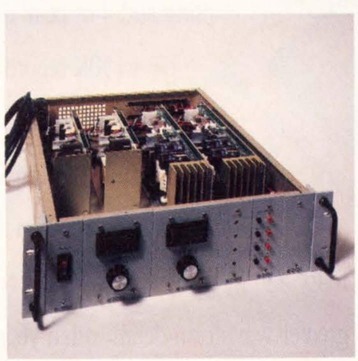
- ☐ 0-6V at 5A for logic and a tracked ± 0-20V, 1A for analog.
- ☐ Each output current limited, the 0-6V output has an overvoltage protector.

Kepco Group MPS Power Supply

Battery/float-chargers.

- ☐ For telecommunications: maintain 12V, 24V and 48V batteries, built-in equalize timer.
- ☐ For burn-in: power up to 3000 Watts, current limited, over-voltage protected. Two output settings, remotely selectable for margining.

Kepco Group TBC Float Chargers/Power Supplies



Kepco Custom System Power Assemblies

We will stuff a 19″ rack (5¼ or 7″) full of switchers to your requirement. With modules from 3 Watts to 3000 Watts, in a wide selection of voltage ranges, we can accommodate most needs.

- ☐ LCD output meters.
- ☐ Test points.
- ☐ Pilots, trimmers, circuit breakers. Convenient ⅛ rack panel format allows multiple control and monitoring.

Kepco Power Assemblies.

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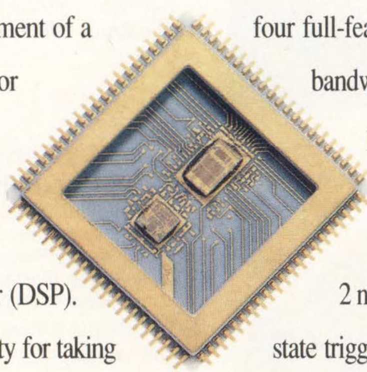
You have to build a to build just

The new Tek TDS Series

More than a million Tektronix oscilloscopes have all been leading up to this: the most powerful, versatile, and intuitive instruments ever developed for the mainstream of test and measurement.

The new TDS 500 Series is the culmination of everything Tek has learned in the design, manufacture and use of digitizing oscilloscopes. It's an achievement made possible only by the unique integration of acquisition functions and combinational trigger logic onto a single board.

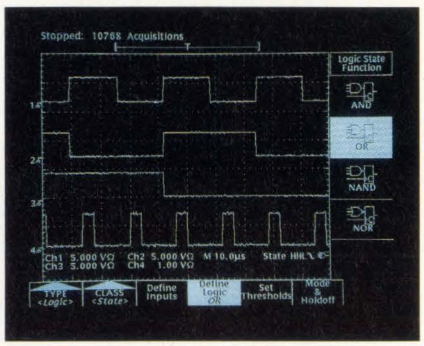
Only by the development of a milestone multiprocessor architecture.



Only by the addition of Tek's TriStar™ Digital Signal Processor (DSP).

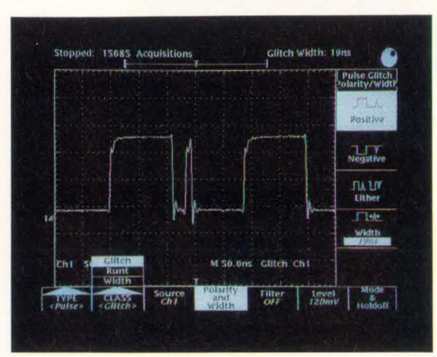
Only by Tek's capacity for taking the hard work out of high performance.

The TDS Series performs, *live,* updates and measurements that inhibit most other digitizing scopes. Its real-

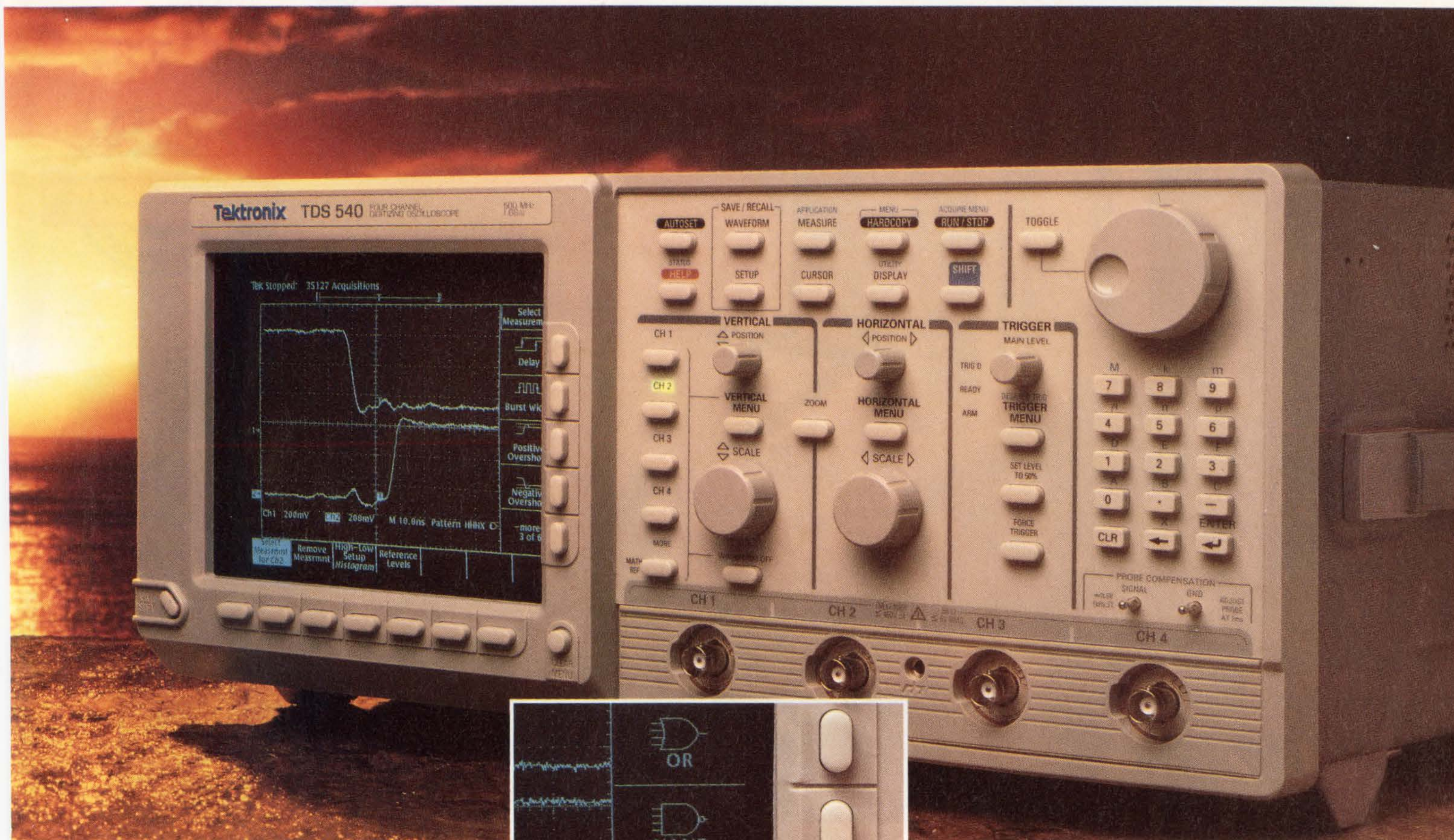


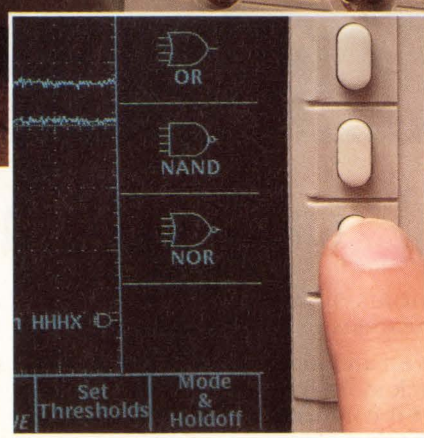
time DSP lets you perform single-shot averaging and extend resolution to 12 bits. The TDS Series arms you with up to four full-featured channels. 500 MHz bandwidth. Up to 1 GS/s sampling and 4 ns peak detect. Up to 50K record lengths. Time interval, 2 ns glitch, runt, pattern and state triggers. With acquisition sensitivity and fast overdrive recovery bringing greater waveform detail within your grasp.

And if you think oscilloscopes aren't as easy to use and comprehend as they



million oscilloscopes one like this.





could be, you owe yourself a demo of the TDS. Its simplified front panel, VGA-quality display resolution, on-line help text, innovative icons that instantly differentiate menu functions — all add up to a scope that makes the user's manual more a formality than a necessity.

The TDS Series signals the start of a new generation of friendlier, more powerful instruments from the world's leading supplier of digitizing and analog oscilloscopes. To get a first-hand feel for why performance like this only comes along about once in a million scopes, contact your Tek sales engineer or call **1-800-426-2200.**

One company measures up.

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CIRCLE NO. 13

55A-186067

Once again, HP has its name in lights.

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

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

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

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

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

Once again, HP sets the stage for quality, reliability, and innovation. To get the star treatment from HP, call **1-800-752-0900, ext. 2367,** and ask for our FREE red & green SMT LED sample kit. And see what the biggest name in lights can do for you.

There is a better way.

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CG08102

NEWS BREAKS

EDITED BY SUSAN ROSE

8051 RAM UPPED TO 512 BYTES

Signetics' 8051-chip variants have increased on-chip RAM—two of the microcontrollers deliver 512 bytes of on-chip RAM, double the standard 256 bytes in many chips. One reason for adding memory was to increase on-chip stack space for C programs. These chips need increased memory, as engineers are increasingly turning to C for microcontroller-based embedded-systems applications. You can buy ROMless (80C528), 32-kbyte ROM (83C528), and 32-kbyte EPROM (87C528) versions. One-time-programmable versions are also available. The chips come in 16- or 20-MHz versions and run at speeds as low as 3.5 MHz. The 40-pin chips include four 8-bit I/O ports, two serial ports, three 16-bit timers, a watchdog timer, and an I^2C serial interface. Prices for the 16-MHz chips start at $7.50 (10,000). The chips are sampling now. Signetics, Sunnyvale, CA, (408) 991-2000.—Ray Weiss

DESIGN APPLICATION FLIES WITH FALCON

The Manufacturing Adviser/PCB is a design-for-manufacturability tool for pc-board design, built on the Mentor Falcon Framework's decision support system (DSS). The software references parts lists, ASCII netlists, or design information indirectly generated from the company's design-creation tools to component libraries that you either create or that come with the tool. These libraries contain mechanical, thermal, and manufacturing data for analysis. To perform the analysis, you provide a set of manufacturing rules and constraints, against which the software compares your design—at many levels of completion. As a result of the analysis, you can change component package types, use fewer or more board layers or a different board size, manufacture at another site, or adjust any parameter that impacts your ability to manufacture a board. The application, developed by Texas Instruments' Information Technology Group, features a component library of more than 800 component package styles. Although the first release only supports through-hole board technologies, the second release, slated for early 1992, will include surface-mount- and mixed-technology-board support. The software costs $16,900 and is available on HP/Apollo workstations; Sun and HP Series 700-based software will be available in early 1992. Mentor Graphics, Wilsonville, OR, (503) 685-7000, (800) 547-3000.
—Michael C Markowitz

VIDEO WINDOW GENERATOR OFFERS CONTINUOUS SCALING

The Pixel Semiconductor subsidiary of Cirrus Logic has developed an IC that accepts digitized video and puts it in a window on your computer monitor. The Px007 video window generator handles interlaced or progressive-scan video in the luminance-chrominance color space used for broadcast video. You provide digitized data in 24-, 16-, or 12-bit formats at input sample rates as great as 15 MHz. The device then removes any gamma correction and converts the data into the RGB color space used by computer monitors. It hands the data to your computer's display memory and lets you program the output resolution to match your system's needs. You can select from 2 to 8 bits per color channel.

To help you fit the picture into an on-screen box, the device offers independent X and Y scaling and support for window clipping. It scales the video by using linear interpolation, not pixel dropping. You can, therefore, scale to single pixel resolution so as to fill arbitrarily sized boxes completely. To facilitate window clipping, the device provides framing signals that mark the beginning of video fields and lines. The device comes in an 80-pin plastic quad flatpack. Samples are presently available for $55 (1000), with volume production scheduled by the fourth quarter of 1991. Cirrus Logic, Fremont, CA, (510) 623-8300, FAX (510) 226-2160.—Richard A Quinnell

BUS BOARD HAS 32-BIT BIDIRECTIONAL COMMUNICATIONS

Designers that need a high-speed parallel-data link into VMEbus systems can use the DB-PCOMM board from Matrix. The VMEbus daughter card includes a front-panel connector that provides a 33-Mbyte/sec, 32-bit bidirectional data link to data acquisition systems, array processors, or other computers. The parallel-communications port uses EIA-485-compatible drivers and receivers. The board routes the data to and from the VSBbus or direct to the CPU local bus when used with the company's CPU boards. An auxiliary control port on the board's front panel provides 16 input and 16 output lines for status and control. The card costs $2995 and is available now. Matrix Corp, Raleigh, NC, (919) 231-8000, FAX (919) 231-8001.—Maury Wright

DIGITAL-IC TESTER HITS 660 MHz

Hewlett-Packard Co believes its 83000 Model F660 is now the highest-speed digital-IC tester that any firm offers as a standard product. The tester, which is compatible with the firm's 82000-series IC-evaluation systems, is suited to device characterization as well as to production testing. It tests devices (including GaAs and ECL parts) that have as many as 512 pins at clock rates as high as 660 MHz, and does so without multiplexing (a technique that sacrifices channel capacity to improve speed). The system, which uses a "tester-per-pin" architecture and backs each pin with as much as 4 Mbits of memory, boasts pin-to-pin skew of 80 psec. Unlike most other high-performance testers, the system houses all of its test electronics in the unit to which you attach a device handler. The company calls this liquid-cooled unit a mainframe because of its size (although some companies would call it a test head). Additional cabinets house a heat exchanger and the system's power supply. The entire system occupies 28 ft^2. Other features include compressed-data storage and fiber-optic links between the controlling workstation and the mainframe. The tester costs $1.6 million for 256 channels; additional channels are $5500 each. Hewlett-Packard Co, Boeblingen, Germany, (800) 752-0900 (in the US). —Dan Strassberg

PROGRAM AND TEST PLDS ON BENCHTOP TESTER

The ETS200-PRO tester lets you program fuseable-link and electrically erasable PLDs and then test them. The 25-MHz tester is configurable with as many as 192 channels and 64-kword, test-vector memory. Split-cycle input/output operations on all pins let you test μPs and other devices with bidirectional buses. A fully configured 96-pin system with 16-kword-deep vector memory, programmable power sources, and a software interface to simulators costs less than $32,000. Options include a dc parametric unit, additional power sources, and software utilities. Hilevel Technology, Irvine, CA, (714) 727-2100, FAX (714) 727-2101.—Doug Conner

VXIBUS-BASED TESTERS AIM TO LOWER DEVELOPMENT COSTS

Schlumberger Technologies has announced three pc-board test systems designed around the VXIbus modular-instrumentation standard. The $75,000 S760VXI is a core architecture. The $150,000 S765VXI is based on the core architecture and adds a test-head interface, a control console, power supplies, IEEE-488 instruments, and custom-designed VXI modules for specific high-volume applications. The S790VXI

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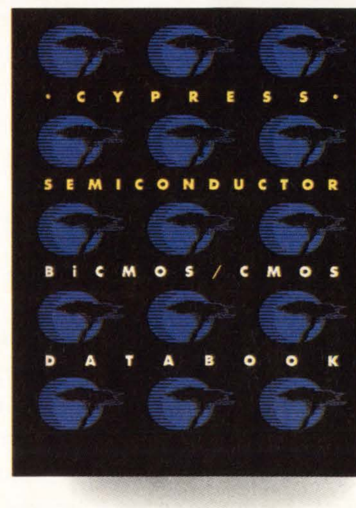

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is a high-perfomance mixed-signal tester that combines the company's universal digital-pin electronics with VXI instruments in a synchronized configuration built around a single high-speed backplane. Prices for the mixed-signal tester begin at $275,000, with typical configurations expected to cost $750,000. Deliveries range from 60 to 120 days ARO. All three systems use the firm's CATE (Computer-Aided Test Engineering) software, a framework for integrating CAE and test-development tools. The software holds down the cost of developing new products by providing a common interface for developers of R&D characterization tests, production tests, and diagnostic routines used for post-sale support and troubleshooting. Schlumberger Technologies, San Jose, CA, (408) 437-5129.—Dan Strassberg

IN-CIRCUIT EMULATOR SUITS 8XC751/2 MICROCONTROLLERS

The DS-752 real-time in-circuit emulator from Ceibo lets you develop systems using Philips 83C751/2 and 87C751/2 microcontrollers. The product avoids the need for bond-out chips by using proprietary code to access internal buses of a standard microcontroller part. A 5×6×1-in. package houses the emulator. A ribbon cable links to target hardware, and an RS-232C cable connects the unit to your PC. The emulator requires a 5V supply, or uses an optional ac adapter. The software-support package includes a source-level debugger for C and Programming Language for Microprocessors, on-line assembler and disassembler, conditional breakpoints, and a 32-kbyte trace buffer. An internal clock source lets you debug software in the absence of target hardware. The emulator costs $960. Ceibo, Herzelia, Israel, (52) 555387, FAX (52) 553297. In US, (617) 863-9927, FAX (617) 863-9649.—Brian Kerridge

READ-CHANNEL IC INCORPORATES PROGRAMMABLE FILTER

GEC Plessy Semiconductors's PCA2400 read-channel IC shrinks the physical volume of components in hard-disk drives. The chip incorporates all of the analog electronics normally associated with a disk drive's read channel, such as the pulse detector, data separator, data encoder and decoder, and write-precompensation electronics. In addition, the device includes two functions that previously required additional chips: a programmable filter and a clock systhesizer for zone-bit recording. The chip handles data rates to 24 Mbits/sec. The chip also features eight power-down modes because small hard-disk drives, such as the 2.5- and 1.8-in. products, often run from batteries, and thus need the ability to draw only the amount of power appropriate to the immediate task at hand. Power dissipation for the 5V IC ranges from 15 mW in its shutdown mode to 1W in its full-write mode. Samples of the device will be available in November and production units will cost $10 in OEM quantities. GEC Plessy Semiconductors Inc, Scotts Valley, CA, (408) 438-2900, FAX (408) 438-5576.—Steven H Leibson

EXPLORING C SOURCE CODE

Microtek Research's Xray Source Explorer lets programmers learn and re-engineer C source code. The $695 tool builds graphical views of the source code—horizontal calling tree—that you can parse for special views. The software lets users navigate through the source code, moving down the calling tree and calling up source code as needed. The tool is compiler smart (the company builds cross development tools for a range of processors). Programmers can interactively check on which routines call a given function. You can break tasks down into multiple subtrees for ease of use, and trees can be selectively pruned of functions, library functions, or entire subtrees. The software is X-window Motif compatible and runs on Sun workstations. Microtek Research Inc, Santa Clara, CA, (408) 980-1300.—Ray Weiss

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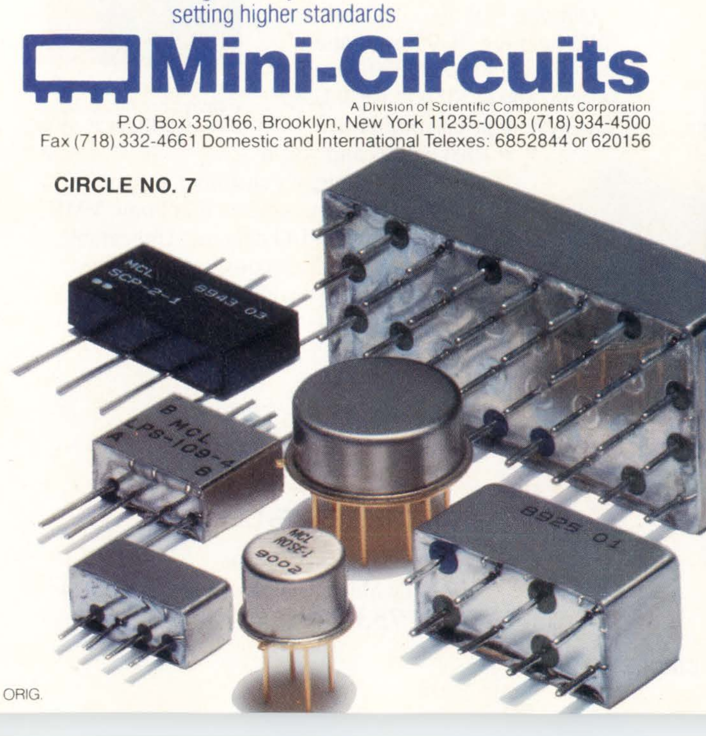

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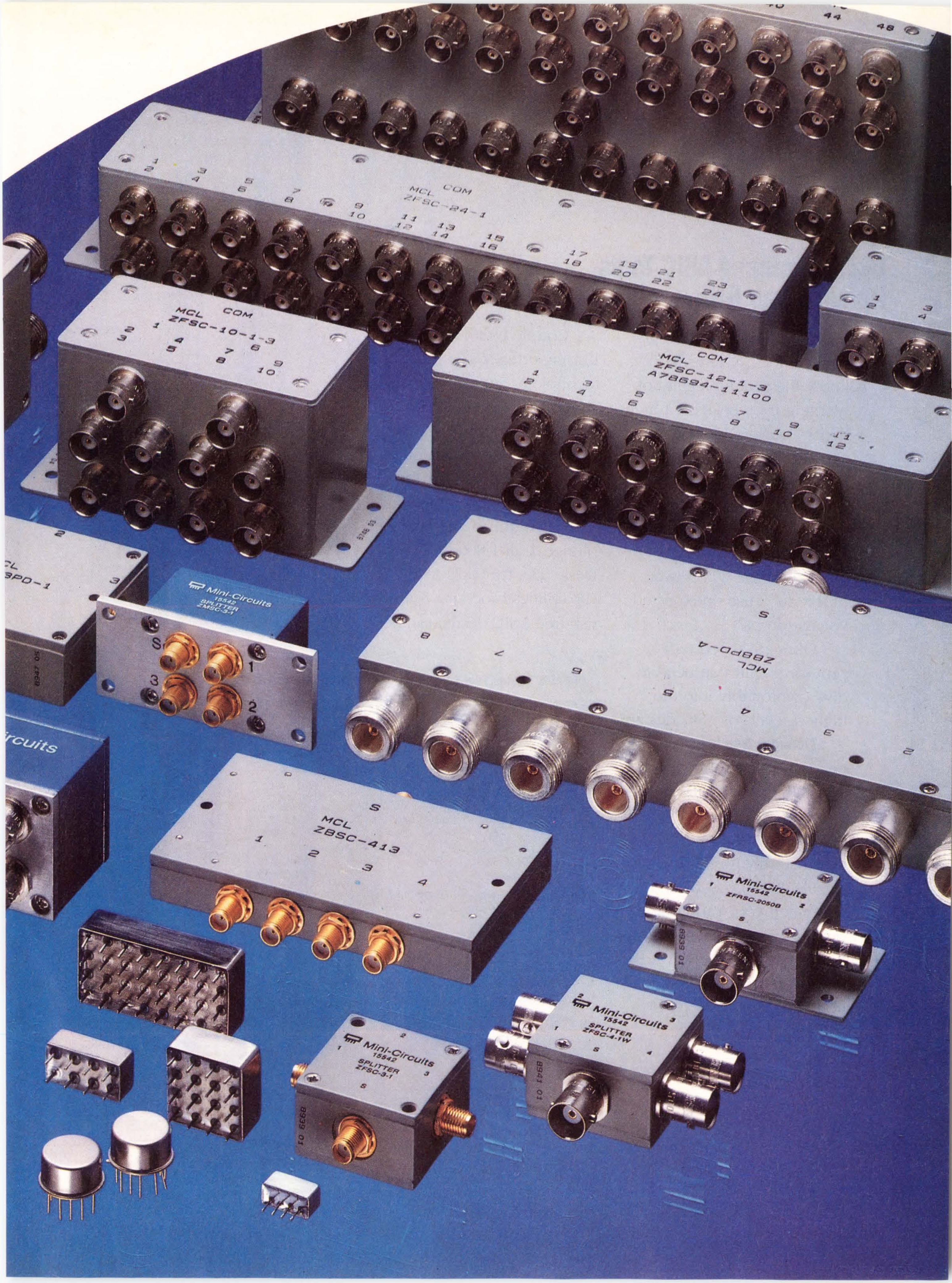
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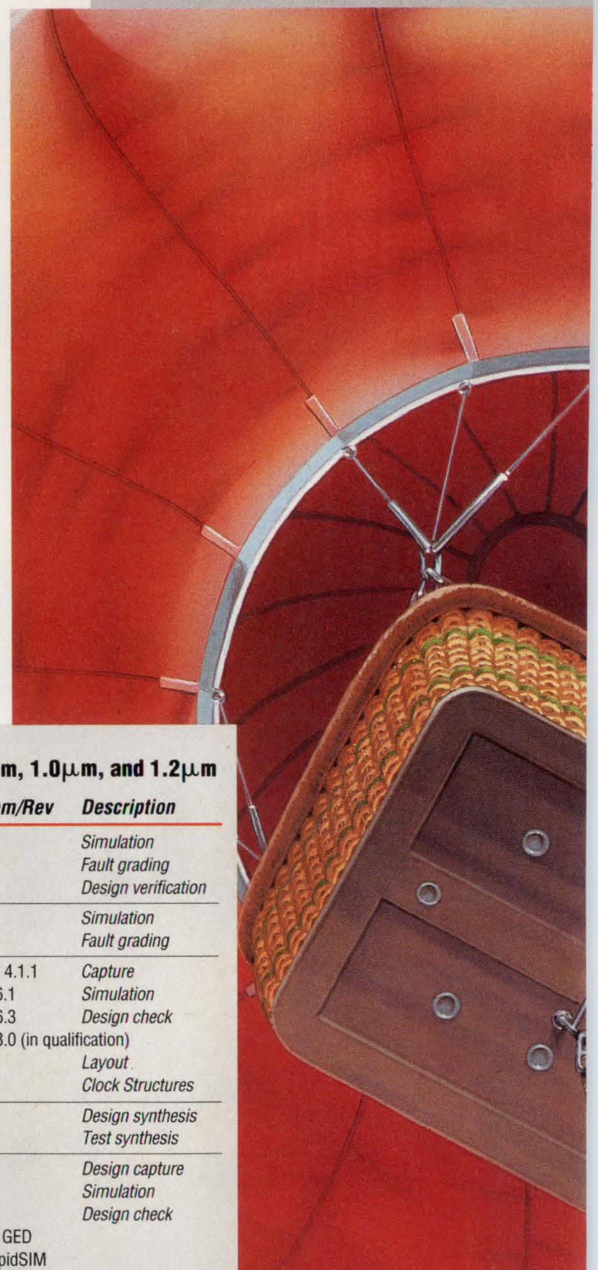

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Vendor	*Platform*	*Operating System/Rev*	*Description*
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IKOS		4.0 up	*Simulation* *Fault grading*
Mentor Graphics	HP/Apollo DNx Series HP9000 Sun/SPARC Solbourne	DNIX 5.03, Sun OS 4.1.1 Digital application 6.1 Digital application 6.3 Digital application 8.0 (in qualification) Parade	*Capture* *Simulation* *Design check* *Layout* *Clock Structures*
Synopsys	Sun/SPARC Interface to Mentor, Valid, Viewlogic	Sun OS 4.1.1	*Design synthesis* *Test synthesis*
Valid	Sun/SPARC Sun-3 DECstation 3100 IBM RS6000	Sun OS 4.1.1 GED, ValidSIM, RapidSIM ULTRIX, ValidSIM, GED GED, ValidSIM, RapidSIM	*Design capture* *Simulation* *Design check*
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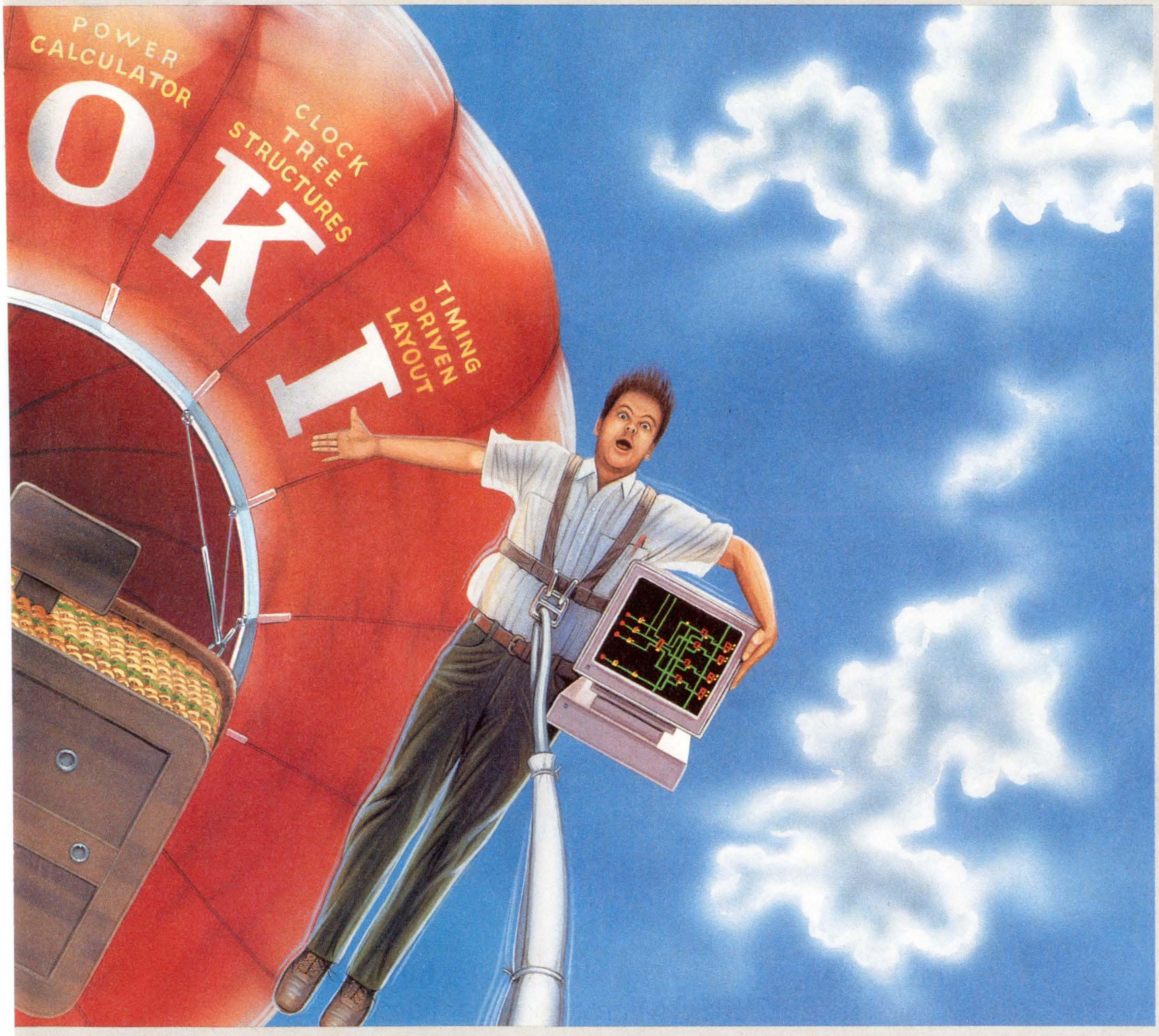

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Two more shortcomings of engineering schools

I enjoyed reading Jay Fraser's article on engineering graduate schools (EDN, June 6, 1991, pg 244). In my opinion it touched on many of the shortcomings of today's higher education, but there are two that he missed: enforced boredom and lack of effective time management. As a professional with more than 14 years' experience, I have no interest in sitting through a class, required by whatever institution I might attend, rehashing what I already know.

I've looked into a number of schools over the years and find that I'm required to take courses I could teach. I have yet to find a "name" school (although they may exist) that allows seasoned professionals to use prior experience against required credits to get an advanced degree.

Seriously, with the pace of today's changing technology, most professionals find themselves reading more material in a year than when they were in college. When you add to this volume of reading the experience of having written five embedded operating systems, worked at the kernel level in three others, and written sensor-processing software, it's absurd to consider taking a course in operating systems theory, taught by an upper-level graduate student, where your final project is to write a simple or even moderately complex operating system.

Frankly, I've always wondered whether this attitude is about money (how can institutes charge for a degree if, after testing, all you need is one course to get a master's degree?) or we're viewed as corrupt. Our knowledge is somehow not true to the faith. We are "less" than those who have remained pure.

Paul Meyers
GTE Government Systems
Fort Hood, TX

(Ed Note: Some schools may let you "test out" courses. You do have to pay the course fee at some of these schools, but passing a final exam gets you credit for the course.)

NEXT WEEK IN EDN

EDN News Edition's October 17 Comdex issue will feature a Product Watch on graphics boards and a special Comdex section that will cover products introduced at the show. Also look for a Career Opportunities article on artificial intelligence.

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“The MultiSim Interactive Designer is excellent – it's the first CAE tool that works well with a top down design approach. It's set up so you can build and simulate block by block, and its speed makes it easy to find your mistakes, make changes, and try again without a lot of time spent recompiling.”
Steve DeLong,
Technical Team Leader
Jim Walsh,
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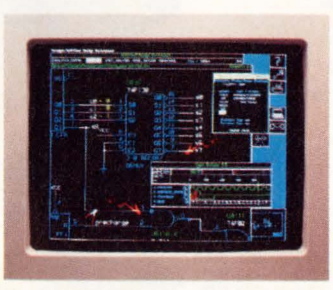
“We design and test complex boards for military and commercial satellites, and LASAR gives us two critical advantages: accuracy and reliability. LASAR's ability to accurately predict timing hazards caused by IC lot variations and design errors gives us complete confidence in the manufacturability of the boards we design. And when we hand off a new board design to the test group, we've got a good head start because our test engineers also use LASAR and its testability analysis tools to develop the test program sets.”
Ed Faller,
Senior Engineer
General Electric Company



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FTB1-6	5950-01-225-8773	TMO2.5-6	5950-01-215-4038
T1-1	5950-10-128-3745	TMO2.5-6T	5950-01-215-8697
T1-1T	5950-01-153-0668	TMO3-1T	5950-01-168-7512
T2-1	5950-01-106-1218	TMO4-1	5950-01-067-1012
T3-1T	5950-01-153-0298	TMO4-2	5950-01-091-3553
T4-1	5950-01-024-7626	TMO4-6	5950-01-132-8102
T9-1	5950-01-105-8153	TMO5-1T	5950-01-183-0779
T16-1	5950-01-094-7439	TMO9-1	5950-01-141-0174
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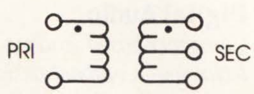
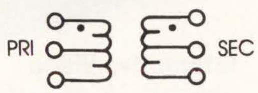
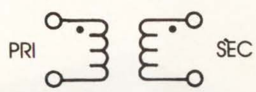
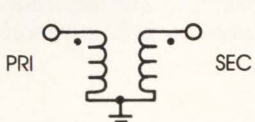
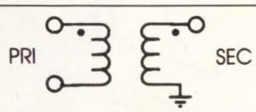
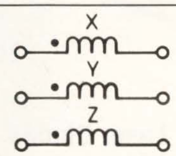




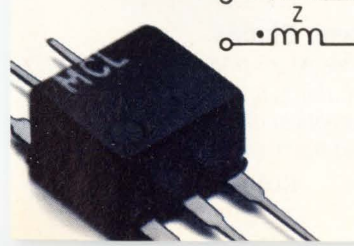








case style number see opposite page		MODEL NO.	Ω RATIO	FREQUENCY MHz	INSERTION LOSS 3dB MHz	2dB MHz	1dB MHz	PRICE $ Qty. (1-9)
A*	T	T1-1T	1	.05-200	.05-200	.08-150	.2-80	4.45
		T1-6T	1	.003-300	.003-300	.01-150	.02-50	6.95
		T2-1T	2	.07-200	.07-200	.1-100	.5-50	4.95
		T2.5-6T	2.5	.01-100	.01-100	.02-50	.50-20	4.95
		T3-1T	3	.05-250	.05-200	.1-200	.5-70	4.95
		T4-1	4	.2-350	.2-350	.35-300	2-100	3.25
		T4-6T	4	.02-250	.02-250	.05-150	0.1-100	4.45
		T5-1T	5	.3-300	.3-300	.6-200	.5-100	4.95
		T8-1T	8	.03-140	.03-140	.10-90	1-60	7.95
		T13-1T	13	.3-120	.3-120	.7-80	5-20	4.95
		T16-6T	16	.03-75	.03-75	.06-30	.1-20	5.65
	TH	T4-1H	4	10-350	10-350	15-300	25-200	5.95
	TMO	TMO1-1T	1	05-200	.05-200	.08-150	.2-80	7.95
		TMO2-1T	2	.07-200	.07-200	.1-100	.5-50	8.45
		†TMO2.5-6T	2.5	.01-100	.01-100	.02-50	.05-20	8.45
		†TMO3-1T	3	.05-250	.05-250	.1-200	.5-70	7.95
		TMO4-1	4	.2-350	.2-350	.35-300	2-100	6.25
		TMO5-1T	5	.3-300	.3-300	.6-200	5-100	8.45
		TMO13-1T	13	.3-120	.3-120	.7-80	5-20	8.45
B*	TT	TT1-6	1	.004-500	.004-500	.02-200	.1-50	6.95
		TT1.5-1	1.5	.075-500	.075-500	.2-100	1-50	5.95
		TT2.5-6	2.5	.01-50	.01-50	.025-25	.05-10	6.45
		TT4-1	3	.05-200	.2-50	.2-50	1-30	5.95
		TT4-1A	4	0.1-300	0.1-300	0.2-250	0.3-180	6.95
		TT25-1	25	.02-30	.02-30	.05-20	.1-10	9.95
	TTMO	TTMO25-1	25	.02-30	.02-30	.05-20	.1-10	11.95
		TTMO1-1	1	.005-100	.005-100	.01-75	.05-40	11.45
		TTMO4-1A	4	0.1-300	0.1-300	0.2-250	0.3-180	13.95
C	T	T1-1	1	.15-400	.15-400	.35-200	2-50	3.25
		T1.18-3	1.18	0.01-250	0.01-250	0.02-200	0.03-50	5.65
		T1-6	1	.01-150	.01-150	.02-100	.05-50	5.65
		T1.5-1	1.5	.1-300	.1-300	.2-150	.5-80	4.45
		T1.5-6	1.5	.02-100	.02-100	.05-50	0.1-25	5.65
		T2.5-6	2.5	.01-100	.01-100	.02-50	.05-20	4.45
		T4-6	4	.02-200	.02-200	.05-150	.1-100	4.45
		T9-1	9	.15-200	.15-200	.3-150	2-40	3.95
		T16-1	16	.3-120	.3-120	.7-80	5-20	4.45
		T36-1	36	.03-20	.03-20	.05-10	.1-5	6.95
	TO	TO-75	1	10-500	—	10-500	40-250	6.95
	TH	T1-1H	1	8-300	8-300	10-200	25-100	5.95
		T9-1H	9	2-90	2-90	3-75	6-50	6.45
		T16-H	16	7-85	7-85	10-65	15-40	6.45
	TMO	TMO1-02	1	1-800	1-800	2-500	—	9.45
		TMO1-1	1	.15-400	.15-400	.35-200	2-50	6.25
		TMO1.5-1	1.5	.1-300	.1-300	.2-150	.5-8	8.45
		†TMO2.5-6	2.5	.01-100	.01-100	.02-50	.05-20	7.95
		†TMO4-6	4	.02-200	.02-200	.05-150	.1-100	7.95
		TMO6-1	6	.3-200	.3-200	.5-150	5-50	7.95
		TMO9-1	9	.15-200	.15-200	.3-150	2-40	7.95
		TMO16-1	16	.3-120	.3-120	.7-80	5-20	7.95
D	T	T2-1	2	.050-600	.050-600	.1-400	.5-200	3.95
		T3-1	3	.5-800	.5-800	2-400	—	4.45
		T4-2	4	.2-600	.2-600	.5-500	2-250	3.95
		T8-1	8	.15-250	.15-250	.25-200	2-100	3.95
		T14-1	14	.2-150	.2-150	.5-100	2-50	4.95
	TMO	TMO2-1	2	.050-600	.050-600	.1-400	.5-200	7.95
		TMO3-1	3	.5-800	.5-800	2-400	—	8.45
		TMO4-2	4	.2-600	.2-600	.5-500	2-250	7.95
		TMO8-1	8	.15-250	.15-250	.25-200	2-100	7.95
		TMO14-1	14	.2-150	.2-150	.5-100	2-50	8.45
	FT	FT1.22-1	1.22	.005-100	.005-100	.01-50	.05-25	35.95
		FT1.5-1	1.5	.1-400	.1-400	5-200	1-100	35.95
E	FTB	FTB-1	1	.2-500	.2-500	.5-300	1-100	36.95
		FTB1-6	1	.01-125	.01-125	.05-50	.1-25	36.95
		■FTB-1-75	1	.5-500	.5-500	5-300	10-100	36.95
F	T	T-622	1	0.1-200	0.1-200	0.5-100	5-80	3.25
		T626	1	0.01-10	0.01-10	0.2-5	.04-2	3.95



■ Denotes 75 ohm models

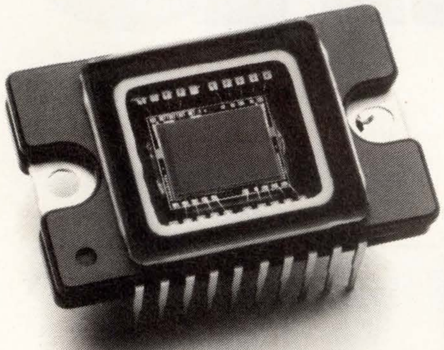
* FOR A AND B CONFIGURATIONS

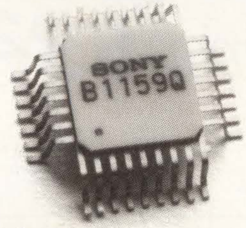
Maximum Amplitude Unbalance
- 0.1 dB over 1 dB frequency range
- 0.5 dB over entire frequency range

Maximum Phase Unbalance
- 1.0° over 1 dB frequency range
- 5.0° over entire frequency range

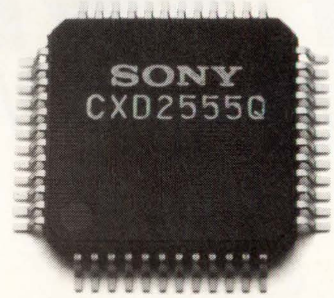
CIRCLE NO. 30

No guts.





ECL Standard Logic
Wide range of high-speed, high-performance ECL logic devices. Low cost and design simplicity.



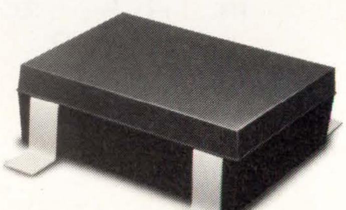
Digital Audio
Consumer-based leading-edge technology. Compact design. Small package. Capable of CD-ROM interface.

CCD Image Sensors
The CCD technology that led to Sony's leadership in color video cameras is now available to you.

Interactive Video
Sony's A/V IC leadership applies directly to new multimedia systems. Superior bipolar linear technology in encoder/decoder.

High Speed SRAMs
Broad family covers all your fast-processor, cache-memory requirements.

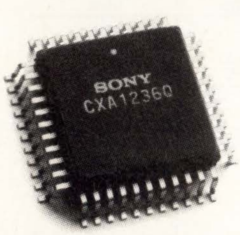
ECL Gate Arrays
Super high-speed operation combined with low power consumption and extensive I/O interfaces.

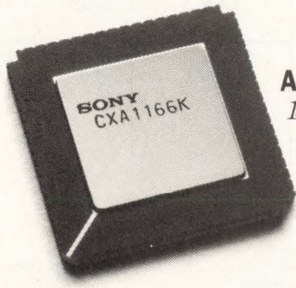


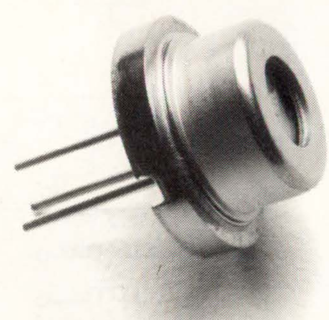
GaAs FETs
State-of-the-art performance, reliability and uniformity. Ideal when low noise is critical.

1-Meg SRAMs
Largest, most diverse family in the industry. The first products scheduled to come from our new San Antonio fab.

STRAM
High speed performance, self-timed RAM with register, synchronous SRAM.







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18 models including the world's fastest. Fewer pins, smaller packages, low power consumption, and guaranteed low error rates.

D/A Converters
High speeds to 500 MHz, low glitch energy, and low power consumption in very small packages.

Laser Diodes
Wide power range, high reliability, huge selection. Ideal for optical disk, laser printer and microsurgery designs.

ASK EDN

EDITED BY JULIE ANNE SCHOFIELD

A chip for a song

I am looking for the manufacturer of melody-generator chips. These chips are the ones found in the musical birthday cards sold in any card shop.
Barry Cowen
Harvard Apparatus
South Natick, MA

The Cahners CAPS system, which is available from Cahners Technical Information Services, yielded the following manufacturer:

Samsung Semiconductor
3725 N First St
San Jose, CA 95134
(408) 434-5400
FAX (408) 434-5653

Samsung lists a variety of consumer electronic chips: radio chips, audio amplifiers, radio control, and so on. One is the KA223C 9-program music selector.

A faster way to test EPROMs

After burning programs in EPROMs, we verify the coded contents by addressing the PROM's address/data digital readout. This time-consuming method works, but is there a quicker way of displaying the PROM's contents? Would modifying our computer terminal's hardware or software help speed things up?
Ralph Cruz
Engineering Manager
Scalar Industries
Elmhurst, IL

You didn't say whether you wanted to display or test the PROMs' contents. To test them, we suggest two routes. The first is to use a μP to calculate a checksum and compare it to the checksum in the EPROM under test. The second route is to compare the new EPROM to a known-good one using the circuit in **Fig 1**.

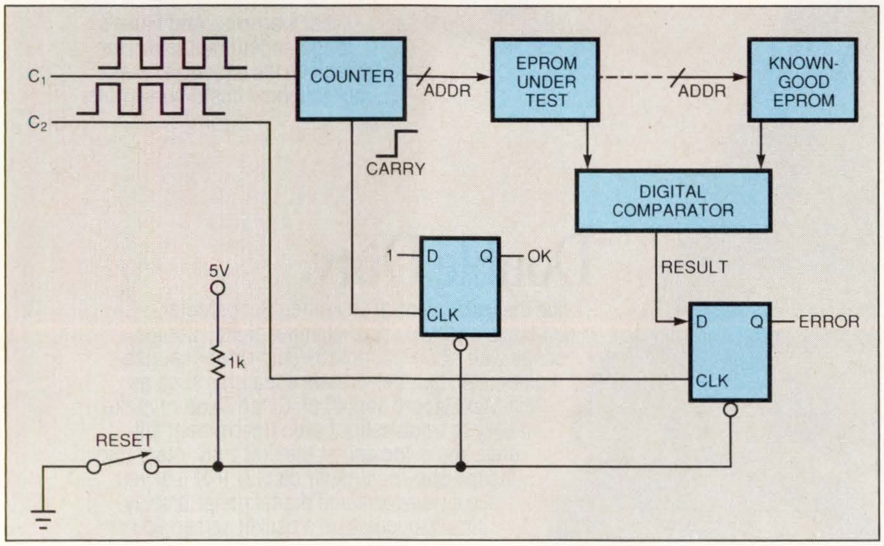


Fig 1—This circuit employs two D flip-flops, *a counter, and a digital comparator to test a new EPROM by comparing it with a known-good device.*

Take care when measuring the human heart

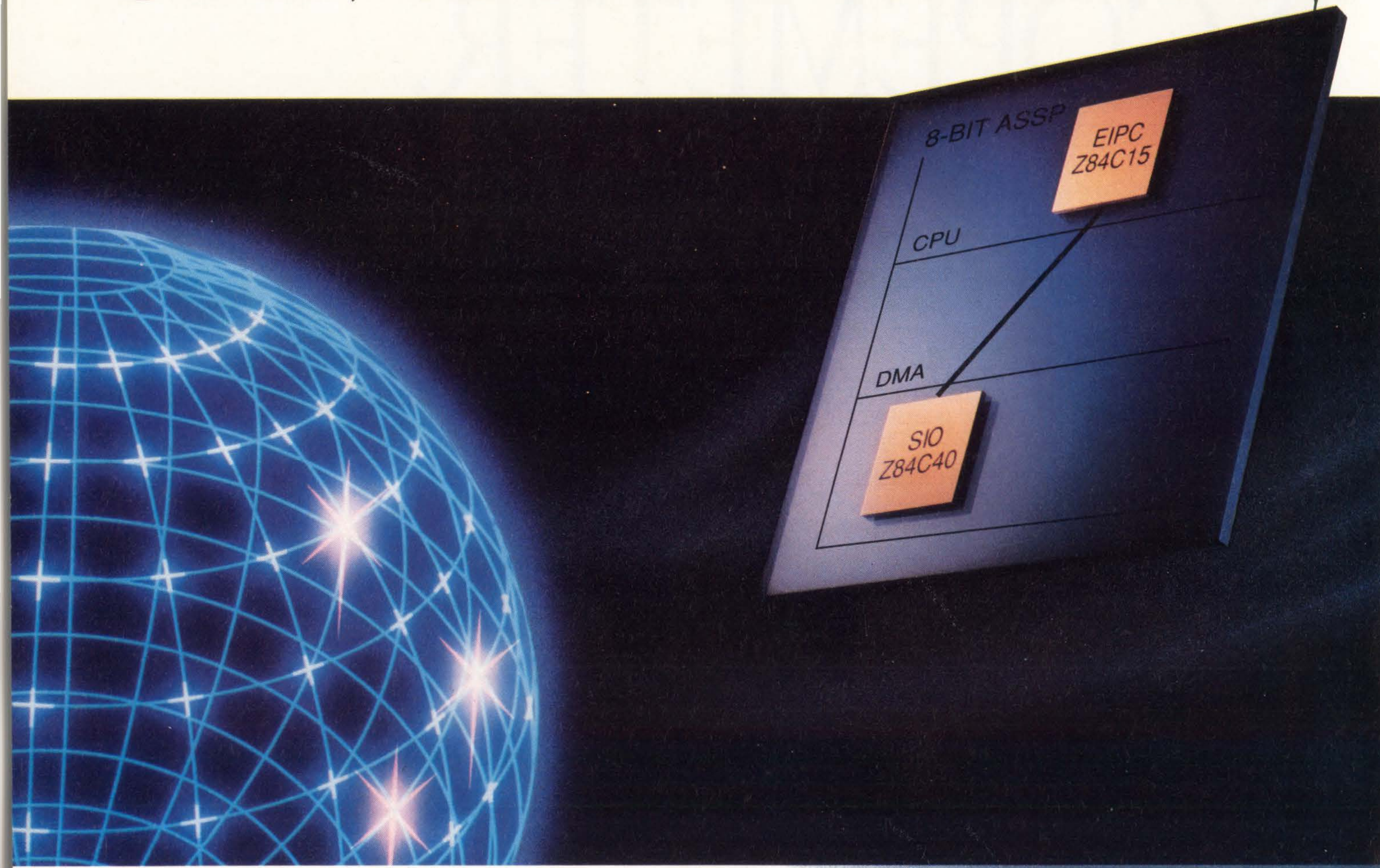
I am a member of the Association for the Advancement of Medical Instrumentation (AAMI). I'm a voting member of the Cardiac Monitors Subcommittee, which develops and maintains the American National Standard for cardiac monitors, heart-rate meters, and alarms. In the July 4 issue you printed a request by a reader who wished to work with very small signals, such as EKG heartbeats and recording-studio-quality signals (pg 37). Your reply was good, addressing some of the technical basics. But biomedical measurements involve safety issues that far overshadow those basics.

If one is measuring the ECG (an alternate spelling, which I prefer), one must address the issue of leakage currents. Excessive leakage currents through a human heart can kill. The heart is an electromechanical organ. It can be disrupted by a random noise current of sufficient magnitude and forced into ventricular fibrillation. This is the most lethal of all cardiac arrhythmias and can only be terminated by specially trained and equipped medical professionals. For this reason, the American National Standards Institute (ANSI), in conjunction with AAMI, has established the standard "Safe Current Limits for Electromedical Apparatus," document ES1. I strongly urge readers to consult this document before making electrical measurements of the human heart. It is available from AAMI at 3330 Washington Blvd, Suite 400, Arlington, VA 22201.

Noise rejection in electrocardiography is decidedly nontrivial, where typical body surface potentials are on the order of 1 mV p-p, with 60-Hz common-mode noise voltages due to capacitive coupling on the order of 170V p-p. I urge anyone interested in this or other related matters to contact AAMI at the above address.
Richard W Bowser
Lead Computer Systems Engineer
Creighton University
Cardiac Center
Omaha, NE

Thank you for your expert comments and suggestions.

Universal Flexibility.

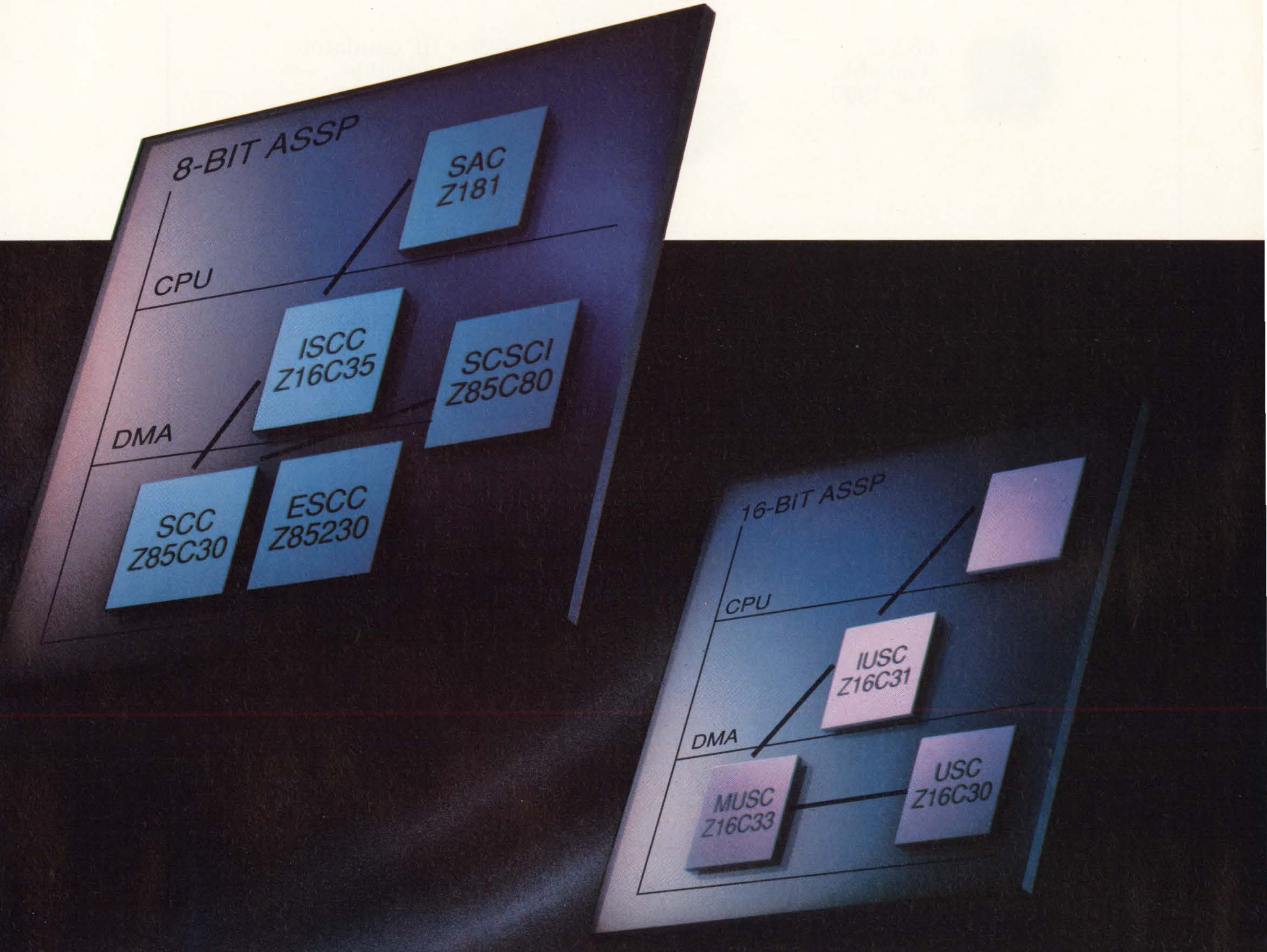


Zilog's SCC™ and USC™ datacom controller families give you a tremendous selection and the most flexibility in protocols, system interfaces and data transfer rates in the industry.

At Zilog, we understand our markets. We provide the devices that meet the needs of datacommunication designs right now, yet we always have an eye on the future. We offer serial communications controllers that ensure quick, easy and flexible interconnection of hosts and peripherals into LANs and WANs. And we provide flexibility in protocols allowing designers to build CPU-based boards with custom software, rather than hardware or firmware.

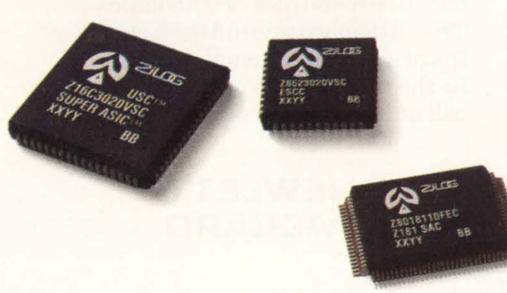
Our SCC and USC families of 8- and 16-bit SCC controllers range from Serial Input/Output controllers (SIO™ controller) and the versatile industry standard SCC controller that's used in all Appletalk® networks . . . to the Enhanced SCC (ESCC™ controller), which boosts performance up to 10 times. Plus our Integrated USC (IUSC™ controller), which provides sophisticated buffer management capability, is perfect for handling fast, packetized data across networks. And you get simplified, faster system operation with an on-board DMA. Since all these controllers offer code compatibility in their families, you're also assured a quick, easy migration path.

There's no question that ASSPs are the best option for a rapidly growing number of designs. At Zilog we've been producing ASSPs and refining Superintegration™ design methodology longer and better than anyone, which is why we provide the largest library of familiar



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

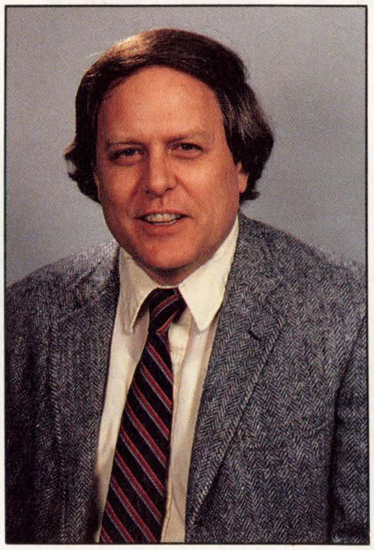
To find out more about Zilog's Datacom families, or any of our rapidly growing Superintegration product families, contact your local Zilog sales office or your authorized distributor today. Zilog, Inc., 210 East Hacienda Ave., Campbell, CA 95008-6600, (408) 370-8000.



Zilog
Doing It Right

CIRCLE NO. 38

Make FPGA design easier



The FPGA (field-programmable gate array) industry is choking itself by trying to turn application support operations into profit centers. Engineers can get reams of priceless design ideas for every kind of IC except FPGAs. Engineers who want optimized design elements for FPGAs must pay for so-called "macro libraries." This shortsighted policy contrasts sharply with the tactics that the company MMI first used to woo digital designers from TTL to PAL devices.

MMI published a series of application notes explaining how to recast common TTL design elements into PAL devices. The company also gave away Palasm, a software tool that could compile the PAL-device designs into fuse maps acceptable to device programmers. MMI obviously had a clear idea of which business it was in: the IC business, not the software business.

Today's FPGA vendors lack this clear vision: They seem uncertain as to whether they are in the IC business or the software business. Right now, only a few talented, experienced designers produce designs that use virtually every gate in an FPGA and that run at rates in excess of 70 MHz. Most designers struggle to achieve a fraction of that performance from the very same devices. Yet it's those struggling designers facing their first few FPGA designs who will provide the big market for FPGA suppliers.

Instead of locking up the technology of FPGAs in expensive macro libraries, FPGA vendors should be working to extract the expertise of the talented, experienced few and disseminate that expertise as quickly, widely, and inexpensively as possible to all other designers.

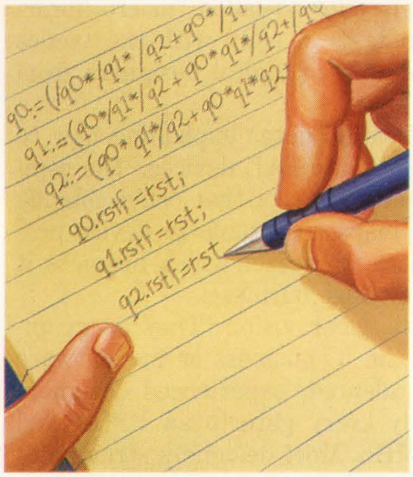
Charles H Small
Senior Editor

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

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

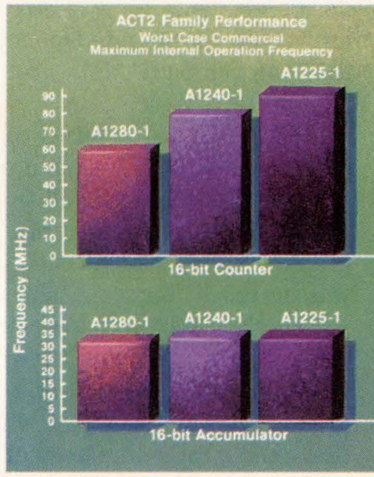
Send me your comments via FAX at (617) 558-4470, or on the EDN Bulletin Board System at (617) 558-4241 300/1200/2400, 8, N, 1.

You Design Actel FI
You Do A PLD. But Th



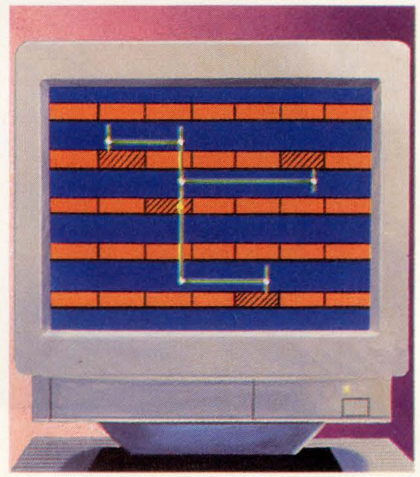
Use PLD Tools.

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



Fast. Fast. Fast.

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



100% Automatic Place And Route.

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

Announcing A Simple Way To Get From PLDs To FPGAs.

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

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

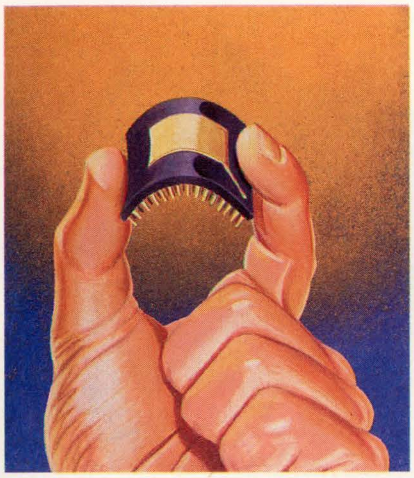
Actel devices offer everything you want in an FPGA. Like high I/O and flip-flop counts. And 100% automatic place and route gets you to market fast.

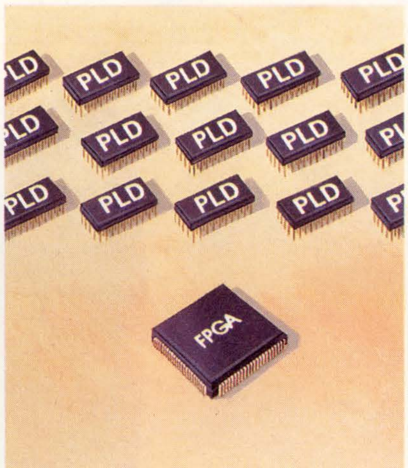
Once your FPGA is designed, our Action Logic™ System (ALS) converts the captured design into a completed device in minutes. To give you true, high-density, field-programmable, channeled gate arrays.

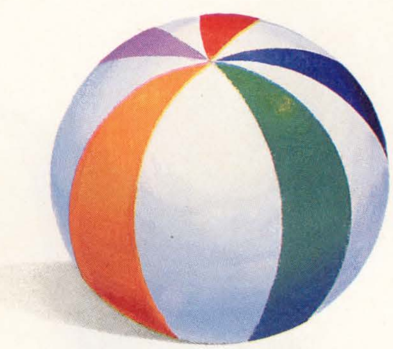
Other FPGA manufacturers fall short on design verification. Our exclusive Actionprobe® diagnostic tools, give you 100% observability of internal logic signals. So you don't have to give up testability for convenience.

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

GAs The Same Way
e Similarity Ends There.







More Flexibility And Capacity.

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

Small Footprint.

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

More Fun.

Designing Actel FPGAs is so simple that you'll have more time to do the things that made you want to become an engineer in the first place. Or just relaxing. You've earned it.

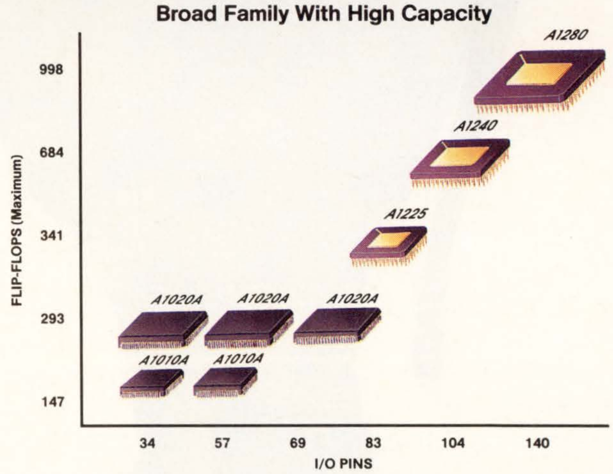
ful A1280. With 8,000 gates, up to 998 flip-flops, and 140 I/O pins, it's the highest capacity FPGA today. And our A1240-1 is the fastest. In the A1240-1, 16-bit counters run at 75 MHz, 16-bit accumulators at 33 MHz. Enough capacity and speed to handle almost any application.

The FPGA Design Guide

The superior speed, capacity, and auto place and route capabilities of our FPGAs are made possible by Actel's revolutionary PLICE® antifuse programming element. The advanced technology that makes our family of FPGAs an ideal way to unleash your engineering creativity.

Call **1-800-228-3532** for your free FPGA Design Guide.

Broad Family With High Capacity

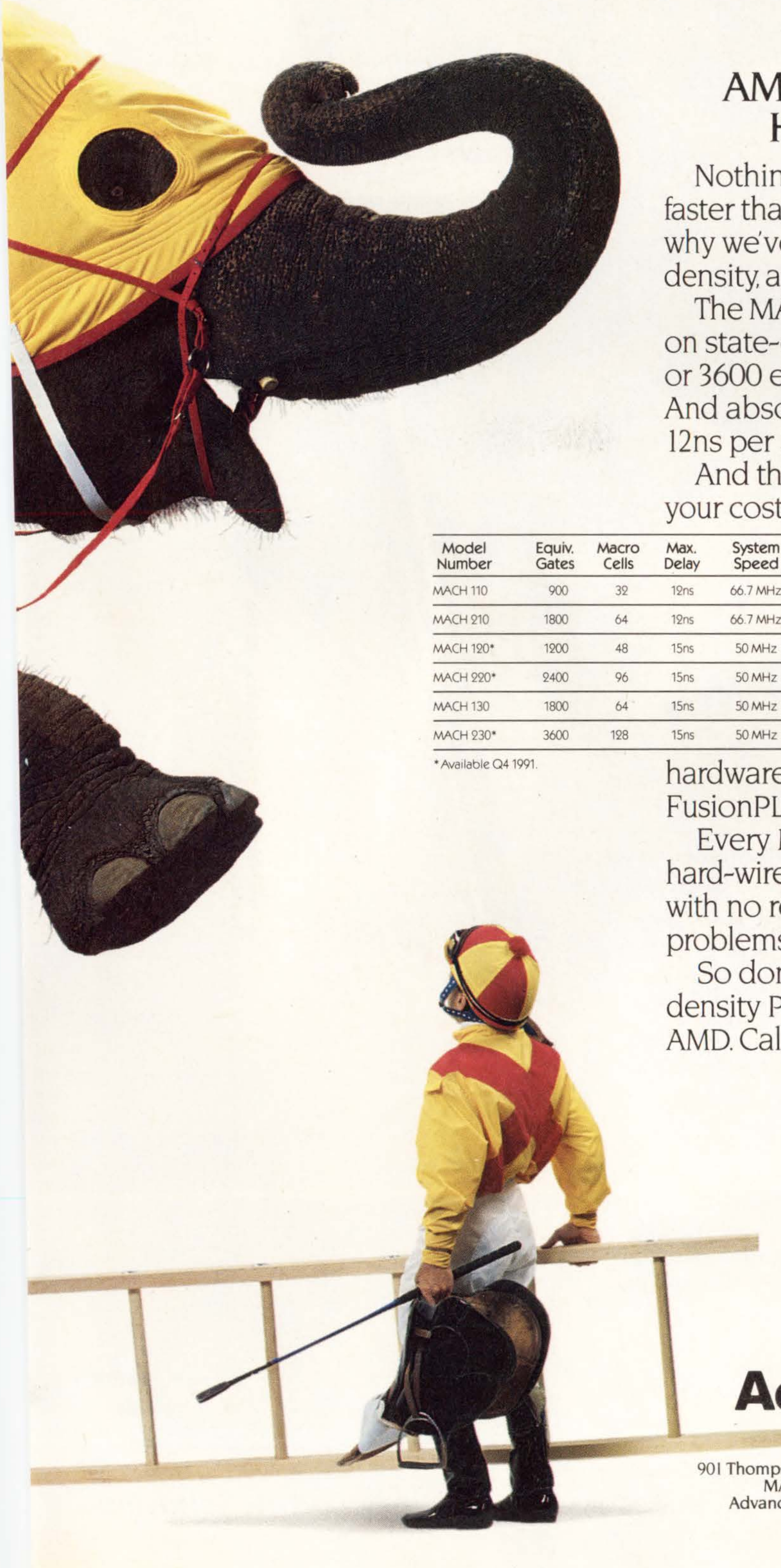


Actel

Risk-Free Logic Integration

CIRCLE NO. 41

And Speed Were
rd Combination.



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

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

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

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

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

* Available Q4 1991.

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

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

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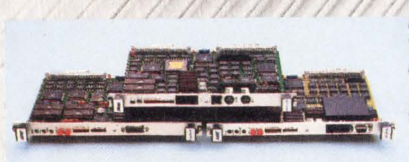

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CIRCLE NO. 43

ANALOG SIMULATION VS BREADBOARDING

Software clues balance bench-level intuition

Combining breadboarding and simulation lets you and your analog circuit benefit from the best of both worlds.

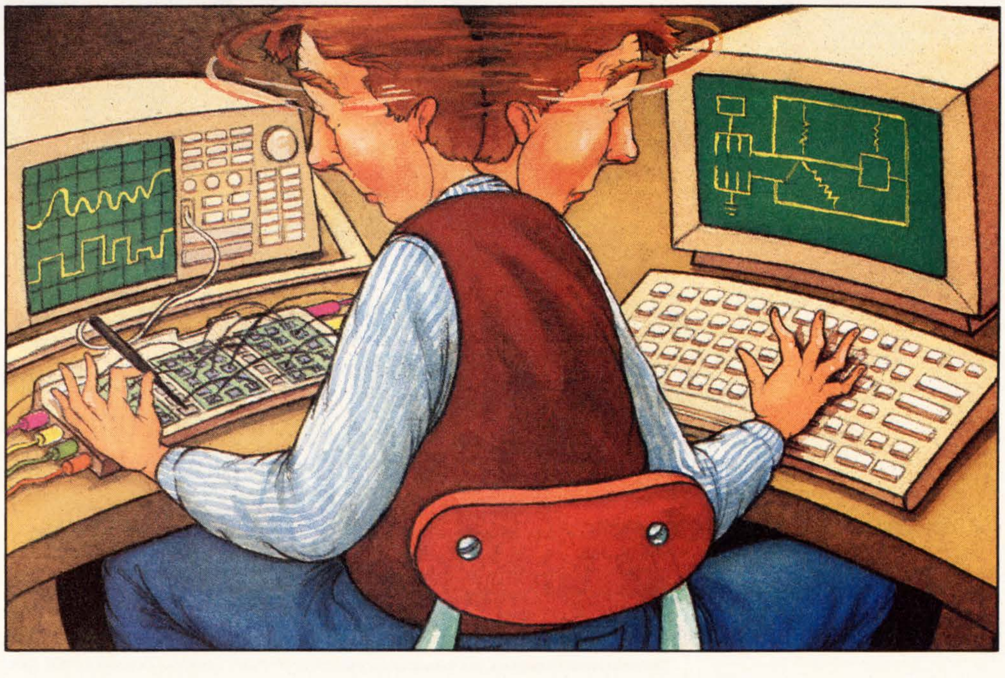
Anne Watson Swager,
Regional Editor

If you're like many analog designers, you tend to be wary of simulation. But if you exclusively rely on traditional breadboarding techniques, you're overlooking simulation's potential to provide you with valuable design insight. Simulation can provide clues to a circuit's performance without your ever having to remove old parts or search for, procure, and install new ones. Simulation gives you a chance to prove design concepts, consider design tradeoffs, and glimpse those things that are hard to see—or dangerous to test—on the bench.

However, just as with a circuit's performance, a simulator is only as good as its design. Without a fair amount of knowledge and some feel for the performance of a particular simulation package, you can make erroneous assumptions. And without accurate and comprehensive models that can predict real behavior, simulation is a futile exercise.

Enter the age-old design tool, the breadboard. Breadboarding offers you a real-world look at your circuit and a chance to design out those unexpected but real-world phenomena. Troubleshooting breadboards forces you to become intimately familiar with parts of your design you may not have considered.

Unfortunately, the breadboard is not always a perfect tool either. Breadboards can sometimes be flukes—some chance combination of the best or worst performers of every component in your design. You may be able to build an astonishing breadboard, but never see a repeat performance in production. When you make breadboards using part samples from IC manufacturers, you have to keep in mind those devices' datasheet tolerance spreads.



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Analog simulation vs breadboarding

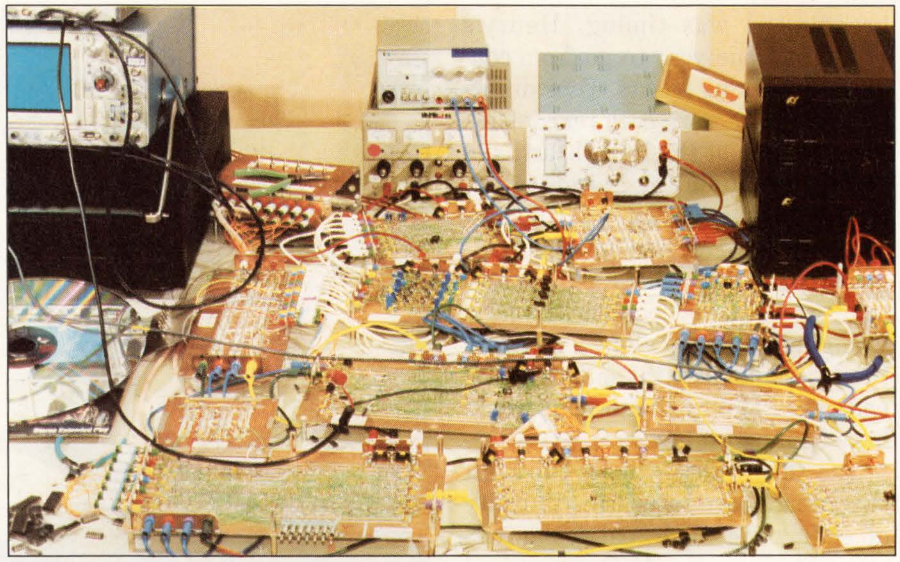
As pc boards become denser and more complex, they are increasingly difficult to build up quickly in the lab. High-frequency breadboards present the greatest design challenge. These breadboards can suffer from ground loops—a situation in which a computer simulation never finds itself. The layout of high-frequency breadboards is so critical that unless the breadboard exactly matches your production model, the test results of the two won't even come close to matching.

To be fair, simulation and breadboarding both have bugs. You can spend hours trying to find a crossed wire on your breadboard or the reason your Spice simulation generates a bizarre error message. These hours aren't spent analyzing your design, but debugging your design tool.

The best strategy is to combine the two techniques to arrive at a satisfactory design as quickly as possible. It's often difficult to know when to stop simulating or when to stop battling it out with a troublesome circuit on the bench. Clearly, deciding how much time and effort to spend simulating versus how much to spend breadboarding is a balancing act.

Charles Hymowitz, vice president of Intusoft, makers of IS Spice, outlines what he sees as the ideal simulation-and-breadboarding scenario. Try to simultaneously build a breadboard and write your simulation models and code. At some point, compare the simulation's results with the circuit's performance. Once you have some confidence in the simulation's match of the breadboard's characteristics, you can use simulation tools to their fullest. You can compare performance differences using different components and values, run sensitivity analyses, and use simulation to make subtle design tradeoffs.

This approach sounds like engineering heaven: an unlimited amount of time to figure out how well, and why, everything works the way it does. Unfortunately, real job pressures require you to limit the time you spend on each technique.



Breadboarding part or all of an IC *is sometimes necessary. Engineers at Analog Devices' Precision Monolithics Div built this breadboard to help them design a consumer audio chip. By using simulation and breadboarding simultaneously, the designers completed the project sooner than if they had used either method exclusively.*

Steve Hageman, a designer of power-supply circuits and a frequent author on Spice subjects, relies mostly on his analytical design and breadboarding skills to test circuit designs. But when he's stumped, he turns to Spice. He uses Spice as a learning tool, not as something he banks on to prove the validity of a complete design.

The nature of your final product will help determine whether you should spend more time breadboarding or simulating. An obvious product comparison is the pc board versus the IC. In the case of the pc board, a breadboard that approximately matches the form factor and manufacturing materials of the final product is worthy of extensive bench time. For boards that are particularly dense, a few companies, such as Ariel Electronics, offer quick prototyping services. The company's Circuitwriter Model 100 system is currently in beta-site testing. The system fabricates a fully functional multilayer board by extruding polymer thick films. The process generally takes less than a day.

If you think building a breadboard for a circuit that will eventually reside in one IC package is a waste of time, think again. Even semiconductor manufacturers do some breadboarding. For example, a project group at Analog Devices' Precision Monolithics Div (PMD) (Santa Clara, CA) built a breadboard for the SSM2125 Dolby prologic surround matrix decoder. The chip operates in home-theater applications.

Peter Henry, the project manager, explains that the group built the breadboard for several reasons. First, the chip is an audio device; it had to sound good. The designers wanted to actually listen to the results to judge the sound quality before committing to silicon. Computers just can't make such subjective judgments.

A second reason they built the

breadboard was timing. Henry's group had one year to go from concept to working silicon. Four different designers were each responsible for a portion of the breadboard and the corresponding simulation. Henry postulates that if the project's designers had used breadboarding alone, the development time would have been three years. Using simulation alone, creating the IC would have taken two years, and, says Henry, "The chip would have sounded funny."

The third reason the group built the breadboard was the difficulty of simulating their particular circuit. Their audio design required transient ac-signal analysis—the type of analysis that requires the longest simulation time. The IC includes approximately 2000 analog-circuit components. Many of these components implement nonlinear functions, such as rectifiers and log amps. Spice-like simulators can have convergence problems when simulating nonlinear circuits.

***You can work in both the analog and digital realms** using GEC Plessey Semiconductors' PDM prototype modeling design kit. The system lets you design, capture, simulate both digital and analog, and emulate a complete mixed-signal ASIC before committing it to silicon.*

The group didn't stop with Spice-level simulations but also used Analogy's Saber behavioral simulator. The audio circuit was too big to simulate entirely using a full transistor-level simulation. As the designers ran behavioral simulations of various sections, they substituted transistor-level models for behavioral models. For Henry's group, even simulating at the behavioral level was an enormous task.

To build their giant breadboard, the IC designers used a combination of their own kit parts, commercially available logic, and scavenged cells. According to PMD's Henry, kit parts ideally have the same geometries as the final ICs. Usually the geometries differ somewhat, but kit parts come as close as you can get.

Extrapolating breadboard performance to an IC is tricky. In the case of pure analog or mixed analog/digital ICs, breadboards can provide useful information, but definite differences exist between board-level and silicon-level performance. Most notably, parasitics on a pc board are quite different from those that exist on an IC. Parasitics can both help and hurt you: Circuits will run faster in an IC, but an IC version of a stable breadboard circuit may oscillate.

Nonetheless, many vendors of analog ASICs provide kit parts for designers who want to breadboard part or all of their circuits **(Ref 1)**. In addition to kit parts, GEC Plessey sells the PDM design system, which lets you breadboard the analog portion of your IC while emulating the digital portion.

Another way to "breadboard" ICs is to get access to quick, inexpensive silicon. Orbit Semiconductor offers a prototyping service called Foresight. The Foresight service holds multiproject wafer runs every four weeks with a turnaround time of four weeks. You can use the service to build low-volume, low-cost circuits using the company's fabrication processes.

Faith runs thin

Regardless of whether you're working at the board or IC level, balancing the time you spend breadboarding with the time you spend simulating depends on the amount of faith you have in the results of each method. The bottom line is that your simulation will lie to you if you ask it to. Part of any troubleshooting or debugging exercise is to recognize when your breadboard or simulation is producing deceptive results.

Take Spice as an example. Although Spice has existed for some 20 years now, a surprisingly large number of users don't know how Spice really works. "Too many people rely on Spice too much," says Intusoft's Hymowitz. For example, all versions of Spice are based on a small-signal model. "Small signal" implies that Spice takes a straightforward view of a transfer function.

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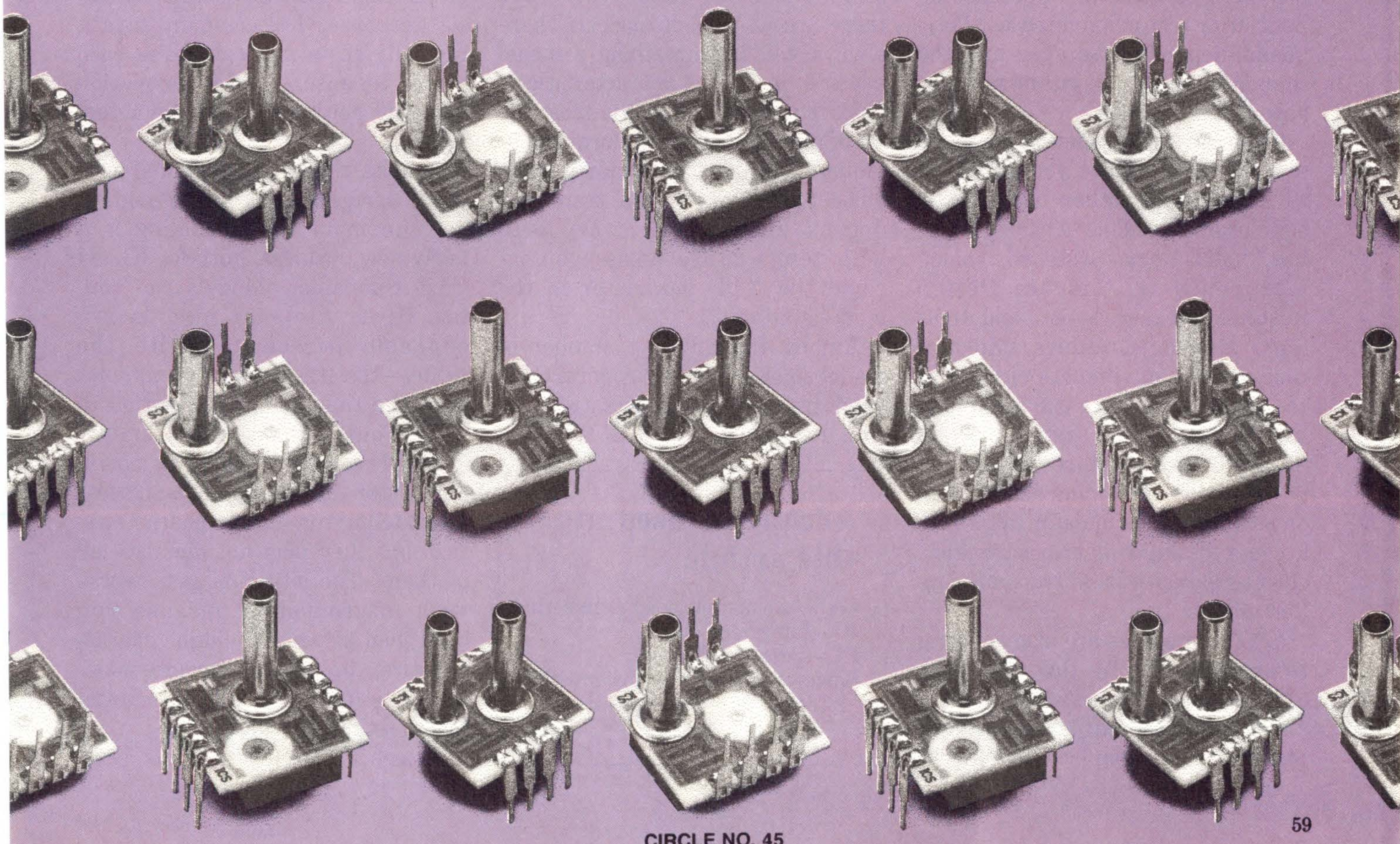

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Analog simulation vs breadboarding

To calculate the gain of an op amp, for example, Spice multiplies the input by the ratio of the feedback and input resistors. If you run an ac analysis with an op-amp model that has a gain of 10 and 10V inputs, Spice will tell you that the op amp's output will swing 100V. It's up to you—or the CAE vendor, who can add upgrades to basic versions of Spice—to recognize that no op amp can swing wider than its power-supply rails.

To make matters even more confusing, different versions of Spice have different model and analysis characteristics. Most commercial Spice packages are based on Berkeley's Spice2G.6, but a few, such as Contec Microelectronics' version of Spice, are based on Spice3. Spice3 does some things that the 2G.6 version can't, but at the price of not including some of the earlier version's features (**Ref 2**). For example, Spice3 has added pole-zero analysis but does not do Fourier or distortion analysis. Polynomial-dependent sources and the source-stepping algorithm are also absent from Spice3.

The type of information you need to know about Spice you also need to know about other higher-level simulators, such as Analogy's Saber, Valid Logic Systems' Analog Workbench II, Cadence Design Systems' Analog Artist, and tools from Mentor Graphics. Most of these tools can simulate circuits at the Spice level; some can also simulate circuits at the system and behavioral levels. More simulation packages are including features to ensure that the simulator takes into account real-circuit characteristics, such as parasitics and transmission-line effects.

CAE companies are also working to produce software that takes into account a breadboard's physical layout. Although automatic layout tools are commonplace for digital systems, few such tools exist for analog systems. One of the few analog-system tools is Valid Logic Systems' Analog Systems Lab. The software uses your design rules to keep certain interconnect distances short, specify net lengths to reduce stray capacitance or inductance, and specify rules regarding thermal or impedance considerations.

Learning more about your simulator and taking advantage of a simulator's ability to model real physical effects will ease many of your misgivings. However, the primary reason for simulation skepticism and inaccuracy is models. Ultimately, faith in your simulation comes from faith in your models' accuracy.

Simulation models can suffer from many limitations: They aren't accurate enough, they take up too much simulation time, or they don't emulate the behavior that's most critical or troublesome to your design. Intusoft's Hymowitz says there are no perfect models. There always will be something a model doesn't do, some characteristic it doesn't imitate. Often the most basic of models doesn't perform an obvious function. For example, the basic Spice model of a transistor doesn't automatically vary beta with temperature unless you include the XTB parameter in the model statement.

Among the growing number of model sources are IC vendors, CAE vendors, and consultants (**Ref 3**). Ron Kielkowski of RCG Research is a consultant who develops models upon request. In addition, virtually all analog simulators come with some sort of model library. HSpice from Meta-Software has a standard device library that includes bipolar transistors, MOSFETs, op amps, ADCs, and DACs.

Sometimes, the models you want simply don't exist. Creating models takes great effort and can eat up chunks of time (**Ref 4**). Several vendors offer model-building software. For example, Microsim Corp's PSpice Parts option—$450 to $950, depending on the hardware type—lets you convert information from a component manufacturer's data sheet into parameter values for PSpice. Some vendors will also build models for you upon request.

Valid Logic Systems claims its Analog Workbench II has one of the largest analog-model libraries in the industry. The company provides data that compares manufacturers' device characteristics with the models' response. The company says it carefully tests and calibrates each model to ensure close correlation with the performance of the actual device.

Despite the availability and supposed performance of these models, keep in mind that modeling is a fairly new business, both for IC and CAE companies. Models can contain flaws. Also, the most knowledgeable person to write the model—the IC's designer—may not have the time or the inclination to do so. Thus, someone not as familiar with a design may create the model. Transistor models come the closest to modeling real-device characteristics, but they may not simulate all of them. The situation gets worse with macromodels because you can't nail down individual characteristics; the nature of macromodeling is to lump various characteristics together.

Intusoft's Hymowitz has seen

Acronyms used in this article

CAE—Computer-aided engineering
IC—Integrated circuit
PC—Personal computer
Spice—Simulation program with Integrated-circuit emphasis

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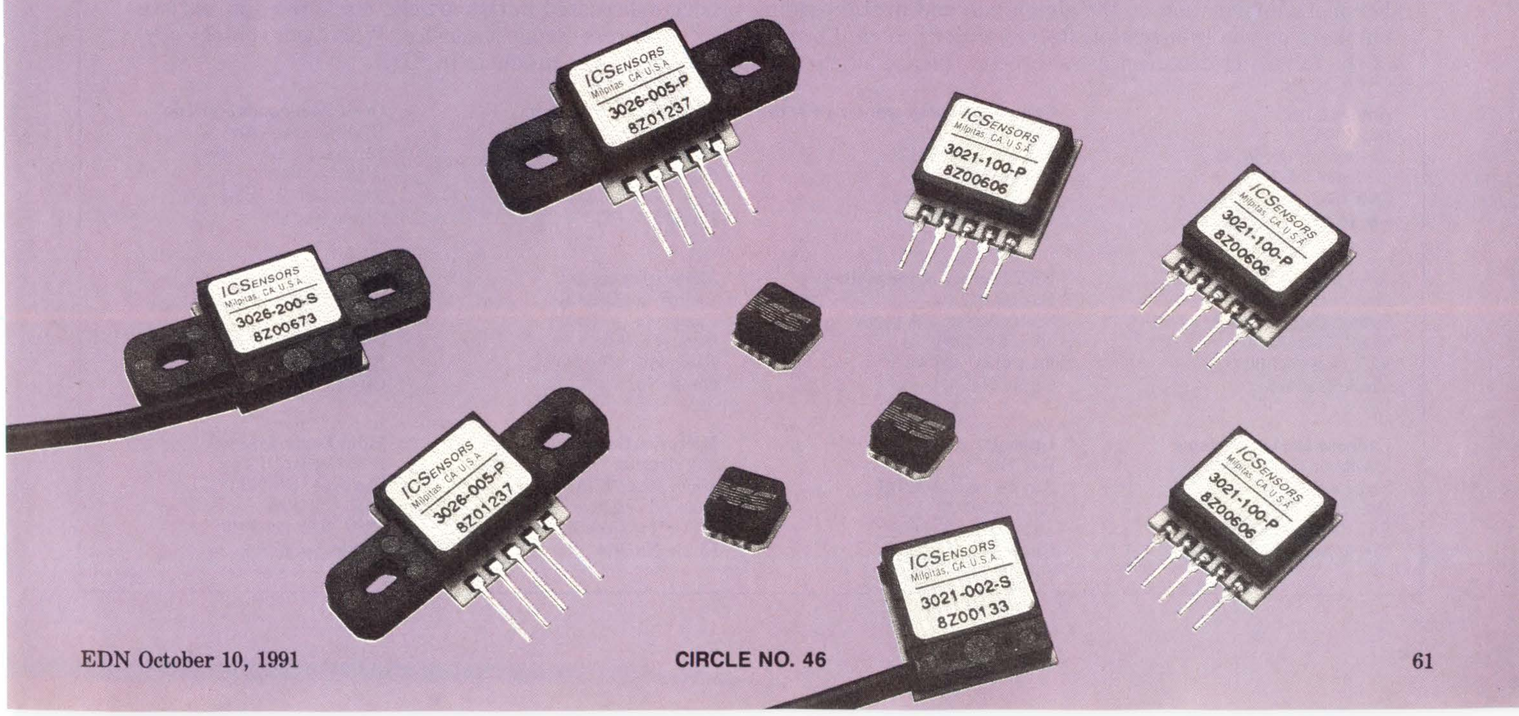

CIRCLE NO. 46

Analog simulation vs breadboarding

bug-ridden models firsthand. He's had to reconfigure models from IC vendors to make them Spice compatible because the models included elements that Spice couldn't recognize, such as negative capacitors. He has also found errors in the models themselves. One notable case was a model for an LM111 comparator that used npn input transistors instead of the real device's pnps. When you run a simulation using the erroneous model, current flows the wrong way.

So before you use your models in a simulation, put them through their paces. Figuring out which characteristics models do and don't include can be difficult. Spend some time testing models and comparing IC and model performance. Once you have data in hand that proves the validity of these models, and perhaps more importantly, once you have models that include parameters critical to the performance of your company's final product, you can justify placing more faith in simulation.

Over time, the pitfalls of simulators and the inaccuracies of models will diminish. But simulation problems are often the result of a user's assumptions. According to Hymowitz, "The people who have the most trouble are the ones who don't see the subtleties. There is no substitute for knowing what you're doing."

Many good simulation and modeling texts (**Refs** 5 and 6) and articles exist—many more than can be listed here. Both Intusoft and RCG Research offer Spice classes. Intusoft offers a 1-day course. RCG Research offers three 1-day courses that cover everything from syntax to dealing with time-step-control and convergence problems to how to write macromodels and behavioral models. Both novice and experienced users can benefit from the Spice insight these courses provide.

You might also want to beef up your breadboarding skills, which invariably boil down to troubleshooting skills. Bob Pease's book on analog troubleshooting (**Ref 7**) presents an armamentarium of tips for debugging both analog and digital circuits. But ultimately, no amount of reading or course taking can substitute for hard-earned experience. EDN

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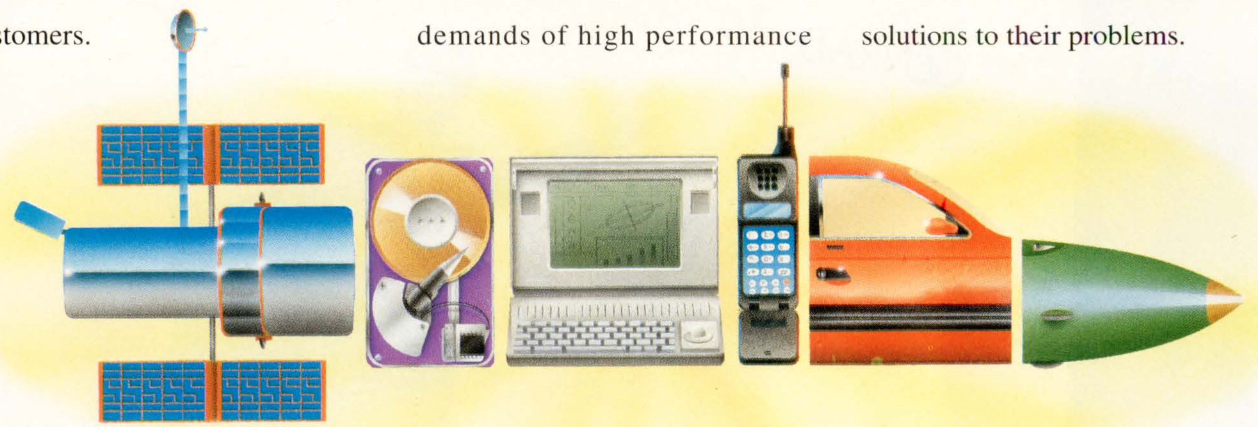

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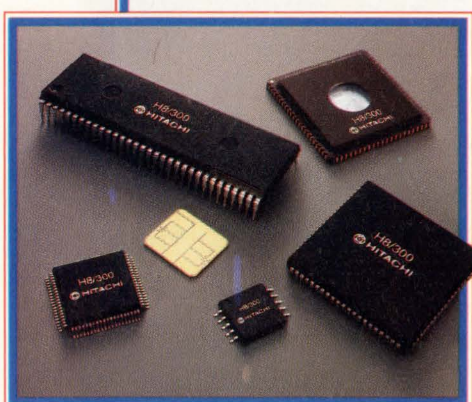

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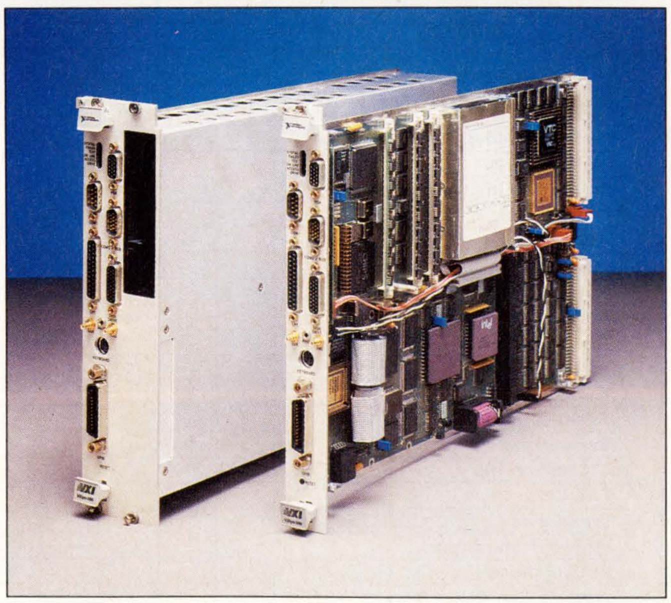
Dan Strassberg,
Associate Editor

You aren't necessarily an iconoclast if you conclude that the VXIbus (VME extensions for instrumentation) is a bad idea; that the engineers who thought up the modular-instrumentation standard four years ago should at least be fired and probably shot. Others have come to similar conclusions. But there are a couple of problems with that view: it's shortsighted and it comes from only the most superficial look at the technology. Shrinking staffs and shortened product-development cycles leave many engineers little time to research a subject adequately. But those who take the trouble to learn about VXI will find that the bus' value is much greater than it seems at first.

A good place to start looking into VXI is in **Table 1**, which lists approximately 50 vendors of VXI products. The **table** divides the products into 29 categories and shows which firms offer products in each category. To learn how to contact the vendors, consult the "For more information . . . " **box**. The **table** and **box** are shortened versions of a directory published in the August, 1991 issue of Bode Enterprises' *VXIbus Newsletter*; they appear here through the publisher's cooperation. The complete directory describes each product briefly and indicates its price. (In the US, newsletter subscriptions cost $195/year. See the **box** for Bode Enterprises' contact information.)

A cursory look at VXI quickly reveals most of the bus' cost shortcomings but none of its economic advantages: With VXI, your instruments don't have front panels, so if your system doesn't work, you can't do any debugging by exercising the components manually. And with VXI, before you can get even one instrument to do any more than sit on your bench and look kind of frumpy, you have to spend nearly $10,000 on a mainframe (a card cage, backplane, and power supply). Every VXI system needs a controller, and controllers cost several thousand dollars. Moreover, some VXI instruments cost more than



VXI modules' plain exteriors *can hide impressive technology. C-size embedded controllers, such as these i386-based units from National Instruments, can include high-capacity hard disks. In addition, the double-width unit houses a floppy-disk drive. Pricing starts at $7800.*

Table 1—VXI Source Directory

Vendor	Function and arbitrary-waveform generators	Pulse, pattern, and word generators	Attenuators and amplifiers	Synchro instruments	Digital voltmeters	Digital counters	Digitizers and DSOs	L-C-R and power meters, etc	A/D and D/A converters	Digital stimulus/response test units	Digital I/O	Signal processors	Scanners, switches, and multiplexers	Interconnect devices	VXI ICs	Power-supply controllers, programmable resistors	Frequency and voltage standards	MATE and MIL-STD modules
AD Data Systems													•					
Analogic Corp									•		•		•					
Ascor Inc										•			•					
Augat Inc																		
Automated Technology																		
BICC-Vero Electronics																		
Blakell AQL																		
Bruel & Kjaer												•						
Cal-Av Labs Inc			•															
C&H Engineering Inc																		
Colorado Data Systems	See Tektronix/CDS																	
Dawn VME Products																		
Digital Technology																		•
EIP Microwave Inc	•					•												
Elgar Corp																•		
Elma Electronics Inc																		
Genrad Inc																		
Giordano Associates										•	•							
Hewlett-Packard Co	•		•		•	•	•	•	•	•	•		•	•				
Hilevel Technology																		
ICS Electronics Corp																		
ILC Data Devices				•														
Intepro Systems																•		
Interface Technology		•													•			
Interlogic Industries																		
LeCroy (Struck GmbH)											•					•		
Mac Panel Co														•				
Matrix Systems Corp													•					
Mupac Corp																		
National Instruments																		
NCR																		
NH Research																•		
Nortek													•					
North Atlantic Ind's				•														
Proteus Corp																		
Racal-Dana Instrument	•					•				•	•		•	•			•	
Radisys Corp																		
Schlumberger						•												
Schroff Inc																		
Serendipity										•								
Talon Instruments										•								
Tasco Electronics Inc		•								•								•
Tektronix/CDS	•	•		•	•	•	•	•	•	•	•		•			•		•
Testniques																		
Tracewell Enclosures																		
Transmagnetics Inc				•														
TTI Testron Inc														•				
TYX Corp																		
Veretest Inc		•						•										
Virginia Panel Corp														•				
VXI Solutions																		
Wavetek San Diego Inc	•				•													
Westest										•								
Wind River Systems																		

Software	Embedded computers and subsystems	Slot 0 and IEEE-488/VXI interfaces	Mainframes and backplanes, OEM	Mainframes, D-size	Mainframes, C-size	Mainframes, B-size	Development and starter systems	Prototype cards, adapters, and miscellaneous modules	System integration	Systems
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their rack-and-stack counterparts—as much as 25 or 30% more.

You have to do a little digging to learn that once you've paid the high up-front costs, the total cost of developing a VXI-based test system can be significantly lower than that of building a system based on conventional rack-and-stack instruments. The savings grow as you gain experience with VXI, and they're likely to grow further over time; for example, as vendors develop ASICs to interface with the bus. (Interface Technology is now selling such an IC.) Already, a few VXI instruments are priced dramatically lower than their rack-and-stack counterparts. For example, Racal-Dana offers a time-interval analyzer and a microwave counter that each cost about 40% less than competing conventional units.

VXI wins converts

Once you've built your first VXI system, you probably won't need inducements to use the bus again; your first experience may well turn you into a VXI convert. Although early on you undoubtedly will find aspects of VXI that don't please you, you're sure to discover that the bus offers some potent advantages. For example, nearly all test systems require some custom hardware, and VXI cuts the cost of building it. The basic packaging scheme provides the infrastructure to facilitate custom module designs: You don't have to select or design an enclosure or a power supply. Often, the bus provides all the connections a custom module needs, so you don't even have to choose connectors.

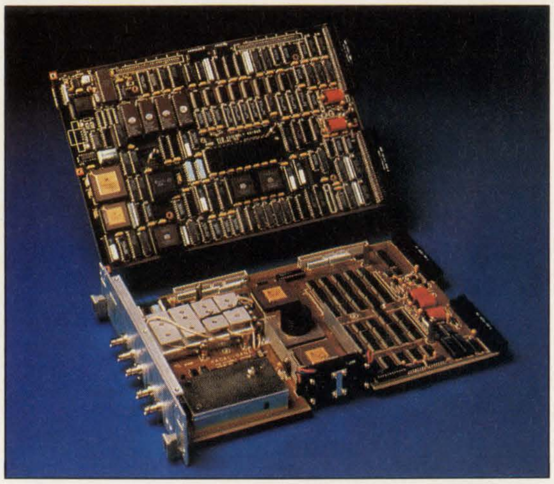
One large systems manufacturer estimates that the fully burdened cost of a test engineer is $10,000/month, of which only about one-third is the engineer's salary. For this firm, VXI has more than paid for itself through a 2-month reduction in the average time engineers spend designing and debugging custom modules for each test system.

Good things in small packages

VXI's cost savings don't end with custom modules. VXI's most obvious improvement over rack-and-stack instruments is its small size. The size reduction, which can be crucial in flight-line test systems and military applications, may not seem to provide a very compelling incentive to use the bus on the factory floor. But reducing instrument size often allows you to build in one equipment rack a test system that previously required two racks or more. Though significant, the reduction in rack cost isn't the big item here. More important are the savings in cabling costs that result from the system's smaller size and from placing as many as a dozen instruments in a single chassis.

Lower cost isn't the only benefit that results from reducing the number and length of cables; performance improves too. If your system involves high-speed signals, triggering, or synchronization, a VXI embodiment will perform more predictably than an equivalent unit built from rack-and-stack instruments. In some cases, the improved performance can translate into higher throughput because you will no longer need to add waits to programs to compensate for poorly controlled cable delays.

In the microwave area, VXI systems now can include instrument modules in two forms. Two years ago, a battle of sorts erupted between advocates of competing technologies. A group led by Hewlett-Packard insisted that the correct way to integrate microwave capabilities into VXI was to use a separate, shielded chassis. To that end, HP released its MMS (Modular Measurement System) architecture to the public domain. MMS has been adopted by a group of vendors that has since set up a consortium of its own, now numbering nine members. Meanwhile, other vendors, led by Racal-Dana, demonstrated that they could successfully package microwave instruments as standard VXI modules. Several firms now offer such units.



The technology inside VXI modules *often is far from prosaic. But to realize this, you have to look under the cover and reckon the improvements VXI brings to throughput, performance, and total system cost. Racal-Dana's $15,000 2351 Time-Interval Analyzer, a double-width C-size unit, costs about 40% less than some stand-alone instruments that perform similar functions.*

Next to small size, faster operation than IEEE-488-based systems is VXI's most-talked-about advantage. Nevertheless, at the moment, most users are taking advantage of only a small fraction of VXI's speed potential.

Discussing VXIbus speed points out a truism: Ask an engineer what you think is a simple question, and you'll almost invariably find that the question isn't simple; it only appeared so because you didn't understand the problem. VXI's speed is a complex and controversial topic that has already been the subject of several technical papers and will doubtless elicit even more. Speed is closely tied to instrument architecture, to bus protocols, and to the design of the software used in VXIbus systems. The software issues lead to discussions of debugging techniques and of tradeoffs between test-program development time and test-system throughput.

Communicate three ways

VXI offers three protocols for communicating with instruments: message based (word-serial), register based, and shared memory. With message based data transfers, you send commands to a module as strings of ASCII characters and the module returns data in the same form. The modules must have sufficient intelligence to recognize the commands. This mode of operation should be familiar to users of IEEE-488 instruments; communication via IEEE-488 is message based.

Indeed, some of the first VXI modules were little more than repackaged IEEE-488 instruments. If a company already builds a rack-and-stack instrument and wants to get an equivalent VXI unit to market in a hurry, repackaging the existing product as a message-based VXI module usually presents few challenges—especially if manufacturing cost is not a big concern.

Repackaging a rack-and-stack instrument has other advantages too: Potential users who are familiar with writing programs to control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VXI bus

IEEE-488 instruments will have little difficulty learning how to create programs to control the VXI unit. In fact, when test-system builders choose an external computer as a controller and interface it to a VXI mainframe via IEEE-488, they can program message-based VXI instruments housed in the mainframe exactly as if those units connected directly to the IEEE bus.

Therefore, if a message-based instrument has a reasonably good manual, an instrument vendor can ship the unit without software and be confident that most users will be able to make it work. A new command syntax called SCPI (standard commands for programmable instruments—pronounced skippy by some people; scuppy by others) will, as users gain familiarity with it, further simplify learning how to control message-based instruments. Already, significant numbers of VXI instruments support SCPI.

Some would skip SCPI

Not all producers of VXI instruments are enthusiastic about SCPI, however. Their argument is that you pay in performance for SCPI's flexibility and extensibility and for the high level of readability of SCPI code. SCPI's English-like syntax is relatively verbose. Parsing SCPI commands therefore requires more processing power—and time—than would parsing terse commands.

Tektronix/CDS (formerly Colorado Data Systems) feels that it has an answer to the speed penalty SCPI exacts; the firm calls its scheme Smart Registers. With Smart Registers, commands are terse and somewhat cryptic, but a fixed-program state machine in each instrument can interpret them at high speed. Because of this technique, Tek/CDS takes strenuous exception to a sentiment expressed by several other VXI vendors—that message-based communication doesn't let you take full advantage of the VXIbus's potential for tight integration and high speed.

Note, however, that for many VXI modules, high speed is a bit of a red herring. If a module takes several seconds to make a measurement, as would, say, an 8½-digit multimeter, you should question whether it needs a fast communications protocol. Moreover, the register-based and shared-memory protocols require you to deal with the intricacies of controlling the VXIbus. These protocols bring you into contact with VXIbus-control software and software modules called instrument drivers. With the register-based and shared-memory protocols, these drivers can be quite complex. If you stick with message-based instruments (**Fig 1**), you need not even be aware of such software.

For many types of instruments though (waveform digitizers, digital oscilloscopes, and arbitrary-waveform generators, to name a few),

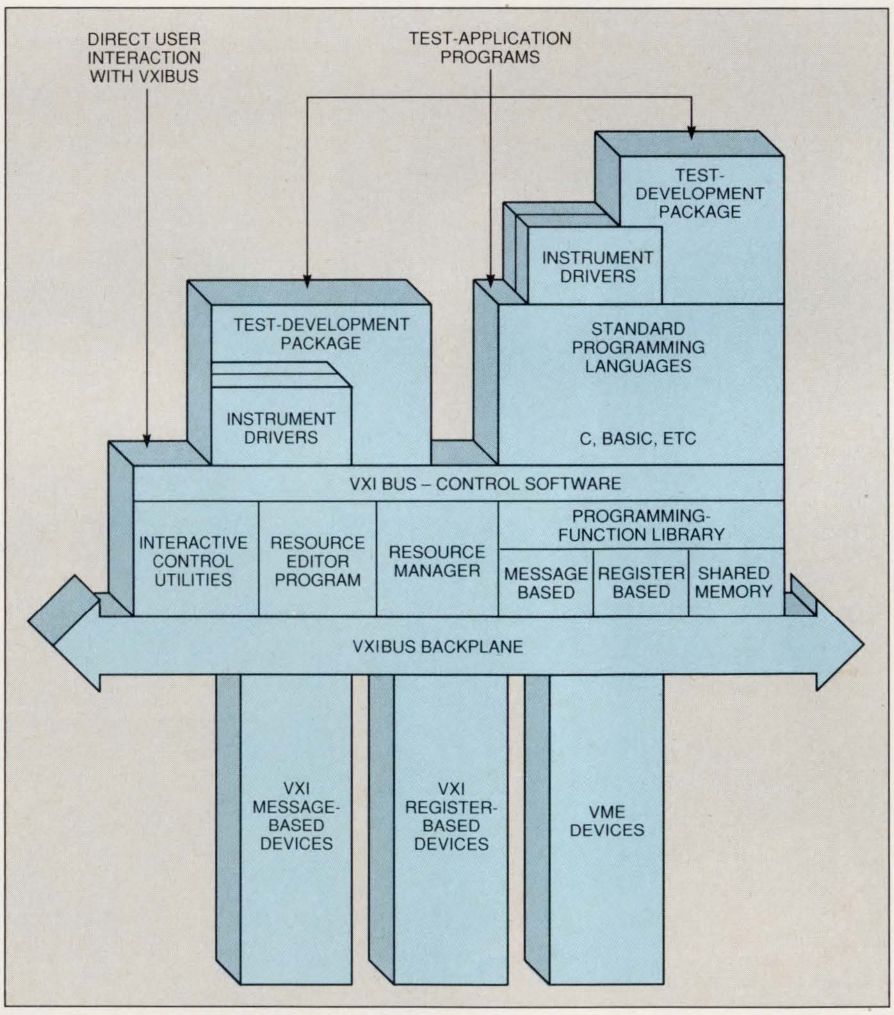

Fig 1—The architecture of software *that controls VXI systems can be a bit daunting. If you use only the word-serial (message-based) protocol, however, your test application program can communicate with VXI instruments as if the instruments directly interfaced to the IEEE-488 bus.*

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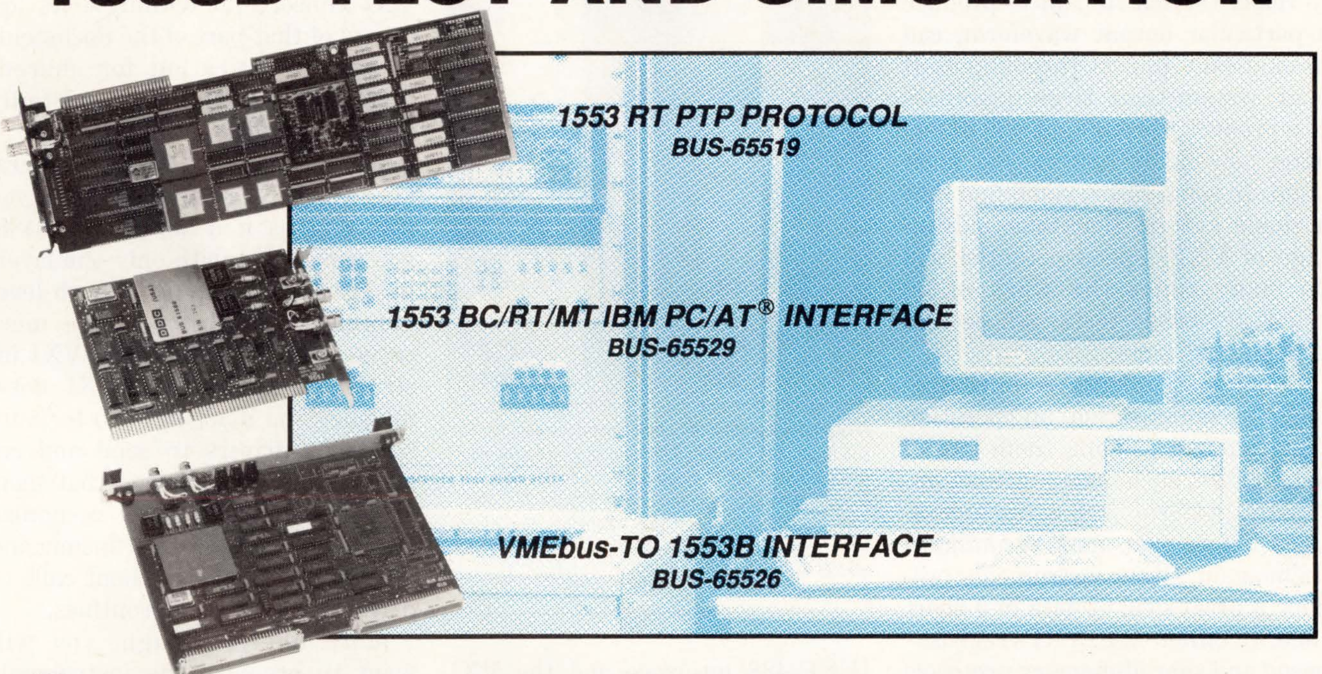

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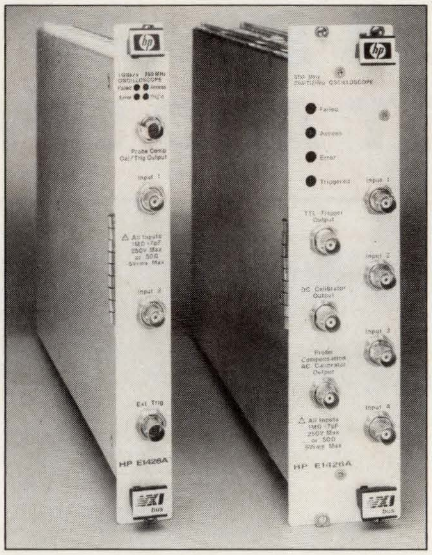
Circle No.. 55 For Literature Circle No. 56 For Sales Contact high-speed data transfers are quite important. With these units, the time required to set up a measurement and retrieve the results, or to ready the instrument to produce a particular output waveform, can dramatically impact throughput. If your system tests large quantities of a product, throughput will determine how many testers you must build. In some cases, you'll find that a single system that takes advantage of VXI's speed potential will do many times the work of an IEEE-488-based tester whose cost is about the same.

Some instruments require frequent reconfiguration, an operation that requires sending them lots of data. Often, such units, once set up, rapidly perform just a few operations before you must reconfigure them again. Other instruments produce a great deal of data in a short time. In either case, VXI's register-based and shared-memory protocols can improve throughput significantly.

Making your point register

With register-based transfers, you write binary data to instrument registers and read measurement results from registers. VXI permits DMA (direct memory access), so an instrument can send large blocks of data to the memory of an appropriately designed embedded controller (or receive large blocks of data from the controller) without keeping the controller from simultaneously performing other tasks.

An embedded controller resides within a VXI cage or mainframe; external controllers reside outside. The most popular method of communicating between external controllers and VXI cages is the IEEE-488 bus. To communicate with a VXI cage via IEEE-488, an external controller must have an IEEE-488 interface and the VXI cage's slot-0 module must connect to the IEEE bus. This arrangement supports only the message-based protocol. It does not allow the controller to closely manage VXIbus traffic the way most embedded controllers can.



Digital storage scopes *have come to the VXIbus. Of course, the display—if you need it—appears on the system controller's CRT. These C-size units come from Hewlett-Packard. The one on the left offers two channels that sample 250-MHz-bandwidth transients in real time at 1G sample/sec. It costs $12,950.*

An alternative to embedded controllers is the MXI Bus, pioneered and released to the public domain by National Instruments. MXI allows external controllers the same degree of VXIbus control as embedded ones.

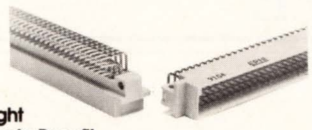
Shared-memory operation is more flexible than register-based communication and is ideally suited to transferring very large blocks of data—for example, for downloading long waveforms to an arbitrary-waveform generator. In the shared-memory mode, an appropriately designed embedded controller can treat instrument memory as an extension of its own memory and instruments can treat portions of the controller's memory as their own. The original VXI spec covered shared-memory operation, but the VXI consortium withdrew its approval of that part of the document. A new specification for shared-memory operation is reportedly about to debut.

As **Fig 1** shows, there are several layers of VXI software. When you use VXI as if it were IEEE-488, you can get by with only one layer: programs written in a high-level language that interchange messages with message-based VXI instruments by way of a VXI slot-0 module. You don't have to have instrument drivers to send and receive the ASCII strings that message-based instruments recognize and produce; you can transmit and receive the strings without calls to drivers or even to subroutines.

More likely, though, you will want to organize the instrument-interface functions into drivers. You can write message-based instrument drivers yourself. You can also purchase them as part of libraries that include drivers for popular instruments. Lastly, you can buy one of the several test-development packages that, among other things, contain tools to assist you in developing and debugging instrument drivers.

If you elect to use the register-based or shared-memory protocols, you change the situation: You now require VXIbus-control software. One way you can get this software is as a part of packages of lower-level support tools that also include instrument-driver libraries. (Examples are NI-VXI from National Instruments and EPConnect from Radisys.) Some test-development packages also include VXIbus-control software.

Although you can directly inter-



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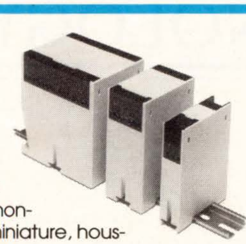

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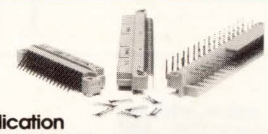

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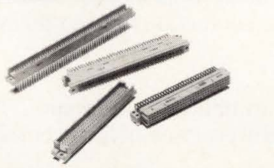

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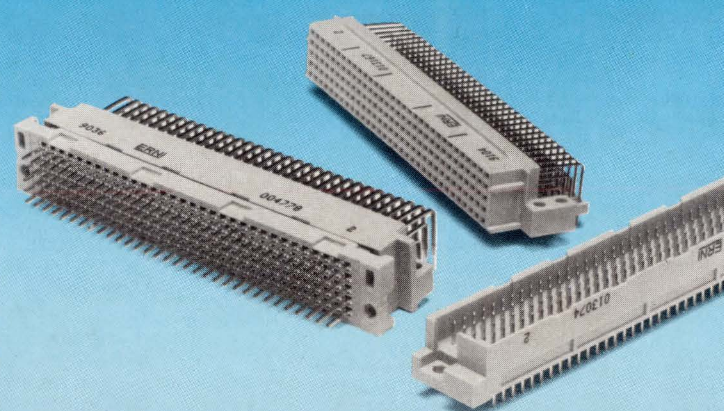

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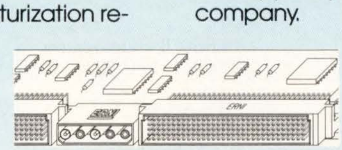

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VXI bus

face test programs to bus-control software, you may be able to simplify your job of writing and debugging programs for a specific application by using a test-development software package. Among other things, most of the packages contain facilities for creating instrument drivers. The best known test-development packages are Hewlett-Packard's ITG and ITG/DOS, National Instruments' Labwindows

For more information . . .

For more information on VXIbus products such as those discussed in this article, circle the appropriate numbers on the Information Retrieval Service card or use EDN's Express Request service. When you contact any of the following manufacturers directly, please let them know you read about them in EDN.

Note: This listing omits those VXI system integrators whose activities are concentrated in military electronics. The directory published in the VXIbus Newsletter (see article text and the listing for Bode Enterprises below) contains information on how to contact such firms.

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and Labview, Tektronix's Tek/TMS, and Wavetek San Diego's Wavetest. ITG is for workstations from HP's 9000 series, Labview is for the Apple Macintosh, and the others are for MS-DOS-based systems.

The test-development packages fall into two groups: The majority interface directly with VXIbus-control software; some actually include the control software. Labwin-

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dows, however, interfaces by way of standard programming languages: C and Basic. The vendor claims that the high-level-language interface produces significant benefits for users—in customizing instrument drivers and in debugging application programs, for example.

Limited options for change

Bear in mind that there is no standard for the interface to the bus-control software. If you pick a particular combination of embedded controller, operating system, and bus-control software, you will have little flexibility to make changes. Furthermore, selecting a test-development package will limit your choice of bus-control software. In most cases, changing the embedded controller or operating system will force you to change the bus-control software. That change will require you to modify your test programs and may very well force you to rethink your choice of a test-development package.

Such pitfalls, as well as the reluctance of a significant group of users to try register-based instruments, could be at the root of a situation that VXI vendors readily admit to. So far, most VXI users—perhaps 90% of them—are developing test programs without the aid of any test-development package. Most test engineers write test programs in high-level languages. C is, of course, a favorite, but in the test world, Basic remains popular.

Moreover, although most of the test-development packages provide tools that can simplify writing instrument drivers, the explicit support the packages provide—in the form of prepackaged drivers for individual VXI modules—is currently limited. That limitation creates yet another pitfall to trap unwary system designers. Once they select a test-development package, they may find that if they choose new instrument modules from companies other than the one that provided the development package, they must either write instrument drivers themselves or turn to consultants.

Some VXI advocates expect to see a small industry develop for supplying instrument drivers. In this scenario, a system developer who needs an instrument driver to use with a specific combination of controller, operating system, VXIbus-control software, and language or test-development package would arrange for a consultant to write it. The consultant would charge approximately the cost, but would reserve the right to sell the driver to other system developers. The consultant's profit would come from the subsequent sales of the driver.

Getting into the driver's seat

Of course, there are instrument drivers and then there are instrument drivers. Some instruments are quite complex, and drivers that support all their functions and modes can occupy hundreds of kilobytes of controller memory. Few applications use all the capabilities of such complex instruments, however; drivers that support only the functions needed by a particular system can be much more compact and easier to develop. If you contract with a consultant to write an instrument driver, and the consultant wants the driver to become a product that he can sell on the open market, the development time can delay your project and you may wind up with a larger and more complex code module than you need.

In MS-DOS systems, large code modules can cause major problems with DOS's 640-kbyte memory limit. Even with an 80386- or i486-based controller, you can't always sidestep such memory problems by placing the drivers in extended memory. If you risk running into a memory limitation, you may have to rule out a general-purpose driver or get your consultant to write the driver in modular form so that you can include only the parts of it your application actually uses.

Keep in mind too, you'll almost inevitably need to make changes. If you purchase instrument drivers from a consultant, make sure that you get the source code or that you have access to tools that let you make changes. (An example of such a tool is the test-development package the consultant used for driver development.) In the absence of the source code or the tools, you can become overly dependent on the consultant.

Sooner or later, VXI users and software vendors will work out streamlined methods to deal with such problems. When those methods exist, VXI will realize its potential for combining expeditious program development with high operating speed. One hardware-based solution has already appeared: Some recently introduced VXI instruments support the register-based protocol as well as message-based communication using SCPI commands. In the future, units will undoubtedly appear that support both message-based and shared-memory operation.

With such instruments, you can quickly get your system running using message-based communication to, say, check out a pilot production run. Then, as production volume and throughput demands increase, you can change critical portions of your program to the register-based or shared-memory modes. You

won't have to rewrite the whole program—only the parts that benefit from faster communication. Several influential VXI advocates see this mixed-mode capability as the way VXI instrument architectures will evolve.

System-level VXI products

Though widely held, the perception that VXI technology is intended for construction of one-of-a-kind or few-of-a-kind test systems is incorrect. Within the last year, three vendors of board-test systems, Genrad, Hewlett-Packard, and Schlumberger, have announced system-level product lines based on VXI technology. In the power-supply test field, several vendors, including Elgar, Intepro, and NH, also have VXI-based system lines.

System vendors point out that, unlike in-house test-development groups that buy modules and put together unique VXI-based testers, customers who buy systems expect heavy-duty applications-development support tools. High on the list of such tools are application-program debugging aids. Happily for the system suppliers, the universe of instruments they offer is limited, whereas in-house test groups can integrate virtually the entire spectrum of VXIbus and VMEbus products into their systems. Restricting the list of module types that a system can contain permits a system vendor to focus on providing a comprehensive tool set.

Not everything that VXI has going for it is technical or economic in nature, though. Users are reassured by VXI's broad industry support and especially by the high level of commitment from the two largest test equipment firms, Hewlett-Packard and Tektronix. With HP and Tek behind VXI, users are convinced that their investment in VXI won't become obsolete any time soon.

Reinforcing the apparent instrument-industry consensus in favor of VXI are statements like one made recently by Keithley Instruments (Cleveland, OH). Keithley was an early member of the VXI consortium, but it publicly took a wait-and-see attitude toward the bus. Keithley now says that you should not be surprised to see it announce

VXI products before the end of 1992. The firm considers more than one of its product lines to be good candidates for the bus.

Broad-based support from well-capitalized companies is something lacking in lower cost alternatives to VXI. Instruments that plug into IBM PCs' ISA bus have been around a lot longer than VXI, and most of them cost considerably less. Although, in general, ISA-based instruments provide lower speed and accuracy than VXI units do, many offer remarkable value. An important difference between ISA-based instruments and VXI is that although vendors of the ISA-based units are more numerous than VXI vendors, most of the ISA-based-instrument companies have annual sales in the tens of millions of dollars; a few have sales in the hundreds of millions and none have sales in the billions.

PCXI doesn't compete with VXI

A leading supplier of PC-based instruments, Rapid Systems (Seattle, WA), has been addressing the problem of making users feel secure in choosing PC-based units. Rapid Systems hit upon the idea of creating a consortium and developing a standard, just as the VXI consortium did. Rapid has dubbed the new standard PCXI (for personal computer extensions for instrumentation). By the time you read this, the PCXI consortium should have ratified a revision of the PCXI standard that encompasses the 32-bit EISA Bus. Nevertheless, Rapid Systems steadfastly refuses to call PCXI an alternative to VXI. Instead, says General Manager Bo Ray, you should think of the two standards as complementary.

In sum, today's outlook for VXI is positive. If you expected that by this time VXI would have revolutionized the test equipment business, you're probably disappointed. But the VXI standard is just four years old. Significant numbers of VXI products have been available for only about two years. Four years into its life, IEEE-488 was no closer than VXI is today to becoming the universal standard it eventually became.

Although the pace of change in electronics is a good deal faster now

UPDATE

VXI bus

than it was in the early eighties, when IEEE-488 was four years old, the parallel with VXI is not perfect. IEEE-488 filled a vacuum; before it appeared, there was no industry standard for communicating with instruments. The early adopters of IEEE-488 had few choices; if they didn't pick the then-new standard, their projects were in serious jeopardy. With the exception of people who absolutely must have VXI's speed, early adopters of VXI do have an alternative in IEEE-488.

What VXI offers to the pioneers who embrace it is a chance to build better systems—smaller, more economical systems with higher throughput and improved timing. You need a bit of courage to abandon a sure thing . . . to risk embarrassment or failure in the hope of making an improvement. But for engineers, that kind of risk taking is the name of the game. EDN

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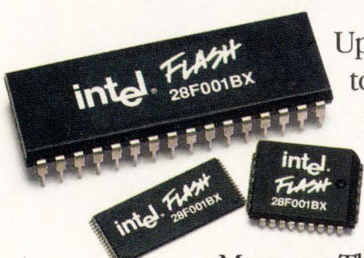

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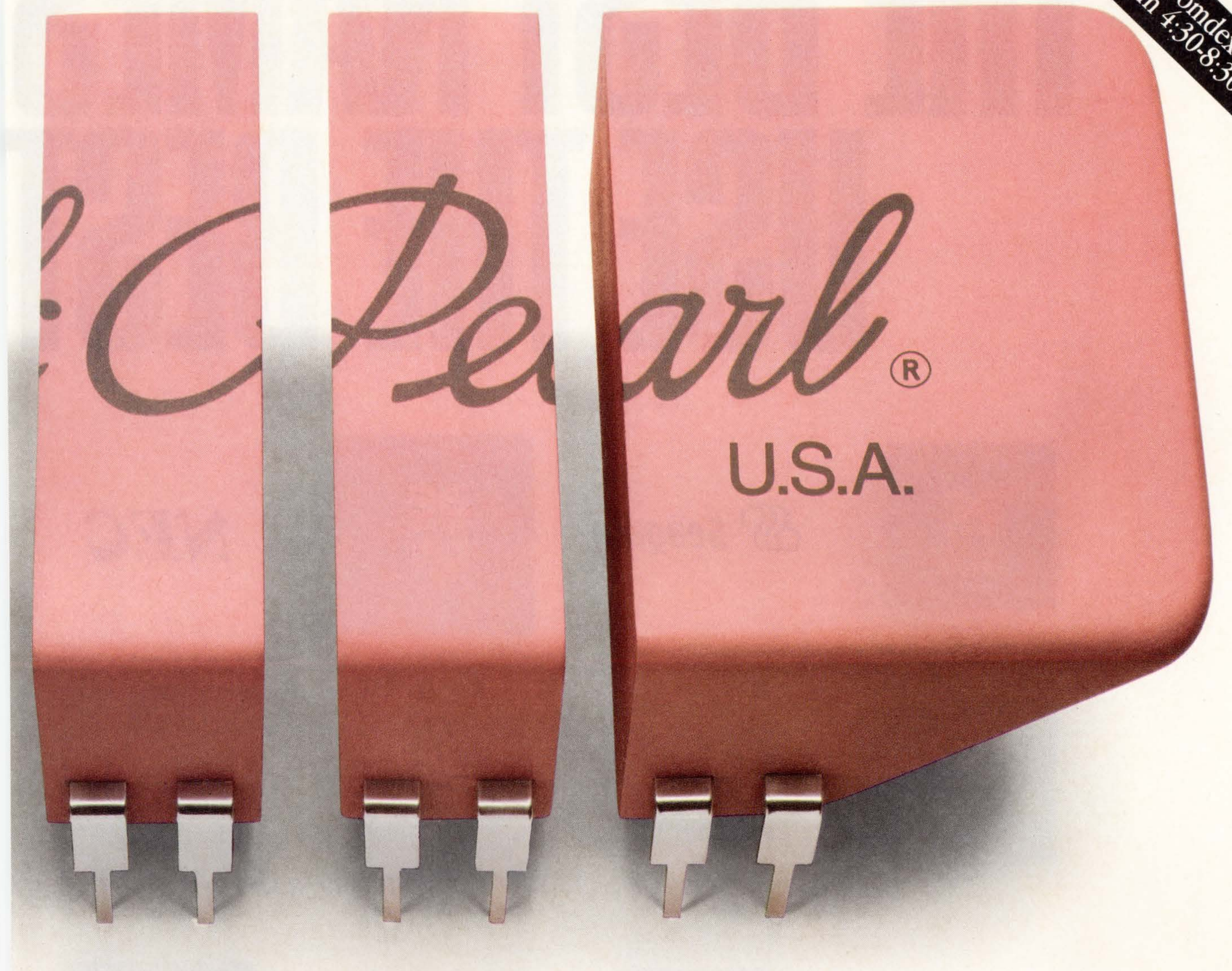

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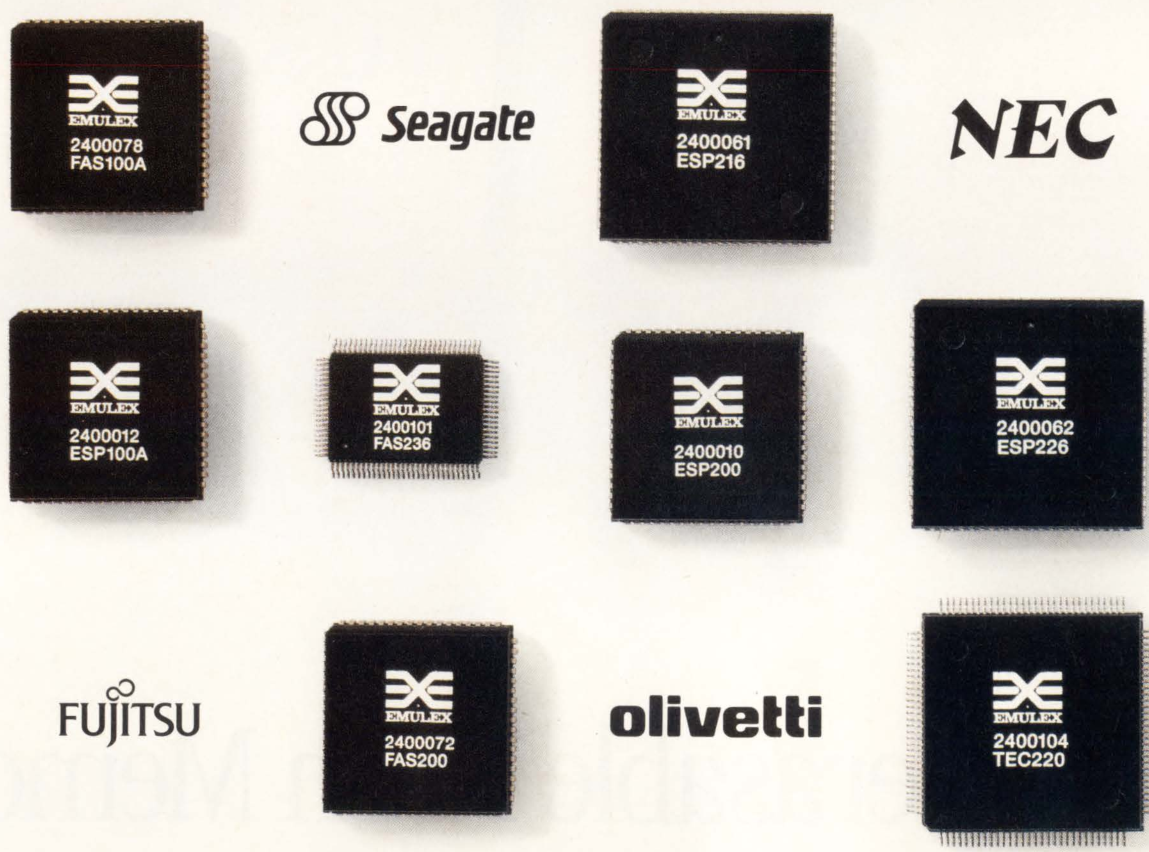

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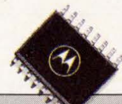

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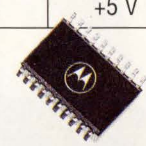

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PC GRAPHICS BOARDS

Boards speed Windows and vie as standards

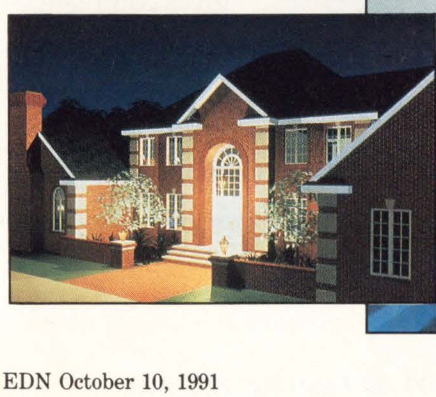
The emergence of Windows 3.0 as a de facto industry standard for PCs means that standard graphics hardware doesn't matter as much as it used to.

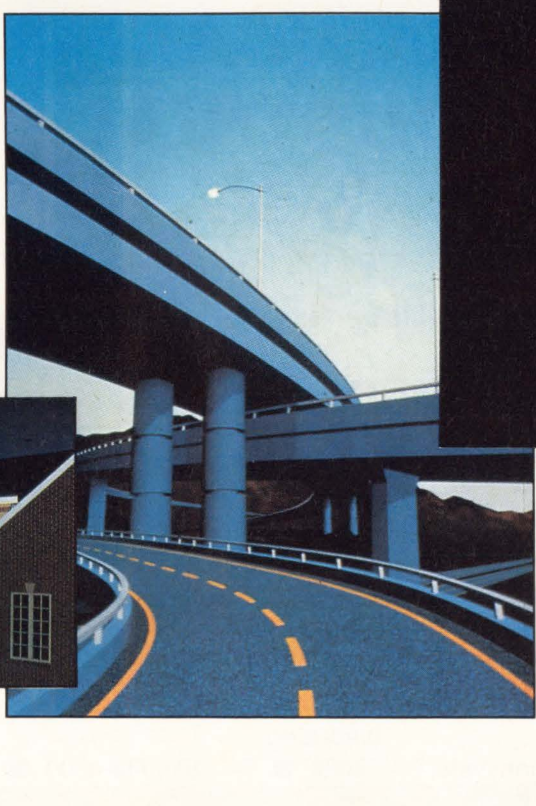
Margery Conner, Contributing Editor

Fall Comdex will showcase the newest trends and the latest confusion in IBM PC graphics. This year's show will be no exception, and the clear trend is the virtually unanimous acceptance of Windows 3.0 as the first de facto graphical-user-interface (GUI) standard for the PC. Because of the processing burden Windows lays on the system processor, Windows accelerator add-in cards will be among the most prevalent new graphics products at the show. Confusion will reign over the future of advanced graphics hardware for the PC, but graphics boards that don't make it as standards might succeed as Windows accelerators.

Windows's acceptance as a standard GUI frees vendors from the tyranny of following standard IBM graphics hardware. In the past, graphics-board vendors had little reason to include enhancements such as hardware zoom and pan and bitblt (bit block transfer) because there was little chance that applications' software drivers would take advantage of the features. The boards were simply too numerous and the drivers too onerous for the application vendors to write.

Now, as long as your application runs under Windows 3.0 and your video board has a Windows driver, your board and the application will be compatible. What you have as a video board or graphics add-in board doesn't much mat-





Contrast these photographs, *which were generated on a Silicon Graphics imaging workstation, with the highest quality graphics you've seen from your PC. Chances are you'll agree that PC graphics still have a ways to go, but based on what you can see at Fall Comdex, the PC's graphics will get there sooner rather than later. (Photos courtesy Wavefront Technologies (Santa Barbara, CA))*

ter as long as the board has a Windows driver. The board vendor optimizes the driver to take full advantage of the board's specific features. For this reason alone, the chances are good that you—if you aren't already—soon will be interested in running even your CAE programs under Windows.

Electronics engineers run a diverse collection of often esoteric programs that have unique and often demanding graphics needs. A standard VGA board is barely acceptable as the graphics adapter for even a low-end CAE workstation.

IBM introduced the VGA and 8514/A boards with its PS/2 line of personal computers. The VGA board enjoyed immediate acceptance. The board has no graphics coprocessing capability and offers little resolution increase compared with the previous EGA standard. But VGA chips were easy for IC companies to clone, so the VGA board quickly became a commodity-priced hardware graphics standard. (In addition, companies improved the resolution and increased the number of colors that VGA boards offered. Versions of these boards may vary from vendor to vendor, but the 1024×768-pixel, 256-color boards are called Super VGA.)

The 8514/A was the first IBM graphics board to have onboard graphics smarts, which made it less easy for the chip vendors to clone. Because the board has only a Micro Channel interface, it didn't work with the vast number of AT bus machines. And because the 8514/A board requires VGA hardware, it is not a stand-alone standard. However, the chip and board companies have adapted the 8514/A for the AT bus, combined it with an onboard VGA chip set, and offer the resulting board as another graphics hardware standard for $500 to $800.

The 8514/A's strengths, such as fast line draws, suited the board for its original purpose: an add-in board that improved graphics for CAD users. However, in IBM's original version, the board's memory-to-memory transfer speed—an important characteristic in any windowing environment—is slow. To overcome this weakness, many of the graphics chip and add-in board companies optimized their versions of the 8514/A board for memory-to-memory transfer and added other features such as hardware zoom.

Part of the uncertainty surrounding the 8514/A's future as a graphics hardware standard stems from concern over IBM's future plans for graphics. Shortly after the 8514/A's introduction, IBM came out with yet another graphics hardware interface, the XGA (extended graphics adapter). Doubt exists as to whether IBM will ever fully implement the 8514/A. However, the momentum of Windows 3.0 as a standard is so strong that most vendors of 8514/A boards are covering their bets by marketing their boards as Windows accelerators.

Jim Anderson, director of strategic marketing at Headland Technology (Fremont, CA), says a board needs three key features to speed Windows. The first is that the graphics hardware use video RAM for the onboard video memory. Because PC-based workstations use fast and powerful system CPUs, graphics processing is limited by either the 8-MHz system I/O bus or the video-memory bandwidth. Using video RAM eliminates the video-memory bottleneck.

The second feature is a 32-bit-wide video-memory bus; the third is onboard hard-wired bitblt capability. Anderson points out that you can get the first two of the three features in high-performance Super VGA boards and claims that these boards cost less than dedicated Windows accelerator boards but speed Windows almost as effectively. Because video RAM costs more than the DRAM (dynamic RAM) used in standard VGA designs, you'll pay about $400 for a video-RAM Super VGA board versus about $150 for a name-brand Super VGA board. Prices for Windows accelerator boards, which have all three key features, start at about $500.

(Keep in mind that these accelerator boards speed graphics displays for existing 386-based systems in which the VGA board is on the system I/O bus. Designers of future systems will be able to gain a speed advantage by putting the VGA board on the processor's

Acronyms used in this article

bitblt—Bit block transfer
CAD—Computer-aided design
CAE—Computer-aided engineering
CPU—Central processing unit
DRAM—Dynamic RAM
EGA—Enhanced graphics adapter
GUI—Graphical user interface
I/O—Input/output
PC—Personal computer
RAM—Random-access memory
SuperVGA—Super video graphics array; 1024×768, 256 colors
VESA—Video Electronics Standards Association
VGA—Video graphics array; 640×480 pixels, 16 colors
WYSIWYG—What you see is what you get
XGA—Extended graphics adapter; 1024×768 pixels, 256 colors; 640×480 pixels, 65,536 colors
8514/A—1024×768 pixels, 256 colors

local bus. For more information, see **box,** "Local-bus VGA boards: Faster for free.")

Windows acceleration encompasses more than just an efficient video-memory interface. Henry Quan, director of marketing at ATI (Ontario, Canada), says that for peak Windows performance, a graphics coprocessor is a must. He is equally emphatic that a hard-wired coprocessor—rather than a programmable processor, such as the Texas Instruments 340x0—is best: "Go with the hardware tailored for the application. As a comparison, would you rather take your car to the neighborhood garage, or to a shop that specializes in your car brand?" Hard-wired coprocessors can have a distinct speed advantage running Windows compared with the 340x0-based boards, but general-purpose coprocessors are often more powerful.

ATI's accelerator boards are based on chip sets that clone the IBM 8514/A board and its proprietary hard-wired graphics coprocessor.

Some vendors tailor their 8514/A boards to enhance specific applications such as desktop publishing. For example, some 8514/A-clone boards feature antialiasing font software, which is necessary for a WYSIWYG display. A 1024-pixel, 14-in. monitor is capable of only 96 dpi; laser printers boast 300 dpi. Antialiasing software makes the screen fonts appear to have the same resolution as the hard copy. Also, Windows pushes the limits of 14-in. monitors in such specifications as refresh rate and resolution and typically runs on a white background, where flicker is most noticeable. You can expect to see 8514/A-based boards with refresh rates well over 70 Hz noninterlaced (the original 8514/A had a refresh rate of 87 Hz interlaced).

Quan, whose company makes 8514/A-type boards, considers the present confusion over the 8514/A's future as a standard to be temporary. "The 8514/A is here today, with a huge installed base of application software," says Quan. "If you wait for XGA, you'll be waiting for almost a year, paying twice as much, and not sure about software support." The 8514/A, he says confidently, will become the next graphics hardware standard for PCs.

Headland Technology's Anderson flatly states that the 8514/A will never make it as a standard. He predicts that the board's value in the short term will be strictly as a Windows accelerator and that by next summer, hardware clones of the XGA board will be available. Anderson is speaking not only from his perspective at Headland, which has bet that video-RAM Super VGA boards will carry users over until the arrival of the XGA clones, but also from his vantage point as chairman of the Video Electronics Standards Association (VESA).

VESA is a consortium of PC-compatible chip and board manufacturers that has been developing a Super VGA standard. Super VGA boards will still not have any on-board processing, but the standard offers greater pixel resolution than does the VGA standard. VESA is also defining the requirements for an XGA standard. Anderson expects the consortium to finalize its XGA specification by this year's Comdex. The first hardware meeting the standard should be available next summer.

Proponents of 340x0-based graphics boards have been indifferent to the arguments over which hardware standard will gain acceptance because boards based on the programmable graphics engine can mimic any hardware standard. With the programmability comes some sacrifice of speed and a price premium: 340x0-based boards generally start at more than $900. Because of their cost, 340x0-based

Local-bus VGA boards: Faster for free

Designers and, ultimately, purchasers of future systems will be able to take advantage of devices such as the HT216 chip from Headland Technologies, which accelerates all VGA graphics—not just the Windows environment—by interfacing the VGA board to the local CPU bus.

Conventional VGA chips—even those physically located on the mother board—interface to the CPU over the system's I/O bus. That bus's 8-MHz speed limits graphics data transfer. So in addition to the processor overhead that Windows adds, the sheer volume of graphical data being transferred makes the I/O bus a prime bottleneck. By interfacing to the local bus, the HT216 can run at the processor's speed, which can be as fast as 33 MHz, and eliminate I/O-bus congestion. The chip's manufacturer claims local-bus VGA boards provide a minimum speed increase of 20% compared with today's fastest VGA boards. Typical speed increases are 200 to 300%.

Also, the chip's price is the same as that of existing VGA chips, so you'll be able to get the performance increase without increasing the cost of your system.

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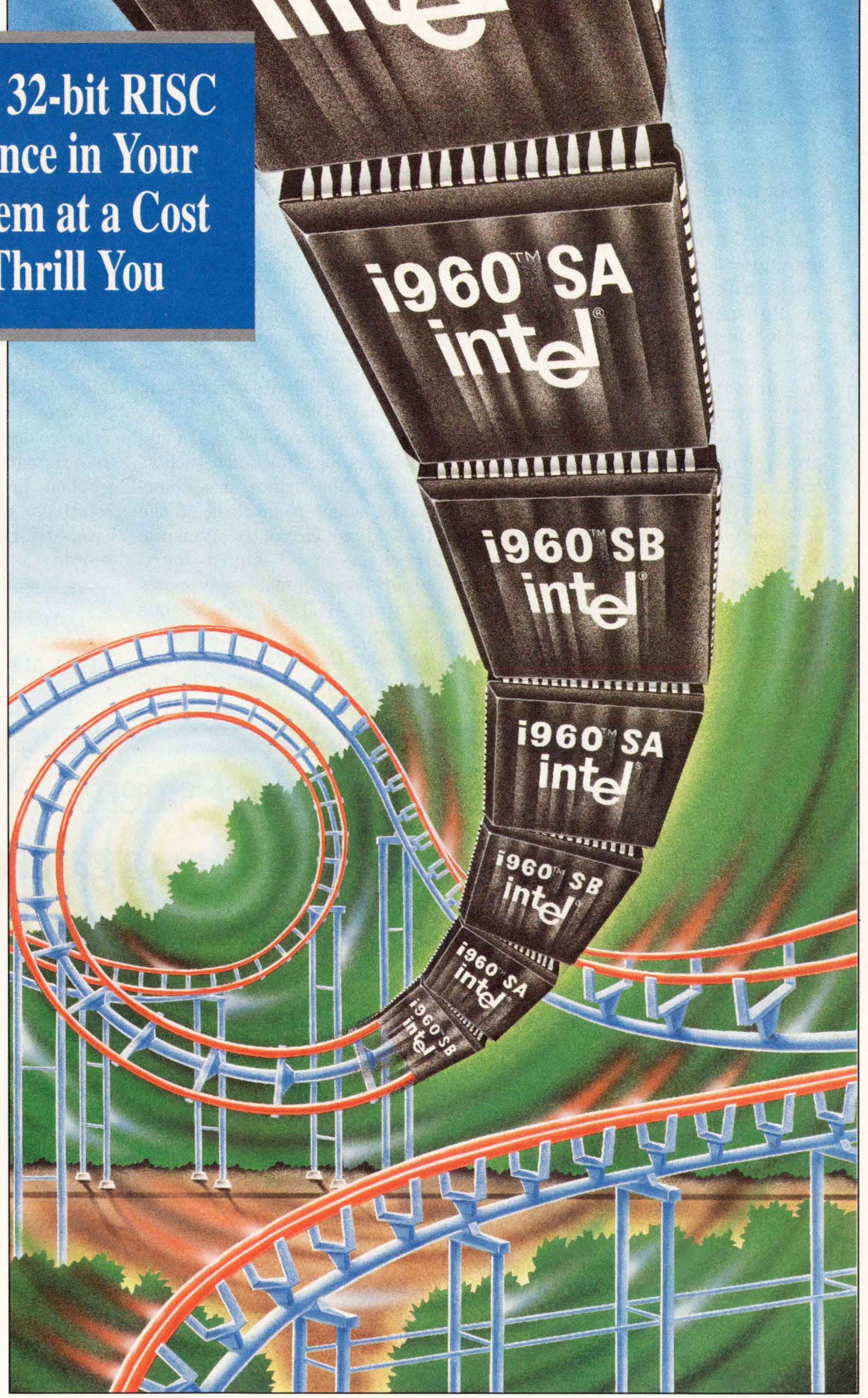

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boards are practical for high-end PC applications, such as CAE/CAD workstations.

Karl Guttag, graphics strategy manager at Texas Instruments, works with designers of a variety of high-end graphics hardware products that incorporate TI's 340x0 graphics processor. He sees the next two to three years as bridging a gap "from what we had in PCs, which was really some pretty klunky graphics, to moving on to hardware that does graphics a lot better with more colors, and then moving on into the imaging world."

A question remains, however, as to whether Windows can support the transition to such a complex graphics environment. Guttag points out that Windows has changed tremendously with each release, "There were pretty radical changes in going from Windows 2.0 to 3.0. For example, it was almost impossible to get beyond 256 colors in 2.0, while in 3.0 you have the ability to go to as many as 32 bits per pixel." Guttag sees this continually evolving nature of Windows as playing to the 340x0's strength in programmability.

ATI's Quan disagrees. He points out that graphics functions, such as bitblts and line draws, are inherently the same regardless of the GUI. And no currently available coprocessor-based board—hard wired or programmable—supports such future GUI features as bus mastering.

Until now, the advances in graphics displays were marked by increases in resolution. Now, inexpensive monitors are reaching their screen-size limits while memory—a requirement for enhanced color—gets cheaper. Graphics PC resolution will likely top out at either 1024×768 or 1280×1024 pixels. Color resolution will soon be a defining characteristic of graphics add-in boards, with 24 bits of color per pixel being a common offering. True color may be the ace in the hole as manufacturers of PC graphics boards seek to position their relatively inexpensive systems as competitors to high-end imaging workstations. EDN

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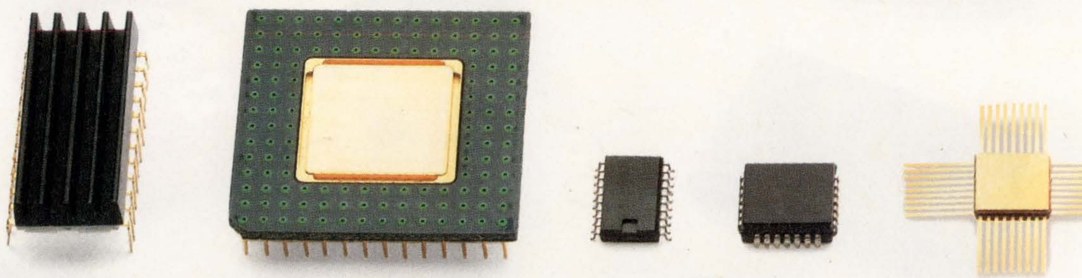

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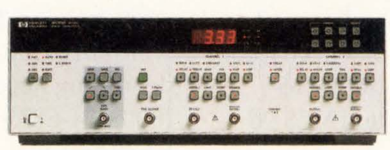

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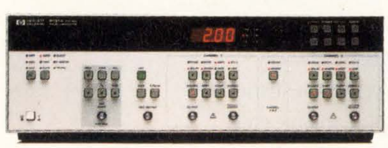

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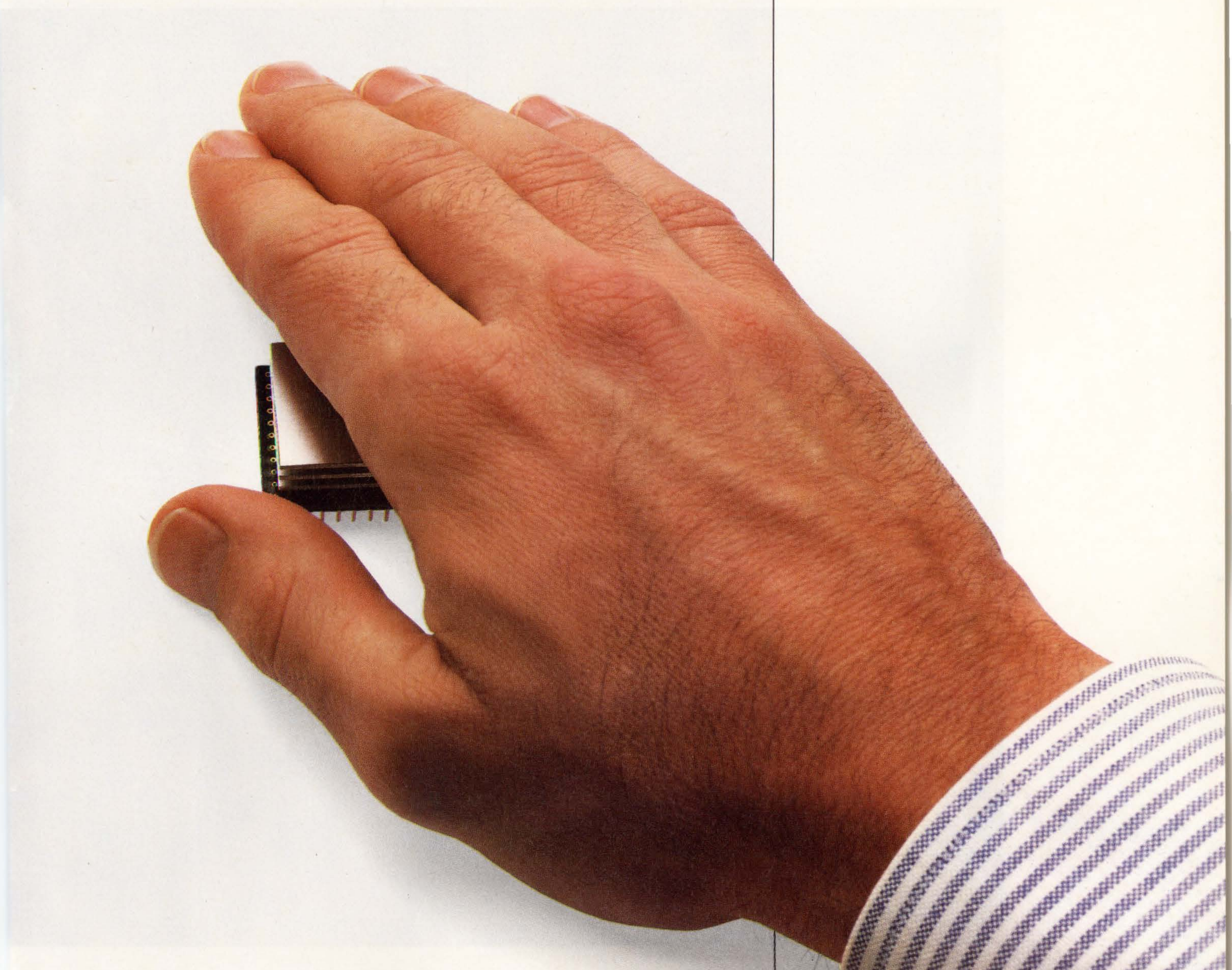

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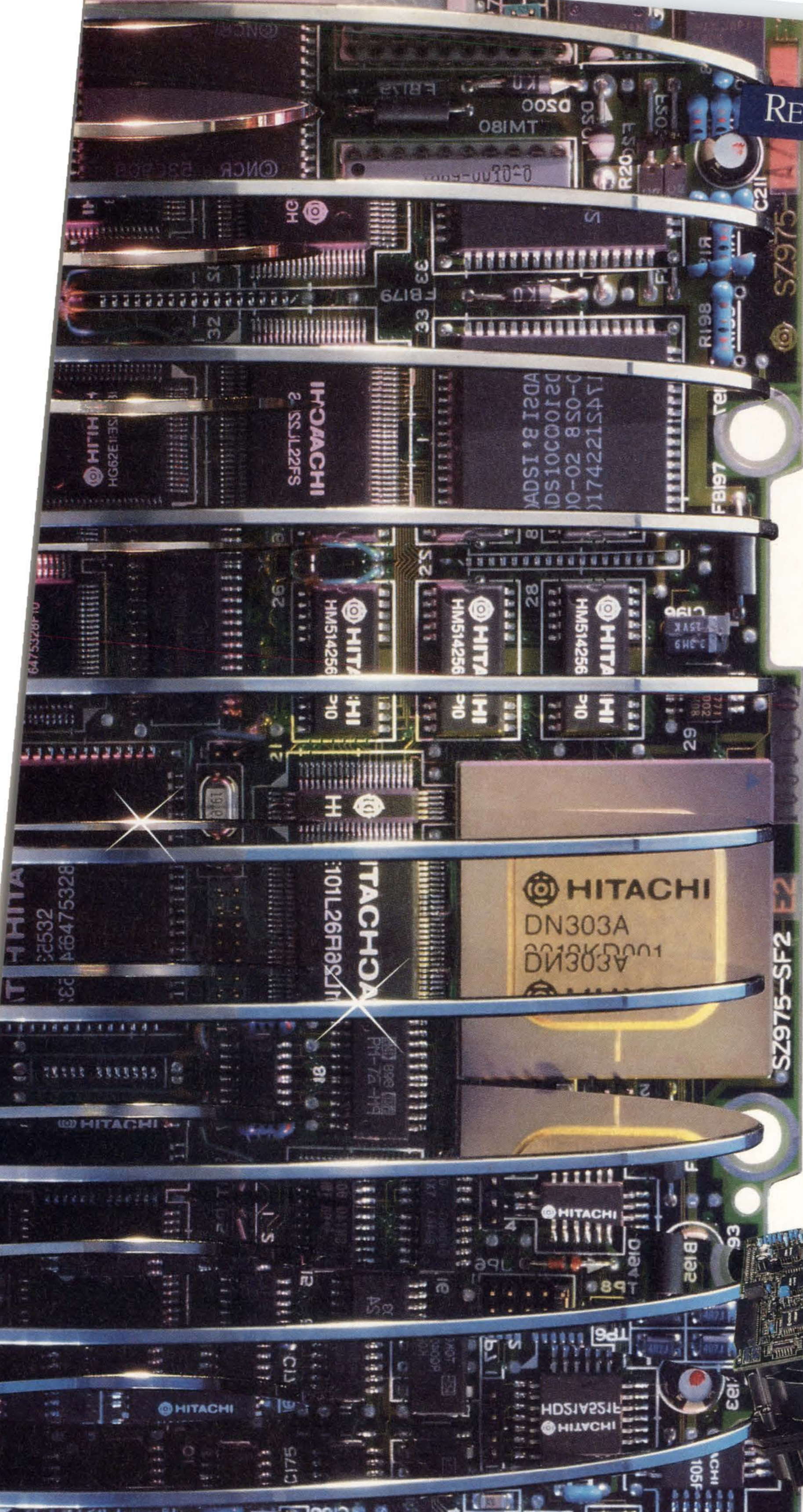
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MASS-STORAGE DEVICES

Price and size shrink while capacity grows

Every year, manufacturers offer smaller mass-storage devices. The move toward smaller peripherals, however, has never been as dramatic as now—1.8-in. hard-disk drives are emerging, and some 3½-in. units can store 1 Gbyte.

Maury Wright,
Regional Editor

As the Comdex Fall extravaganza quickly approaches, there's no question the hot topic of mass-storage devices will be shrinking peripherals. The downsizing theme may sound like same song, 20th verse, but this year you can find examples of smaller floppy-disk, hard-disk, tape, and optical drives. Smaller sizes don't mean less-capable drives though. New 3½-in. Winchesters store more than 1 Gbyte. Helical-scan tape drives offer storage capacities starting at 2 Gbytes. And tiny, 1.8-in. hard-disk drives weigh in at less than 4 oz yet store as much as 40 Mbytes.

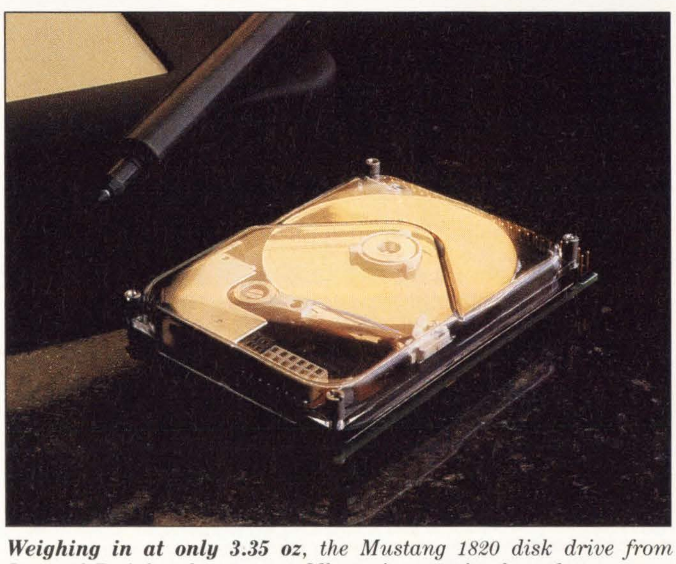
The emergence of portable computers as the fastest-growing segment of the industry provides plenty of motivation for producing smaller peripherals. Customers for portable systems now demand the same levels of capacity, performance, and reliability for portables as they do for their desktop systems. Furthermore, customers have demanded more-compact desktop systems, and slimline desktop-computer design benefits from small drives.

New applications for storage devices also demand smaller peripherals. For example, expect to see on-board navigation systems for automobiles that require one or more types of mass storage, most likely hard-disk drives. And the 2½-in. and smaller disk drives will serve print-spooling and font-storage applications inside laser printers as well. The move to smaller drives makes way for new "stars" in the industry and can breathe second life into some struggling companies while leaving others gasping for air.

Floppy stands ½-in. high

You need not look far to find smaller peripherals. Teac America (Montebello, CA) now offers 3½-in. floppy-disk drives in a 0.5-in.-high package. The company expects to charge about a 15% premium for the low-profile drives compared with its 1-in.-high standard product line. The drives target notebook-computer applications, where system manufacturers are striving to design systems as thin as possible.

However, don't expect to see a move to floppy media smaller than 3½ in. The industry is already struggling with the



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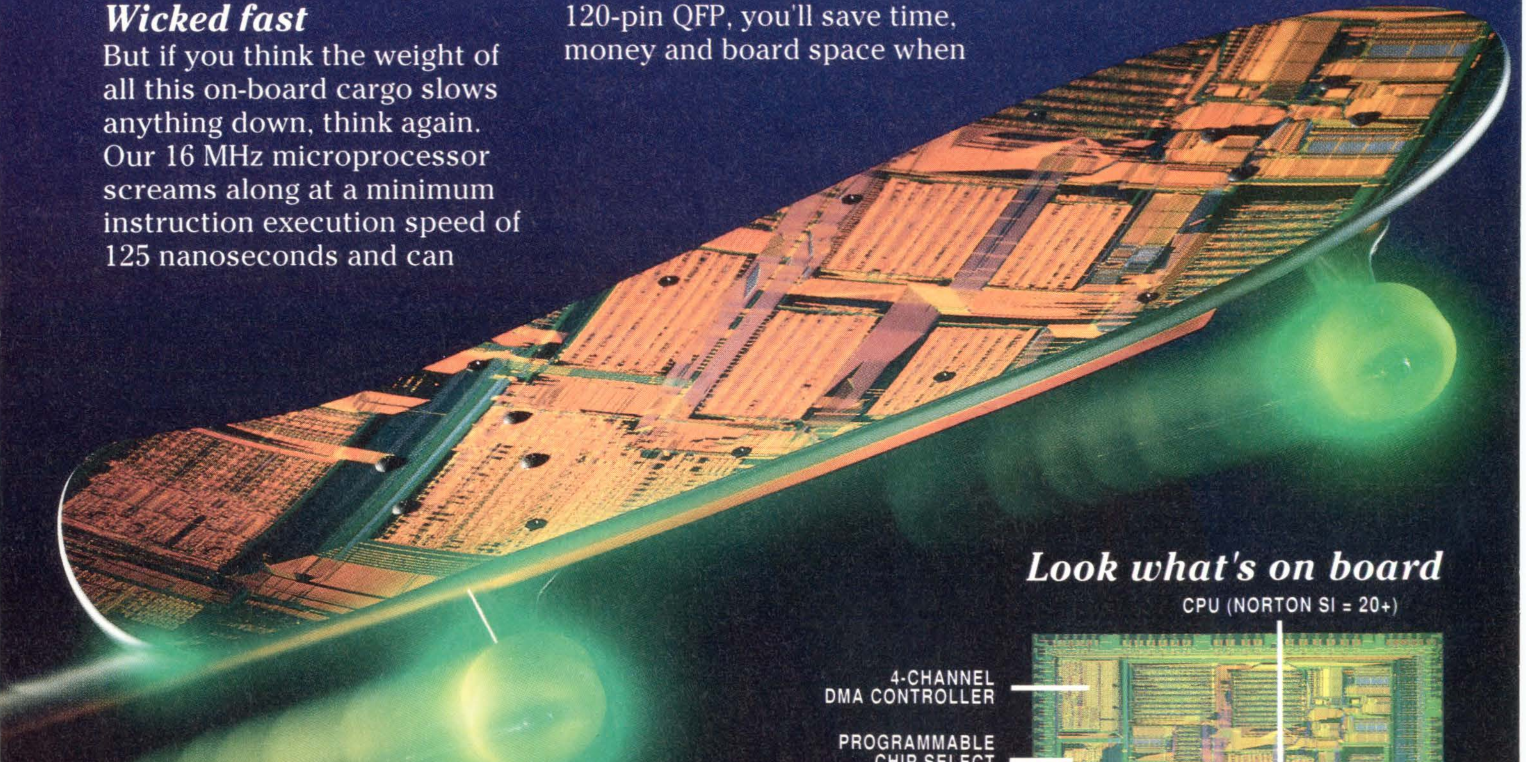

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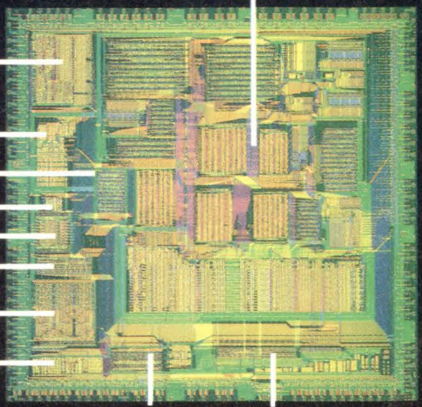

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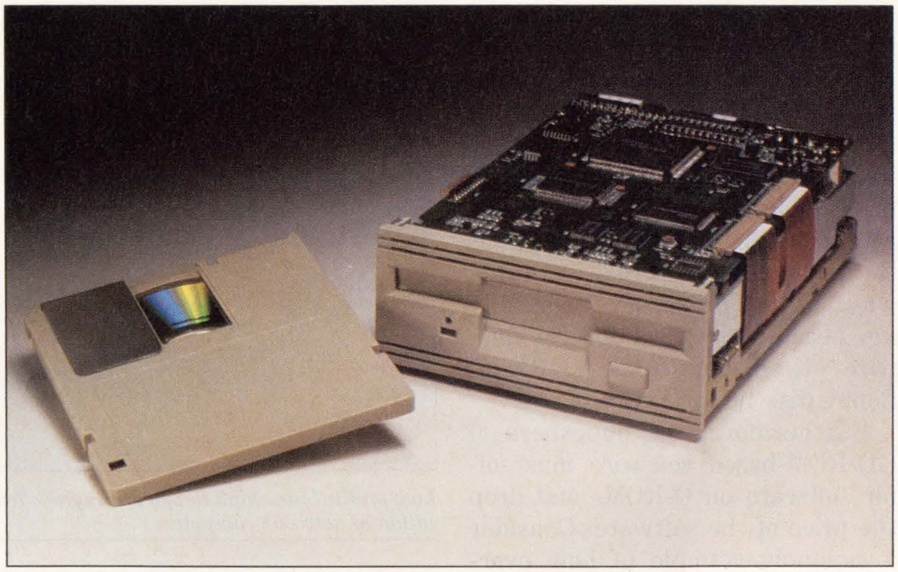
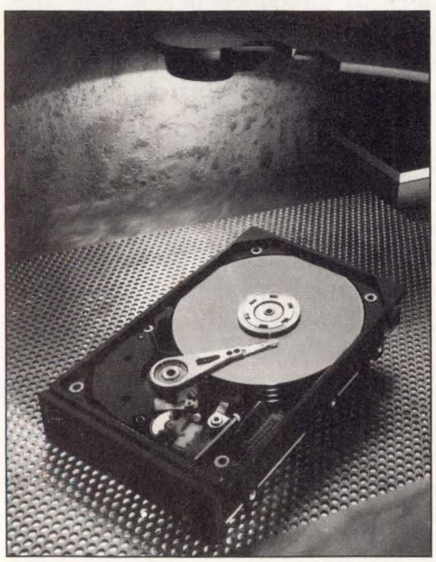
multiple sizes and formats of available floppy drives. System designers that can't live with the 3½-in. floppy will have to do without or use IC-based memory cards for removable storage.

The trend to smaller drives may even mean another chance for optical-drive manufacturers to establish their peripherals in mainstream computing applications. Several factors have hampered the growth of optical drives. The drives don't offer the performance of Winchester drives for primary-storage applications. The drives and media have been 2 to 10 times too expensive for use on the average system. You can partially attribute the high prices of optical drives to the "chicken and the egg" syndrome. Customers won't buy the product until prices drop, and manufacturers can't lower prices until sales volume increases.

Optical products simply come in too many variations of types and sizes. You have to choose between rewritable drives using numerous technologies, WORM (write once, read many) drives, and CD-ROMs. Furthermore, the drives come in



***Compatibility with MO and O-ROM media** allows the OD-3000 3½-in. optical drive from Teac America to serve applications ranging from desktop publishing to software distribution.*



***New 3½-in. form factor, 1-in.-high** disk drives from Seagate Technology offer capacities ranging from 245 to 525 Mbytes.*

form factors ranging from 3½ to 14 in. and comply with a number of different standards for recording formats. Simply put, most of the available optical drives fill niche roles and have high prices associated with niche products.

Last year, 5¼-in. multifunction drives emerged that could work with different types of optical media—for example, drives that can read CD-ROMs and read/write on rewritable media. But manufacturers offer too many different types of drives in the 5¼-in. form factor for a multifunction drive to cover all of the bases.

Small drives focus market

Recently, a number of manufacturers have introduced multifunction drives that use 3½-in. media. The drives use MO (magneto-optical) rewritable technology and store 128 Mbytes on a hard-cased disk that looks similar to a 3½-in. floppy disk. The drives can also read 122-Mbyte O-ROM (optical ROM) disks that perform a function similar to CD-ROMs. Software publishers can produce O-ROM disks cheaply using a stamping process—just like CD-ROM disks. But the O-ROM disks offer an order of magnitude faster seek times than CD-ROMs. The drives can also work with partial-ROM media that combines MO rewritable and O-ROM technology on a single disk.

Late last year, Most Inc (Cypress, CA) introduced the first of these drives, but its entry required a 5¼-in. mounting slot. Over the last three months, Teac America Inc (Montebello, CA), Sony Corp (San Jose, CA), and IBM (Armonk, NY) have introduced drives that fit in the 3½-in. form factor. You can expect to see several more drives introduced this fall.

The drives all include SCSI-2 (Small Computer System Interface) controllers. Performance specs on the products differ. However, the drives typically feature average seek times in the 40- to 50-msec range, and read-channel data rates of about 0.5 Mbytes/sec—about the performance of a Winchester five years ago.

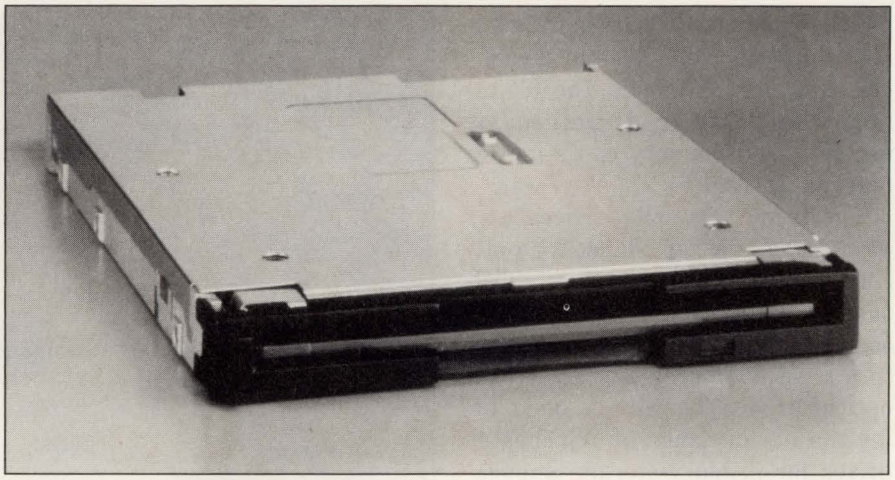
Currently, the price of the 3½-in. optical drives remains well above $1000 for the end user, and MO disks cost $60. Tetsuo Oikawa, manager of Teac's data-storage division, believes that the drives might drop to $500 and the media to $25 in 18 months.

Several variables will determine if vendors of 3½-in. products will make 1992 or 1993 "the year of optical." Prices certainly must drop for the technology to succeed in a big way. Media prices are especially key because users will forever compare MO media to the $1 3½-in. floppy disk lying next to it.

Furthermore, the publishers of CD-ROM-based software must offer software on O-ROMs and drop the price of the software. Consider a common example of how overpriced CD-ROM software can be. You can buy a copy of the *Oxford English Dictionary* for less than $500 at your local bookstore. CD-ROM publishers charge upwards of $1000 for the dictionary even though it cost less to manufacture the CD-ROM version. The cost of audio compact discs—less than $20—gives a good indication of manufacturing cost.

Manufacturers of 3½-in. optical drives have one key advantage that vendors of most new removable storage media don't. Older optical technology has been such an underwhelming success that most customers won't be concerned with moving to a new type of media. Relative to the potential market for 3½-in. optical drives, few users rely on an optical disk drive today.

Tape-drive vendors and customers face the exact opposite situation. For years, tape drives that use the DC-600-style QIC (quarter-inch cartridge) have been the backup devices of choice for systems ranging from high-end PCs to low-end mainframes. But drives that use the DC-600-size cartridge will never fit the 3½-in. form factor. Furthermore, helical-scan drives based on 8-mm video-tape cartridges or 4-mm DAT (digital-audio-tape) cartridges exceed the raw capacity QIC drives offer.



Low-profile ½-in.-high floppy drives *from Teac will play a key role in the further miniaturization of notebook computers.*

System designers and customers alike prefer to buy removable-storage drives that, at a minimum, can read the media produced by the previous year's drives. The customers always want smaller computers and therefore smaller peripherals—especially when the size reduction won't mean decreased capacity. But a move to smaller products often means new, smaller removable media and no compatibility with older products.

Designers that can still use 5¼-in. peripherals have several recently unveiled choices. Archive Technology Inc (Costa Mesa, CA) now offers the Anaconda 2800 family of half-height products that stores 2.1 Gbytes—with no data compression—on a DC-600-size cartridge. The company plans to offer data compression based on compression ICs from Stac Corp (Carlsbad, CA). Typically, data compression doubles tape-drive capacity.

Expect several other QIC vendors to announce drives late this year or early next year. Expect widespread availability next year and a OEM price less than $1000.

Exabyte Corp (Boulder, CO) has finally added a half-height product to its 8200 family of 5¼-in. 8-mm-tape drives. The 8205 features 2.5 Gbytes of raw capacity and includes data compression as a standard feature. The company developed its

Acronyms used in this article

CD-ROM—Compact-disc read-only memory
DAT—Digital audio tape
EPROM—Electrically programmable read-only memory
HDA—Heads and disks assembly
IDE—Integrated drive electronics
LCD—Liquid crystal display
MO—Magneto optical
OEM—Original equipment manufacturer
O-ROM—Optical read-only memory
QIC—Quarter-inch cartridge
SCSI—Small Computer System Interface
VGA—Video graphics array
WORM—Write once, read many

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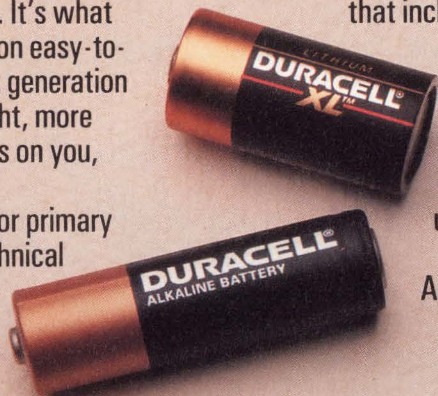

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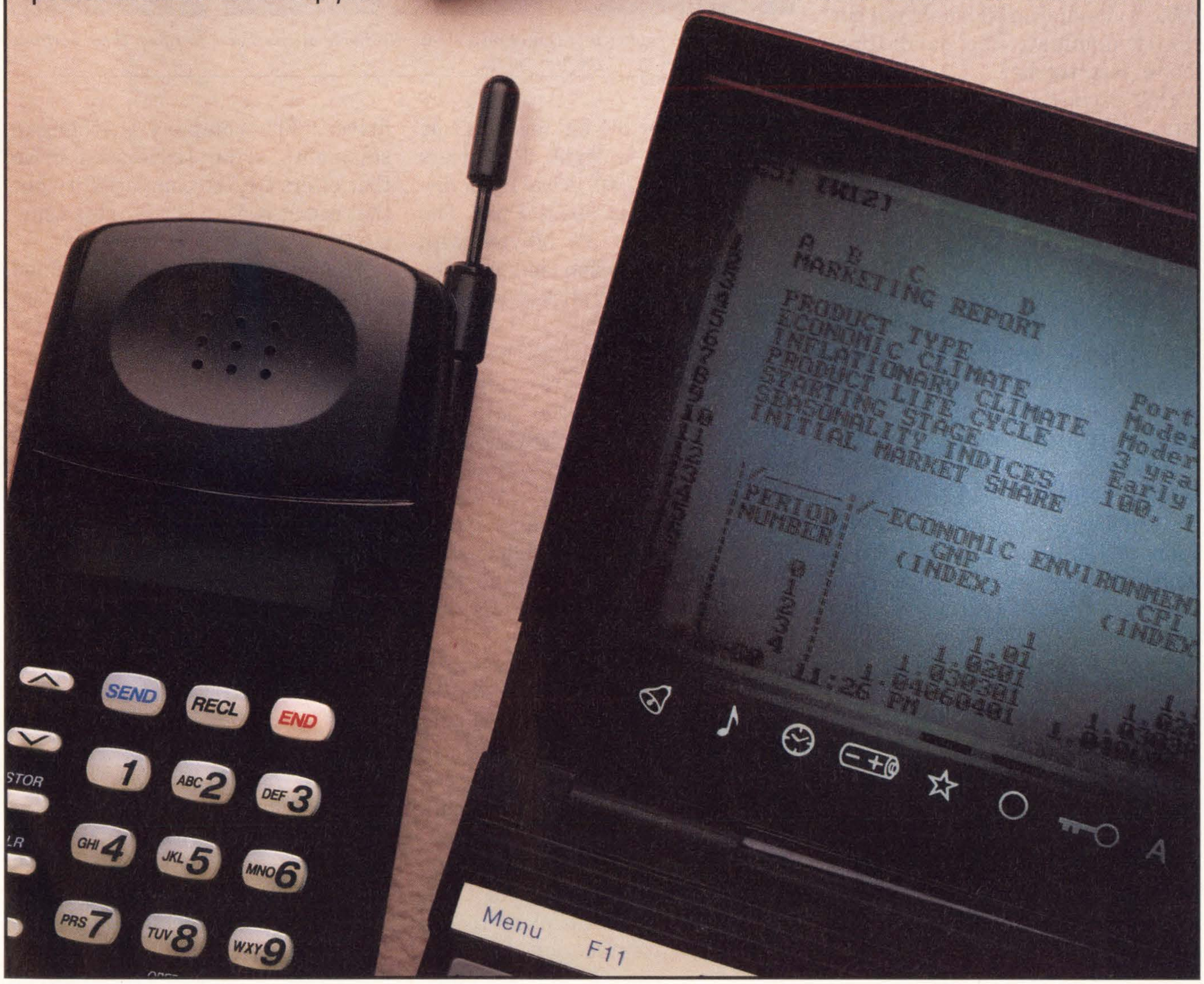

own compression IC based on the IDRC (improved-data-recording-capability) algorithm licensed from IBM. Drive samples will be available in the first quarter of 1992 and will cost less than $2000 in OEM quantities. The company has also added data compression to its 8500 family of products. These drives feature a raw capacity of 5 Gbytes, but they require a full-height mounting slot. Exabyte believes, however, that it can migrate its tape technology to the 3½-in. size in the next two to three years.

An increasing number of system vendors will change to the 3½-in. form factor this year, however. Already, DAT drives and QIC DC-2000-style minicartridge drives currently dominate the small-form-factor tape market.

DAT products that store 2 Gbytes with no compression have been available in the smaller size for a year now. Companies that offer such products include Ardat Inc (Costa Mesa, CA), Hewlett-Packard CO (Cupertino, CA), R-Byte Inc (San Jose, CA), Sony Corp, WangDAT Inc (Irvine, CA), and Wangtek Inc (Simi Valley, CA). DAT drives should be the fastest growing segment of the tape industry over the next year.

***The 85-Mbyte capacity** of Quantum's 2½-in. Go-Drive allows users to equip their portable with the storage of a typical desktop.*

Loader handles DAT cartridge

Cartridge loader mechanisms will soon be dominating DAT news. WangDAT, for example, has demonstrated a loader that holds a DAT drive and four DAT cartridges, yet fits in the standard 5¼-in. full-height form factor. Expect similar products from the other drive manufacturers. And look for DAT drives with 5-Gbyte raw capacity by the Fall of 1992.

Meanwhile, minicartridge drives have become the tape drive of choice in single-user PCs, although less than 10% of such PCs include tape drives. The minicartridge drives fit the 3½-in. form factor, and the price is right. End users can buy a QIC-80 drive from discount houses for about $300. The drives can store 120 Mbytes with no data compression and use the computer's floppy-disk-drive controller as an interface.

The QIC committee that sets standards for such drives has defined two new upgrade paths for minicartridge drives. QIC-385 defines a drive that uses a choice of the floppy interface or the IDE (integrated-drive-electronics) interface now popular on hard drives for PCs. Drives that meet the new standard will store 385 Mbytes with no data compression.

Expect Colorado Memory Systems (Loveland, CO) and Ardat to offer QIC-385 drives with floppy interfaces. Ed Harper, president of Colorado Memory Systems, believes the company will ship such a product in the first half of 1992. Summit Memory Systems Inc (Scotts Valley, CA), the old OEM division of Mountain, plans to use the IDE interface on QIC-385 drives. The company just began shipments of an IDE-based drive that offers QIC-80 compatibility but that can also store 305 Mbytes using a proprietary format.

The QIC committee also defined a QIC-410 class of drives that uses the SCSI interface and stores 410 Mbytes. QIC-410 drives use more expensive heads than do QIC-385 products and therefore won't be price competitive. But the QIC-410 products will transfer data faster and feature a more-sophisticated error-correction scheme. Expect the QIC-410 drives to find applications in file servers and workstations that already include SCSI.

Teac America appears to be the leading advocate of QIC-410. The company has a 155-Mbyte drive, the MT-01, available now with a SCSI interface. Teac has proposed that the QIC committee adopt the format used in the MT-01 as downward-compatible with the QIC-410. Teac also plans to build QIC-410 drives. The MT-01 offers yet another feature—the 3½-in. drive stands only 1-in. high. The drive is

the first tape product to match the low-profile size that is increasingly popular in disk drives.

Manufacturers of Winchester disk drives have a huge advantage compared with the other types of mass storage—the media is nonremovable. Therefore, system designers can move to smaller sizes with no regard for what they used the year before. Never before has the industry seen such a dramatic move to smaller drives as it will this year.

***With models ranging from 20 to 85 Mbytes**, Conner Peripherals holds a dominant market position in 2½-in. drives.*

Small drives store 1 Gbyte

A number of companies have developed 5¼-in. drives that store 2 Gbytes. Don't expect those products to draw rave reviews though. In the past three months, IBM, Toshiba (Irvine, CA), Seagate Technology (Scotts Valley, CA), and Micropolis (Chatsworth, CA) all introduced 1-Gbyte 3½-in. products. One year ago, you couldn't buy 400-Mbyte 3½-in. drives. But indications are that the 1-Gbyte units will be available in volume just after the first of the year.

Seagate followed with announcements of 1-in.-high 3½-in. drives in unprecedented capacities. The company now offers the ST3283 (245 Mbytes), the ST3500 (426 Mbytes), and the ST3600 (525 Mbytes) in the low-profile package. Prices range from $700 to $1795 for evaluation drives available now. Expect production quantities to be available around the end of the year. You can expect to see competing products from Quantum Corp (Milpitas, CA), Conner Peripherals (San Jose, CA), and Western Digital (Irvine, CA).

Except in mainframe and some server applications, 3½-in. drives have replaced 5¼-in. units as the drive of choice. The question remains whether 3½-in. drives will be relegated to a niche as capacity ramps up in 2½-in. drives.

Richard Freedland, president of Helios Inc (Sunnyvale, CA), has a informed perspective on the downsizing issues because his company builds servo writers for disk-drive manufacturers. Freedland reports that the moves from 14- to 8- to 5¼- to 3½-in. form factors provided drive designers with as many advantages as it did new challenges. For example, smaller platters meant less mass and therefore simpler, lower-power motors.

Freedland believes two key areas will make it tough for 2½-in. drives to achieve the reliability and price-per-Mbyte levels that 3½-in. drives offer. Freedland points out that the castings used as the HDA (heads-and-disks-assembly) enclosure on 2½-in. drives will be less structurally sound. In fact, companies are using more plastics to lower HDA weight. Furthermore, Freedland believes that imperfections in ball bearings result in bearing runout specs that are a significant percentage of the innermost track diameter in 2½-in. and smaller drives.

Freedland readily admits, however, that the disk-drive industry often works miracles over 1- to 2-year periods, and that anything is possible. The 3½-in. size does seem to suit system vendors for desktop applications however. Maurice Webb, global commodity manager at Sun Microsystems (Mountain View, CA), reports that Sun's primary interest is lower prices for 3½-in. and smaller drives, not smaller size. Webb points out that each succeeding smaller form factor has produced lower cost drives in the same capacities than did the preceding larger form factor.

Leading 2½-in. drive vendor Conner Peripherals simply claims it will supply the drives the customer demands. The company also has a strong presence in 3½-in. drives. Other companies that seek to build market share in the 2½-in. arena include Areal Technology Inc (San Jose, CA), JVC (Huntington Beach, CA), Quantum, Seagate, Toshiba, and Western Digital. All of the com-

panies except Areal and JVC also offer 3½-in. drives.

Conner's 85-Mbyte drives currently lead the pack in terms of capacity. Areal, however, just announced a 120-Mbyte drive. You can also expect Maxtor (San Jose, CA) to introduce a 2½-in. drive with leading-edge capacity shortly.

In all likelihood, not all of the companies with 2½-in. drives will succeed unless the small drives can compete with 3½-in. drives' prices and reliability. Thus far, the vendors shipping drives find eager customers because of the demand for notebook computers. Furthermore, the price of notebook systems allows drive vendors to make a nice profit margin on the drives. Once enough vendors ramp-up production, selling drives will become more of a challenge.

One 2½-in. drive specialist has already fallen. Prairietek (Longmont, CO) was the first to announce and ship drives. In fact, the company had the market for 20-Mbyte 2½-in. drives to itself for a year. But problems with higher-capacity versions and price pressures recently lead the company to file for bankruptcy with the intention of dissolving.

Drives hit 1.8-in.

Just as 2½-in. drives celebrate a second birthday, you can buy one of the next-generation 1.8-in. drives. Start-up Integral Peripherals (Boulder, CO) has begun shipping 20-Mbyte units and plans to have 40-Mbyte drives in production by mid-1992. The drives measure $2\times3.03\times0.59$ in., and the 20-Mbyte 1820 weighs 3.35 oz. You also get state-of-the-art performance with the drives—a less than 20-msec average seek time and a 32-kbyte buffer.

Steven Volk, president of Integral, believes that the drives will be a key enabling technology for a new class of small computers called subnotebooks. Volk believes you will see 80386-based subnotebooks introduced shortly that use the 1.8-in. drives, include a full keyboard and a VGA LCD display, and weigh 2 to 3 lbs. Volk also believes the drives can be used in palmtop and pen-based systems. The 1820 drive requires 3.5W of power to spin up, only 2W during read/write operations, and only 0.015W in sleep mode. Therefore, you could power the drive with disposable batteries.

Some prognosticators have mentioned flash EPROM or battery-backed RAM as competition for the 1.8-in. drives. Volk points out that the disk drive will have a substantial cost advantage. He believes that Integral's disk drives will sell for $10 to $11 per Mbyte by next summer. But he sees flash EPROM costing at least $45 per Mbyte in the same time frame. Finally, Volk believes that Integral will ship a 100-Mbyte 2½-in. drive within two to three years.

Integral will have company in the market shortly. Another startup, Minister (San Jose, CA), has a drive ready for introduction. Also, industry stalwarts such as Conner, IBM, Quantum, and Western Digital all belong to an industry organization that set the size and mounting-hole standards for the 1.8-in. drives. And yes, the organization is looking to define a smaller form factor—1¼-in. EDN

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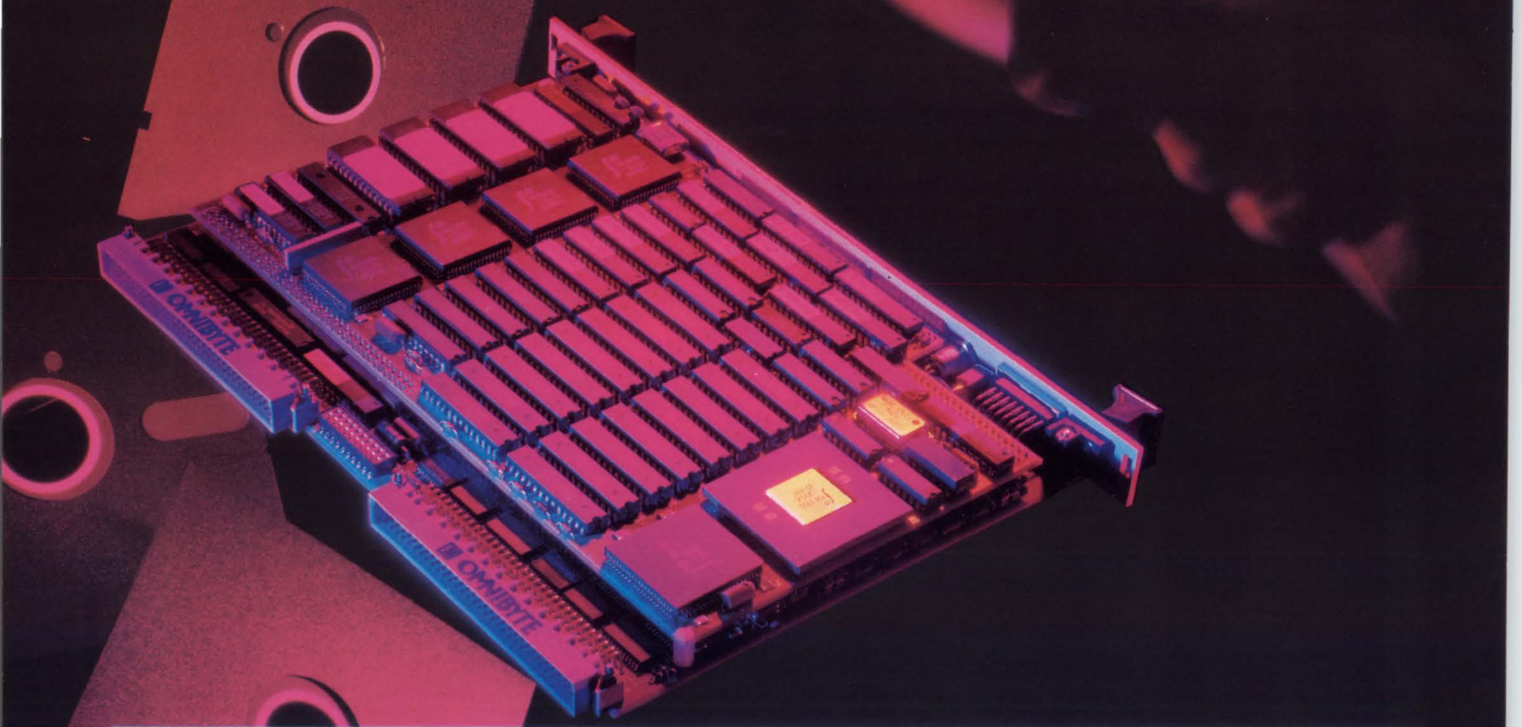

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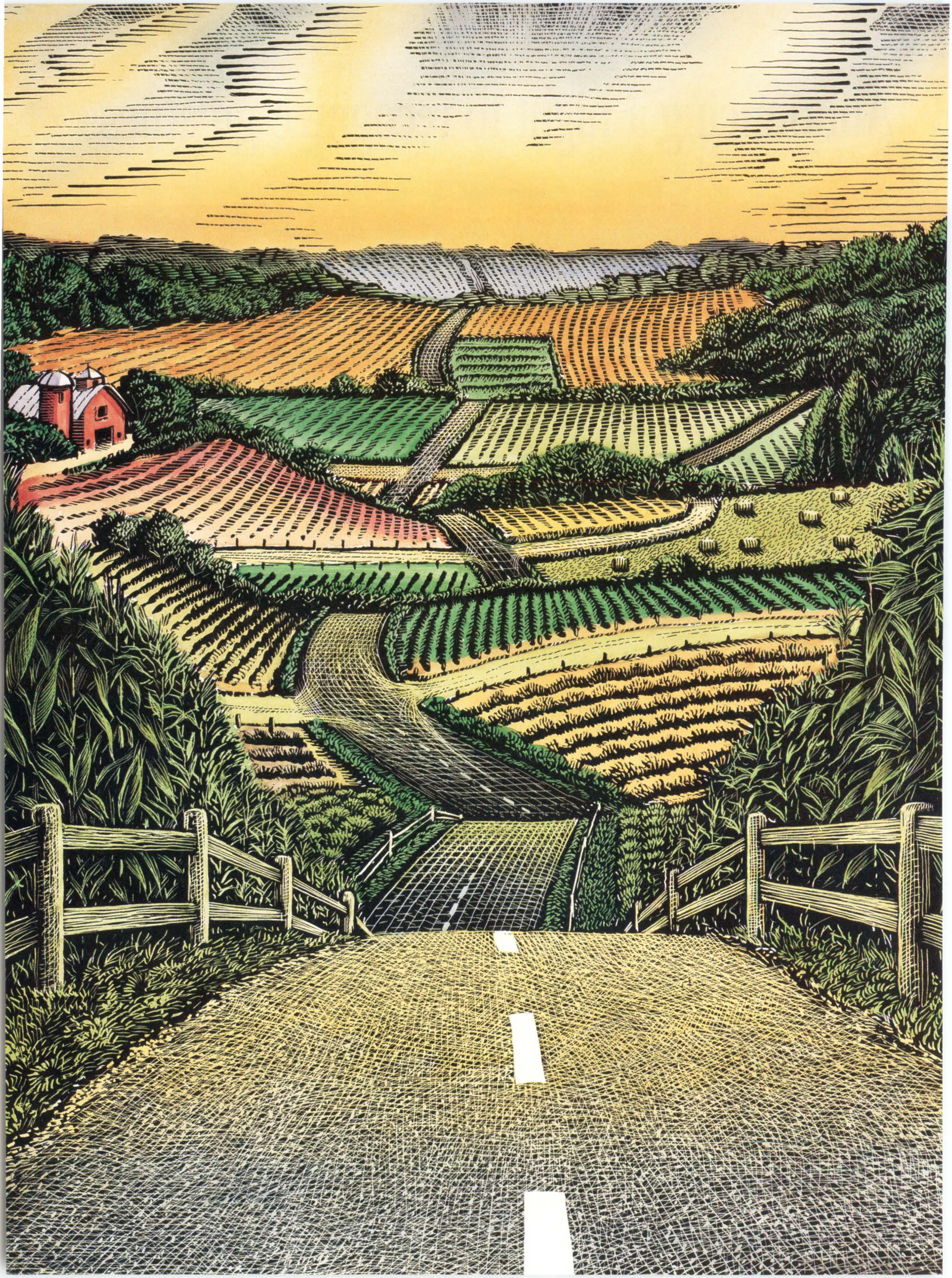
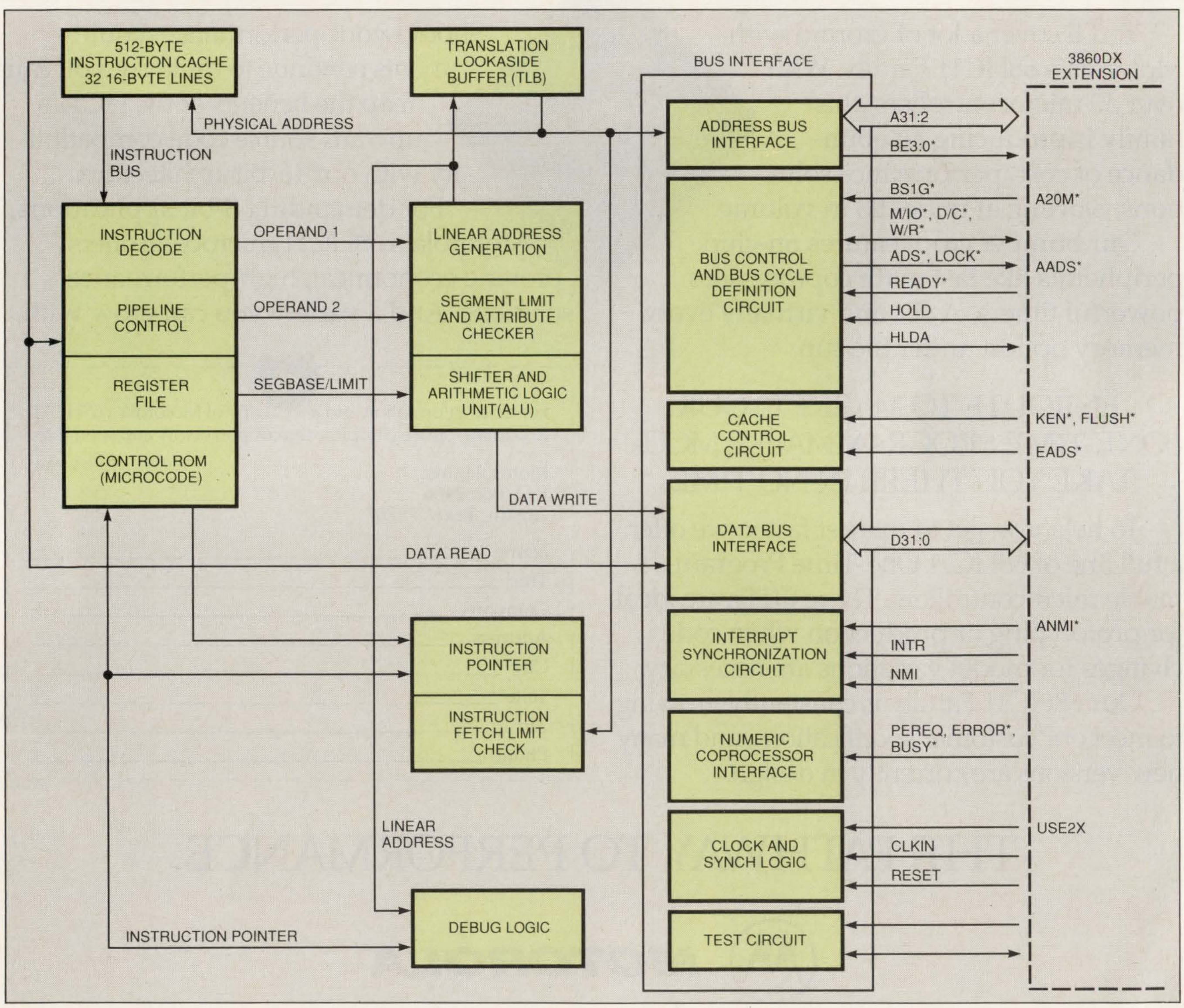


x86-compatible CPUs' supervisory layer lets you customize PC designs

One problem that plagues PC manufacturers is differentiating their computers based on something other than price. Although previously not a supplier of CPUs, Chips and Technologies has developed the x86-compatible family of μPs. This family includes a hardware and software layer, operating between the CPU hardware and the system BIOS, which allows you to customize your PC designs. Called Superstate, this OEM-programmed layer can intercept I/O and interrupts, perform power management functions, and arbitrate between two incompatible operating systems running on the same CPU.

Superstate is available embedded within the company's 8680,



Acting as a layer between the system hardware and BIOS, *Superstate can intercept interrupts and I/O calls.*

38605SX, and 38605DX µPs. The $35 (10,000) 8680 is source-code compatible to the Intel 8086 in a 160-pin plastic flatpack. The chip adds a CGA-compatible flat-panel and CRT controller, keyboard interface, direct IC-card interface, 16C450-compatible UART, PC-XT-system peripheral logic, and a serial port to the core CPU. This single-chip XT offers a 64-Mbyte memory map as a result of its 26-bit address. A 4-stage pipeline improves system throughput by reducing instruction latency.

In addition to the Superstate capability, the 132-pin 38605SX ($110 (1000) for the 25-MHz device) and the 144-pin 38605DX ($215 (1000) for the 40-MHz device) contain a 512-byte direct-mapped instruction cache as an enhancement to Intel's 80386SX and 80386DX. Adding these capabilities costs these devices pin compatibility with the existing µPs; the $90 (1000) 38600SX and $180 (1000) 38600DX retain pin-compatibility at the expense of Superstate and the internal cache. A 176-pin socket accommodates any of the four µPs, attaining maximum design flexibility and lowest inventory cost. Even though all implementations contain a 5-stage pipeline to improve performance, the I-cache on the 605 chip is better at keeping the pipe full.

Operating transparently to the user and the application, Superstate can monitor and trap hardware and software interrupts before TSRs (terminate-stay-resident) or interrupt handlers see the input. Trapped, Superstate's microcoded software can cause register-value substitution or interrupt-handler emulation. Such capability allows the system to translate data from incompatible peripherals or to operate with "virtual" peripherals.

You can also program the Superstate hardware—via control registers protected from application-generated I/O and memory instructions—to monitor system activity. Global monitoring allows the hardware and software layer to power-down peripheral devices if they aren't used by the system for a programmable amount of time. Furthermore, since the hardware shadows the port, Superstate can intercept operating-system monitoring routines and make the peripheral appear to be on.

Additional features within Superstate allow a trace-buffer capability that enables programmers to trace back breakpoint bugs. One function of this capability is to indicate when an instruction's execution has been completed—ensuring that marketing engineers can provide accurate instructions-per-cycle benchmark data.—***Michael C Markowitz***

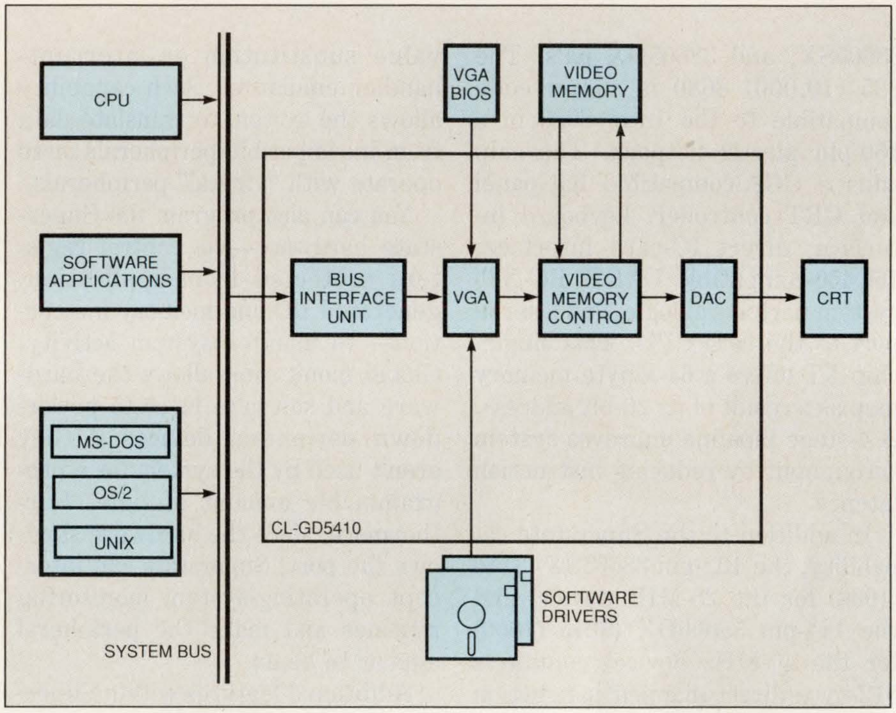
Chips and Technologies Inc, 3050 Zanker Rd, San Jose, CA 95134. Phone (408) 434-0600. FAX (408) 943-9315.

Circle No. 697

VGA controller IC provides RAMDAC and bus interface on chip

The CL-GD5410 VGA controller IC integrates RAMDAC and bus-interface circuits and supports color and monochrome display applications. In fact, you can build a minimally configured 3-chip graphics card using the VGA IC and two dynamic RAMs (DRAMs). The high level of integration makes the IC ideal for use on low-cost VGA cards or in mother-board VGA applications. The IC also provides super VGA resolutions, such as 1024×768 pixels.

Fig 1 depicts the VGA IC used in a typical VGA application. Designs only require video memory, a BIOS, and a crystal (not shown) in addition to the VGA IC to implement a complete controller. You can also combine the VGA BIOS with the system BIOS to further reduce chip count.



Two DRAMS and the VGA chip *can implement a complete VGA controller in mother-board applications that use the CL-GD5410 VGA IC with an integrated RAMDAC and bus interface.*

The IC has a dual-frequency synthesizer that provides separate clock signals to handle CRT and memory timing. The video-memory circuitry can handle your choice of 256k×4-, 256k×16-, and 512k×8-bit DRAMs. Furthermore, the memory-control circuitry can work with as much as 1 Mbyte of memory with no jumpers or switches. You can use page-mode DRAMs with the chip to lower memory cost without affecting performance.

The RAMDAC supports the VGA-industry-standard 256 colors. Designs can bypass the RAMDAC's on-chip color look-up table and use 15- or 16-bit-per-pixel true-color mode to display 32k or 64k simultaneous colors. You can use the IC with an external RAMDAC to produce even more colors.

VGA designs that use the IC offer standard 640×480-pixel resolution. The IC can also drive a display with 800×600-pixel resolution and support 64k colors. Finally, the controller can handle 1024×768-pixel displays in interlaced and noninterlaced mode and display as many as 256 colors. The IC also has on-chip support for a VGA pass-through connector.

The bus interface circuits in the VGA chip can connect directly to ISA, EISA, and Micro Channel Architecture system buses. You can use the IC with an 8- or 16-bit host bus. The bus interface can operate at speeds as fast as 12.5 MHz.

Samples of the $25 (1000) IC are available. Expect production quantities in the first quarter of 1992. The company also plans to offer a demonstration kit that includes a working board as an example of how to use the IC. The kit also has evaluation software drivers and BIOS. —***Maury Wright***

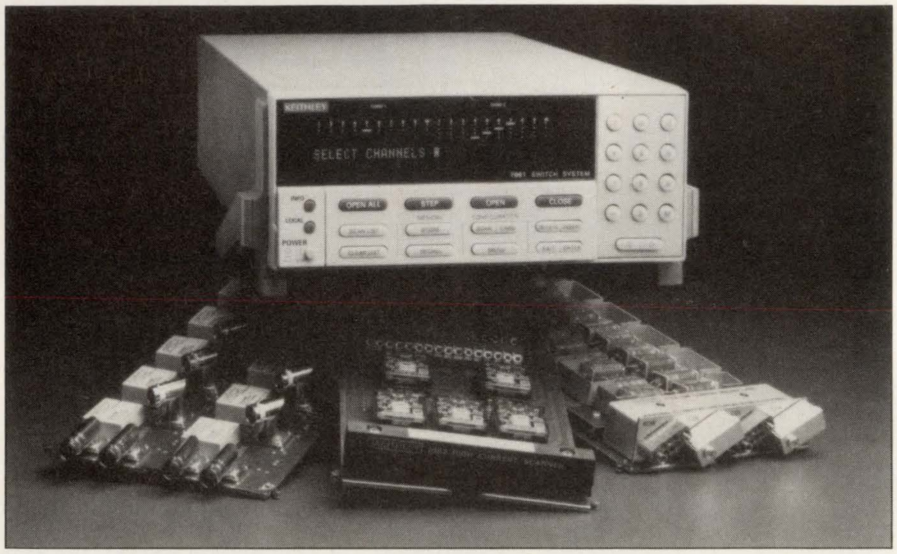
Cirrus Logic Inc, 3100 W Warren Ave, Fremont, CA 94538. Phone (415) 623-8300. FAX (415) 226-2240.

Circle No. 698

Switching mainframe minimizes wiring and ensures signal integrity

According to the vendor, the Model 7001 mainframe provides the highest density switching of any half-rack mainframe in the test and measurement market. It can handle as many as 80 channels of 2-pole switching, and it simplifies system setup. The mainframe has two slots that can accommodate any of 33 cards for switching capabilities from 30 nV to 1.3 kV, 10 fA to 5A, and dc to 500 MHz.

A vacuum-fluorescent, front-panel status display lets you simultaneously observe the open/closed positions of every channel in your system. Three switching cards provide the mainframe with configuration data. By allowing you to check card configuration and channel status at a glance, the mainframe simplifies system programming, modifying, and debugging. The display also provides error messages, help, setup, and configuration prompts.



Using a vacuum-fluorescent front-panel display that shows the status of all channels simultaneously, *the Model 7001 2-slot switching mainframe handles as many as 80 channels of 2-pole switching.*

You can program and control switching via the mainframe's IEEE-488 bus, or you can eliminate the computer and control channel spacing, scan spacing, and the number of scans directly by using pushbuttons located on the front panel. You have access to 100 nonvolatile memory locations for storing switch patterns and ten additional nonvolatile memory locations for storing instrument setup data. This device can also scan as many as 200 channels/sec.

A built-in Trigger-Link provides six trigger lines that you can access via a rear-panel DIN connector. Each line is programmable from either the front panel or the IEEE-488 bus. This feature lets you reconfigure the trigger interaction between instruments without having to switch cable positions. The Trigger-Link also minimizes the trigger latency and jitter problems that can complicate trigger timing. As a result, you can program precise, repeatable triggering of multiple instruments with higher throughput than is possible over the IEEE-488 bus.

The mainframe contains an analog backplane that automatically makes intercard connections inside the chassis. For most applications, this backplane eliminates any need for card-to-card wiring.

Two interconnect options let you tailor the mainframe for frequent wiring modifications or relatively stable configurations. By using a detachable, screw-terminal connection board, you can easily make changes and combine different types of wire on the same card. For production-test applications in which the system setup is unlikely to change, a multipin connector lets you disconnect cards quickly without removing the connector from the mainframe.

The Model 7001 mainframe sells for $1795. Three plug-in cards designed specifically for use in the mainframe are also available for $995 each: the Model 7011 40-channel multiplexer card; the Model 7012 4 × 10-channel matrix card; and the Model 7013 20-channel independent-switch card.—***JD Mosley***

Keithley Instruments Inc, 28775 Aurora Rd, Cleveland, OH 44139. Phone (800) 552-1115; (216) 248-0400. FAX (216) 248-6168.

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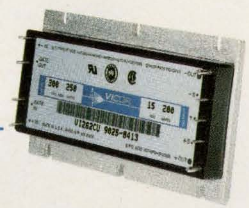

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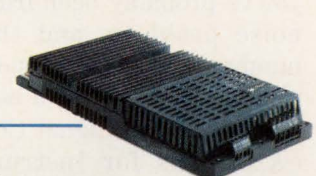

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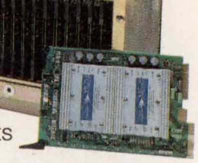

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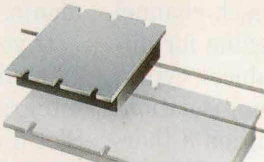

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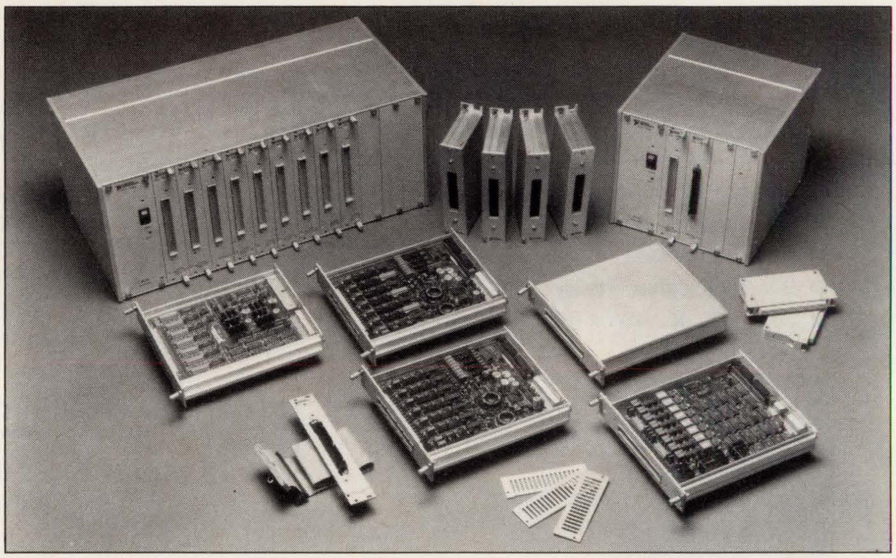
Mainframe provides signal conditioning for as many as 384 instrument channels

If you have tried to use your PC to perform signal conditioning for hundreds of channels of data, you've probably been frustrated by noise problems and the limited number of expansion slots in your computer. However, a new product line called the Signal Conditioning eXtensions for Instrumentation (SCXI) provides mainframes, modules, and terminal blocks that can simplify and improve your signal-conditioning efforts. SCXI adds an instrumentation front end to your PC-based data-acquisition system.

Begin with either the SCXI-1000 mainframe that conditions as many as 128 channels by accepting four 32-channel modules, or the SCXI-1001 mainframe, which accepts 12 modules, for 384-channel-max conditioning. Each has Slot 0 capabilities, a power supply, and separate analog and digital buses for transferring data and control signals. The larger unit occupies 7 in. vertically in a 19-in.-wide equipment rack; the smaller unit, which is also 7 in. high, is narrower than full-rack width.



The SCXI has been developed to condition hundreds of signals, while maintaining greater than 12-bit accuracy. *The product line, including a choice of mainframes and an array of modules, amplifiers, and terminal blocks, provides a cost-effective way to link general-purpose computers with the latest plug-in data-acquisition boards.*

Then select from an array of plug-in modules, such as a 32-channel multiplexer amplifier, an 8-channel isolation amp, and an 8-channel S/H amp. To simplify cabling, the SCXI-1180 feedthrough panel lets you route all signals to the front of the SCXI mainframe. Terminal blocks and adapters simplify connections to the modules and route signals from the mainframe to different types of data-acquisition boards. The SCXI-1181 general-purpose breadboard lets you design custom SCXI modules.

An independent configuration for each multichannel module is possible for different signal types, including thermocouples, strain gauges, resistance temperature detectors (RTDs), thermistors, microvolt, millivolt, volt, 4 to 20 mA, and 0- to 10-mA sources. SCXI creates a low-noise shielded environment outside the noisy PC chassis.

A configuration for each channel in a module is also possible for different signals or transducer types. For example, a 4-channel isolation-amp module could condition a thermocouple on channel 0, an RTD on channel 1, a strain gauge on channel 2, and a current on channel 3. In addition, a reconfiguration is possible for gain and bandwidth in each module.

Because your plug-in data-acquisition boards receive only high-level signals, SCXI maintains a high S/N ratio. Furthermore, you won't encounter the bottleneck problems that are prevalent in IEEE-488 and RS-232C systems.

SCXI devices have guarded analog buses for signal routing and calibration, trigger buses for timing coordination, and shielded power supplies. A serial bus for controlling and interrogating modules has a quiet mode that halts all digital activity during sensitive measurements.

If you need to connect more than 12 modules to your system, you can integrate multiple mainframes. The Slot 0 module in each chassis maintains the channel order of all the modules in the chassis.

The manufacturer's latest versions of Labview, Labwindows, and Labdriver will have new function calls for configuration and calibration of the SCXI system. Prices for mainframes and modules range from $75 to $1495.—***JD Mosley***

National Instruments Corp, 6504 Bridge Point Pkwy, Austin, TX 78730. Phone (800) 433-3488; (512) 794-0100. FAX (512) 794-8411.

Circle No. 696

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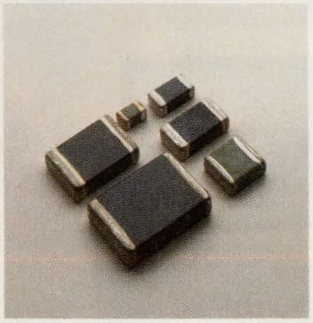
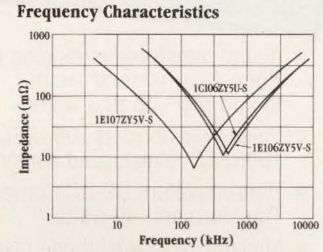


Frequency Characteristics



New Multilayer Ceramic Capacitor

		25V10μF		25V22μF	
		Dimensions (mm)	Case Code	Dimensions (mm)	Case Code
NEW	Y5U (Z5U)	2.7×5.7×2.5	C205M*1 C205F	5.0×5.7×2.5	C505F
CONVENTIONAL	Y5U	6.3×10.0×3.0	C610F	—	
	Y5V	4.0×8.0×2.5	C408F	6.3×10×3.0	C610F

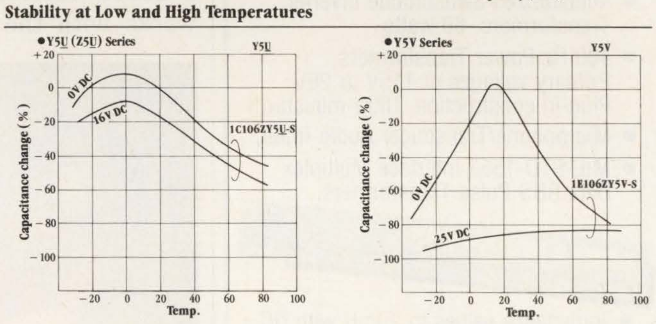
*New product C205M: Nickel/Tin Plate Termination

Ceramic Capacitor End Termination

Nickel/Tin Plate Termination*1	IE106ZY5U-SD
Fired-on End Termination	All Case Code

*1 The product is the experimental stage

Stability at Low and High Temperatures



Characteristics

Temp. Characteristics Y5U (Z5U)				Temp. Characteristics Y5V			
	25V	50V	75V		25V	50V	75V
10μF	IE106ZY5U-C205M IE106ZY5U-C205F	IH106ZY5U-C505F	IN106ZY5U-C610F	10μF	IE106ZY5V-C408F	IH106ZY5V-C610F	IN106ZY5V-C812F
22μF	IE226ZY5U-C505F	IH226ZY5U-610F	—	22μF	IE226ZY5V-C610F	IH226ZY5V-C812F	—
33μF	IE336ZY5U-C610F	IH335ZY5U-C812F*1	—	33μF	IE336ZY5V-C610F	—	—
47μF	IE476ZY5U-C812F*1	—	—	100μF	IE107ZY5V-C812F	—	—

*1 C812F (8×12.5×3mm): The product is in the experimental stage.

TOKIN

Tokin Corporation
Hazama Bldg., 5-8, Kita-Aoyama 2-chome, Minato-ku, Tokyo 107, Japan
Phone: 03-3402-6166 Fax: 03-3497-9756

Tokin America Inc.
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Phone: 708-215-8802 Fax: 708-215-8804
Boston Branch
945 Concord Street, Framingham, Massachusetts 01701, U.S.A.
Phone: 508-875-0389 Fax: 508-875-1479

CIRCLE NO. 170

ICE handles three members of 29000 μP family

The Eclipse 29K in-circuit emulator (ICE) substitutes for the AMD 29000, 29030, and 29050 μPs. The emulator operates at 40-MHz clock speeds (max) and sports a 1-Mbyte, zero-wait-state emulation memory. The instrument's multilevel triggering and multiway branching permit store control, position counts, time tags, and pass counts at each trigger level.

The emulator has a 32-ksample × 256-bit trace buffer and 63 event recognizers. Thirty-two bits of the trace buffer are available for user-defined inputs; the others are dedicated to the μP. You can program all the event recognizers to trigger over a range of events, not just on a single, specific event.

The instrument's control software can run under Windows 3.0. The bundled high-level debugger is a 29000 version of XRay, which works with the company's compilers. The system's integrated debugging facility provides a windowed interface for debugger and emulator functions. This integration links hardware triggers and trace buffers and performance analysis with the debugger's monitoring capabilities, software breakpoints, and source-level symbolic references.

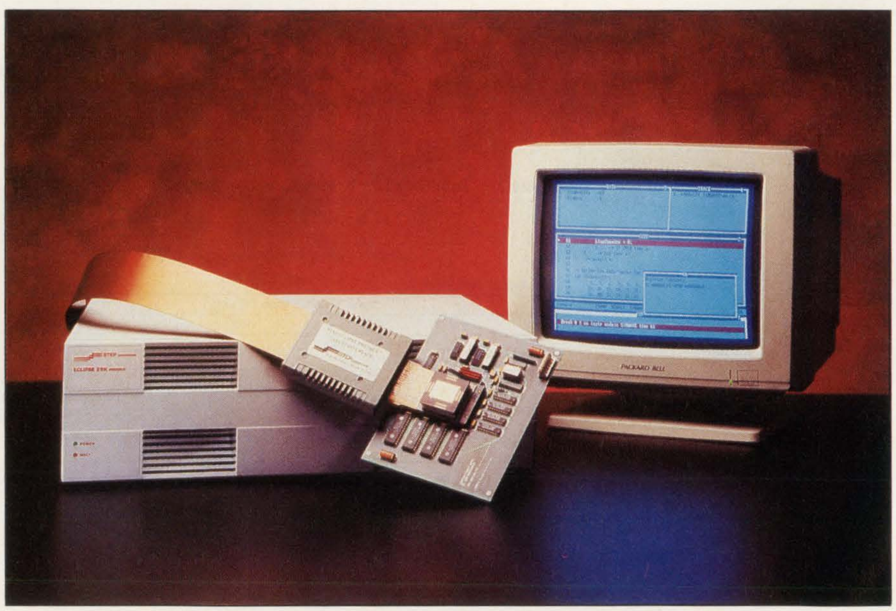
Software-performance analysis tools include code coverage, execution statistics, and timing. Emulation statistics include interrupt latency and instruction-cache efficiency.

The software runs on MS-DOS computers and uses the PC's parallel port for downloads. A fully loaded system costs $41,000.

—Charles H Small

Step Engineering, 661 E Arques Ave, Sunnyvale, CA 94088. Phone (800) 538-1750; (408) 733-7837. FAX (408) 773-1073. TWX 910-339-9506.

Circle No. 694



The Eclipse 29K in-circuit emulator *substitutes for the AMD 29000, 29303, and 29050 μPs.*

HI-7153

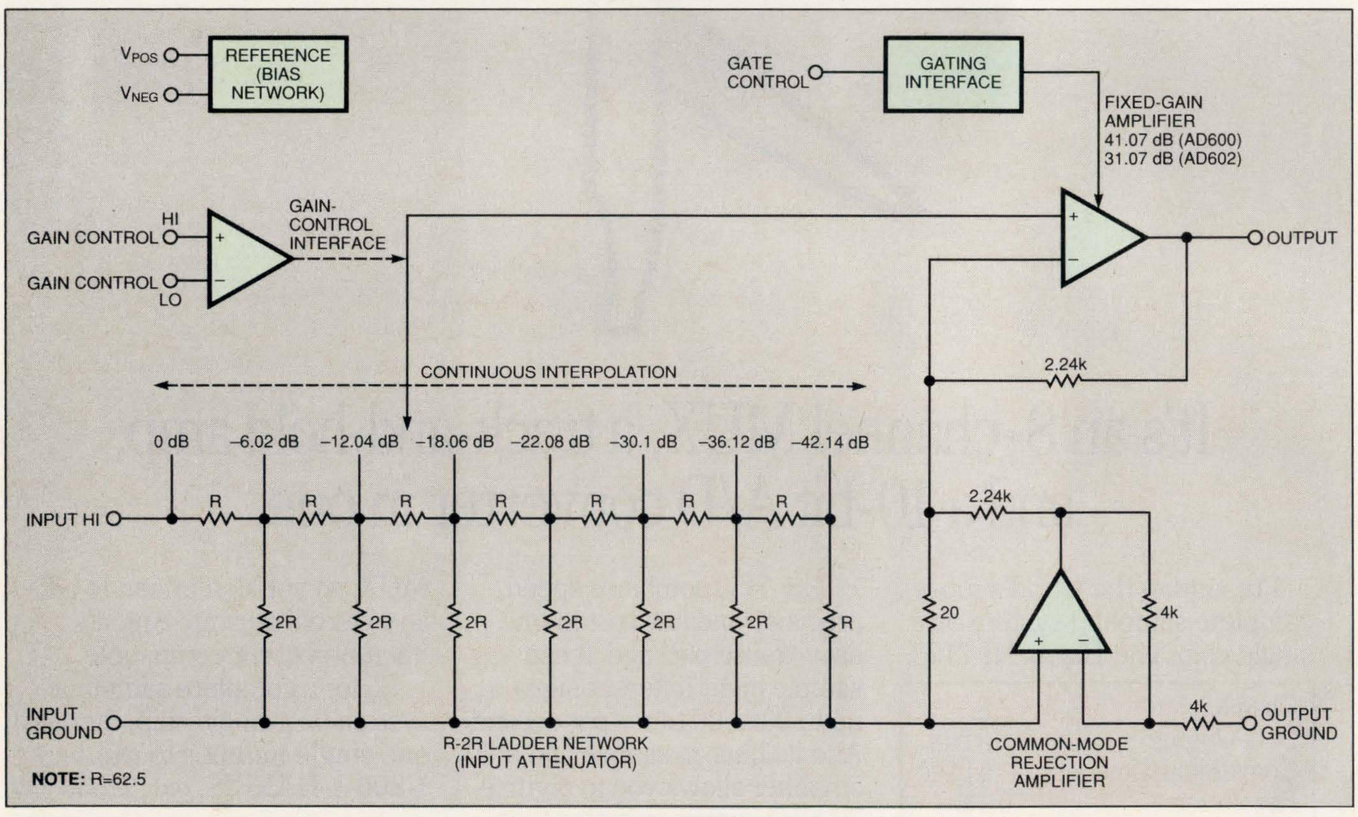
Variable-gain amplifier lowers noise and distortion but keeps bandwidth at 35 MHz

Most voltage-controlled amplifiers use some sort of nonlinear circuit element directly in the signal path. These nonlinear elements increase distortion and noise and often force bandwidth tradeoffs as you vary the gain. The internal architecture of the AD600 and AD602 prevents you from having to make this tradeoff and also provides low input noise of 1.4 $nV/\sqrt{Hz}$, and low-distortion performance of −60 dBc at outputs of ±1V. The amplifiers' typical 3-dB bandwidth is 35 MHz and is essentially independent of the gain setting. The dual-channel AD600 and AD602 provide gain ranges of 0 to 40 dB and −10 to +30 dB, respectively.

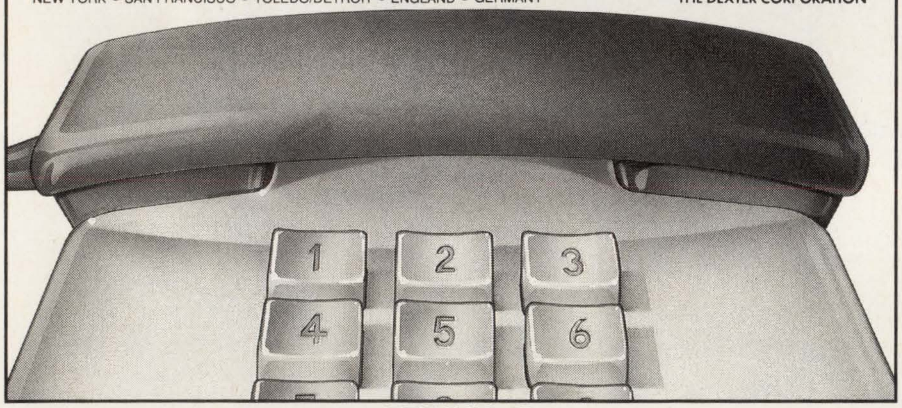
A 2-stage design enables the amplifiers to achieve their specs. The first stage is a variable attenuator comprising an R-2R, binary-weighted ladder network. This network is made from seven sections of fixed resistors, and it attenuates the input by 6.02 dB in each section. A proprietary circuit technique interpolates between these tap points and provides for continuous attenuation.

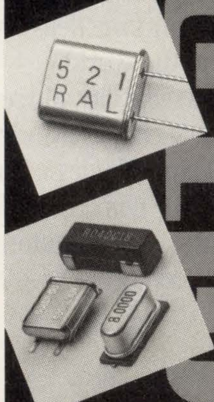
The second stage is a fixed-gain amplifier that provides a gain range of either 41 or 31 dB. This 2-stage design provides the amplifier with many advantages. First, the fixed amplifier can have negative feedback, which increases gain accuracy. Also, since the fixed amplifier never has to handle large input signals, its design can be optimized for low distortion and noise. The main advantage is that both the input attenuator and fixed amplifier are linear, and as such, introduce very little distortion.

This architecture ultimately results in a precise decibel-scaled gain law that stems directly from the recursive nature of the ladder network. For control voltages between −0.625 and +0.625V, the amplifiers provide a linear—in terms of dB—output between their respective gain-range extremes. The instantaneous S/N ratio for 1V rms outputs and a 1-MHz noise band-



***A 7-section ladder network followed by** a fixed-gain amplifier implement a variable-gain architecture that provides each channel of the AD600 (one channel shown) and AD602 with low noise, low distortion, and a bandwidth that's independent of gain.*





UPDATE

width is typically 76 and 86 dB for the AD600 and AD602, respectively. The absolute gain accuracy of each device is ±0.5 dB. The group delay is flat to 10 MHz and is stable at ±2 nsec.

Each amplifier's maximum power dissipation is 125 mW. The gain-control interfaces are fully differential with an input resistance of approximately 15 MΩ. They have a scale factor of 32 dB/V defined by the internal voltage reference. The response time of this interface is less than 1 μsec.

The two amplifiers' specs particularly suit ultrasound applications, but their wide bandwidth and low distortion are also useful for other automatic-gain-control and programmed-gain applications. Using appropriate precautions and a few extra components, you can cascade the amplifiers to achieve a gain-control range of 80 dB. The devices are available in either 16-pin DIPs or SOICs and operate over the commercial temperature range of 0 to 70°C. They cost $15 (100).

—Anne Watson Swager

Analog Devices Inc, 181 Ballardvale St, Wilmington, MA 01887. Phone (617) 937-1428. FAX (617) 821-4273.

Circle No. 699

IT'S HERE

Turn to page 163 in this issue to introduce yourself to Jim Williams and his study of high-speed analog design. Jim will inform and entertain you in our October 24, 1991, edition of EDN Magazine with articles on common problems with op amps and amplifiers with low offset and drift. Stay tuned for more.

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CIRCLE NO. 99

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Poof, they're gone. Bulky battery packs, slow hard disks and more. You see, where memory cards make sense, the new Intel 4MB Flash Memory Card provides a high-density, read/write, truly nonvolatile portable storage solution.

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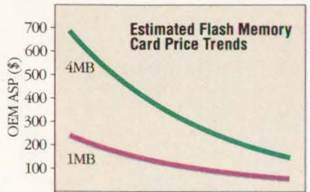

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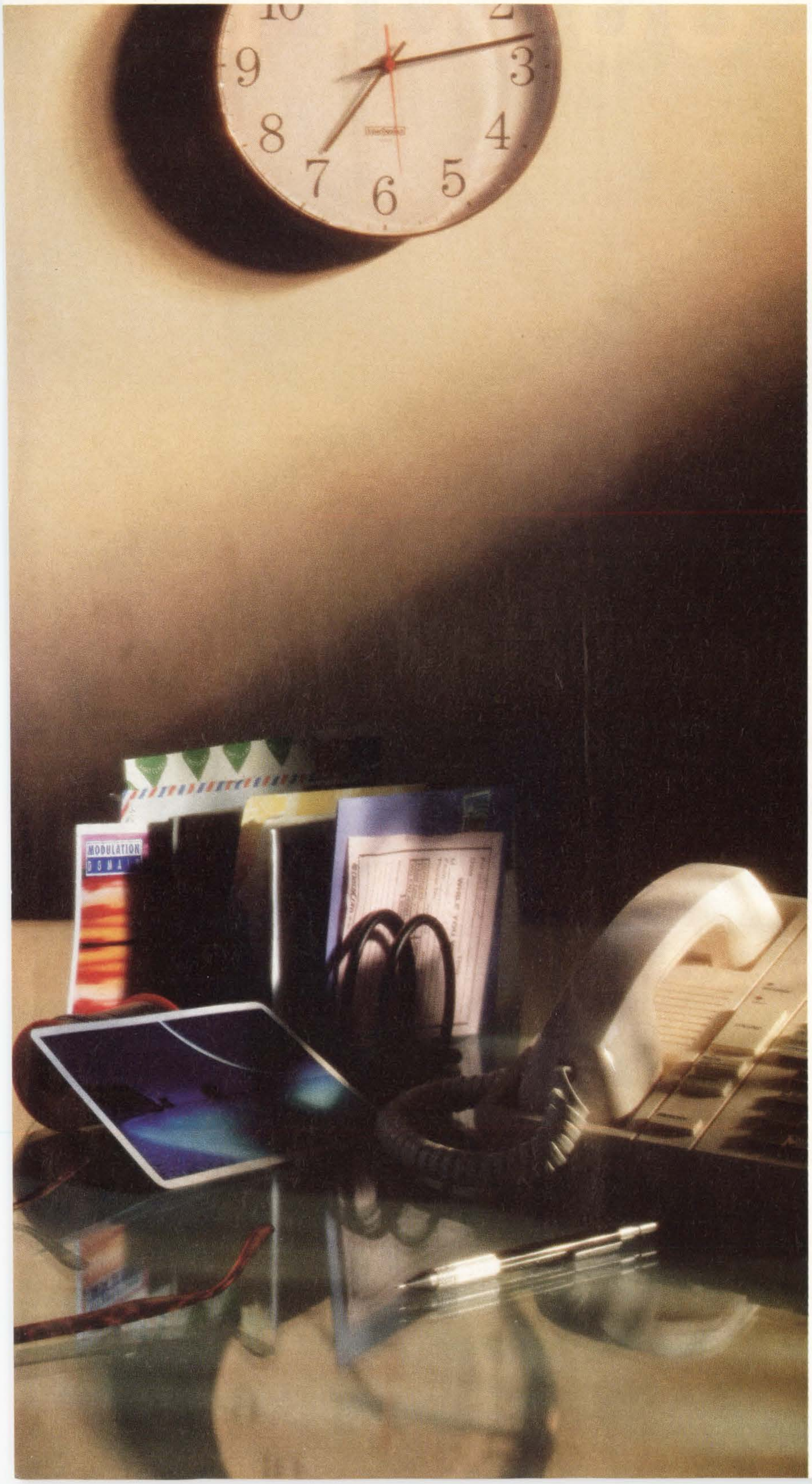

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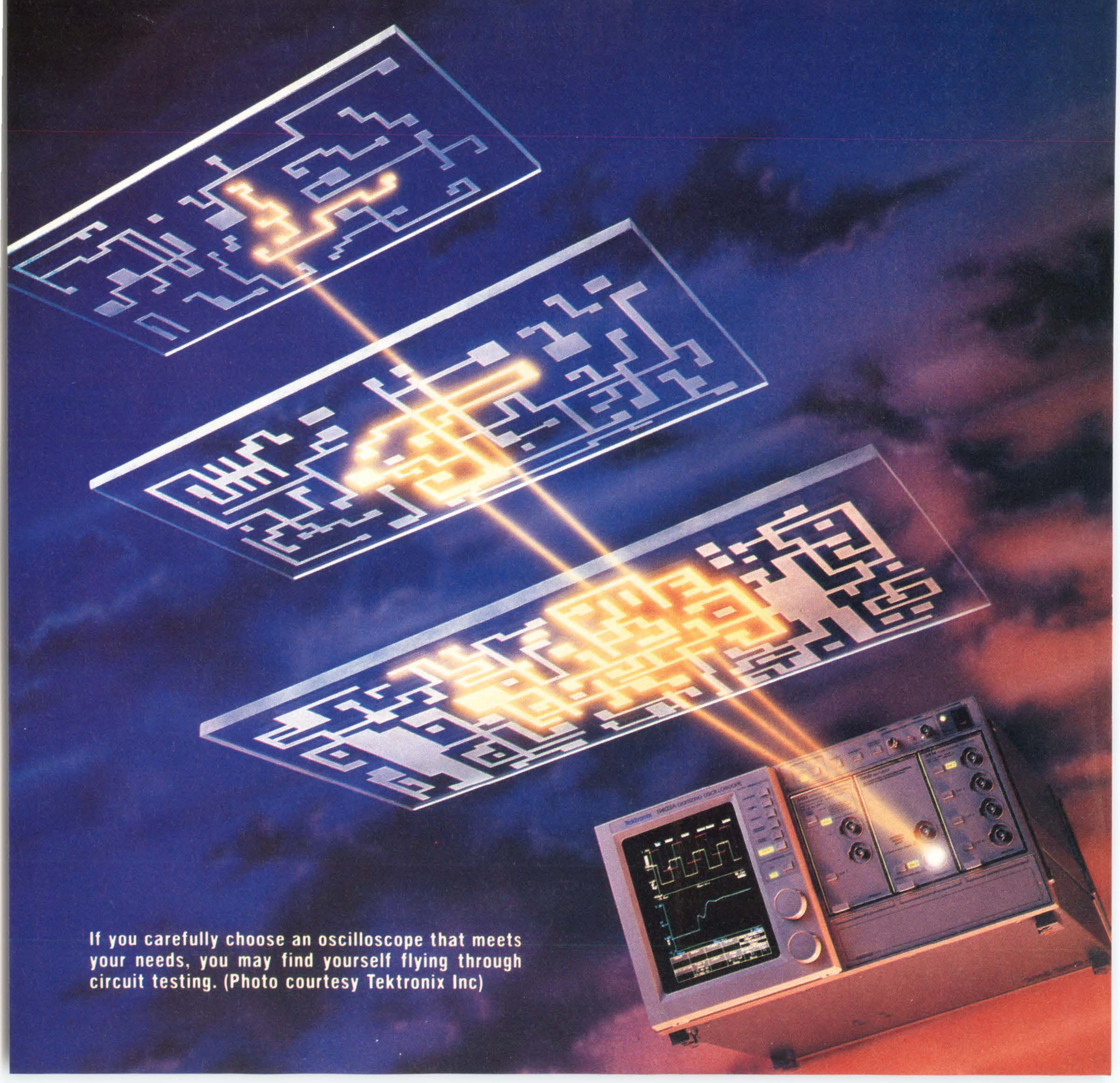
CIRCLE NO. 101

EDN SPECIAL REPORT

HIGH-PERFORMANCE OSCILLOSCOPES



If you carefully choose an oscilloscope that meets your needs, you may find yourself flying through circuit testing. (Photo courtesy Tektronix Inc)

DOUG CONNER, REGIONAL EDITOR

Using the right oscilloscope for your application will make your work easier, save you time, and, in the long run, save you money. To select the right scope, you need to analyze your application and determine what features and specs will meet your requirements. You need to be sure you can acquire the necessary signals and observe and measure them accurately.

The bandwidth of an oscilloscope is such an important specification that it's usually the scope's principal identifier. For digital circuits, however, the rise time is often a more pertinent specification than bandwidth. The two are approximately related by the equation:

bandwidth = 0.35/rise time.

A 100-MHz scope has an approximately 3.5-nsec rise time. A 1-GHz scope has a 350-psec rise time.

You need to choose an oscilloscope that can display the signals and make the measurements your application requires. Examining specs and features closely before choosing will pay off—using the right instrument will speed your work.

You don't want to use a 100-MHz scope to look at a 100-MHz waveform or a signal with a 3.5-nsec rise time. If you do, the rise time of the signal and the scope will rms together to give you a rise-time measurement of about 4.9 nsec, a 40% error. The general rule of thumb is to select a scope with a bandwidth that is three to five times the bandwidth of the signals you will be observing. If you follow that rule, you will keep rise-time measurement errors between roughly 2 and 5.5%.

Although the products covered here all have bandwidths of 200 MHz or higher, the considerations apply equally well to lower-bandwidth oscilloscopes.

Consider signal repetition rate

The next most important consideration of the acquisition system is the signal repetition rate. When all oscilloscopes were analog, you only had to determine whether you could observe the signal with a nonstorage analog scope. If the signal was single shot or so infrequent that viewing even with a hood was impossible, then you could only choose between using a storage scope or using a nonstorage scope and photography.

When dealing with digital scopes, the signal-repetition-rate considerations change. All digital scopes are storage scopes. And digital scopes don't suffer from dim viewing problems—whatever data the scope acquires, you can view. The signal-repetition-rate consideration for digital scopes is whether you can wait for enough triggers to acquire sufficient data with repetitive acquisitions or if you need real-time acquisition to acquire all the data around one trigger event.

Digital scopes use one or more of three basic types of sampling methods: real time, random repetitive, and sequential. Many digital scopes offer both real-time and random repetitive sampling.

The maximum speed of the A/D converters in a scope usually limits the real-time sample rate. Currently, 2 Gsamples/sec is the maximum available sample rate on digital scopes. Some digital scopes achieve high sample rates by circumventing their slow converters. These scopes use CCDs to sample and hold the analog values at a high rate, then the A/D converters convert the values at a lower rate.

The usable bandwidth for real-time data acquisition ranges from about one-tenth the sample rate to about four-tenths of the sample rate (if you can accept considerable distortion). On some of its scopes, Hewlett-Packard combines predigitizing analog filters and digital reconstruction filters to obtain an undistorted real-time bandwidth of one-quarter the sample rate. However, one-tenth is the usual rule of thumb and the best number to use when the scope doesn't have advanced interpolation methods to help reconstruct a close approximation of the original waveform.

When operating at the maximum sampling rate, many scopes interleave digitizers, leaving only one channel available. For example, Tektronix's TDS540 is a 4-channel scope with four independent 250-Msample/sec digitizers. You can operate four channels at 250 Msamples/sec, two channels at 500 Msamples/sec, or one channel at 1 Gsample/sec.

The highest performance digital oscilloscopes have a maximum usable real-time bandwidth in the 200- to 800-MHz range, with 500 MHz being a more practical limit. For higher single-shot bandwidths, you need to use analog scopes. Tektronix's 7104 offers a 1-GHz bandwidth for real-time events. The company's image-intensifying microchannel plate technology permits

Currently, 2 Gsamples/sec is the maximum available sample rate on digital scopes.

viewing or photographing a single acquisition at the 1-GHz bandwidth. An optional digitizing camera lets you store real-time waveforms.

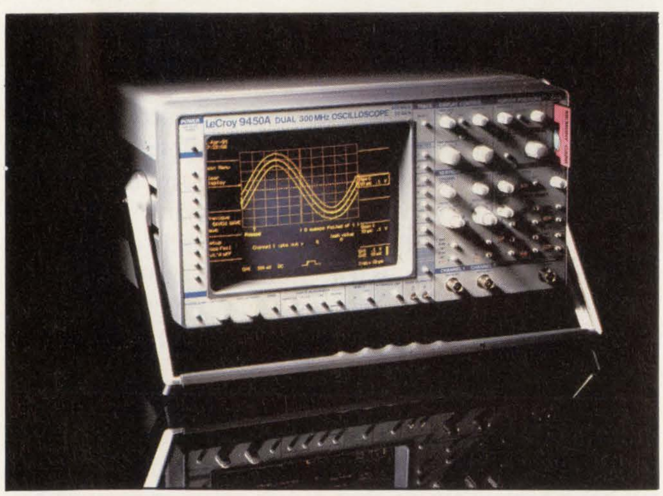
If you need to acquire a repetitive signal, a digital scope can acquire a waveform over a period and provide bandwidths as high as 50 GHz. Digital scopes use random-repetitive or sequential sampling modes to acquire repetitive signals.

Sequential sampling provides high bandwidth

Sequential sampling takes a single data point after each trigger event, incrementing the delay between trigger event and sample acquisition after each trigger. This sample-and-hold (S/H) approach allows high resolution of both voltage and time on high-bandwidth signals. Sequential-sampling scopes can achieve 8- to 16-bit voltage resolution and timing resolution to a fraction of a picosecond. Because sequential sampling only takes a single data point after each trigger, acquiring a full record of data will require 500 to several thousand trigger events, depending on the record length of the particular scope.

Sequential-sampling scopes offer the highest bandwidths for repetitive signals, but they have two drawbacks when compared with general-purpose digital scopes. First, the S/H circuitry is typically up front before any amplifiers, and protection circuitry is out of the question if you plan to acquire high-bandwidth signals. So you must be careful to keep the scope inputs away from damaging voltages including static discharge. Second, sequential sampling does not provide the pretrigger capability found on random-repetitive-sampling scopes.

A 2-GHz bandwidth for less than $20,000 is available in the digital sequential sampling PM3340 from Philips.



The 4k×4k display resolution of LeCroy's 9450A is far superior to any other digital scope. A removable memory card and 50,000-point record lengths are other outstanding features of this 300-MHz digital oscilloscope.

Digital scopes that use random repetitive sampling have their sampling systems running continuously, filling up memory and then overwriting it. Thus, you can set up the scope for a complete pretrigger acquisition, so that when a trigger event occurs, the scope can stop acquisition and save data that it collected up until the trigger. You can also set your digital scope for long post-trigger acquisitions or any combination of pre- and post-trigger. The scope places each sample point in the correct time location in memory relative to the trigger. By collecting data points around many trigger events, the time resolution for random-repetitive-sampling scopes goes as low as 10 psec. In addition, Textronix's 11A81 plug-in has recently pushed the maximum bandwidth for random-repetitive-sampling scopes from 1 to 3 GHz.

When considering a digital scope's acquisition system, you commonly think of maximum sample rate and vertical resolution as the key specifications, but if you don't also consider the record length, you may be expecting better timing resolution than you can achieve.

At maximum sweep speeds, you'll get the advertised timing resolution of the scope, but as you reduce sweep speeds, the scope's timing resolution will eventually drop. The record length determines the sweep speed or time window size when a digital scope will lose resolution. The equation is

$$\text{time resolution} = \text{time window/record length.}$$

For example, consider a 10-psec time resolution and a 1k record length. If you solve for time window, you get 10 nsec, or one typical 10-div display at 1 nsec/div. If you slow down the time window beyond 10 nsec (1 nsec/div in our example), you'll start dropping resolution. If you want maximum timing resolution for pulse-width or rise-time measurements, you have to keep the time window short. If the waveform characteristic you are measuring is longer than 10 nsec—or whatever the maximum time window is—the scope must operate at lower resolution.

If you use a scope with a 50k-point record length you can keep the 10-psec resolution for a 500-nsec time window or 50 nsec/div. Using an oscilloscope that has long records, you can acquire longer stretches of a waveform and still make full-resolution measurements. Longer record lengths are also a benefit when making single-shot acquisitions. The longer record makes it more likely you'll capture all of the data you need and, because of the short time period, do so with high resolution.

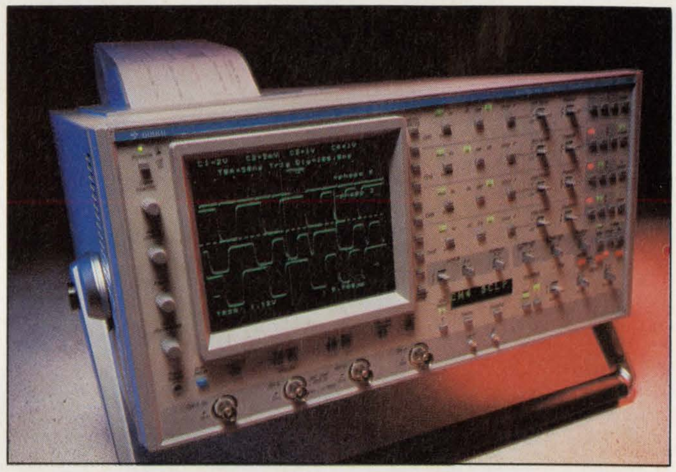
Another concern with digital scopes that relates to horizontal resolution and record length is glitch capture. As you reduce the sweep speed, the time-resolution steps become relatively large, especially with short record lengths. Your waveform could be riddled with large glitches that the scope could miss or that could show up only occasionally.

If you use the timing resolution equation above, you'll see the potential for missing glitches. For example, at 10 μsec/div (100 μsec full window size across 10 div), a digital scope with a 1k record length would have timing resolution of 100 nsec. A 20-nsec pulse could easily slip through undetected, especially on a single-shot acquisition.

To overcome the glitch problem, some scopes offer a glitch capture mode. Glitch capture modes typically acquire and display both the highest and lowest amplitude measured in each time interval. If a glitch is present, these two amplitudes will show it.

Instead of, or in addition to, a glitch capture mode, some oscilloscopes provide triggering on glitches. The triggering system uses a trigger level in combination with a time qualifier.

For example, you can look for any pulse that is greater than 2V that lasts for less than 100 nsec. Depending on the scope, you may be able to bracket times. For example, you could look for a signal that lasts for more than 5 nsec but less than 20 nsec.



Two 800-Msample/sec digitizers give the 4094 digital scope from Gould a 200-MHz bandwidth for single-shot or repetitive signals. An internal plotter provides hardcopy output.

Tektronix's TDS 520 and 540 series digital scopes can trigger on signals that cross one level but fail to cross a second level before returning across the first. The "runt triggering capability," as Tektronix refers to it, allows you to trigger on problem signals that might otherwise be difficult to find. By using levels of 0.8V and 2.0V, you can trigger on pulses that go above the maximum TTL logic low but never reach the minimum logic high level before returning low.

Another aid in triggering on just the event you want is logic triggering. Typically limited to four channels, logic triggering lets you select high and low patterns or patterns plus a clock for triggering on a specific state.

While tracking down or solving a problem you'll often want to examine a waveform closely. For zeroing in on a detailed view of a waveform, several approaches are available. Analog oscilloscopes usually offer a delayed sweep or second timebase so you can delay for

Acronyms used in this article

CCD—Charge-coupled device
CRT—Cathode-ray tube
FFT—Fast Fourier transform
IEEE-488—Institute of Electrical and Electronics Engineers bus standard 488
rms—Root mean square
RS-232C—Recommended standard 232C
TTL—Transistor-transistor logic

One of the charms of analog scopes is the simplicity of their acquisition systems.

some period after the initial trigger and then be able to display a portion of the signal with an expanded time scale.

A few digital scopes also offer dual timebases. Other digital scopes provide detailed viewing using two other methods. The first is simply a windowing function that lets you change the timebase on a second display window to look at the waveform expanded by some factor. Typically the maximum window expansion factors of scopes are limited to 20 to 1000 times. The windowing

Table 1—Representative high-performance oscilloscopes having bandwidths of 200 MHz or higher

Manufacturer	Model	Type (D=digital, A=analog, S=sequential sampling)	Bandwidth (input)	Number of channels (T=trigger)	Channels at maximum sample rate, Msamples/sec	Maximum record length (points)	Vertical resolution (bits)	Dual timebase	Interfaces IEEE-488	Interfaces RS-232C	Weight (lbs)
Analogic	6100/640-1	D, S	1 GHz	4	NA	32k	16	✓	O	O	40
Gould	4090	D	200 MHz	2	1×800	2k	8	✓	✓	✓	25
	4092	D	200 MHz	2	2×800	2k	8	✓	✓	✓	25
	4094	D	200 MHz	4	2×800	2k	8	✓	✓	✓	25
Hewlett-Packard	54100A	D	1 GHz	2+2T	2×40	1k	7		✓		42
	54100D	D	1 GHz	2+2T	2×40	1k	7		✓		42
	54110D	D	1 GHz	2+2T	2×40	1k	7		✓		59
	54111D	D	500 MHz	2+2T	2×1000, 1×2000 O	16k	6 to 8		✓		59
	54121T	D, S	20 GHz	4	NA	1k	12		✓		52
	54122T	D, S	12.4 GHz	4	NA	1k	12		✓		55
	54123T	D, S	34 GHz	4	NA	1k	12		✓		52
	54124T	D, S	50 GHz	4	NA	1k	12		✓		52
	54502A	D	400 MHz	2	2×400	2k	6	windows	✓		22
	54503A	D	500 MHz	4	2×20	1k	8	windows	✓		22
	54504A	D	400 MHz	2	2×200	2k	8	windows	✓		22
	54510A	D	250 MHz	2	2×1000	8k	8		✓		22
LeCroy	7200/7242	D	500 MHz	2 to 4	1×2000, 2×2000 O	50k	8	O	✓	✓	57
	9450A	D	300 MHz	2	2×400	50k	8	✓	✓	✓	33
Philips	3092	A	200 MHz	2+2	NA	NA	NA	✓	✓	✓	18
	3094	A	200 MHz	4	NA	NA	NA	✓	✓	✓	18
	3323	D	300 MHz	2	2×500	4k	10		✓	✓	39
	3340	D, S	2 GHz	2	NA	4k	10		✓	✓	39
Tektronix	TDS520	D	500 MHz	2	1×500	5k, 50k O	8	✓	✓		27
	TDS540	D	500 MHz	4	1×1000	5k, 50k O	8	✓	✓		27
	2440	D	300 MHz	2	2×500	1k	8		✓		24
	2465B	A	400 MHz	4	NA	NA	NA	✓	✓		21
	2467B	A	400 MHz	4	NA	NA	NA	✓	✓		21
	11402A	D	3 GHz	2 to 12	1×20	10k	10	✓	✓	✓	42
	11403A	D	3 GHz	2 to 12	1×20	10k	10	✓	✓	✓	42
	11801A	D, S	50 GHz	1 to 136	NA	5k	8	✓	✓	✓	49
	CSA404	D	3 GHz	2 to 12	1×20	10k	10	✓	✓	✓	42
	CSA803	D, S	50 GHz	1 to 4	NA	5k	8	✓	✓	✓	49
	DSA601A	D	1 GHz	2 to 12	1×1000	20k	8	✓	✓	✓	67
	DSA602A	D	1 GHz	2 to 12	1×2000	32k	8	✓	✓	✓	71
	7104	A	1 GHz	2	NA	NA	NA	✓	✓		45

Notes:
1. NA = not applicable
2. O = optional

approach lets you view both the original timebase and the expanded display, so you can scroll along the signal and see where the window display is in relation to the trigger.

The second approach is to use just a digital delay from the trigger. You can scroll along the signal from trigger point to the delay limits of the scope by changing the delay value. You can scroll forward in time using pretrigger. Although the expanded display information is equivalent to that of a dual-timebase scope, you don't have the ability to see the big picture that shows where the expanded window you are looking at is in relation to the trigger.

Trigger features such as "delay by event" may make the lack of dual timebases less of a problem for some applications. If the reason you need the big picture of the waveform is so you can count over to the fifteenth pulse, you can let the scope do the counting by using a delay-by-event triggering mode. You enter the number of events to delay and the scope starts the display on the next edge.

Display (M=monochrome, C=color)	Controls (D=dedicated, K=menu keys, T=touch screen)	Price ($)	Comments
M	D, K	15,390	
M	D, K	8950	
M	D, K	9950	
M	D, K	10,950	
M	K	16,900	
M	K	21,900	
C	K	23,900	
C	K	29,900	
C	K	30,400	
C	K	32,400	Price for full-functional scope including plug-ins.
C	K	36,400	
C	K	44,400	
M	K	7450	
M	K	5950	
M	K	6750	
M	K	10,950	
M	D, K	36,900	Price with 2 channels.
M	D, K	13,990	
M	D	2990	
M	D	3390	
M	D, K	9250	
M	D, K	19,500	
M	D, K	9490	
M	D, K	13,900	
M	D, K	7990	
M	D	6460	
M	D	12,950	
M	D, K, T	15,700	+ ~$9000 for plug-ins.
C	D, K, T	16,950	+ ~$9000 for plug-ins.
C	D, K, T	27,500	+ ~$11,000 for sampling head.
C	D, K, T	22,000	+ ~$9000 for plug-ins.
C	D, K, T	25,150	+$11,000 for sampling head.
C	D, K, T	24,745	+ ~$9000 for plug-ins.
C	D, K, T	32,635	+ ~$9000 for plug-ins.
M	D	31,500	+plug-ins.

Digital scopes excel in measurements

The goals behind triggering on and acquiring a waveform are to observe it and often to make measurements. Every high-performance digital scope offers a variety of pulse-parameter measurements such as rise and fall times, pulse width, and amplitude.

Digital scopes' timing accuracy of 0.1% or better is typically far superior to that of an analog scope, and their vertical accuracy of 1 to 2% is also better. Not only are their measurements more accurate than analog measurements, digital scopes make them automatically, saving time and eliminating any concerns about the subjective judgment or the skill level of the person operating the oscilloscope. Of course, some scope makers have reduced these concerns by adding A/D conversion circuitry to their analog scopes to allow automatic measurements.

Some digital scopes push waveform processing much further than others. In addition to the standard waveform measurements, you can find features such as measurement statistics, waveform arithmetic, integration, differentiation, FFTs, and inverse FFTs. These features can save you much time and energy in addition to providing valuable information. For example, mean and standard-deviation values give you a better understanding of circuit noise and jitter.

If you want to determine the slew rate of a signal, you could measure the voltages at two points on the waveform and the time between the points and calculate the slew rate. But waveform differentiation gives you an instant display of slew rate vs time.

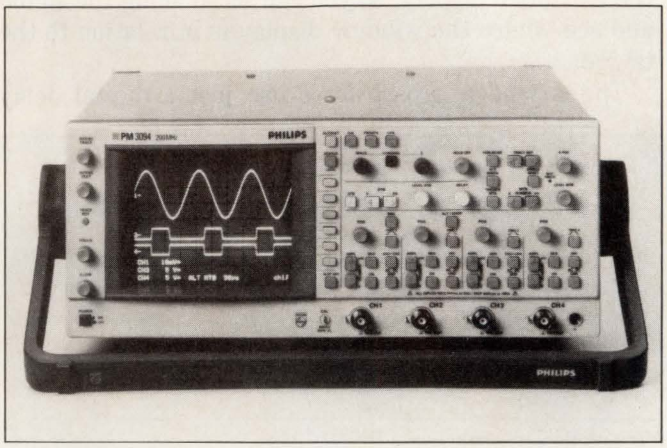
Using waveform arithmetic, if you want to measure the current through a resistor vs time, you can display the voltage difference divided by the resistor value vs time. If the scope you're using doesn't support math functions, you either have to take the data manually and convert it or interface the scope with a computer using IEEE-488 or another interface.

Tektronix's DSA family of scopes can perform FFT computations. These scopes can rapidly convert time-domain information to amplitude vs frequency. If you'd like to see the data filtered, you can perform basic filtering on the frequency-domain data using lowpass, highpass, bandpass, band reject, or combinations of these filters. You can see the effects of the filtering in the time domain by using the invert FFT function on the filtered signal.

Scopes that offer FFT capabilities place special demands on the acquisition system for voltage and timing accuracy. If you're looking into scopes that perform FFTs, you might want to try them out on pure sine waves—or other cases where you know what to expect—to see how well they perform.

Histograms show data distributions

Some high-performance oscilloscopes generate histograms so you can see not only the mean and standard deviation of measurements but also the data distribution. Some of the scopes that generate histograms use a 2-D histogram database. As the scope acquires data, it puts each new acquisition in the correct histogram location. Tektronix's CSA 404 and CSA 803 use a 3-D database and generate the histogram from the database. The scope counts the number of times it activates each display pixel and stores the count in a $512 \times 256 \times 16$-bit data array. It then generates a color-

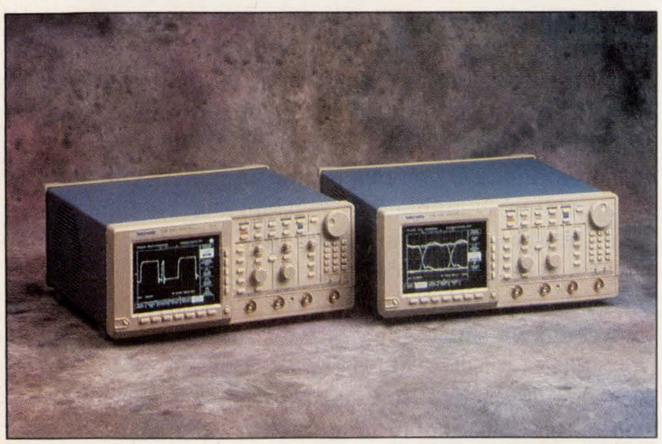


Four 200-MHz channels for less than $3400 make analog scopes such as the PM 3094 from Philips an economical alternative.

graded display and a histogram showing the distribution. You can select and display new histogram parameters without reacquiring data, the scope just extracts the needed information from the database.

When considering a high-performance digital oscilloscope for extensive waveform processing work, keep in mind that the computer power can either be integral with the scope or external and linked through an interface such as IEEE-488 or RS-232C.

The advantages to having all the processing done in the scope are speed and convenience. Functions performed by the scope are typically faster than downloading the data and processing by computer. The advantages to having your computer do the processing are that you can perform as much processing as you like and a scope with less internal processing power will cost you less. However, some waveform processing functions are integral to the acquisition system of the scope and you cannot move them through an interface to a computer.



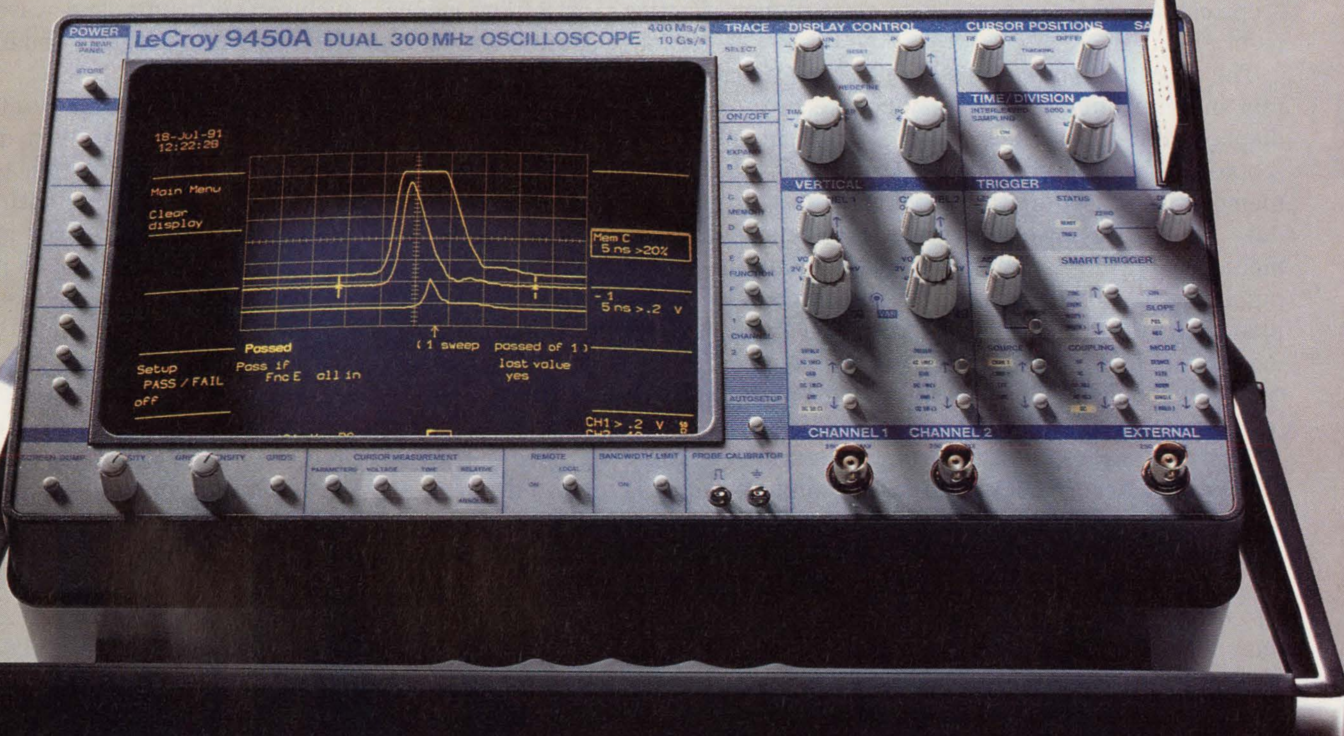
The 500-MHz bandwidth and optional record length of 50,000 points are key specifications of the TDS 500 family from Tektronix. The TDS 520 has two channels and two 250-Msample/sec digitizers. The TDS 540 has four channels and four 250-Msample/sec digitizers.

Improving resolution of single-shot data

Performing digital signal processing on LeCroy's 7200 and Tektronix's TDS 500 family to increase the effective resolution on single-shot acquisitions at low sweep speeds is an example of waveform processing that you can't download to a separate computer. All high-performance digital scopes allow you to average data on repetitive waveforms to increase effective resolution. Averaging typically allows the equivalent of two to four bits of increased resolution for repetitive signals.

A digital scope can use the same approach on a sin-

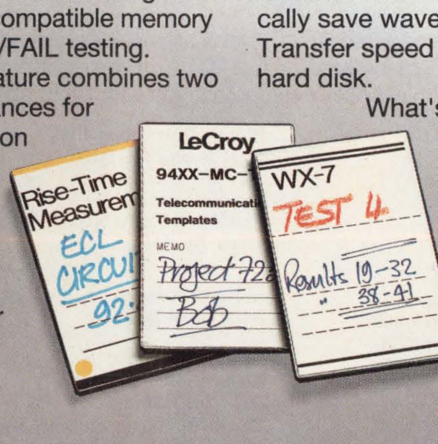
The next step in oscilloscope technology.



Spend a few minutes with LeCroy's new dual-channel 9450A and you'll see why nothing even comes close in decision-making power.

It's the first oscilloscope to offer next-generation performance. With a DOS-compatible memory card system. And automatic PASS/FAIL testing.

In fact, the PASS/FAIL feature combines two types of testing. You can set tolerances for up to four different measurements on one channel. And on the second channel, simultaneously compare another waveform to a specified template. If a test fails, the 9450A will act as instructed. (Such as print the waveform and continue or store on the memory card.)



The 9450A's memory card system is another first. (It's been built into other LeCroy oscilloscopes, too.) The cards give you full read and write capabilities on DOS-compatible PCs. You can also automatically save waveforms after each acquisition. Transfer speed is up to 10 times faster than with a hard disk.

What's more, memory cards are available for various applications, so you can tailor the 9450A to your specific needs.

Now, the next step is up to you. Simply write or call your nearest LeCroy office for further information or a demonstration.

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gle-shot acquisition when operating at slow timebase settings. A digitizer that is converting at the rate of 250 Msamples/sec may only need a data point every μsec to fill in the display record. Because the digitizer acquires 250 samples in the 1-μsec time interval, the scope can average the samples to get a higher effective resolution.

The processing power of a digital scope is also important in determining the display update rate. Although display refresh rates are not a problem on digital scopes, processing new data and getting it into display memory is. A few digital scopes have fast display update rates. Because the many different operating modes can greatly affect the display update, as do the number and type of automatic measurements, scope manufacturers have a difficult time specifying the update rate. Display update rate is one important reason why you should see a scope operating before purchasing it.

Another display spec to consider is re-arm dead time. The re-arm dead time of the fastest digital scopes is still several orders of magnitude slower than that of an analog scope. An analog scope just has to re-arm the trigger and slew the beam back for the next trace. In contrast, a digital scope typically needs to move data from acquisition memory into display memory, perform measurement computations, and operate the display.

The display quality is important because that's how you'll get most of the information from a scope, and in many cases the display is important to scope control too. The key specifications of a scope display are size, resolution, and whether the display is color or monochrome. The size is important for easy viewing. A standard analog scope has a 10×8-cm display. Digital scopes often have additional information displayed such as softkey menus, touch-screen menus, and waveform parameter readouts. The extra information usually requires additional display area.

The display resolution also plays an important part in getting all the information on screen. Most digital scopes don't have sufficient vertical resolution to put up a split-screen display of two waveforms with 8-bit display resolution on each waveform. LeCroy stands out on display resolution with between 2k and 4k points of vertical resolution depending on the scope model.

Color displays show much more than a pretty picture. The color quickly establishes which measurements belong to which signal. Color is also useful for comparing overlapping waveforms and showing color-graded displays of time or voltage variation. Because color displays are considerably more expensive than monochrome, you'll only find them on expensive scopes.

After a scope acquires and displays data, you often need to store the data for future use. Most analog scopes still depend on photography. All digital scopes provide digital-waveform storage. Some scopes use nonvolatile memory for all or part of the waveform memory. In addition, most digital scopes provide direct connection to printers for generating hardcopy records.

A few digital scopes provide removable memory

Manufacturers of high-performance oscilloscopes

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

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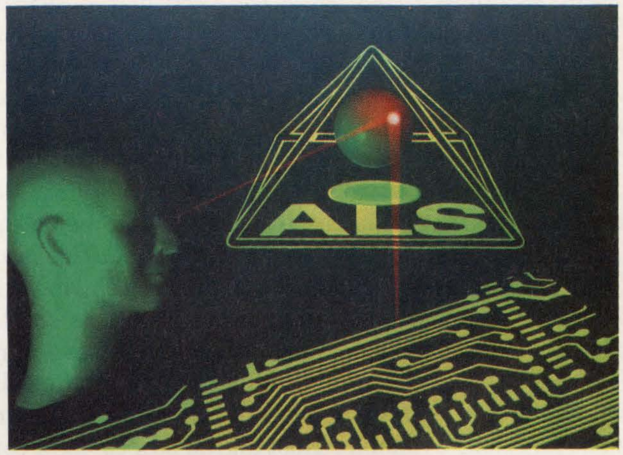

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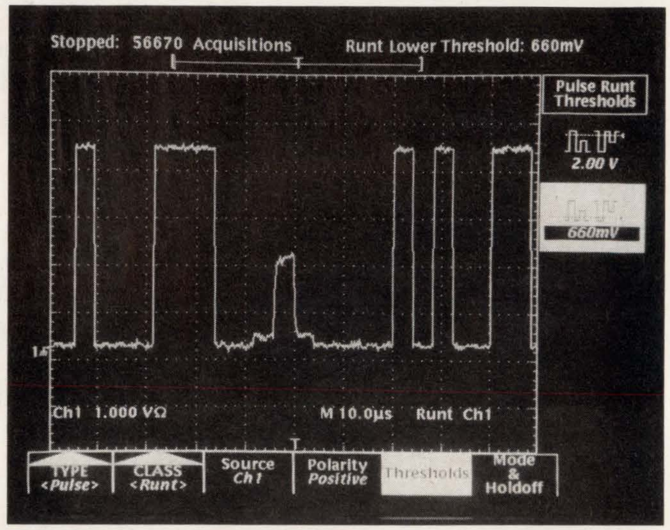
either as floppy disks, as is the case in the DSA600 family from Tektronix, or as memory cards, as used by LeCroy. The removable memory offers some conveniences such as being able to store waveforms while working and then downloading them through a computer later for hardcopy or for on-computer documentation. You can also save instrument setups on the storage medium so you can recall customized scope setups.

Scope controls are a secondary but competitive issue. Control of analog oscilloscopes typically remains with dedicated knobs and keys. Dedicated controls are the best choice for instruments because they save time. However, they are impractical on many digital oscilloscopes due to the large number of control and measurement functions available. Most digital scopes use a combination of dedicated keys for frequently used functions and softkeys with menus for less commonly used functions.

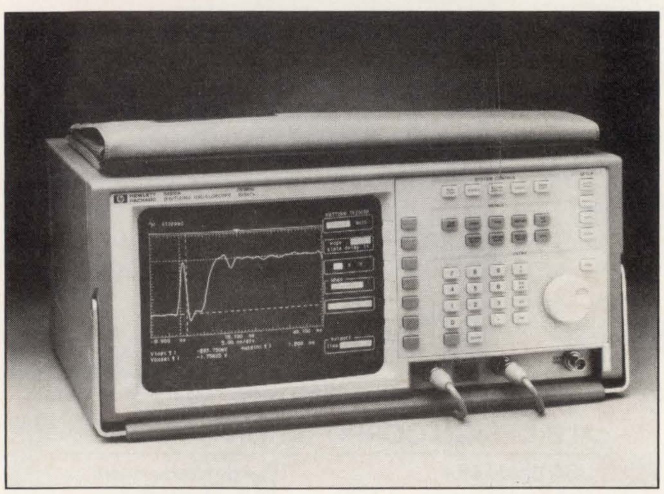
One of the charms of analog scopes is the simplicity of their acquisition systems. Analog scopes route the input signals through amplifiers and use the resulting outputs to control where they spray electrons in a CRT. Analog scopes have displays that are easy to interpret and show no artifacts of digitizing. If you don't know what you're doing with a digital scope, you might find yourself looking at a stored signal when you think you are probing a circuit. Analog scopes give you undigested data, and they give it to you rapidly.

If your primary use for a scope is to observe signals rather than take measurements, analog scopes are fine, and their fast, simple operation is an advantage. Of course, digital technology is creeping in everywhere, so many analog scopes can make automatic measurements and offer automatic setup—features found on all high-performance digital scopes.

As analog scopes become more digital, it becomes more obvious that the future of high-performance oscilloscopes favors digital technology. Although analog scopes are efficient instruments for some circuit situations, particularly analog, digital scopes are usually superior for making accurate, repeatable measurements and for working with digital circuits. At the lower bandwidths, analog scopes continue to offer attractive prices. In digital scopes, the trend is toward faster sampling speeds, faster display updates, and greater display processing.



Advanced trigger features can help you zero in on a problem that's normally difficult to capture. The photo shows the runt triggering capability on Tektronix's TDS scopes. A signal that has crossed the logic low threshold but not the logic high threshold causes the scope to trigger when the signal drops low again.



Two independent 1000-Msample/sec channels on the 54510A from Hewlett-Packard offer single-shot waveform capture of 250-MHz signals for less than $11,000.

Reference

1. Conner, Doug, "High-bandwidth DSOs push beyond 20 GHz," *EDN*, Jan 4, 1990, pg 61.

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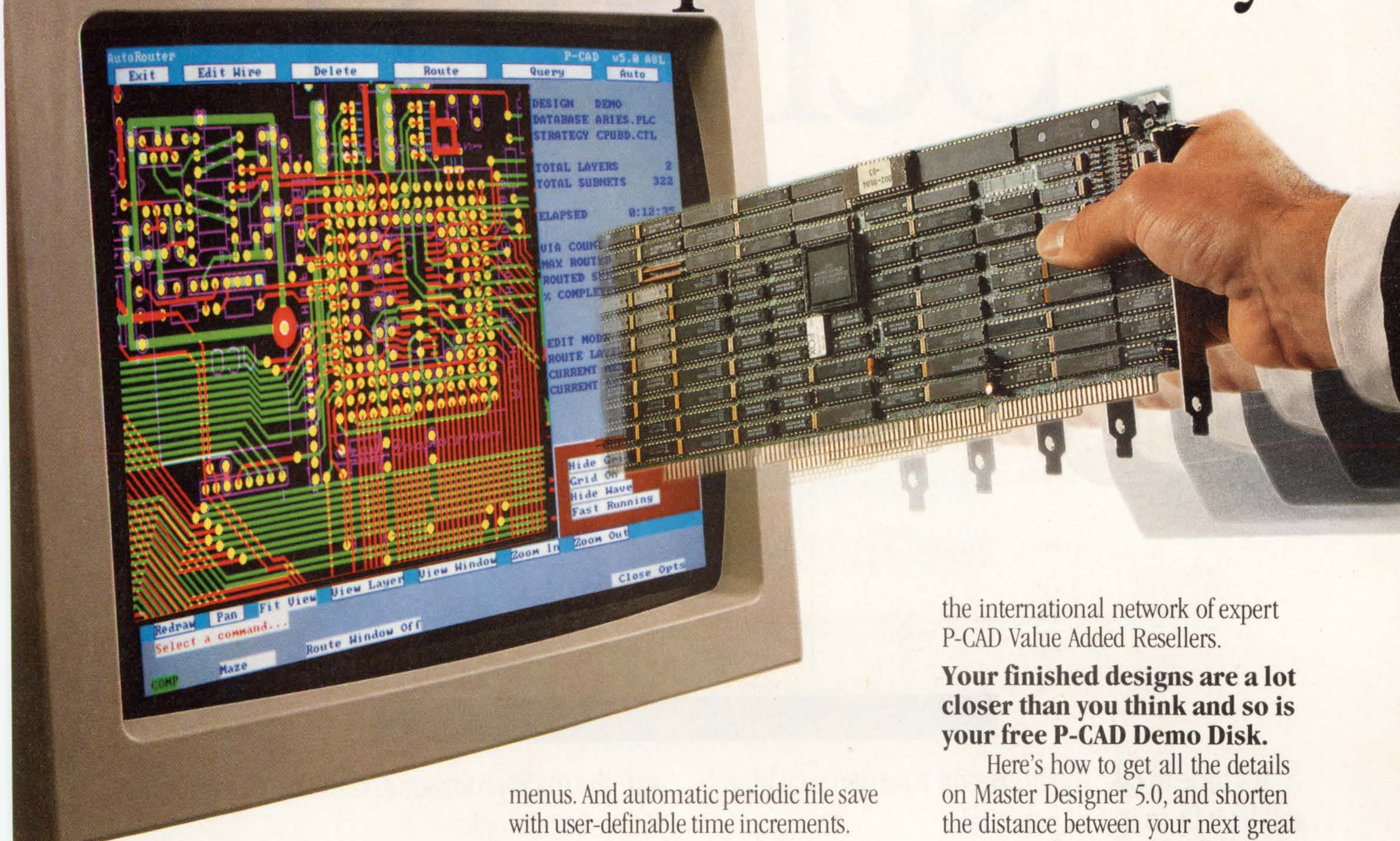

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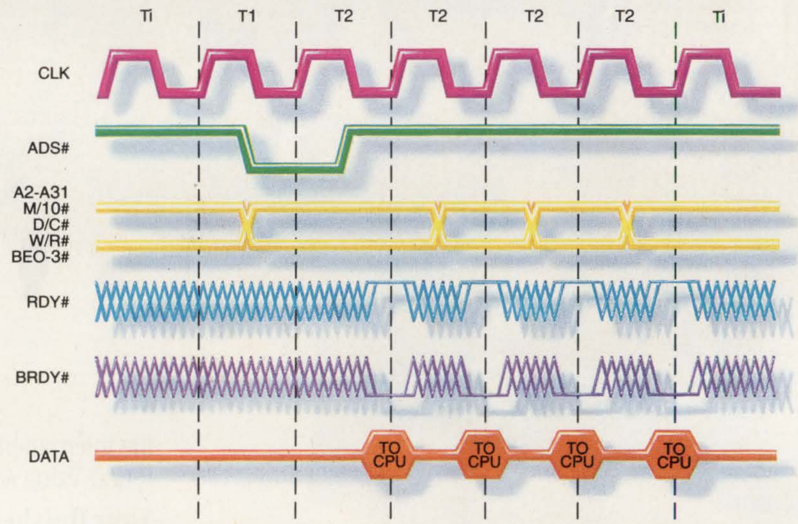

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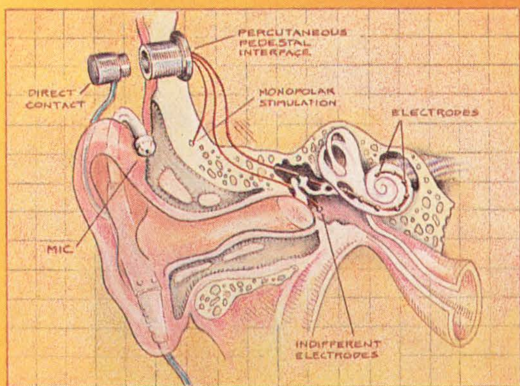

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THE JIM WILLIAMS PAPERS

MOST ENGINEERS THINK designing analog circuits for high-frequency and high-speed applications is a black art known only to a few wizards. If you are among that majority, prepare to enter the sorcerers' inner circle. Jim Williams has pried loose the secrets of practical, high-speed analog design. By codifying his observations, he has moved high-speed analog design away from the art realm and toward the engineering domain.

Williams presents his discoveries in the articles that follow. Each article is self-contained, so you won't have to read the first article to understand the second. He delves into the mysteries of power-supply bypassing, parasitic coupling, and compensation. He discusses ways to prevent amplifiers from oscillating, how to keep oscillators stable, and how to couple high-speed analog circuits to the digital world. He even discusses the problems you'll face when your analog circuits outperform your test equipment. In short, he tells you how to obtain full performance from your high-speed analog silicon.

Regarding this undertaking, Williams writes

Even the most veteran designers sometimes feel that nature is conspiring against them. In some measure this is true. Like all engineering endeavors, high-speed circuits can work only if you negotiate compromises with nature. Ignorance of or contempt for physical law is a direct route to frustration. Mother Nature laughs at dilettantes and dabblers. She crushes arrogance unknowingly.

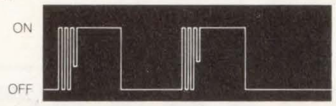
Over the past 15 years, the name Jim Williams has become synonymous with analog design in EDN. He published his first article in EDN on May 5, 1975, while teaching and conducting research at the Massachusetts Institute of Technology. In 1979, he started a 3-year stint as a linear designer at National Semiconductor Corp. Williams joined Linear Technology Corp (Milpitas, CA) in 1982 and continued to write innumerable articles about his designs, which today cover almost every analog function you can name.

Williams' devotion to the art of analog design drives his successful and unconventional career. Although he has no formal degree in engineering—Williams describes his experience with formal education as an incredible impedance mismatch—Williams was designing circuits, or in his words, "bumbling around circuits," long before he'd heard of calculus. Williams now describes himself as a floater. He spends about half of his time as a staff scientist doing what he's done for the last 15 years: designing circuits and writing about them. The rest of the time he's either acting as a mentor for engineers at his company or designing circuits for specific customers.

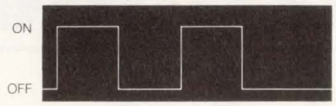
Despite working in the competitive business of selling semiconductors, Williams manages to balance the commercial aspirations of his employer while designing and writing about circuits that often include a competitor's device. You are about to read his latest opus—the product of one year's effort. These secrets didn't pry loose easily, and Williams has a mountain of breadboards for proof. EDN is proud of its long-standing relationship with Jim Williams and is proud to present a work of this caliber.

Illustration by John Schreck

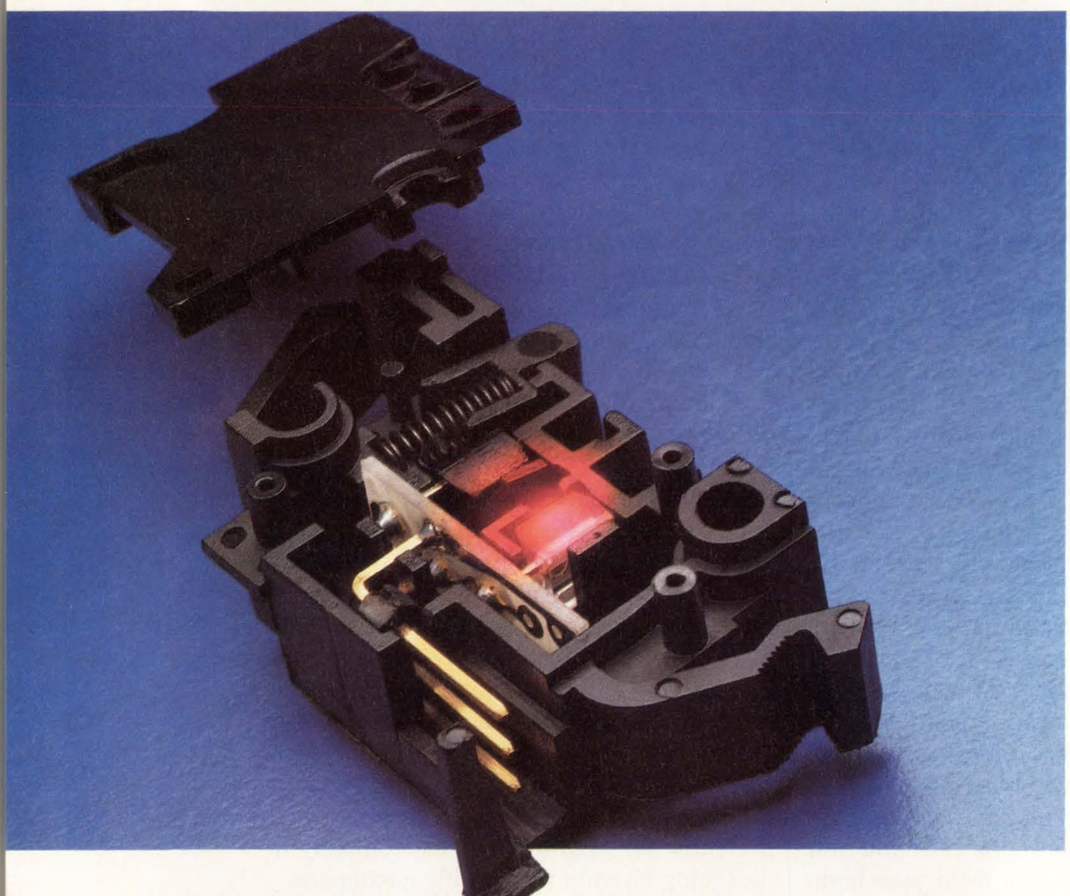
If you had this...



and we gave you this...



think what you could do!



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The *Logic Switch* uses an infrared emitter and phototransistor sensor combination. An internal "flag" interrupts a beam of infrared light from emitter to sensor, thus changing the switch's output when activated.

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The *Logic Switch* is so new, we wouldn't presume to guess at all its uses. Instead, we invite you to examine it firsthand and try it out on *your* ideas. Call Cherry at 708-360-3500, and we'll send qualified engineers a free *Logic Switch* and a specifications sheet.

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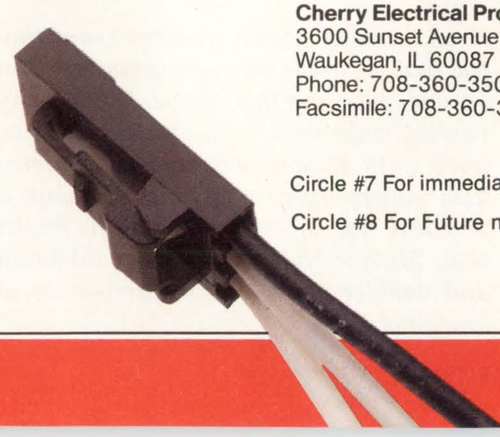


Circle #7 For immediate need

Circle #8 For Future need

THE

JIM WILLIAMS

PAPERS

The mysteries of probing

Unless you master the mysteries of probing and oscillography, you'll be doomed to measuring the errors in your setup and oscilloscope, not the errors in your circuit.

Jim Williams, *Linear Technology Corp*

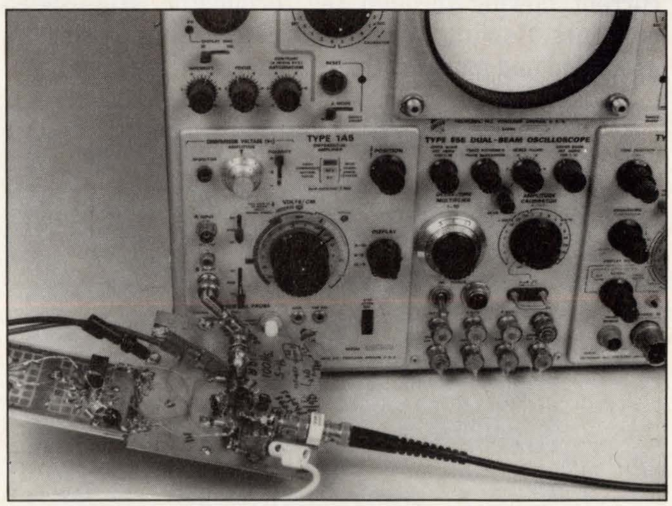
Measuring a high-speed linear circuit is a classic problem in observability. The problem is twofold: Stimulating and probing the circuit without disturbing its behavior and ensuring that the waveforms on your oscilloscope's screen are valid representations of your circuit's behavior. Problems can start before you apply power to your prototype.

Even something as simple as cabling requires thought. All coaxial cable is not the same. Always route high-speed signals to and from your circuit board with good-quality coaxial cable. Use cable appropriate to your system's characteristic impedance.

Poorly chosen cable materials or construction methods can introduce odd effects at very high speeds, resulting in distorted waveforms. A poor cable choice can adversely affect 0.01% settling in the 100- to 200-nsec region. Similarly, poor-quality cable can spoil even the cleanest pulse generator's 1-nsec rise time or purity. All too typically, inappropriate cable can introduce tailing, rise-time degradation, aberrations following transitions, nonlinear impedance, and other undesirable effects.

Other potential cabling problems begin at your circuit's input. The driven end of an input cable is usually an instrument (such as a pulse or signal generator), presumably endowed with proper characteristics by its manufacturer. The cable and its termination, selected by the experimenter, often cause problems.

Fig 1a shows severe ringing on the pulse edges at the output of an unterminated pulse-generator cable. Reflections cause this ringing and you can eliminate it by terminating the cable. Always terminate the source with its characteristic impedance when driving cable or long printed-circuit traces. In the high-speed



One of the secrets of probing is that *sometimes the best probe is no probe. Oscilloscopes are so well designed that a 25-year-old scope suffices for 90% of today's applications.*

linear domain, any conductor longer than one inch is suspect.

In **Fig 1b** the cable is terminated, but ripple and aberration are still present following the high-speed edges. In this instance the terminating resistors' leads are lengthy (~¾ in.), sabotaging the wideband termination. The best terminating resistors for 50Ω cable are the BNC coaxial type. Their impedance vs frequency is flat into the GHz range. Although these terminators are practical on the test bench, they are rarely board-level components.

These coaxial terminators should not simply be resistors in an enclosure. Good grade, 50Ω terminators maintain true coaxial form. They use a carefully designed 50Ω resistor. The terminators' designers devoted significant effort to the connections to the actual resistive element. In particular, the terminators have the largest possible connection-surface area to minimize high-speed losses.

Termination resistors

The best termination resistors for pc-boards are carbon or metal-film types having the shortest possible lead lengths. These resistors' "end-cap" connections provide better high-speed characteristics than the rod-connected composition types' connections. Wirewound resistors, because of their inherent, pronounced inductance, are completely unsuitable for high-speed work. This prohibition includes noninductive types of resistors.

Another termination consideration is disposing of the current flowing through the terminator. High-speed currents flowing from the terminating resistor's grounded end must not disrupt your circuit's operation. For example, returning terminator current to ground near the grounded positive input of an inverting op-amp would be unwise. The high-speed, high-density current flow could cause serious corruption of the op amp's reference. For example, 5V pulses through a 50Ω termination generate 100-mA current spikes.

This possible corruption is another reason why, for bench testing, the coaxial BNC terminators are preferable to discrete, breadboard-mounted resistors. In the coaxial types, the termination current returns directly to the source generator and never flows in the breadboard. Select terminations carefully, and evaluate the effects of their placement in your test setup.

Figs 2a and **2b** illustrate these terminators' performance nicely. In **Fig 2a**, a 1-GHz sampling scope (Tektronix 556 with 1S1 sampling plug-in and P6032 probe) monitors a 1-nsec pulse with 350-psec rise and fall times. The waveform is clean, with only a slight hint of ring after the falling edge. The setup used in **Fig 2a** is a high-grade BNC coaxial terminator. The setup in **Fig 2b** does not share these attributes. Rather, a 50Ω carbon-composition resistor with lead lengths of about ⅛ in. terminate the generator. The waveform rings and tails badly on turn-off before finally settling. Note that the sweep speed required a 2.5× reduction to capture these unwanted events.

Connectors, such as BNC barrel extensions and tee-type adapters, represent a discontinuity in the cable and can introduce small but undesirable effects. In general, you should use them as close as possible to a terminated point in the system. Using them in the middle of a cable run provides only minimal absorption of their mismatch and reflections.

The worst offenders among connectors are adapters.

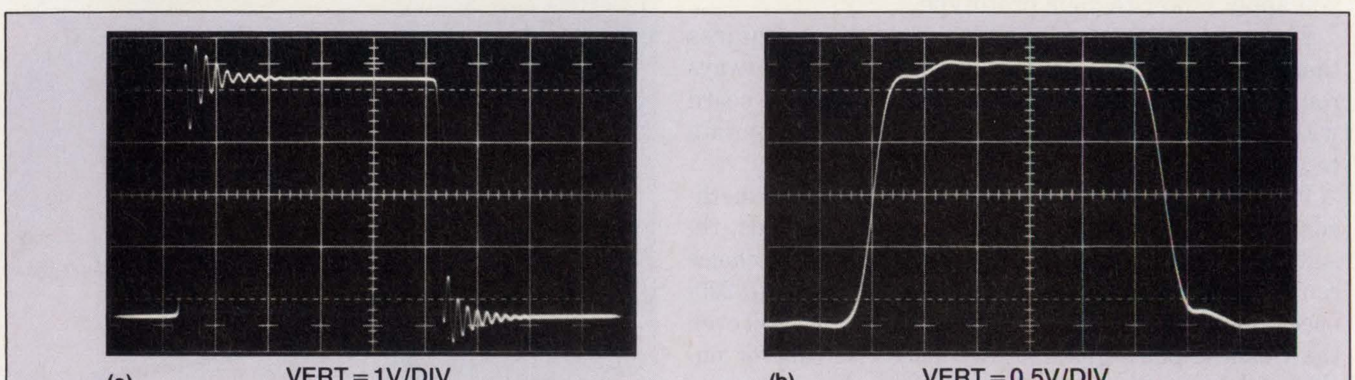


***Fig 1—In scope photo a,** an unterminated cable causes severe ringing. In **b**, improperly spec'ed termination resistors reduce, but do not eliminate, ringing.*

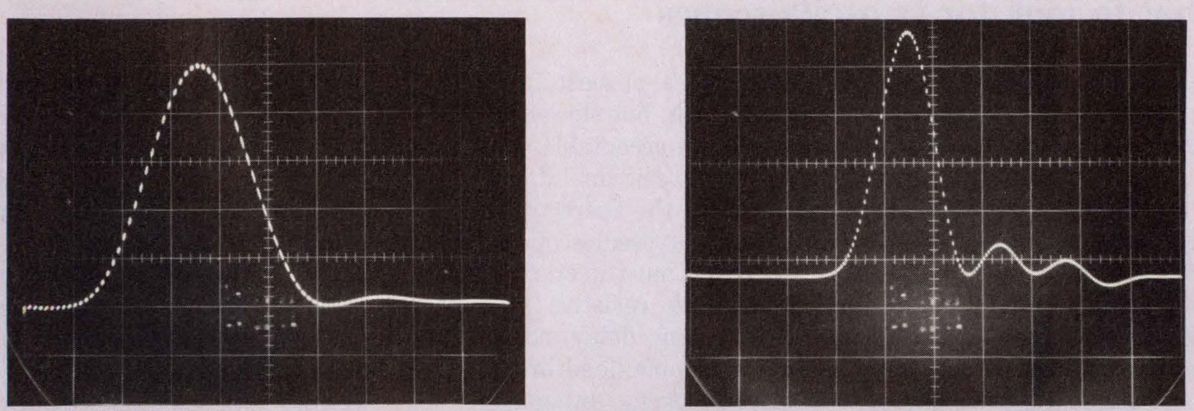


*Fig 2—**Coaxial-termination resistors (a)** are superior in performance to carbon-composition resistors (**b**).*

The lack of standard connectors among wideband instrumentation makes this situation unfortunate. The mismatch caused by a BNC-to-GR874 adapter at the input of a wideband sampling scope is small, but clearly discernible on an oscilloscope. Similarly, you can readily measure mismatches in almost all adapters on a high-frequency network analyzer, such as the Hewlett-Packard 4195A—even in theoretically identical adapters of different manufacture. (For additional wisdom and terror along these lines, see **Ref 1**.)

BNC connections are easily the most common, but not necessarily the most desirable, wideband connectors. The ingenious GR874 connector has notably superior high-frequency characteristics, as does the type N. Unfortunately, it's a BNC world out there.

Choosing the proper probe

After you find the type of connector that is best for your needs, you must choose a probe. Your oscilloscope's probe becomes an integral part of the circuit under test. Therefore, choosing which oscilloscope probe to use for a measurement is absolutely crucial.

Sometimes, however, the best probe is no probe at all. In some circumstances, connecting critical breadboard points directly to the oscilloscope is not only possible, but preferable. Connecting directly to critical breadboard points provides the highest possible grounding integrity, eliminates probe attenuation, and maintains bandwidth. In most cases, however, the direct connection is mechanically inconvenient, and often the oscilloscope's electrical characteristics (particularly input capacitance) will not permit it.

Of course, this mechanical inconvenience is why equipment makers developed oscilloscope probes in the first place, and why they have put so much effort into their probes' development. (**Ref 2** is an excellent reference for the designing of probes.)

Probes are the most overlooked source of oscillographic mismeasurement. The most obvious culprit is probes' input resistance, but input capacitance usually dominates in a high-speed measurement. You can lose much time chasing phantom circuit events that are actually caused by improperly selected or applied probes. Pay particular attention to the probe's input capacitance. Standard 10-MΩ, 10× probes typically have 8 to 10 pF of input capacitance, with 1× types having much higher input capacitance.

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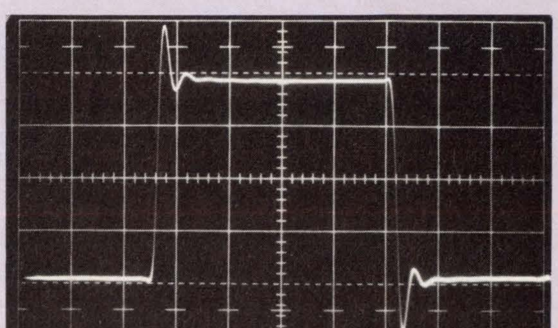

*Fig 3—**The capacitance of a probe clipped** to another node in the circuit distorts this amplifier's response.*

What to look for in oscilloscopes

The modern oscilloscope is one of the most remarkable instruments ever constructed. Perhaps only the zealotry devoted to timekeeping equals the protracted and intense development devoted to these machines. That instruments manufactured 25 years ago still suffice for more than 90% of today's measurements is a tribute to past oscilloscope designers. The oscilloscope-probe combination you select for your high-speed work is the most important equipment decision you can make.

Ideally, your oscilloscope should have at least 150-MHz bandwidth, but slower instruments are acceptable if you understand their limitations. Be certain of the characteristics of your probe-oscilloscope combination. You must keep rise time, bandwidth, resistive and capacitive loading, delay, noise, channel-to-channel feedthrough, overdrive recovery, sweep nonlinearity, triggering, accuracy, and other limitations in mind. High-speed linear circuitry demands a great deal from test equipment, and you can save yourself countless hours by knowing your instruments well.

Engineers have wasted obscene amounts of time pursuing "circuit problems" that in reality arose from misunderstood, misapplied, or out-of-spec equipment. Intimate familiarity with your oscilloscope is invaluable in getting the best possible results with it. In fact, you can get good results with seemingly inadequate equipment if you know and respect the equipment's limitations.

Familiarity with equipment and thoughtful measurement technique permit useful measure-

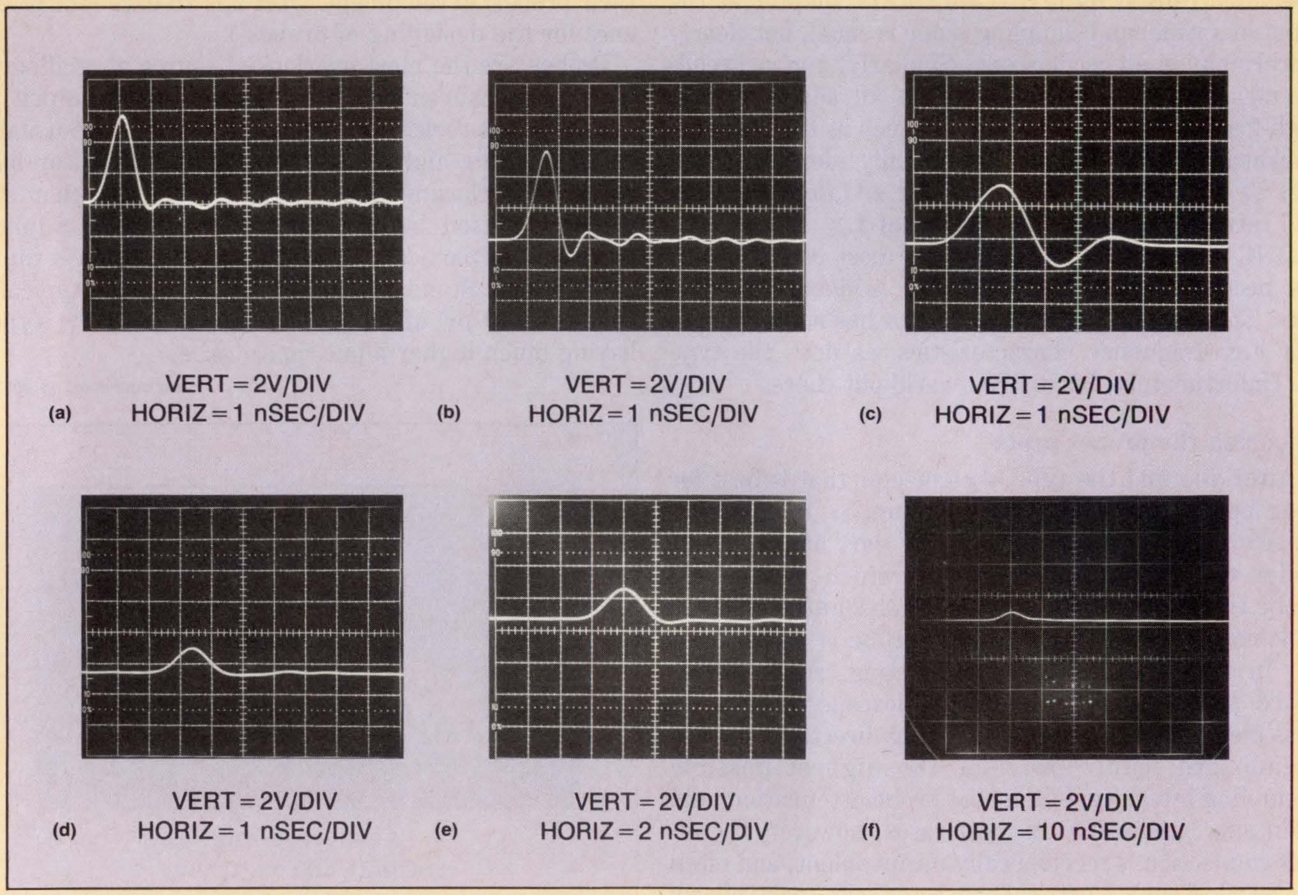

Fig A—This series of photos shows *what the fast pulse in* ***Fig 2a*** *(pg 167) looks like on a variety of oscilloscopes.*

ments seemingly beyond instrument specifications. A 50-MHz oscilloscope cannot track a 5-nsec rise-time pulse, but it can measure a 2-nsec delay between two such events. Using such techniques, you can often deduce the desired information. In some situations no amount of cleverness will work and you must use the right equipment (for example, a faster oscilloscope).

Sometimes "reality checking" a limited-bandwidth instrument with a higher-bandwidth oscilloscope is all that you need to do. For high-speed work, brute-force bandwidth is indispensable when needed, and no amount of features or computational sophistication will substitute. Most high-speed circuitry does not require more than two traces to get where you are going. Versatility and many channels are desirable, but if your budget is limited, spend for bandwidth.

Probe-oscilloscope combinations of varying bandwidths produce dramatic differences in their displays. The series of scope photos in this box shows what a fast pulse looks like on various oscilloscopes. **Fig 2a** (pg 167) in the main text shows the output of a very fast pulse (**Ref 3**) monitored with a 1-GHz sampling scope (Tektronix 556 with 1S1 sampling plug-in). At this bandwidth the 10V amplitude appears clean, with just a hint of ringing after the falling edge. The rise and fall times of 350 psec are suspicious, as the sampling oscilloscope's rise time is also 350 psec.

Fig Aa shows the same pulse observed on a 350-MHz instrument with a direct connection to the input (Tektronix 485/50Ω input). Indicated rise time balloons to 1 nsec, while displayed amplitude shrinks to 6V, reflecting this instrument's lesser bandwidth. Poor grounding technique (1½ in. of ground lead to the ground plane) creates the prolonged rippling after the pulse fall.

Fig Ab shows results from the same 350-MHz oscilloscope with a 3-GHz, 10× probe (Tektronix P6056, 50Ω input). Displayed results are nearly identical, because the probe's high bandwidth contributes no degradation. Again, deliberate poor grounding causes overshoot and rippling on the pulse's falling edge.

Fig Ac equips the same oscilloscope with a 10× probe specified at a 290-MHz bandwidth (Tektronix P-6047). Additionally,

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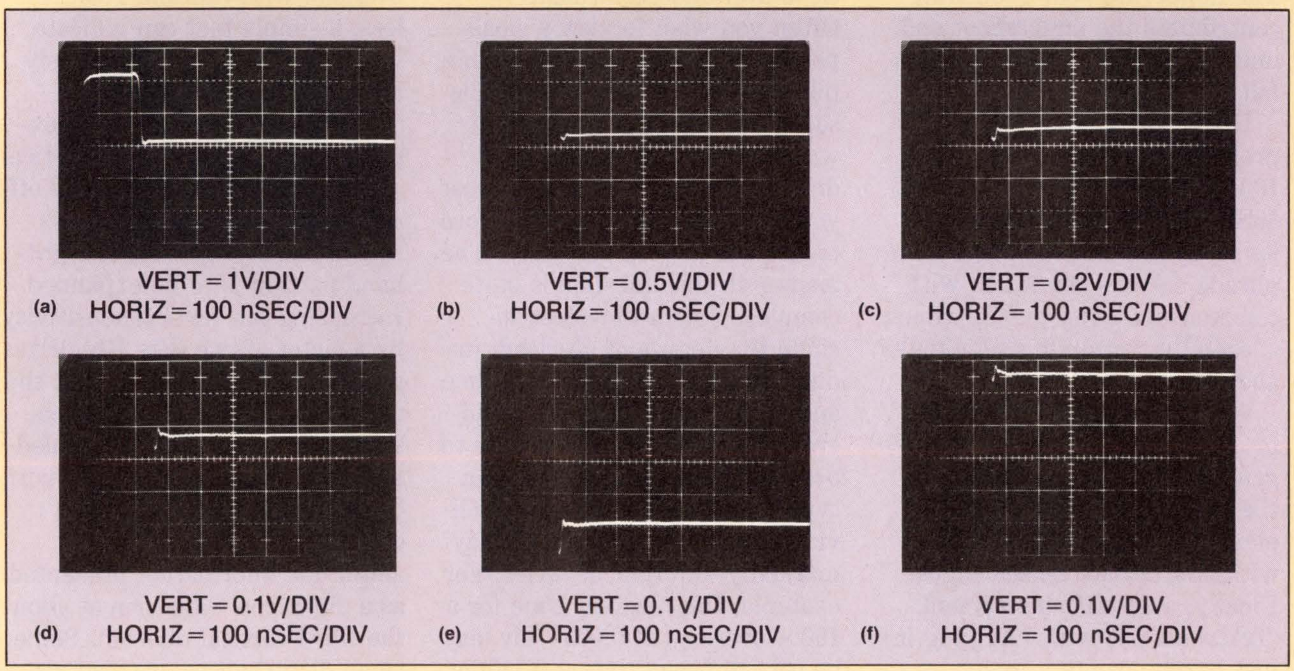


***Fig B—Your particular oscilloscope may** perform peculiarly when overloaded, as this series of scope photos demonstrates.*

The probe-caused problem in **Fig 3** shows up as output peaking and ringing. In other respects the display is acceptable. A second 10× probe connected to the amplifier's summing junction causes this output peaking. Because the summing point is so central to analyzing op-amp operation, it often has a probe attached. At high speeds, the probe's 10-pF input capacitance causes a significant lag in feedback action, forcing the amplifier to overshoot and hunt as it seeks the null point. Minimizing this effect calls for probes having the lowest possible input capacitance, mandating FET types or special passive probes. Account for the effects of probe capacitance, which often dominate the probe's impedance at high-speeds. A standard 10-pF 10× probe, combined with a 1-kΩ source resistance, forms a 10-nsec lag.

But, by far, improper grounding is the greatest source of error in probe use. Poor probe grounding can cause ripples and discontinuities in the observed waveform. In some cases the choice and placement of a probe's ground strap will affect waveforms on another channel. In the worst case, connecting the probe's ground wire will virtually disable the circuit being measured. The cause of these problems is the parasitic inductance in the probe's ground connection.

Fig 4 shows an amplifier output that rings and distorts badly after rapid voltage excursions. Here, the circuit is not at fault; the probe's ground lead is too long. For general-purpose work, most probes come with ground leads about six inches long. At low frequencies this length is fine. At high-speed, the long ground lead looks inductive, causing the ringing shown.

Fast probes always come with a variety of spring clips and accessories designed to aid in making the

What to look for in oscilloscopes *(continued)*

the oscilloscope was in its 1-MΩ input mode, reducing bandwidth to a specified 250 MHz. Amplitude degrades to less than 4V, and edge times similarly increase. The deliberate poor grounding contributes the undershoot and underdamped recovery on pulse fall.

In **Fig Ad** a 100-MHz, 10× probe (Hewlett-Packard Model 10040A) substitutes for the 290-MHz unit. The oscilloscope and its setup remains the same. Amplitude shrinks below 2V, with commensurate rise and fall times. Cleaned up grounding eliminates aberrations.

A Tektronix 454A (150 MHz) produced **Fig Ae**'s trace. A pulse generator connected directly to the oscilloscope's input. Displayed amplitude is about 2V, with appropriate 2-nsec edges. Finally, a 50-MHz instrument (Tektronix 556 with 1A4 plug-in) just barely grunts in response to the pulse (**Fig Af**). Indicated amplitude is 0.5V, with edges reading about 7 nsec. This last display is a long way from the 10V and 350 psec that's really there.

A final oscilloscope characteristic is overload performance. Often you wish to view a small portion of a large waveform's amplitude. In many cases the oscilloscope must supply an accurate waveform after the display is driven off screen. How long must you wait after an overload before taking the display seriously? The answer to this question is quite complex. Factors involved include the degree of overload, its duty cycle, its magnitude in time and amplitude and other considerations. Oscilloscope response to overload varies widely between types. Among a given type, individual instruments often display markedly different behavior. For example, the recovery time for a 100× overload at 0.005V/div may be very different than at 0.1V/div. The recovery may also vary with waveform shape, dc content, and repetition rate.

With so many variables, clearly you must approach measurements involving oscilloscope overload with caution. Nevertheless, a simple test can indicate when overdrive is deleteriously affecting an oscilloscope.

Place the waveform to be expanded on the screen at a vertical sensitivity that eliminates all off-screen activity. **Fig Ba** shows such a display. The lower right-hand portion is to be expanded. Increasing the vertical sensitivity by a factor of two (**Fig Bb**) drives the waveform off-screen, but the remaining display appears reasonable. Amplitude has doubled and waveshape is consistent with the original display. Looking carefully, you can see small-amplitude information presented as a dip in the waveform at about the third vertical division. Some small disturbances are also visible. This observed expansion of lowest possible inductive connection to ground. Most of these attachments assume that your circuit has a ground plane—which it should have. Always try to make the shortest possible connection to ground; anything longer than one inch may cause trouble. The ideal probe-ground connection is purely coaxial. Probes mated directly to board-mounted coaxial connectors give the best results.

Sometimes determining if probe grounding is the cause of observed waveform aberrations is difficult. One good test is to disturb the grounding setup and see if changes occur. Touching the ground plane or jiggling probe-ground connectors or wires should have no effect. If you are using a ground-strap wire, try changing its orientation or simply squeezing it together to change and minimize its loop area. If any waveform change occurs, your probe grounding is unacceptable.

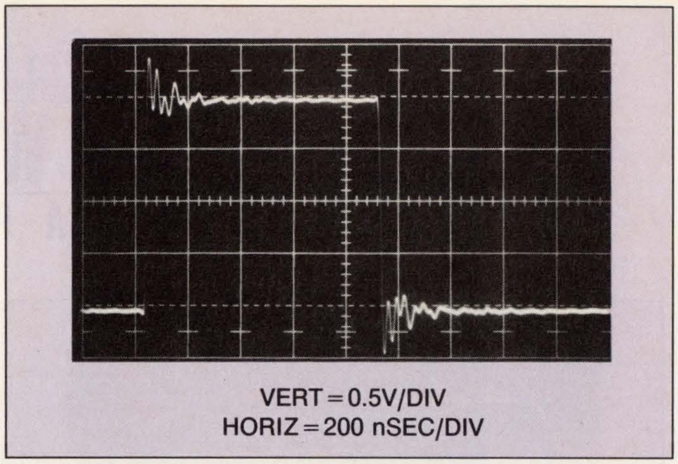


Fig 4—Probe capacitance isn't the only fly in *the ointment; here, an overly long ground lead induces ringing.*

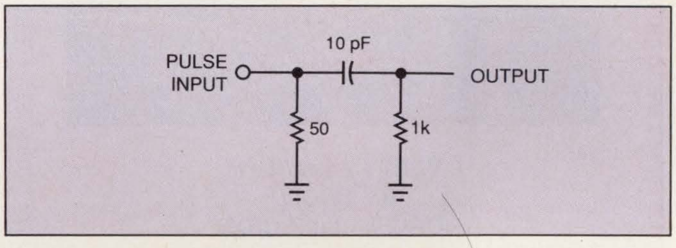


Fig 5—Monitoring this simple circuit's *response to a pulse illustrates several potential probing problems.*

the original waveform is believable.

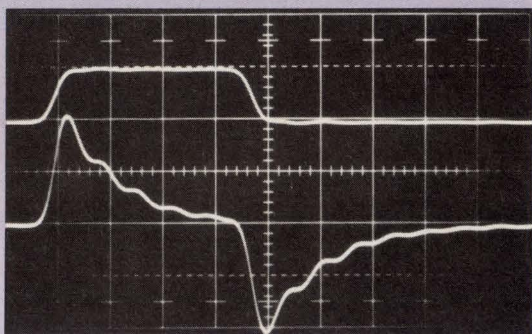
In **Fig Bc**'s display, gain is higher, and all the features of the **Fig Bb** example are amplified accordingly. The basic waveshape appears clearer, and the dip and small disturbances are also easier to see. No new waveform characteristics appear. The **Fig Bd** photo brings some unpleasant surprises. This increase in gain causes definite distortion. The initial negative-going peak, although larger, has a different shape. Its bottom appears less broad than in **Fig Bc**. Additionally, the peak's positive recovery is shaped slightly differently. A new rippling disturbance is visible in the center of the screen. This kind of change indicates that the oscilloscope is having trouble.

A further test can confirm that overloading is influencing this waveform. In **Fig Be**'s photo, the gain remains the same but the vertical position knob has repositioned the display at the screen's bottom. This shifts the oscilloscope's dc operating point which, under normal circumstances, should not affect the displayed waveform. Instead, a marked shift in waveform amplitude and outline occurs. Repositioning the waveform to the screen's top produces a differently distorted waveform (**Fig Bf**). Obviously, for this particular waveform, you cannot obtain accurate results at this gain.

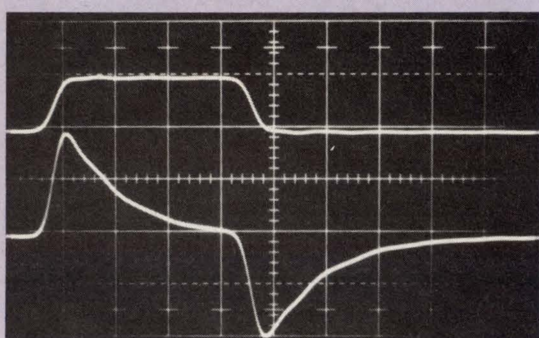
Differential plug-ins can address some of the issues associated with excessive overdrive, although they cannot solve all problems. Two differential plug-in types merit special mention. At low levels, a high-sensitivity differential plug-in is indispensable. The Tektronix 1A7 and 7A22 feature 10-μV sensitivity, although bandwidth is limited to 1 MHz. The units also have selectable highpass and lowpass filters and good high-frequency, common-mode rejection. Tektronix type 1A5, W, and 7A13 are differential comparators. They have calibrated dc nulling ("sideback") sources, letting you observe both small, slowly moving events on top of common mode dc or fast events riding on a waveform.

A special case is the sampling oscilloscope. Because of its nature of operation, a sampling scope in proper working order is inherently immune to input overload, providing essentially instantaneous recovery between samples (**Ref 4**).

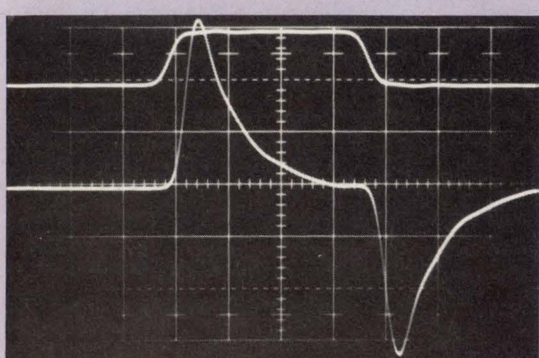
The best approach to measuring small portions of large waveforms, however, is to eliminate the large signal swing seen by the oscilloscope. The **box,** "Measuring amplifier settling time," in the article "Subduing high-speed op-amp problems" (scheduled for the October 24 issue of EDN), shows ways to do this when measuring DAC/amplifier settling time to very high accuracy at high speed.



(a) VERT = A = 5V/DIV
B = 1V/DIV
HORIZ = 10 nSEC/DIV

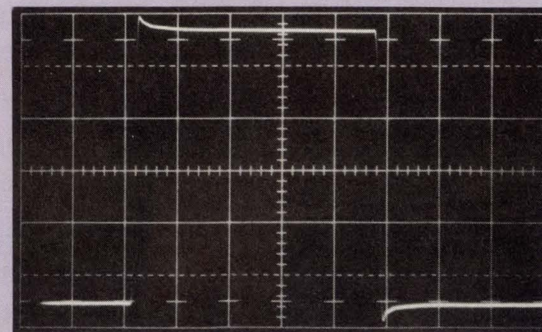


(b) VERT = A = 5V/DIV
B = 1V/DIV
HORIZ = 10 nSEC/DIV

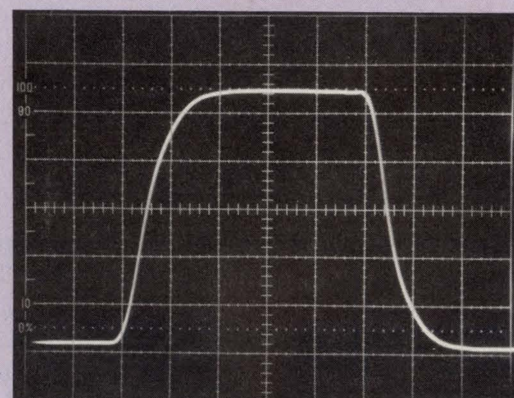


(c) VERT = A = 5V/DIV
B = 1V/DIV
HORIZ = 10 nSEC/DIV

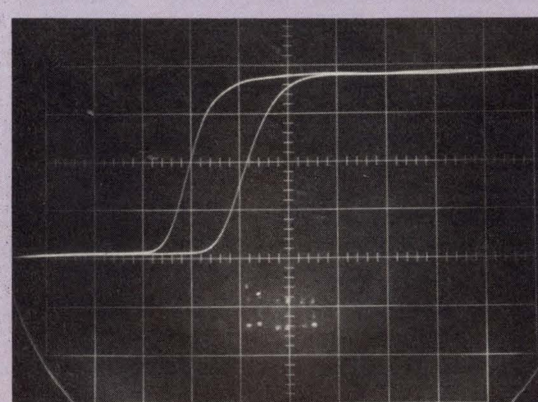
Fig 6—A probe's capacitance and ground-lead *inductance add ringing and distortion to the output (**a**). Substituting a spring clip for the ground lead cleans up the output trace somewhat (**b**). Substituting an FET probe for the ground lead (**c**) reveals a 50% amplitude distortion in **b**.*



(a) VERT = 2V/DIV
HORIZ = 50 nSEC/DIV



(b) VERT = 0.5V/DIV
HORIZ = 20 nSEC/DIV



(c) VERT = A = 0.5V/DIV
B = 0.5V/DIV
HORIZ = 10 nSEC/DIV

Fig 7—In a, a grossly miscompensated or improperly *selected oscilloscope probe causes an op amp to appear to be delivering an 11V output from a 5V supply. In **b**, a probe having insufficient bandwidth rounds off the edges of this waveform. Probes can also add significant delay to observed waveforms (**c**).*

The simple network of the circuit in **Fig 5** shows just how easily poorly chosen or used probes cause bad results. A 9-pF input-capacitance probe with a 4-in. ground strap monitors the output (**Fig 6a**). Although the pulse input is clean, the output contains ringing. Using the same probe with a ¼-in. spring-tip ground-connection accessory seemingly cleans up everything (**Fig 6b**). However, substituting a 1-pF FET probe (**Fig 6c**) reveals a 50% output-amplitude error in **Fig 6b**'s measurement. The FET probe's low-input capacitance allows a more accurate version of the circuit's action. The FET probe does, however, contribute its own form of error. Note that the probe's response is tardy by 5 nsec because of delay in its active circuitry. Hence, you must make separate measurements with each probe to determine amplitude and timing characteristics of the output.

Poorly compensated probe

In **Fig 7a**, the probe is properly grounded, but a new problem pops up. This photo shows an amplifier output excursion of 11V—quite a trick from an amplifier running from ±5V rails. Engineers commonly report this confusing problem when they work on high-speed circuits. The problem arises not because of a suspension of natural law, but from a grossly miscompensated or improperly selected oscilloscope probe. Use probes that match your oscilloscope's inputs and compensate them properly.

Fig 7b illustrates another probe-induced problem. Here the waveform's amplitude seems correct, but the amplifier appears slow, developing pronounced edge rounding. Here, the probe used is too heavily compensated or slow for the oscilloscope. Never use 1× or "straight" probes. Their bandwidth is 20 MHz or less and their capacitive loading is high. Check probe bandwidth to ensure it is adequate for the measurement. Similarly, use an oscilloscope that has adequate bandwidth.

Mismatched probes account for the apparent excessive amplifier delay in **Fig 7c**'s amplifier. The display shows delay of almost 12 nsec for an amplifier that specs 6 nsec. Always keep in mind that various types of probes have different signal-transit delay times. At high-sweep speeds this effect shows up in multitrace displays as time skew between individual channels. Using similar probes will eliminate this problem, but measurement requirements often dictate dissimilar probes. In such cases you should measure the differential delays and then mentally factor them in to reduce error when interpreting the display. Note that active probes, such as FET and current probes, have signal transit times as long as 25 nsec. A fast 10×- or 50Ω-probe's delay can be inside 3 nsec. Account for probe delays in interpreting oscilloscope displays.

Fig 8a depicts a wildly distorted amplifier output. The output slews quickly, but the pulse's top and bottom recovery have lengthy, tailing responses. Additionally, the amplifier's output seems to clip well below its nominal-rated output swing. A common oversight is responsible for these conditions—An FET probe monitors the amplifier's output in this example. The probe's common-mode input range has been exceeded, causing the probe to overload, clip, and distort badly.

The rising pulse drives the probe deeply into saturation, forcing its internal circuitry away from normal

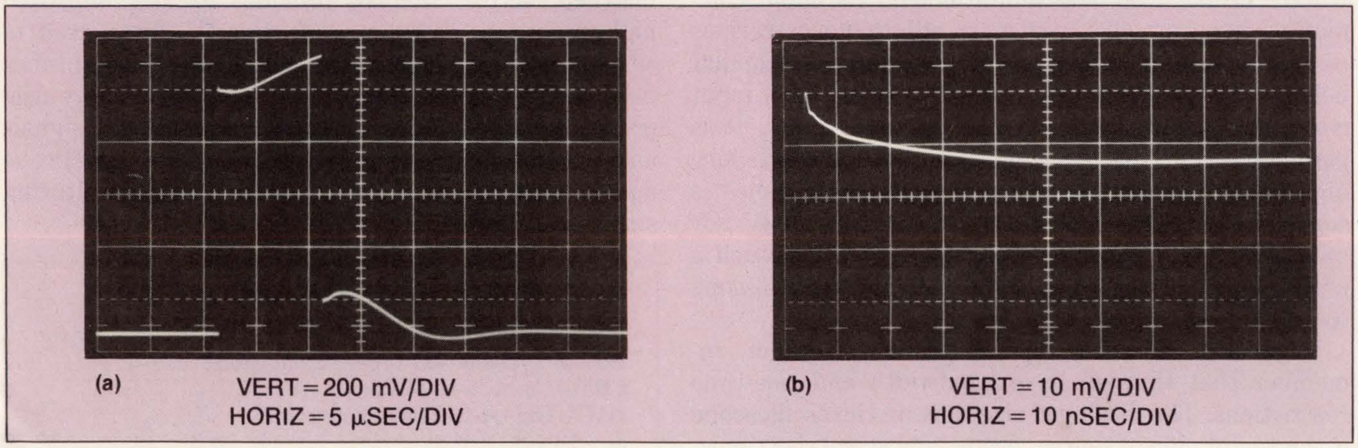


*Fig 8—Section **a** shows the result of overdriving an FET probe's internal circuitry, and **b** illustrates the inadvisability of attaching bargain-basement probes to a high-speed circuit.*

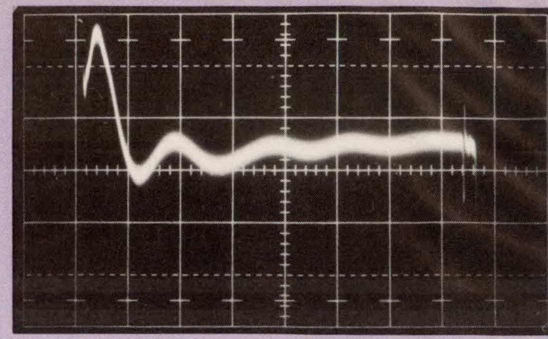


*Fig 9—**What appears to be a circuit's ringing** is actually the oscilloscope recovering from overdrive arising from an off-screen excursion.*

operating points. Under these conditions the displayed pulse top is invalid. When the circuit's output falls, the probe's overload recovery is lengthy and uneven, causing the tailing. More subtle forms of FET probe overdrive may show up as extended delays, but there is no obvious signal distortion. Avoid saturation effects arising from an FET probe's common-mode input limitations (typically ±1V) by using 10× and 100× attenuator heads when required.

A peaked, tailing response is the characteristic depicted in **Fig 8b**. The photo shows the final 40 mV of a 2.5V amplifier excursion. Instead of a sharp corner that settles cleanly, peaking occurs, followed by a lengthy tailing decay. An inexpensive "off-brand" 10× probe picked off this waveform. Such probes are often poorly designed, and constructed from materials inappropriate for high-speed work. Selecting and integrating materials for wideband probes is a specialized and difficult art. Probe designers must expend substantial design effort to get good fidelity at high speeds. Never use probes unless their manufacturer specifies them for wideband operation. Obtain probes from a vendor you trust.

When choosing your probe, also keep in mind that you cannot use all 10× probes with all oscilloscopes indiscriminately; the probe's compensation range must match the oscilloscope's input capacitance. Low impedance probes, designed for 50Ω inputs, (with 500Ω to 1kΩ resistance) usually have input capacitance of 1 or 2 pF. They are a very good choice if you can stand the low resistance. FET probes maintain high-input resistance and keep capacitance at the 1-pF level, but have substantially more delay than passive probes.

FET probes also have limitations on the input common-mode range that you must adhere to or serious measurement errors will result. Contrary to popular belief, FET probes do not have extremely high input resistance—some types are as low as 100 kΩ. It is possible to construct a wideband FET probe with very high input impedance, although input capacitance is somewhat higher than standard FET probes. For measurements requiring these characteristics, such a probe is useful (see **box,** "Build your own oscilloscope tools").

Regardless of which type of probe you select, remember that they all have bandwidth and rise-time restrictions. The displayed rise time on the oscilloscope is the vector sum of source, probe, and scope rise times,

$$T_{RISE} = \sqrt{(T_{RISE}\ SOURCE)^2 + (T_{RISE}\ PROBE)^2 + (T_{RISE}\ OSCILLOSCOPE)^2}.$$

This equation warns that some rise-time degradation must occur in a cascaded system. In particular, if the probe and oscilloscope have the same rise time, the system's response will be slower than either.

Current probes are useful and convenient. The passive transformer types are fast and have less delay than the Hall-effect versions. The Hall types, however, respond at dc and low frequency, while the transformer types typically roll off somewhere below 1 kHz to 100 Hz. Both types have saturation limitations which, when exceeded, cause odd results on the CRT that will confuse the unwary. The Tektronix CT-1 current probe, albeit not nearly as versatile as the clip-on probes, bears mention. Although the CT-1 is not a clip-on device, it may be the least electrically intrusive way of extracting wideband signal information. Rated at a 1-GHz bandwidth, the CT-1 produces 5-mV/mA output with only 0.6-pF loading. The decay time-constant of this ac-current probe is ~1%/50 nsec, resulting in a low-frequency limit of 35 kHz.

A very special probe is the differential probe. You may think of a differential probe as two matched FET probes contained within a common probe housing. This probe literally brings the advantage of a differential-input oscilloscope to the circuit board. The probes' matched, active circuitry provides greatly improved high-frequency, common-mode rejection compared to single-ended probing or even matched, passive probes used with a differential amplifier. The differential probe's resultant ability to reject common-mode signals and "ground noise" at high frequency lets this probe deliver exceptionally clean results when monitoring small, fast signals.

Acronyms used in this article

BNC—BNC coax connector. A twist-lock connector for various types of RG-type coaxial cables.
CRT—Cathode-ray tube
DAC—Digital-to-analog converter
dc—Direct current
FET—Field-effect transistor
IC—Integrated circuit

A final form of probe is the human finger. Probing the circuit with a finger can accentuate desired or undesired effects, giving clues that may be useful. The finger can introduce stray capacitance to a suspected circuit node while you observe the results on the CRT. Two fingers, lightly moistened, can provide an experimental resistance path. Some engineers are particularly adept at these techniques and can estimate the capacitive and resistive effects created with surprising accuracy.

You can mount a miniature coaxial connector on your circuit board and mate whichever type of probe you choose to it. This technique provides the lowest possible parasitic inductance in the ground path and is especially recommended. If you use a current probe, a ground connection is not usually required. However, at high speeds, a ground connection may result in a cleaner CRT presentation. Because no current flows in the ground lead of current probes, a long strap is usually permissible.

Even an ideal probe connection does not guarantee an accurate scope display. **Fig 9** shows the final movements of an amplifier output excursion. Setting the scope at only 1-mV per division, the objective is to view the settling residue at high resolution. Multiple time constants, nonlinear recovery, and tailing characterize this response. Note also the high-speed event just before the waveform begins its negative going-transition. What you are actually seeing is the oscilloscope recovering from excessive overdrive. You should approach any observation that requires off-screen positioning of parts of the waveform with the greatest caution. Oscilloscopes vary widely in their response to overdrive, bringing displayed results into question. Approach all oscilloscope measurements that require off-screen activity with caution. Know your instrument's capabilities and limitations. EDN

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Author's biography

For more information on this article's author, see pg 163

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

Build your own oscilloscope tools

Under most circumstances the 1- to 2-pF input capacitance and 10-MΩ resistance of FET probes is more than adequate for difficult probing situations. Occasionally, however, you may need very high input resistance along with high speed. At some sacrifice in speed and input capacitance, compared with commercial probes, you can construct such a probe.

Fig A shows schematic details. IC_1, a 350-MHz hybrid FET buffer, forms the electrical core

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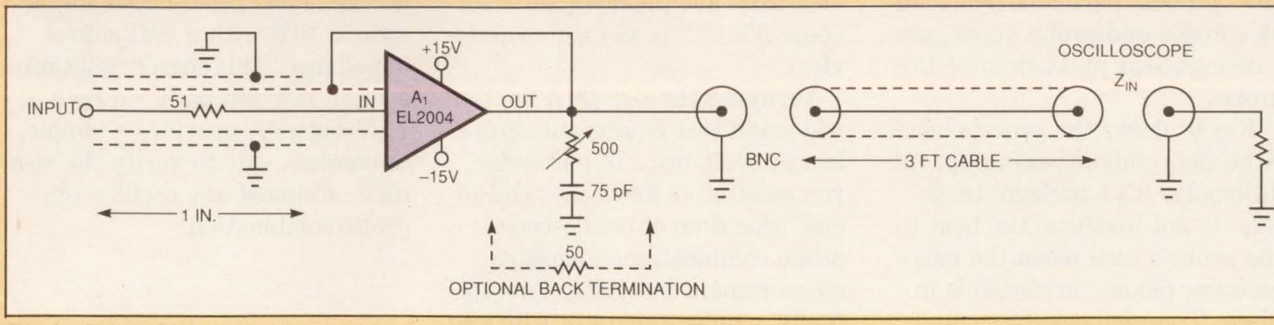


***Fig A—Using this circuit, you can** build your own high-performance FET oscilloscope probe.*

Build your own oscilloscope tools *(continued)*

of the probe. This device is a low input-capacitance, wideband-FET source follower driving a fast bipolar output stage. The input of the probe goes to this device via a 51Ω resistor, reducing the possibility of oscillations in the follower's input stage when the probe sees low ac impedance. IC_1's output drives a guard shield around the probe's input line, reducing effective input capacitance to about 4 pF. A ground-referred shield encircles the guard shield, reducing pickup and making high-quality ground connections to the circuit under test easy.

IC_1 drives the output BNC cable to feed the oscilloscope. Normally, back-terminating the cable at IC_1 is undesirable because the oscilloscope sees only half of IC_1's output. Although a back termination provides the best signal dynamics, the resulting attenuation is a heavy penalty. You can trim the RC damper for best edge response while still maintaining an unattenuated output.

What you can't see in the schematic is the probe's physical construction. You must built the probe very carefully to maintain low input capacitance, low bias current, and wide bandwidth. The probe's head is particularly critical. Make every effort to minimize the length of wire between IC_1's input and the probe's tip. In our lab, we have found that discarded pieces of broken 10× probes, particularly attenuator boxes and probe heads, provide excellent packaging for this probe.

Fig B shows the probe's head. Note the compact packaging. Additionally, IC_1's package transfers its not-insubstantial heat to the probe's case when the snap-on cover (shown in photo) is in place. This reduces IC_1's substrate temperature, keeping bias current down. IC_1's input connects directly to the probe's head to minimize parasitic capacitance. The power supply for IC_1, located in a separate enclosure, feeds in through separate wires. IC_1's output goes to the oscilloscope via conventional BNC hardware.

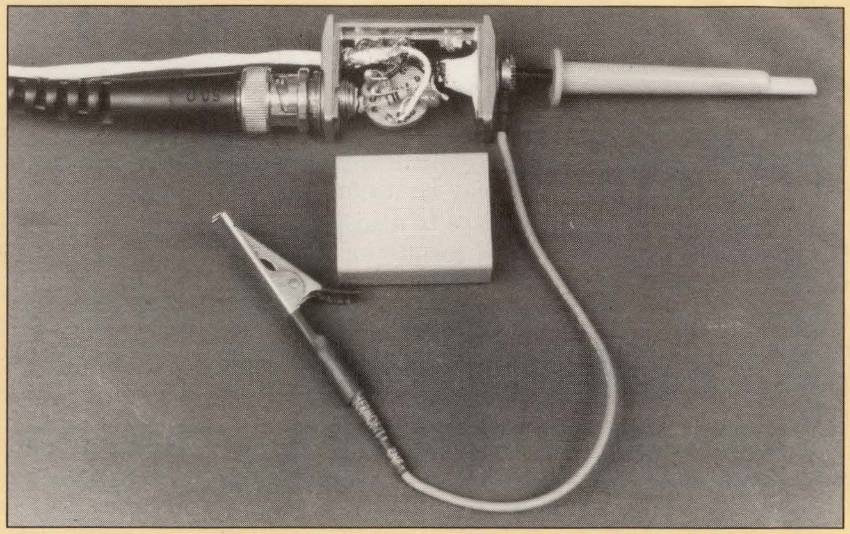


***Fig B—The components in Fig A fit** nicely into a salvaged commercial probe.*

Fig C shows the probe's output responding to an input as monitored on a 350-MHz oscilloscope (Tektronix 485). Measured specifications for Linear Technology's version of this probe include a rise time of 6 nsec, 6-nsec delay, and 350-MHz bandwidth. The delay time splits evenly between the amplifier and cable. Input capacitance is about 4 pF without the probe-hook tip and 7 pF with the hook tip. Input bias current measured 400 pA and gain error about 5% (IC_1 is an open-loop device).

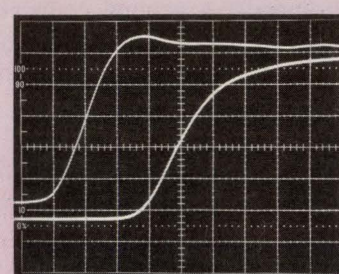
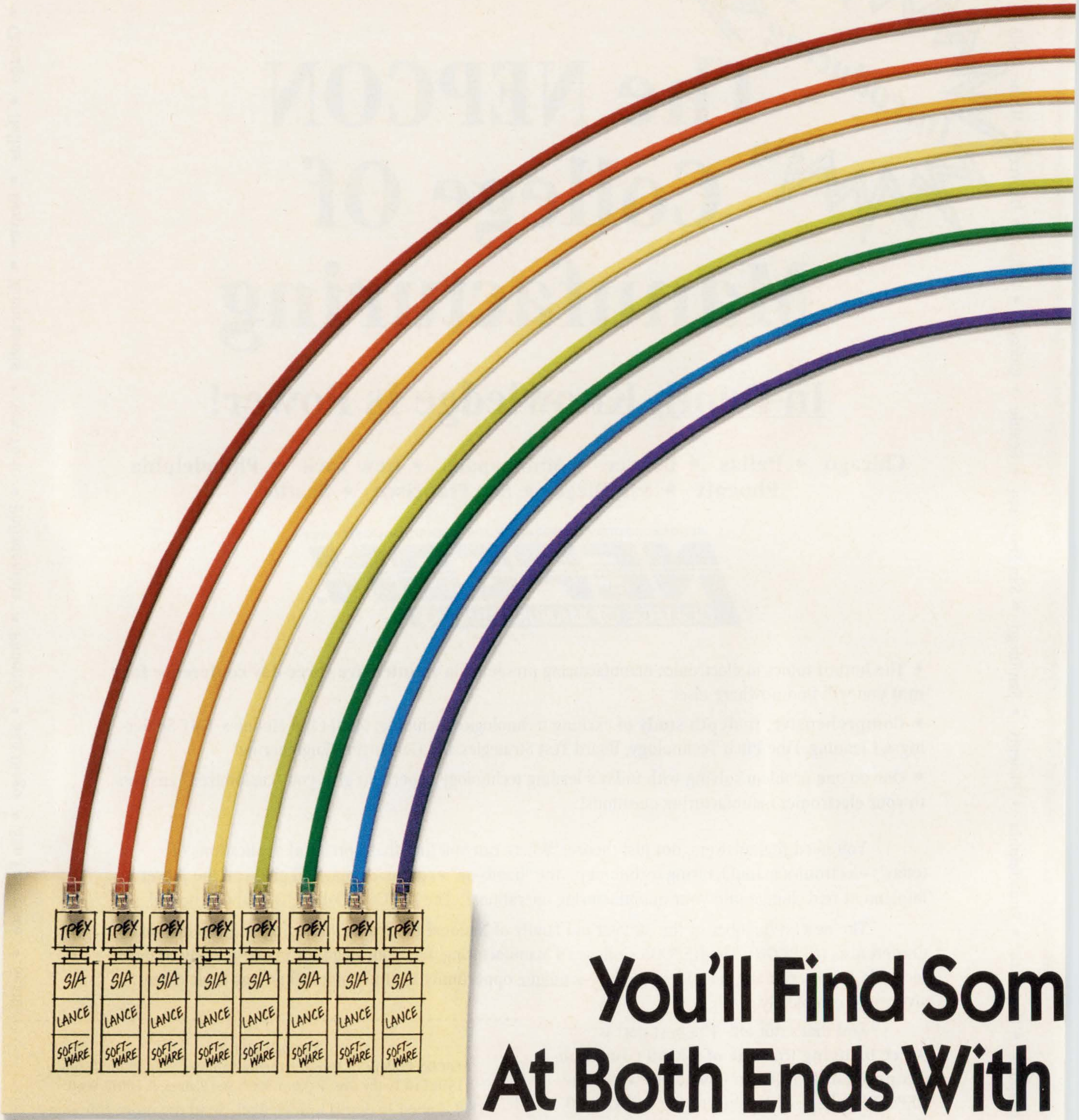


***Fig C—This scope photo shows the homemade probe's** output responding to an input.*

Verifying the rise-time limit of wideband test equipment setups is a difficult task. In particular, you must often know the "end-to-end" rise time of oscilloscope-probe combinations to ensure measurement integrity. Conceptually, a pulse generator with rise times substantially faster than the oscilloscope-probe combination can provide this information. The circuit described in **Ref 1** does this, providing a 1-nsec pulse having rise and fall times less than 350 psec. Pulse amplitude is 10V with a 50Ω source impedance. This circuit, built into a small box and powered by a 1.5V battery, provides a simple, convenient way to verify the rise time of almost any oscilloscope-probe combination.



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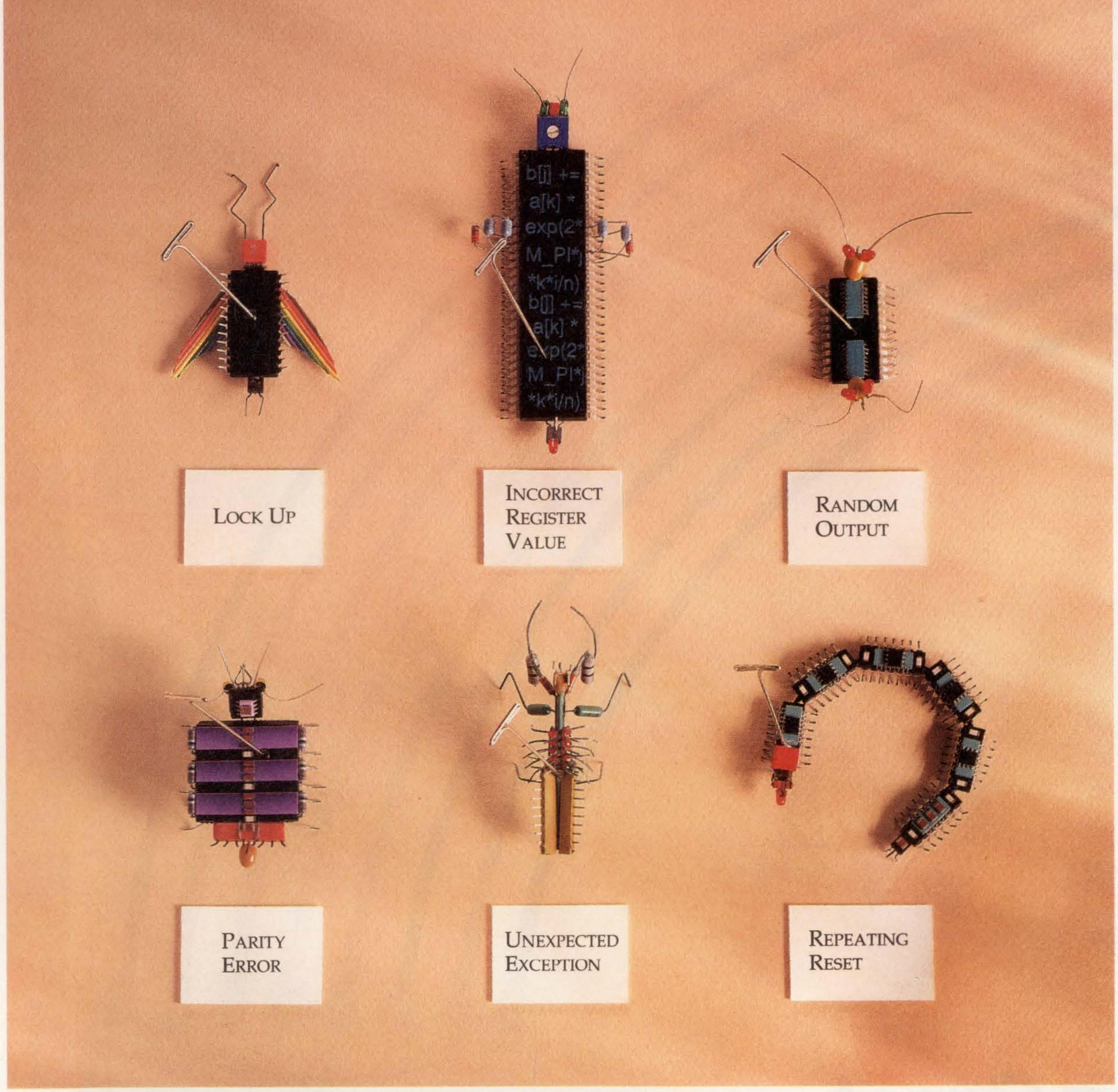

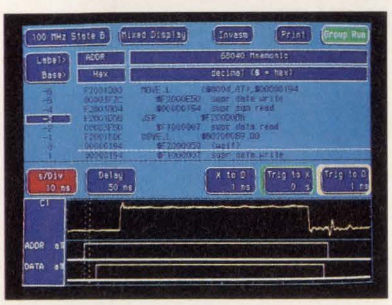

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CIRCLE NO. 110

THE JIM WILLIAMS PAPERS

Correcting power-supply problems

To ensure proper operation of circuits that use high-speed op amps, you need to pay careful attention to power-supply bypassing. Of equal importance are layout techniques and the need to establish a proper ground plane.

Jim Williams, *Linear Technology Corp*

Two of the most common problems encountered in any circuit design that uses high-speed op amps are those of power-supply bypassing and pc-board layout techniques. Of these two problems, power-supply bypassing is by far the most common. Bypassing is necessary to maintain a low supply impedance. Any dc resistance or inductance in supply wires and pc-board traces can quickly raise this impedance to unacceptable levels. A high-impedance supply lets the supply voltage vary as the current levels of the devices connected to it change. Such a situation almost always causes unruly operation of the individual devices. Moreover, several devices connected to an unbypassed supply can "communicate" through the finite-supply impedances, causing erratic operating modes.

Bypass capacitors furnish a simple way to eliminate these problems by providing a local reservoir of energy at the device. A bypass capacitor acts like an electrical flywheel to keep supply impedance low at high frequencies. The choice of the type of capacitor to use for bypassing is a critical issue. **Fig 1** shows the output of an unbypassed amplifier driving a 100Ω load. The power supply the amplifier sees at its terminals has a high impedance at high frequencies. This impedance forms a voltage divider with the amplifier and its load, letting the supply move as internal conditions in the amplifier change. As shown, this action causes local feedback, and oscillation occurs. Therefore, always use bypass capacitors at appropriate supply-rail points.

In **Fig 2** the 100Ω load is removed, and the amplifier

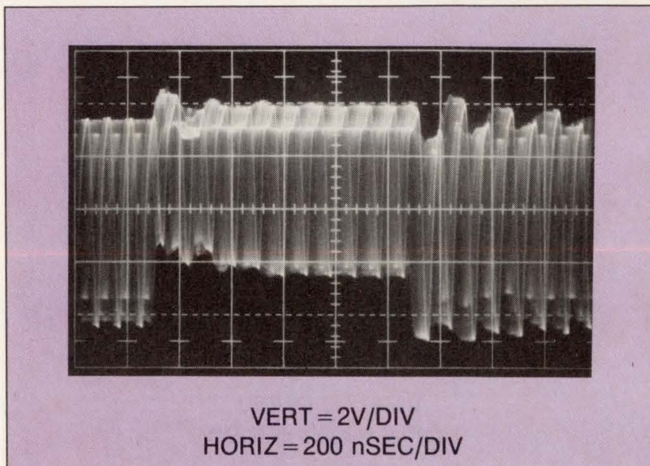

Fig 1—The output of an amplifier *drives a 100Ω load without bypass capacitors.*

displays a pulse output. The unbypassed amplifier responds surprisingly well, but overshoot and ringing dominate. Always use bypass capacitors to avoid overshoot and ringing. In **Fig 3**, the settling is noticeably better, but some ringing remains. This response is typical of lossy bypass capacitors, or good ones placed too far away from the amplifier. Use good quality, low-loss bypass capacitors, and place them as close to the amplifier as possible.

The multiple-time-constant ringing in **Fig 4** often indicates a poor grade of paralleled bypass capacitors or excessive trace length between the capacitors. Although paralleling capacitors of different characteristics is a good way to get wideband bypassing, you need to consider such action carefully. Resonant interaction between the capacitors can also cause such a waveform after a step input. This type of response is often aggravated by heavy amplifier loading. When paralleling bypass capacitors, plan the layout and breadboard with the units you plan to use in production.

Fig 5 addresses a more subtle bypassing problem. The trace shows the last 40-mV excursion of a 5V step almost settling cleanly in 300 nsec. The slight overshoot is due to a loaded (500Ω) amplifier without quite enough bypassing. Increasing the total supply bypassing from 0.1 to 1 μF cured this problem. Use large-value paralleled bypass capacitors when you need very fast settling, particularly if the amplifier is heavily loaded, or sees fast load steps.

The problem of peaking on the leading and trailing corners (**Fig 6**) is typical of poor layout practice. Depicted here, a unity-gain inverter suffers from excessive trace area at the summing point. Only 2 pF of stray capacitance caused the peaking and ringing. Minimize trace area and stray capacitance at critical nodes. Consider layout as an integral part of the circuit, and plan it accordingly.

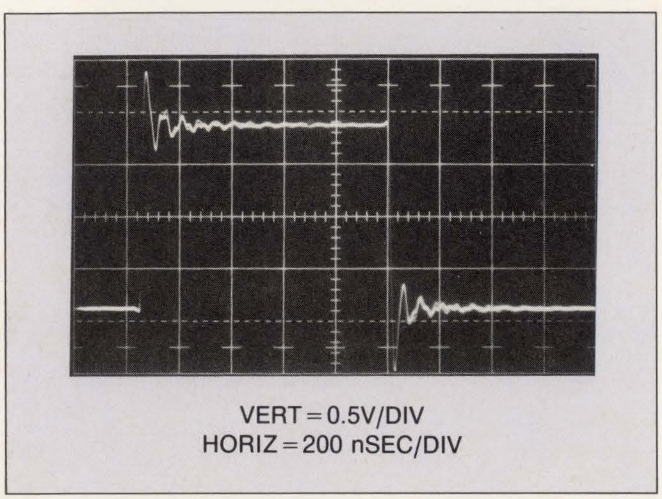

Fig 2—An unbypassed amplifier with no load *can be surprisingly stable—temporarily.*

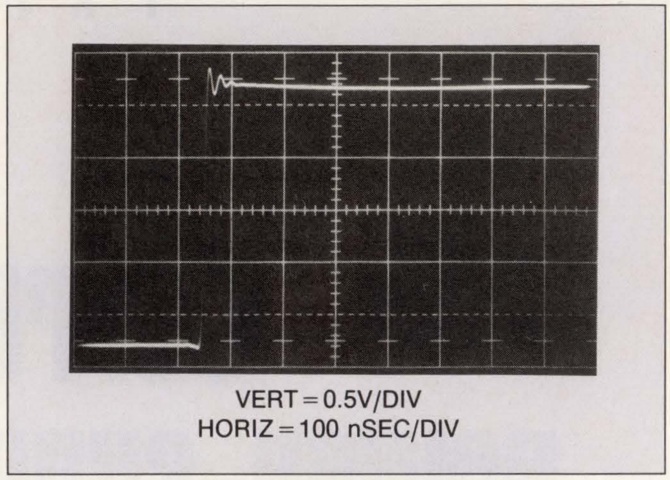

Fig 3—A poor-quality bypass capacitor *allows some ringing in the amplifier's output.*

About bypass capacitors

Bypass capacitors are used to maintain low power-supply impedance at the point of load. Parasitic resistance and inductance in supply lines mean that the power-supply impedance can be quite high. As frequency goes up, the inductive parasitic becomes particularly troublesome. Even if these parasitic terms did not exist, or if local regulation is used, bypassing

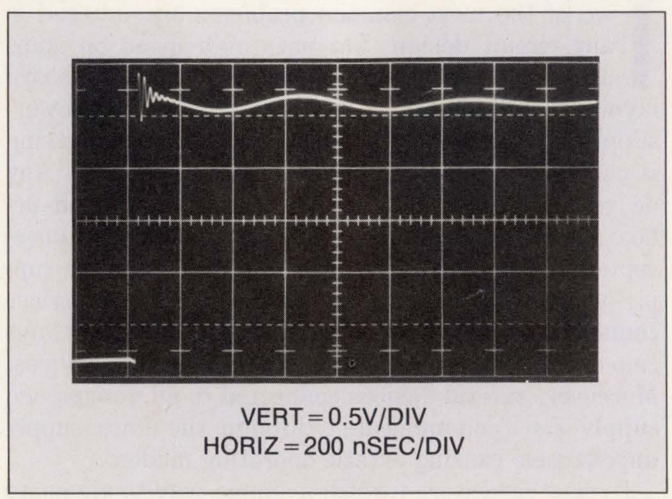

Fig 4—Paralleled bypass capacitors *form a resonant network, which produces ringing.*

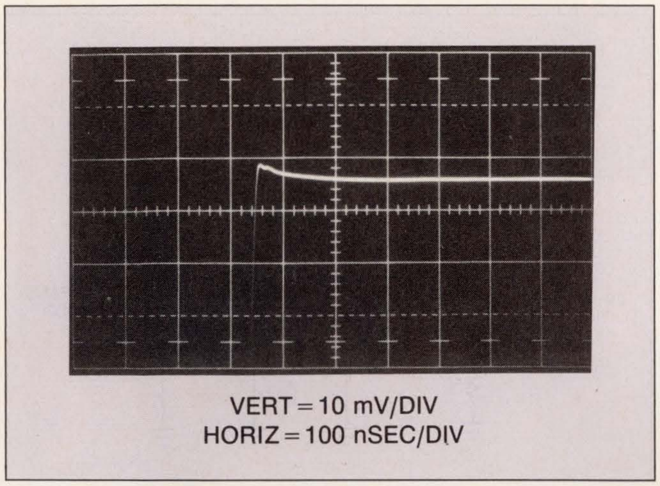

Fig 5—This waveform shows a more subtle bypassing problem. Not-quite-good-enough bypassing causes a few millivolts of peaking.

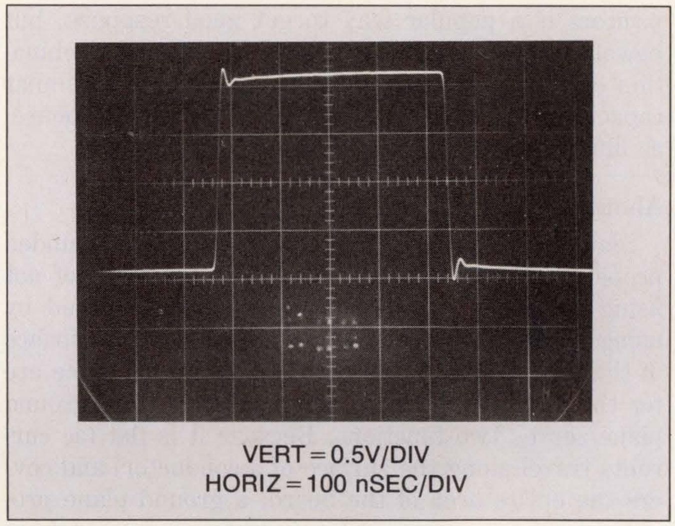

Fig 6—This waveform is a typical result of poor layout. Only 2 pF of capacitance at the summing point introduces peaking on the leading and trailing corners.

is still necessary because no power supply or regulator has zero output impedance at 100 MHz. You determine the type of capacitor to use by its application, the frequency domain of the circuit, cost factors, board space, and many other considerations. It is possible, however, to make some useful generalizations.

All capacitors contain parasitic terms (some examples of which appear in **Fig 7**). In bypass applications, leakage and dielectric absorption are second-order terms, but series resistance (R) and inductance (L) are not. These latter terms limit the capacitor's ability to damp transients and maintain low power-supply impedance. Bypass capacitors must often be large in value to absorb long transients, necessitating electrolytic types that have large values of series R and L.

Different types of electrolytics and combinations of electrolytic and nonpolarized capacitors have markedly different characteristics. Which type (or types) to use is a matter of passionate debate in some circles. The test circuit of **Fig 8** and accompanying photos are useful in evaluating the choices. The photos show the response of five bypassing methods to the transient generated by the test circuit. **Fig 9a** shows an unbypassed line that sags and ripples badly at large amplitudes. **Fig 9b** uses a 10-µF aluminum electrolytic to considerably cut the disturbance, but there is still plenty of potential trouble. A 10-µF tantalum unit (**Fig 9c**) offers cleaner response, and the 10-µF aluminum electrolytic combined with a 0.01-µF ceramic type (**Fig 9d**) is even better. Combining electrolytics with nonpolarized ca-

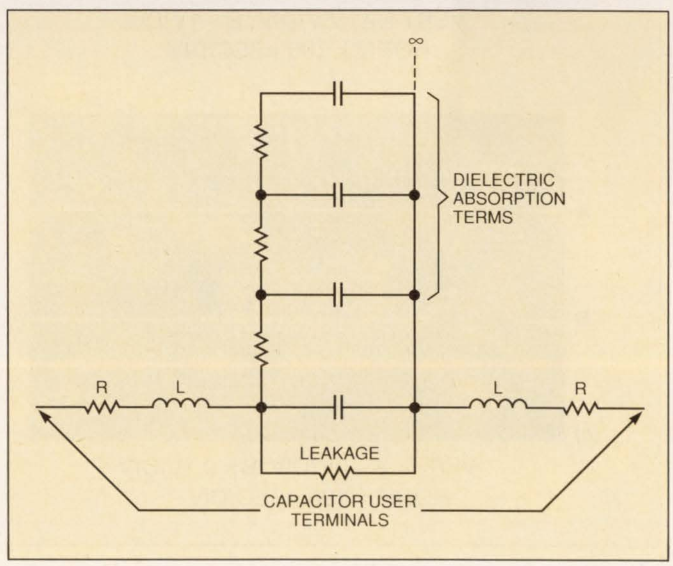

Fig 7—All capacitors have parasitics. In bypass applications, the series resistance (R) and inductance (L) limit the capacitor's ability to maintain a low supply impedance.

Acronyms used in this article

air wire—A connection from lead-to-lead without going to a specific terminal or point.
BNC—BNC coax connector. A twist-lock connector for various types of RG-type coaxial cables.
DAC—Digital-to-analog converter
IC—Integrated circuit
pc board—Printed-circuit board
pc card—Printed-circuit card

pacitors is a popular way to get good response, but beware of picking the wrong pair. The wrong combination of supply-line parasitics and paralleled dissimilar capacitors can produce a resonant, ringing response, as illustrated in **Fig 10**.

About ground planes

Similar to that resulting from a poorly grounded probe, the **Fig 11** waveform shows the result of not using a ground plane. A ground plane is formed by using a continuous conductive plane over the surface of the circuit board. The only breaks in this plane are for the circuit's necessary current paths. The ground plane serves two functions. Because it is flat (ac currents travel along the surface of a conductor) and covers the entire area of the board, a ground plane provides a way to access a low-inductance ground from

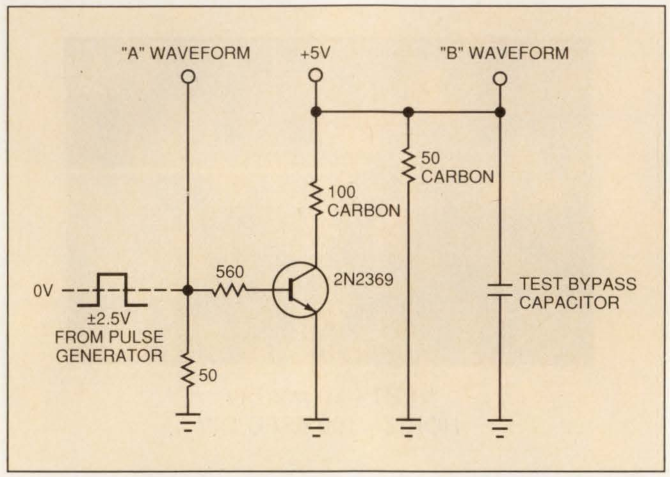

***Fig 8—This test circuit,** together with various types of bypass capacitors, produced the waveforms shown in **Figs 9a** through **d**.*

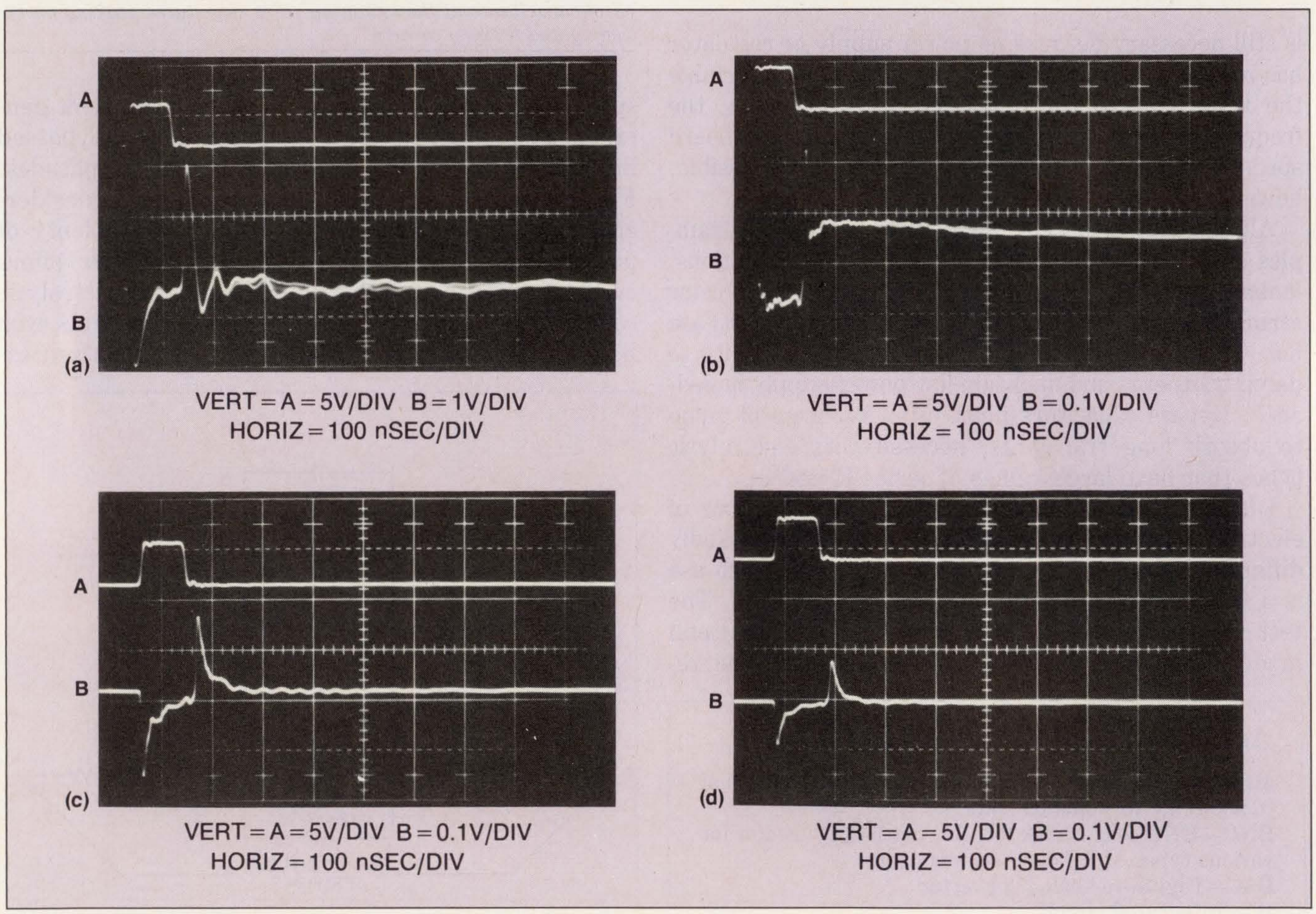

***Fig 9—The response of this unbypassed line (a)** sags and has a high ripple content. A 10-μF aluminum-electrolytic capacitor (**b**) somewhat reduces that disturbance. A 10-μF tantalum capacitor (**c**) offers cleaner response than that shown in **b**. Combining different capacitor types provides further improvement. A 10-μF aluminum capacitor and a 0.01-μF ceramic type (**d**) substantially smooth out the disturbance.*

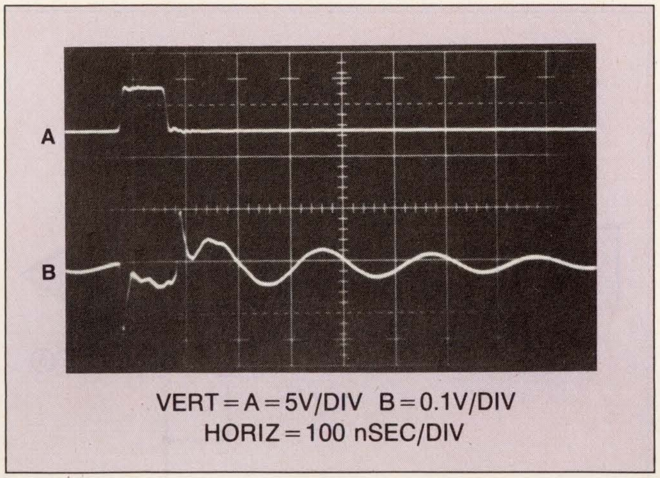

Fig 10—Some paralleled combinations can cause ringing. *Always try various types before specifying.*

anywhere on the board. A ground plane also minimizes the effects of stray capacitance in the circuit by referring them to ground. This reference breaks up potential unintended and harmful feedback paths. Always use a ground plane with high-speed circuitry.

Although the term ground plane is often used as a mystical and ill-defined cure for spurious circuit operation, there is actually little mystery to the usefulness and operation of a ground plane. Like many phenomena, the operational principle of a ground plane is surprisingly simple.

As previously mentioned, ground planes are primarily useful for minimizing circuit inductance. They do this by utilizing basic magnetic theory. Current flowing in a wire produces an associated magnetic field. The field's strength is proportional to the current and inversely related to the distance from the conductor. Thus, we can visualize a current-carrying wire (**Fig 12a**) surrounded by radii of a magnetic field. The unbounded field becomes smaller with distance. A wire's inductance is defined as the energy stored in the field set up by the current flowing through the wire. To compute the wire's inductance requires integrating the field over the wire's length and the total radial area of the field. This computation implies integrating on the radius from $R = R_W$ to infinity—a very large number. However, consider the case that **Fig 12b** illustrates, where two wires in space carry the same current in either direction. The fields produced cancel.

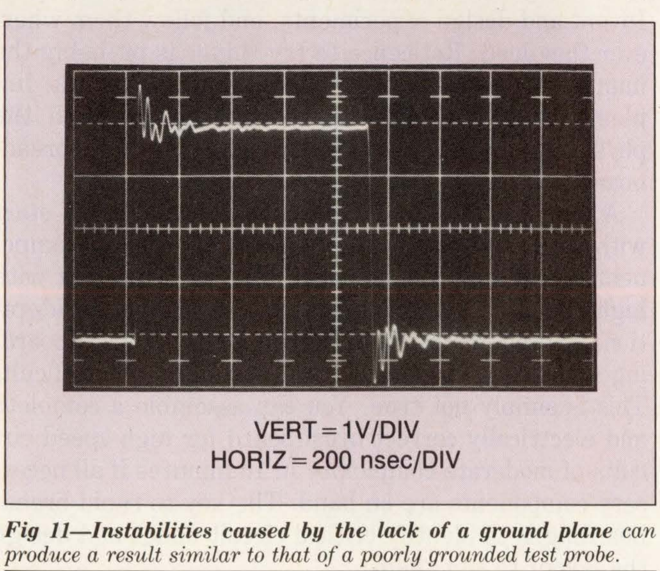

Fig 11—Instabilities caused by the lack of a ground plane *can produce a result similar to that of a poorly grounded test probe.*

When the fields cancel, the inductance is much smaller than in the single-wire case and can be made arbitrarily small by reducing the distance between the two wires. This reduction of inductance between current-carrying conductors is the underlying reason for ground planes. In a normal circuit, the current path from the signal source, through its conductor and back to ground, includes a large loop area. This path produces a large inductance for the conductor and can cause ringing because of LRC effects. It is worth noting that, at 100 MHz, a 10-nH inductor has an impedance of 6Ω. At 10 mA, a 60-mV drop results.

A ground plane provides a return path directly under

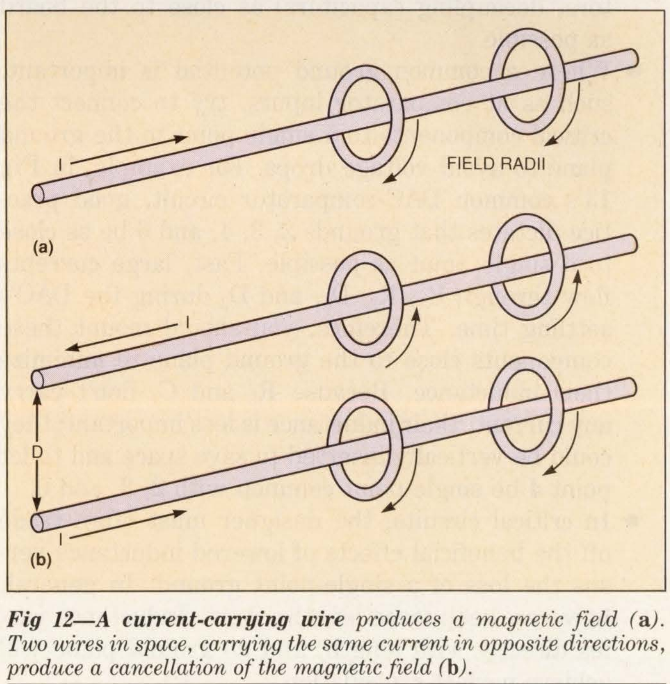

Fig 12—A current-carrying wire *produces a magnetic field (**a**). Two wires in space, carrying the same current in opposite directions, produce a cancellation of the magnetic field (**b**).*

the signal-carrying conductor through which the return current can flow. The conductor's small physical separation means the inductance is low. Return current has a direct path to ground, regardless of the number of branches associated with the conductor. Current will always flow through the return path of lowest impedance. In a properly designed ground plane, this path is directly under the signal conductor. In a practical circuit, it is desirable to "ground plane" one whole side of the pc card (usually the component side for wave-solder considerations) and run the signal conductors on the other side. This procedure will provide a low-inductance path for all the return currents.

Aside from minimizing parasitic inductance, ground planes have additional benefits. Their flat surface minimizes resistive losses due to ac skin effects (ac currents travel along a conductor's surface). Moreover, ground planes aid the circuit's high-frequency stability by referring stray capacitances to ground.

Practical hints for ground planes

The following guidelines are useful in the establishment and use of a ground plane.

- Ground-plane as much area as possible on the component side of the board, especially under traces that operate at high frequency.
- Mount components that conduct substantial fast-rise currents (termination resistors, ICs, transistors, decoupling capacitors) as close to the board as possible.
- Where a common ground potential is important, such as at comparator inputs, try to connect the critical components to a single point in the ground plane to avoid voltage drops. For example, in **Fig 13**'s common DAC-comparator circuit, good practice dictates that grounds 2, 3, 4, and 6 be as close to a single point as possible. Fast, large currents flow through R_1, R_2, D_1, and D_2 during the DAC's settling time. Therefore, you should mount these components close to the ground plane to minimize their inductance. Because R_3 and C_1 don't carry any current, their inductance is less important; they could be vertically inserted to save space and to let point 4 be single-point common with 2, 3, and 6.
- In critical circuits, the designer must often trade off the beneficial effects of lowered inductance versus the loss of a single-point ground. In general, however, keep trace lengths short. Inductance varies directly with length, and no ground plane will achieve perfect cancellation.

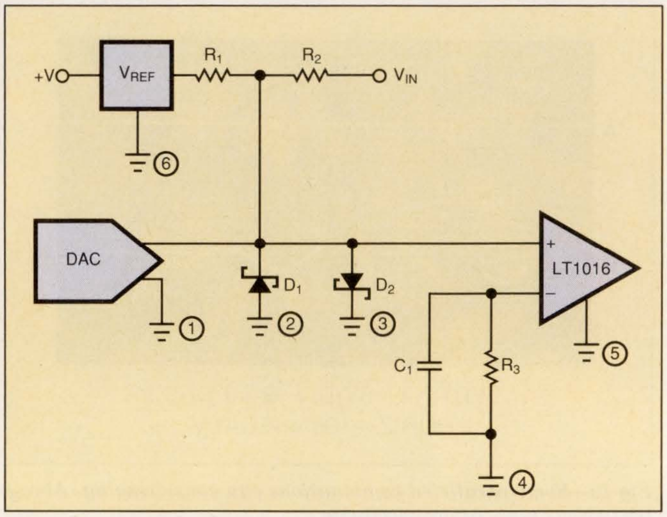

Fig 13—In this combination analog-digital circuit, *good practice dictates that grounds 2, 3, 4, and 6 be as close to a single point as possible.*

Putting the guidelines for capacitor choices and the establishment of a proper ground plane to practical use usually starts with a breadboard. The breadboard is both the designer's playground and proving ground. It is there that reality resides, and where paper (or computer) designs meet their master. More than anything else, breadboarding is an iterative procedure, an odd amalgam of experience guiding an innocent, ignorant, explorative spirit. A key is to be willing to try things out, sometimes for not very good reasons. Invent problems and solutions, guess both carefully and wildly, throw rocks and see what comes loose. Invent and design experiments, and follow them wherever they lead. Reticence to try things is probably the number one cause of breadboards that don't work. Implementing the above approaches begins with the physical construction methods used to build the breadboard.

A breadboard for a high-speed circuit must start with a ground plane. In addition, bypassing, component layout, and connections should be consistent with high-speed operations. Because of these considerations, there is a common misconception that breadboarding high-speed circuits is time consuming and difficult. This is simply not true. You can assemble a complete and electrically correct breadboard for high-speed circuits of moderate complexity in 10 minutes if all necessary components are on hand. The key to rapid breadboarding is to identify critical circuit nodes and design the layout to suit them.

This procedure permits most of the breadboard's construction to be fairly sloppy, saving time and effort. Use all degrees of freedom in making connections and mounting components. Don't be bashful about bending IC pins to suit desired low-capacitance connections, or air-wiring components to achieve rapid or electrically optimum layout. Save time by using components, such as bypass capacitors, as mechanical supports for other components. It's true that printed-circuit construction is eventually required, but when initially breadboarding forget about pc boards and production constraints. Later, when the circuit works and is well understood, you can take care of pc-board adaptations.

The **Fig 14** amplifier circuit is a good working example of breadboarding techniques. This circuit is a high-impedance, wideband amplifier that has low-input capacitance. Q_1 and IC_1 form the high-frequency path, with the 900 to 100Ω feedback divider setting the gain. IC_2 and Q_2 close a dc stabilization loop, minimizing the dc offset between the circuit's input and output. Critical nodes in this circuit include Q_1's gate (because of the desired low-input capacitance) and IC_1's input-related connections (because of their high-speed operation). Note that the connections associated with IC_2 handle only dc, and are much less sensitive to layout. These determinations dominate the breadboard's construction.

Fig 15a shows the initial breadboard construction. The copper-clad board is equipped with banana-type connectors. The connector's mounting nuts are simply soldered to the board, securing the connectors. After adding IC_1 and the bypass capacitors (**Fig 15b**), observe that IC_1's leads have been bent out. Bending the leads permits the amplifier to sit down on the ground plane, minimizing parasitic capacitance. Also, the bypass capacitors are soldered to the amplifier power pins right at the capacitor's body. The capacitor's leads are returned to the banana power jacks. This connection method provides good amplifier bypassing, while mechanically supporting the amplifier. It also eliminates separate wire runs to the power pins.

Fig 15c shows the addition of discrete components in the high-speed path. Q_1's gate is connected directly to the BNC input socket, as is the 10-MΩ resistor associated with IC_2's negative input. Note that the end of this resistor that sees a high frequency is cut very short, while the other end is left uncut. The 900 to 100Ω divider is installed at IC_1, with very short connections to IC_1's negative input. IC_1's 10-MΩ resistor receives similar treatment to that of the BNC-connected 10-MΩ resistor; the high-frequency end is cut short, while the end destined for connection to IC_2 remains uncut. Q_2's collector and Q_1's source, both high-speed points, are tied closely together with IC_1's positive input.

Finally, dc amplifier IC_2 and its associated components are air-wired into the breadboard (**Fig 15d**). Their dc operation permits this, while the construction technique makes connections to the previously wired nodes easy. You can bend the previously uncommitted ends of the 10-MΩ resistors in any way necessary to make connections. All other components associated with IC_2 receive similar treatment, and the circuit is ready for experimentation.

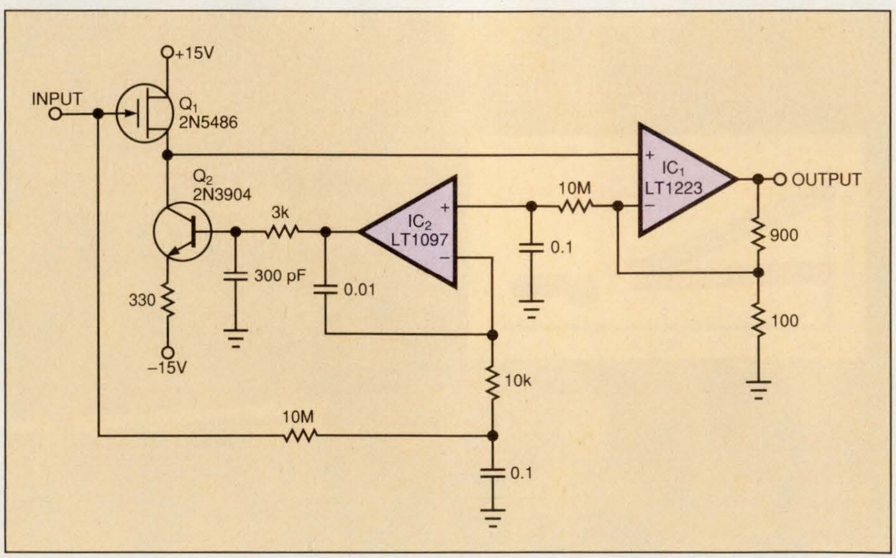

***Fig 14—This stabilized FET-input amplifier** is an example of the breadboarding techniques shown in **Fig 15a** through **d**.*

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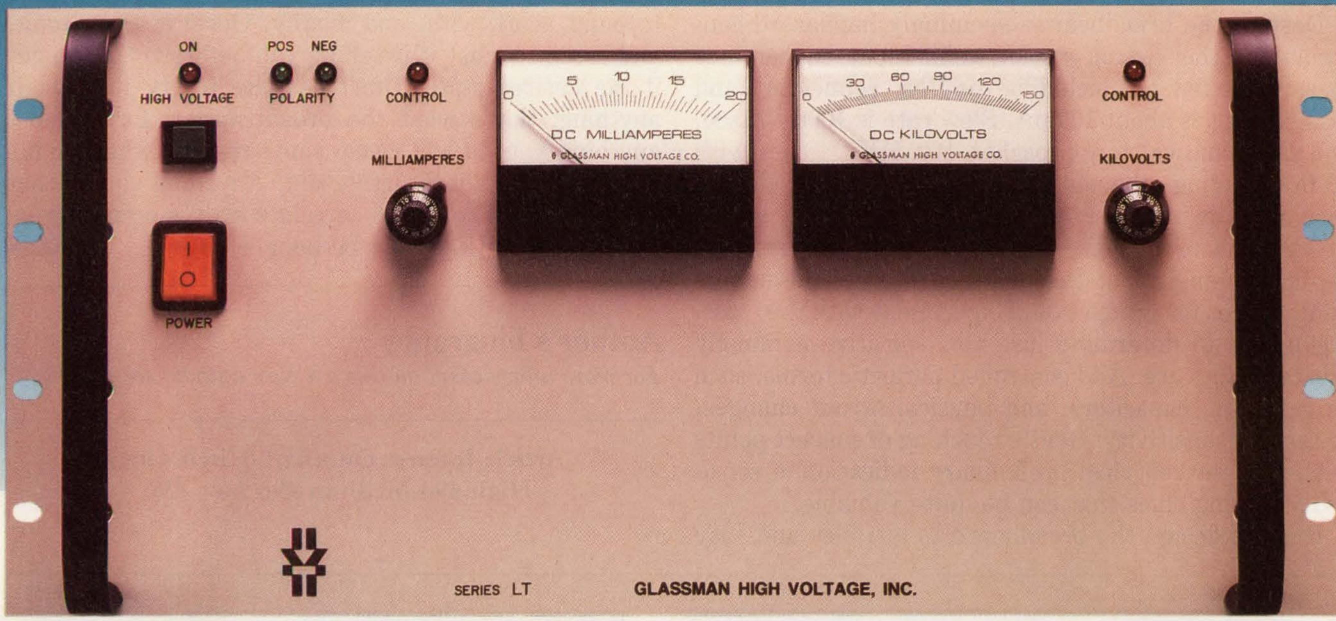

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CIRCLE NO. 112

Despite the breadboard's seemingly haphazard construction, the circuit works well. Input capacitance measures a few pF (including the BNC connector), and bias current is about 100 pA. Slew rate is 1000 V/µsec, and the bandwidth approaches 100 MHz. Even with 50-mA loading, the output is clean, with no sign of oscillation or other instabilities.

Once the breadboard seems to work, it's useful to begin thinking about the pc-board layout and component choices for production. Experiment with the existing layout to determine just how sensitive nominally critical points are. Add controlled parasitic terms, such as resistors, capacitors, and physical layout changes, to test for sensitivity. Gentle touching of suspect points with a finger can yield preliminary indication of sensitivity, giving clues that can be quite valuable.

Finally, design the breadboard to be quick and easy to build, work with, and modify. Observe the circuit, and listen to what it is telling you before trying to get it the desired state. Don't hesitate to try just about anything; that's what the breadboard is for. Almost anything you do will cause some result—whether it's good or bad is almost irrelevant. Anything you do that enhances your ability to correlate events occurring on the breadboard can only be beneficial. EDN

Author's biography

For more information on this article's author, *see pg 163* .

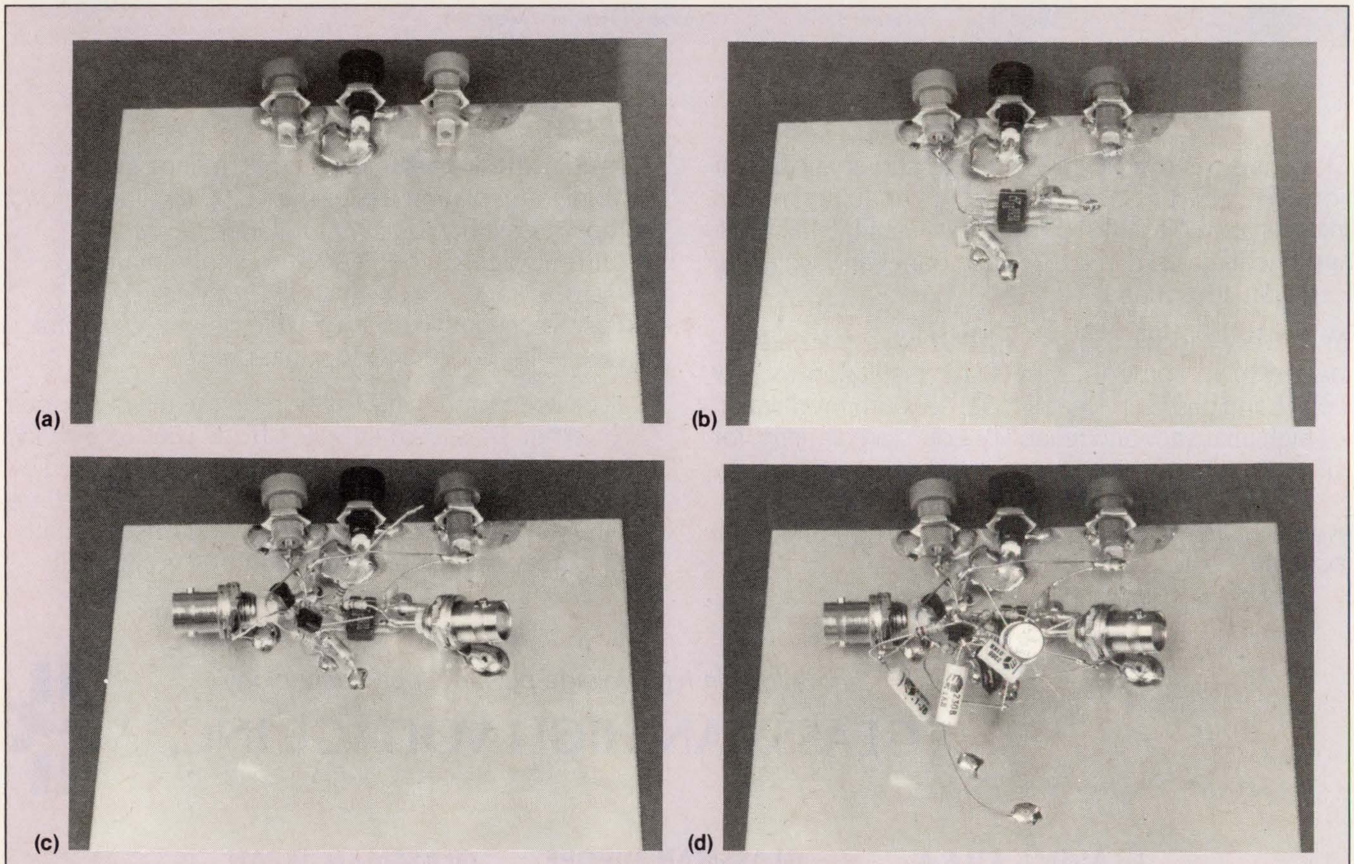

Fig 15—In the initial breadboard construction (a), *banana jacks are soldered to a copper-clad board. With the addition of a high-speed amplifier,* IC_1 *(***b***), bypass capacitors provide support while the bent amplifier pins ease connections and minimize the distance to the ground plane. High-speed discrete components and BNC connectors are added to* **c**. *Note the short connections at the amplifier input pins (left side of package). The uncommitted ends of the 10-MΩ resistors are just visible. Finally, you wire the dc servo amplifier to complete the connections to the 10-MΩ resistors (***d***). This part of the circuit is not layout sensitive.*

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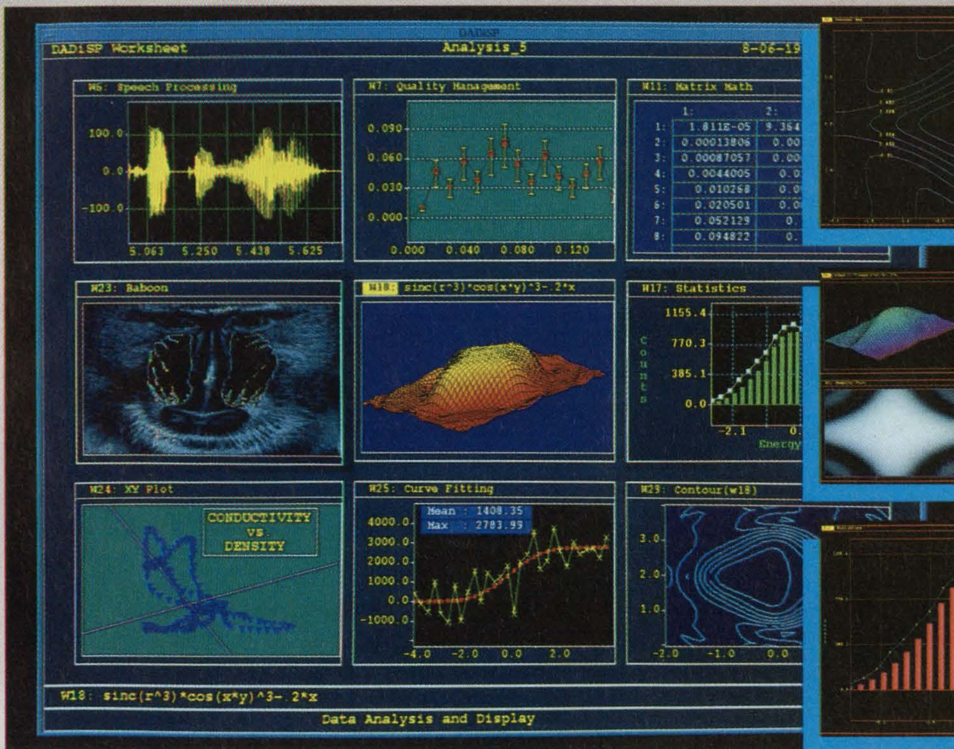

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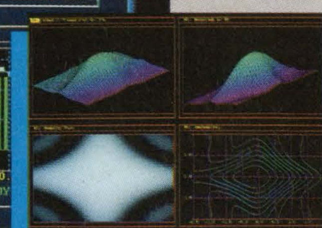

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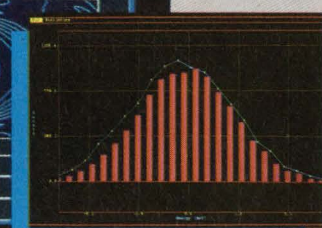

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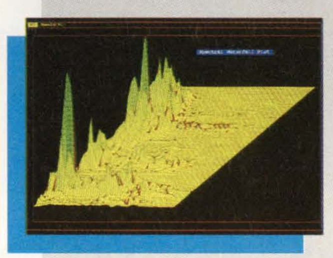

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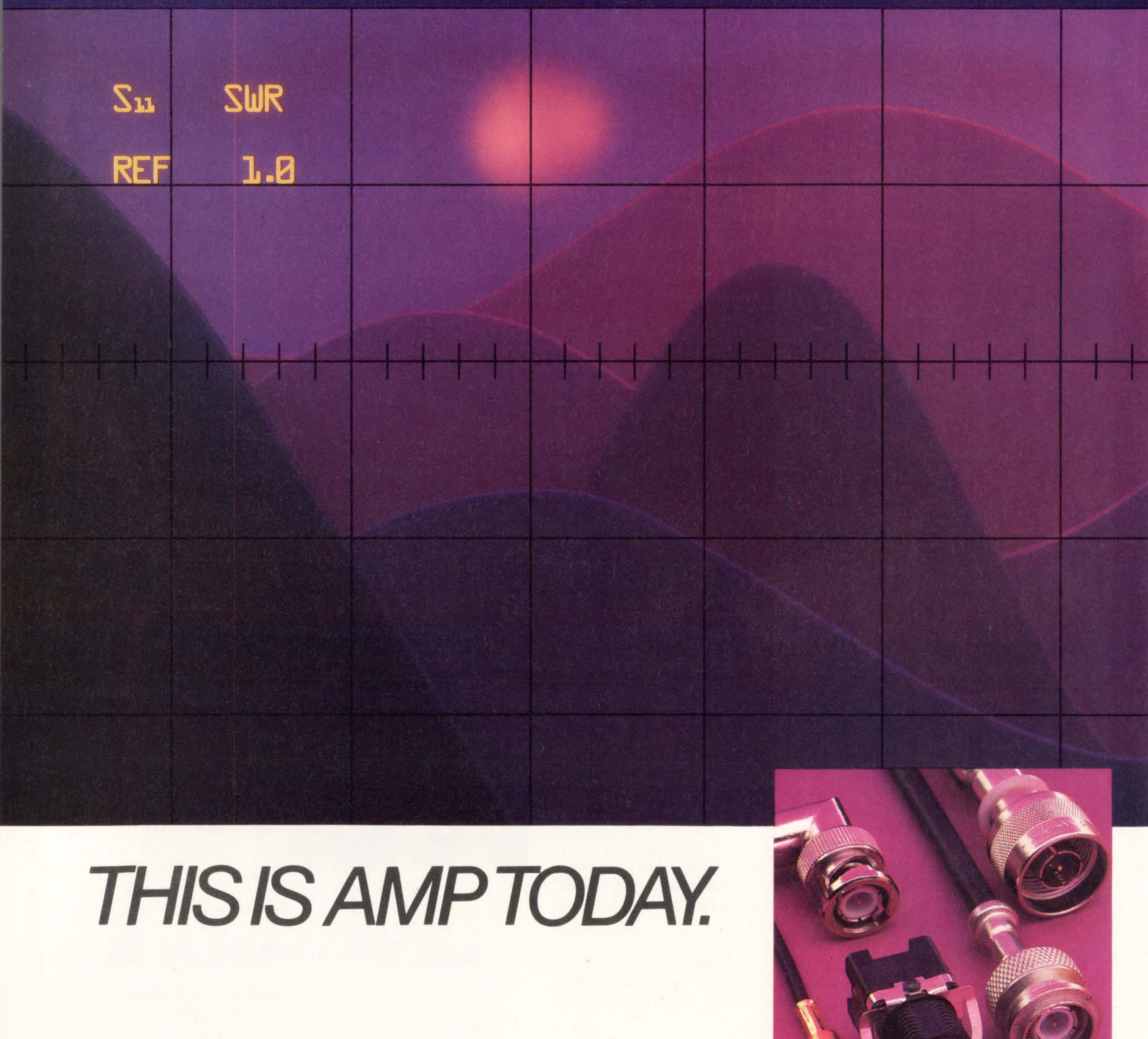

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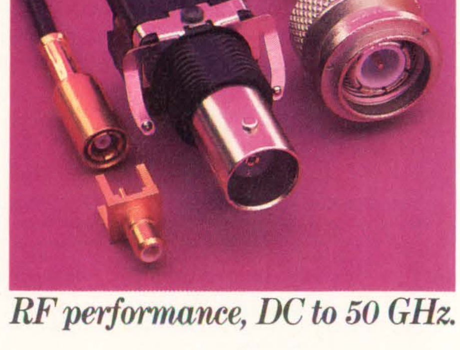

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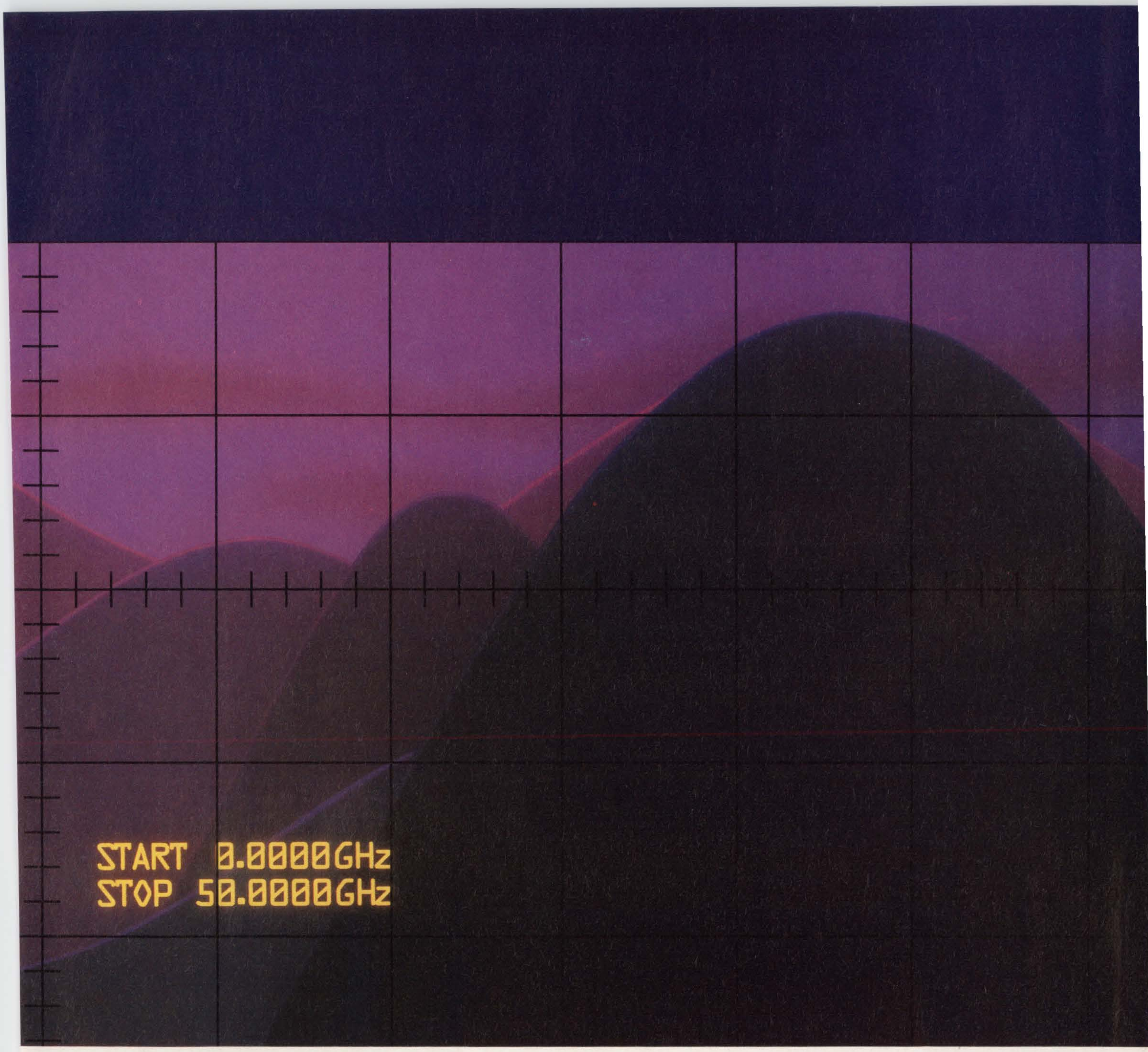

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Parameter		1220	1224	1191	1223	1122	Units
S.R.	Slew Rate (Typ)	250	400	450	1000	80	V/μsec
G.B.W.	Gain Bandwidth (Typ)	45	45	90	100	14	MHz
t_s	Settling Time (to 0.1%) (Typ)	90	90	100	75	340*	nsec
A_{VOL}	Open Loop Gain (Typ)	50	7	45	28	450	V/mV
V_{OS}	Offset Voltage (Max)	1	2	6	3	0.9	mV
I_{OS}	Offset Current (Max)	0.3	0.4	1	—	.00005	μA
I_B	Bias Current (Max)	0.3	8	1.7	3	.0001	μA
e_n	Voltage Noise (f = 10KHz)	17	22	25	3.3	15	$nV/\sqrt{Hz}$
i_n	Current Noise (f = 10KHz)	3	1.5	4	2.1	.002	$pA/\sqrt{Hz}$
	Min Gain Stable	1	1	1	1	1	
I_S	Supply Current (Max)	10.5	9	40	10	11	mA
	Price (100's) $ (PDIP)	3.85	2.85	2.40	2.85	2.50	

*12 Bit Settling Time

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EDITED BY CHARLES H SMALL

Circuit selects transformer-input tap

Jim Knipfer
Liebel-Flarsheim Co, Cincinnati, OH

The automatic voltage selector in **Fig 1** operates on startup to configure an input transformer's primary winding for different applied voltages. The sensing circuit samples the transformer's center tap to keep the circuit's input at 115V ac. Resistor R_1 and varistor V_1 prevent transient voltages from tripping the circuit.

The bridge rectifier—R_2, D_1, and C_1—powers the circuit and provides base drive for transistor Q_1. The dc voltage from the bridge rectifier varies with the input ac voltage.

The 34064 undervoltage sensor, IC_1, trips at 4.6V. Note that IC_1's RESET pin is an output, not an input; the chip's intended function is resetting μP systems. When the rectified line voltage is below IC_1's trip point, RESET is low, which sets up R_3 and R_4 as a voltage divider.

When the input voltage goes above 4.6V, IC_1 trips, setting the RESET output high. RESET's going high turns on Q_1, which energizes relay K_1. K_1 reconfigures the transformer's primary for 220V. To prevent relay K_1 from oscillating or "hunting," resistor R_4 adds hysteresis to IC_1's operation.

Relay K_1 cannot handle the large transient voltages that sometimes occur around the switching point. Transistor Q_2 and resistor R_5 limit current through K_1 to 10 mA. **EDN BBS /DI_SIG #1035** **EDN**

To Vote For This Design, Circle No. 681

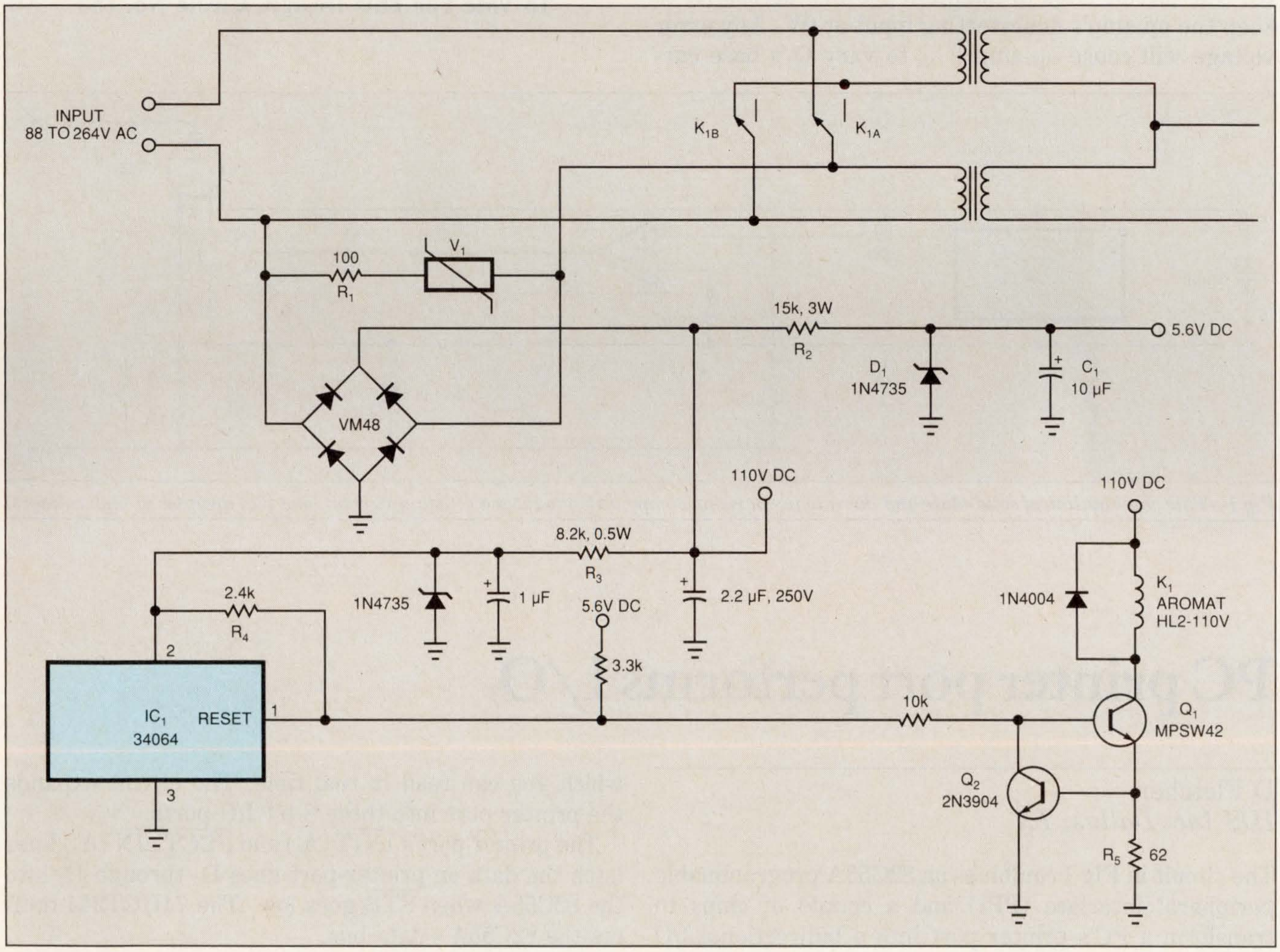

Fig 1—If this circuit sees more than 120V ac on startup, *the undervoltage-sensing IC trips the relay, which reconfigures the transformer's primary for 220V ac.*

Tube sinks constant current

Dave Cuthbert
Tektronix, Beaverton, OR

Contrary to popular belief, you can teach an old tube new tricks. The circuit in **Fig 1** maintains a 50- to 2000-μA constant current over a compliance range of 200 to 10,000V. The frequency response of this load is 1 Hz. Because the circuit is compact and uses a single alkaline D cell for power, you can float it anywhere in a high-voltage circuit. Battery life is approximately 20 hours.

The circuit's pass element is a 1BY2 TV diode operating in the temperature-limited region. The circuit controls the filament's temperature to maintain a constant cathode current.

The 200-mV reference, IC_1, supplies 1 μA through R_1. The circuit tries to maintain 200 mV across R_S to keep the op amp's noninverting input at 0V. Any error voltage will cause op amp IC_{1B} to vary Q_1's base current, which controls the filament's current. (The filament is a spiral of thin barium-oxide-coated wire.) The thermal time constant of the filament creates a pole; therefore, a lead-lag filter stabilizes the circuit's feedback loop. Although varying R_S appears to change the loop gain, such variation compensates for the reduction in the diode's gain at low currents.

Even though the tube has a 36-kV inverse voltage rating, field emission limits the forward-operating voltage to 10 kV. At higher voltages, the electric field at the thin filament becomes high enough for a cold filament to emit electrons; hence, the circuit cannot maintain regulation. International Components Corp carries the tube at a $3.30 list price.

EDN BBS /DI_SIG #1037

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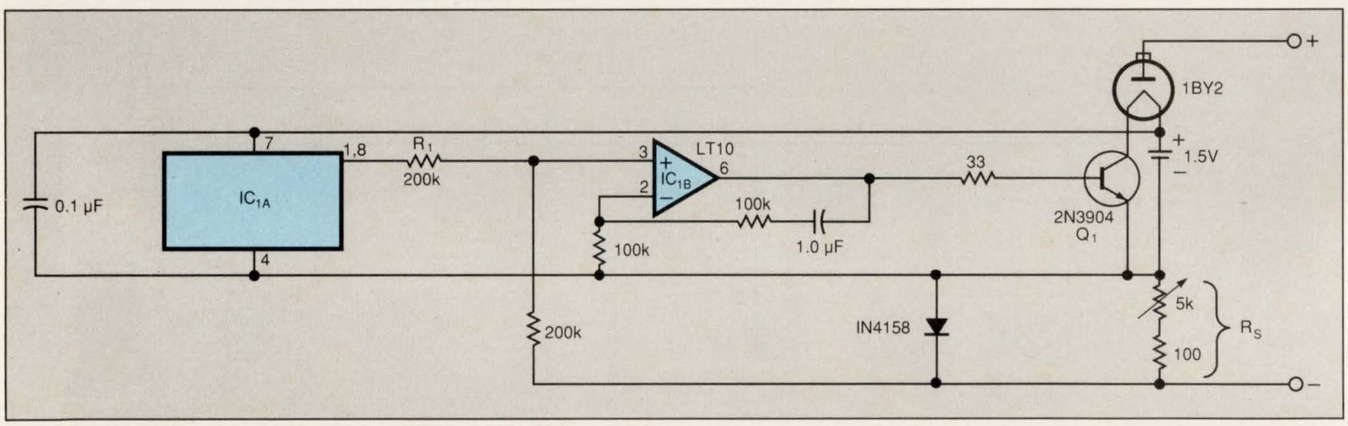

Fig 1—This combination of solid-state *and thermionic-emission components produces a constant-current load that operates at high voltages.*

PC printer port performs I/O

D Fletcher
IDS Inc, Dallas, TX

The circuit in **Fig 1** combines an 82C55A programmable peripheral interface (PPI) and a couple of chips to transform a PC's printer port into a bidirectional I/O port. The printer port provides 12 latched lines, which you can set under program control, and five inputs, which you can read in real time. The circuit expands the printer port into three 8-bit I/O ports.

The printer port's $\overline{\text{INIT}}$ (A_0) and $\overline{\text{SLCT\_IN}}$ (A_1) lines latch the data on printer-port lines D_0 through D_7 into the 82C55A when $\overline{\text{STB}}$ goes low. The 74HCT244 buffers the 82C55A's data bus.

Data from the 82C55A arrives a nibble at a time via the printer port's status lines: SLCT, PE, $\overline{\text{ACK}}$, and

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MODEL	FREQ. RANGE (MHz) f_L to f_U	GAIN dB min	GAIN dB flat††	MAX PWR† dBm	NF dB (typ)	ISOL. dB (typ)	DC PWR V/ma	PRICE $ ea. (10-24)
MAN-1	0.5-500	28	1.0	+8	4.5	40	12/60	13.95
MAN-2	0.5-1000	18	1.5	+7	6.0	34	12/85	15.95
MAN-1LN	0.5-500	28	1.0	+8	2.8	39	12/60	15.95
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MAN-1AD	5-500	16	.05	+6	7.2	41	12/85	24.95
MAN-2AD	2-1000	9	0.4	-2	6.5	28	15/22	22.50
MAN-11AD	2-2000	8	0.5	-3.5	6.5	22	15/22	29.95

††Midband $10f_L$ to $f_{U/2}$, ±0.5dB † 1dB Gain Compression ◊Case Height 0.3 in.
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C118 REV. F

BUSY. During reads, the printer's D_0 line selects the upper or lower nibble via the 74HCT157.

The Turbo C program in **Listing 1** is an example of how to use the circuit. The function *wrt()* outputs data; the function *rd()* inputs data. The program outputs from port A and reads from ports B and C with port A looped back to ports B and C. Note that *rd()* assembles the two nibbles into a single byte.

If you substitute 74HC devices for the 74HCT devices and if the expanded port interfaces to CMOS devices downstream, you can power the circuit by diode-ORing the PC printer port's $\overline{STB}$ and $\overline{AUTO\_FD\_XT}$ lines together.

You can obtain the **listing** and an OrCAD schematic from the EDN BBS's DI Special Interest Group ((617) 558-4241,300/1200/2400,8,N,1—from Main System Menu, first enter ss/di_sig, then rk1034).

EDN BBS /DI_SIG #1034

To Vote For This Design, Circle No. 684

Listing 1—Turbo C control program

```
#include <stdio.h>
#include <dos.h>

#define PORTA 2          /* 82C55A port A */
#define PORTB 3          /* 82C55A port B */
#define PORTC 0          /* 82C55A port C */
#define CNTRL 1          /* 82C55A control port */

/* 82C55A write and read function declarations */

void wrt(int data_prt,int cntl_prt,int port,char outdata);
/* data_prt is printer data output address */
/* cntl_prt is printer control address */
/* port is 82C55A port (A,B,C, or control) */
/* outdata is data to be written to 82C55A */

unsigned char rd(int data_prt,int cntl_prt,int stat_prt,int port);
/* rd( ) returns 82C55A input data */
/* stat_prt is printer status port */

main( )
{

 int printer=0x378,data_out,cntl_out,stat_in,x;
 unsigned char in1,in2,out=0;
 /* printer base addresses: 0x278,0x378,0x3bc */

 for(x=0;x<256;x++,out++) /* loop to output data from port A and read */
  {                       /* from ports B and C */
   data_out=printer; /* set base address */
   cntl_out=printer+2; /* set control address */
   stat_in=printer+1; /* set status address */
   wrt(data_out,cntl_out,CNTRL,0x8b); /* set mode */
   wrt(data_out,cntl_out,PORTA,out);  /* out to A */
   in1=rd(data_out,cntl_out,stat_in,PORTB); /* input B */
   in2=rd(data_out,cntl_out,stat_in,PORTC); /* input C */
   printf("Port A =  %x, Port B = %x, Port C = %x\n",out,in1,in2);
  } /* show results */
}

/* 82C55A write function */

void wrt(int data_prt,int cntl_prt,int port,char outdata)
{
 outportb(data_prt,outdata);      /* write output */
 outportb(cntl_prt,(port<<2|1)); /* enable '244 and /wr */
 outportb(cntl_prt,port<<2);      /* disable '244 and /wr */
}

/* 82C55A read function */

unsigned char rd(int data_prt,int cntl_prt,int stat_prt,int port)
{

 unsigned char indata;

 outportb(data_prt,1);                        /* enable read of d7 - d4 */
 outportb(cntl_prt,port<<2|2);                /* select port and enable /rd */
 indata=((inportb(stat_prt))^0x80)&0xf0;      /* read d7 - d4 */
 outportb(data_prt,0);                        /* enable read of d3 - d0 */
 indata|=((inportb(stat_prt))^0x80)>>4;       /* read d3 -d0, form byte d7 - d0 */
 outportb(cntl_prt,port<<2);                  /* disable /rd */
 return(indata);                              /* return with byte */
}
```

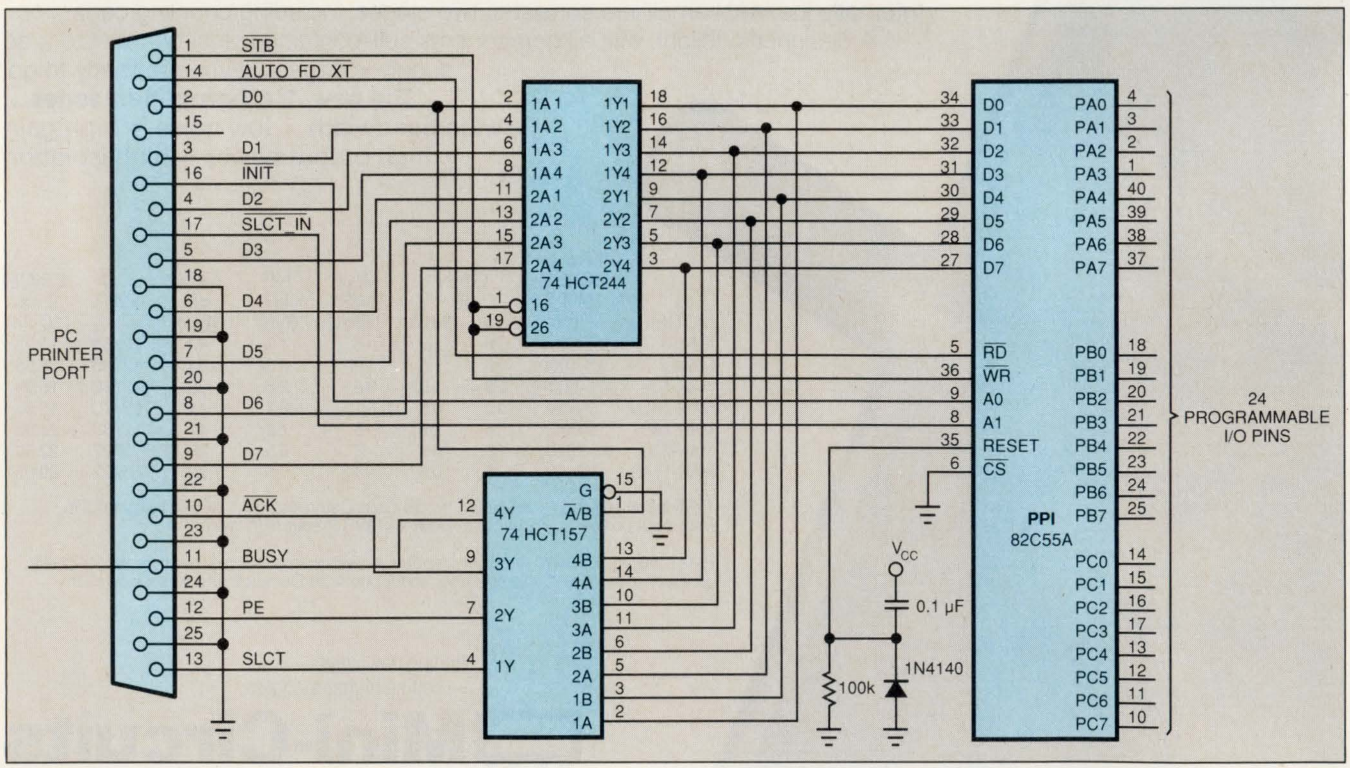


***Fig 1—This circuit enables a PC's** printer port to output data via its data lines and input data, a nibble at a time, via its status lines.*

NEW PRODUCTS

COMPUTERS & PERIPHERALS

DSP Board

- *Contains a TMS320C31 DSP chip and an 80386 µP*
- *A custom IC gives DSP chip direct access to host memory*

The DSP/PC single-board computer is a DSP board for a passive 16-bit ISA bus. It contains a TMS320C31 DSP chip and 2 Mbytes of static RAM, which connect to the company's 10 Mbyte/sec DSP-Link connector. The DSP chip communicates with an onboard 25-MHz 80386 µP via a custom chip set, called Media-Link controller. The controller's signals match the 80386's and the TMS320C31's control signals. The controller transfers data between processors at 66 Mbytes/sec. The 2-chip set also gives the DSP chip direct access to the host's onboard memory and peripherals, such as frame grabbers and hard disks. The host's onboard dynamic RAM has 2 Mbytes, which is expandable to 8 Mbytes. The board has two RS-232C ports, a parallel printer port, and a dual floppy-disk controller. It runs on the Spox operating system. $3500.

Spectrum Signal Processing Inc, Suite 301, 3700 Gilmore Way, Burnaby, BC, Canada, V5G 4M1. Phone (800) 663-8986; (415) 777-4161. **Circle No. 351**

Image-Compression Board

- *Implements the JPEG standard*
- *Digitizes NTSC or PAL video signals*

The Vidcom image-compression board for the ISA bus uses C-Cube Microsystems's CL550B chip, which implements the Joint Photographic Experts Group (JPEG) compression standard. It digitizes NTSC or PAL video signals. The board reduces the memory requirements from 1658.88 Mbytes to 20.736 Mbytes when storing 1 minute of real-time video having 640 × 480 × 24-bit resolution. A 622.08 hard disk can store ½ hour of compressed video data. The compression algorithm reduces the data transfer rate from 27.65 Mbytes/sec to 345.6 kbytes/sec when transferring data from the board to a hard disk. The board also digitizes color or black-and-white images from a scanner having a resolution as high as 8192 × 8192 × 24 bits. $995.

Specom Technologies Corp, 3673 Enochs St, Santa Clara, CA 95051. Phone (408) 736-7832. FAX (408) 736-7861. **Circle No. 352**

VMEbus to NTDS Interface Board

- *Has 68020 µP and a VIC068 VMEbus controller chip*
- *Conforms to MIL-STD-1397 type D, E, or J specifications*

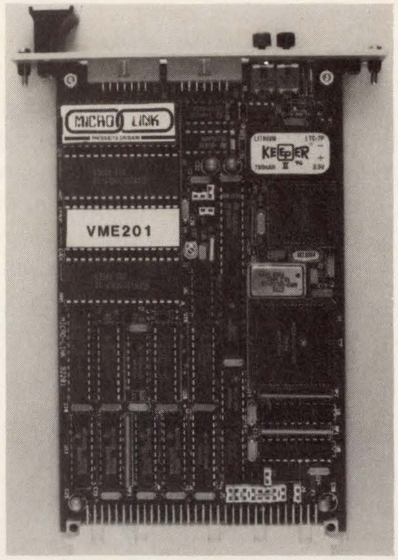
The Serial Hawke board adapts a VMEbus system to the Navy Tactical Data Systems's (NTDS) serial interface. The 6U or 9U board contains a 68020 µP, a VIC068 VMEbus controller chip, as much as 1 Mbyte of DRAM, as much as 1 Mbyte of EPROM, and 512 kbytes of dual-port RAM, which is accessible to the CPU and the VMEbus. It's available in three versions that conform to MIL-STD-1397 specifications. One version conforms to the type-D, coaxial-cable interface. A second version conforms to the type-E, triaxial-cable interface, and a third version conforms to a type-J, fiber-optic interface. An RS-232C port lets a computer or dumb terminal access onboard development software. You can install as many as 16 boards in a card cage. Type D and Type E boards, $4495; Type J board, $4695. Delivery, stock to six weeks ARO.

Sabtech Industries Inc, 5411 E La Palma Ave, Anaheim, CA 92807. Phone (714) 970-5311. FAX (714) 970-5377. **Circle No. 353**

VMEbus Single-Board Computer

- *Has slot-1 controller and a 16-MHz 68HC000 μP*
- *Draws less than 300 mA*

The VME201, a single-board computer (SBC) for the VMEbus, has a 16-MHz 68HC000 μP and complete slot-1 controller functions. It features two RS-232C ports, a 16-bit interrupt timer, four 32-pin JEDEC memory sockets for as much as 2 Mbytes of EPROM or 1 Mbyte of static RAM, a calendar clock, and a watchdog timer. An interrupt controller prioritizes interrupts from 12 sources including the seven VMEbus interrupts, Sysfail, an abort switch, an onboard DUART, and the watchdog interrupt. A standard version typically draws 700 mA from a 5V supply, and a low-power version draws less than 300 mA. Software options include Microware's OS9 and PDOS VMEPROM operating systems as well as the company's Microbug debugger and monitor. $350 (100).



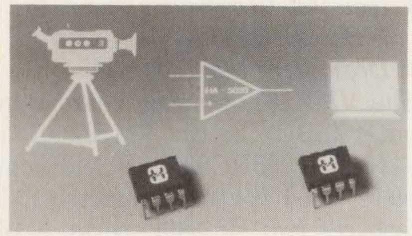
Micro-Link, 14602 N US Highway 31, Carmel, IN 46032. Phone (800) 428-6155. **Circle No. 369**

INTEGRATED CIRCUITS

Current Feedback Amplifier

- *Operates at 100 MHz*
- *Suitable for video, communications, and data acquisition*

The HA-5020 100-MHz current-feedback amplifier offers 800 V/µsec slew rate and 90-nsec settling time. Video performance parameters for the amplifier include 0.1-dB gain flatness, 0.02% differential gain, and 0.03° differential phase. Other key specifications of the amplifier are its 2-mV offset voltage, 20 µV/°C offset drift, 3-mA bias current, 20-MΩ input resistance, 50-dB common-mode rejection ratio min, and 100-MHz unity-gain bandwidth. An on-chip disable function eliminates the need for multiplexers in multichannel designs. Available in 8-pin SOIC and DIPs, the amplifiers operate over 0°C to 75°C and −40°C to +85°C ranges. $2.85 and $3.25 (100), respectively.



Harris Semiconductor, Box 883, Melbourne, FL 32901. Phone (800) 442-7747, ext 1134.

Circle No. 354

Voltage Comparator

- *Data outputs provide 30 mA and drive 50Ω loads*
- *Has typical propagation delays of 650 psec*

The SPT9689 dual voltage comparator has a tracking bandwidth of 900 MHz at −3 dB, open-loop gain of 66 dB, propagation delays of 650 psec typ, and an input signal overdrive of 20 mV. Propagation-delay variability is less than 100 psec with 5- to 50-mV input overdrive. The comparator uses a differential input stage with a common-mode range of −2.5 to +4V and a typical input offset current of less than ± 1 µA. The chip is offered in 20-lead LCC packages in industrial temperature range. Additional options include 16-lead ceramic sidebrazed DIPs and unpackaged die. Military versions are also available. $11.70 (1000).

Signal Processing Technologies, Marketing Dept, 1510 Quail Lake Loop, Colorado Springs, CO 80906. Phone (719) 540-3999. FAX (719) 540-3970. **Circle No. 355**

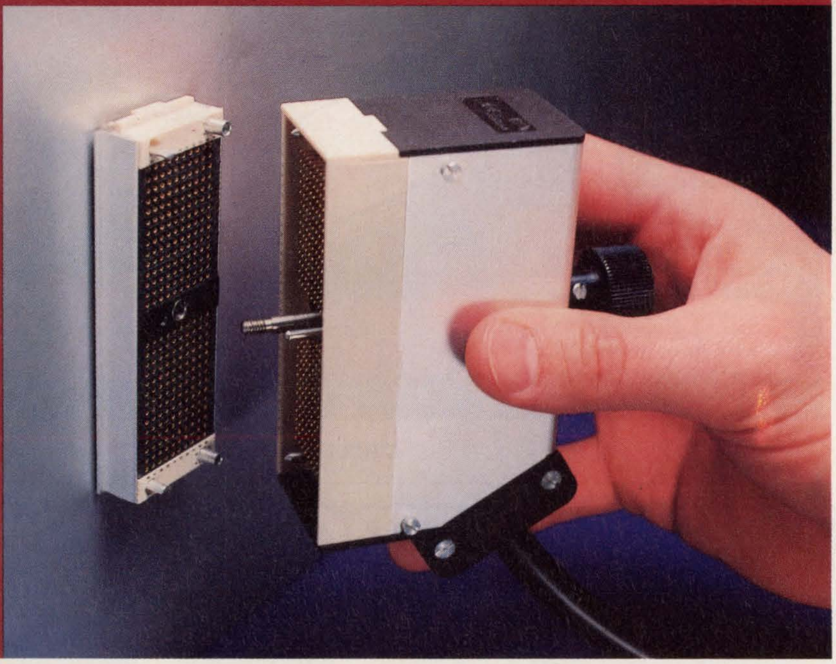
End the connector compromise...

1. **CONTACT WIPE ELIMINATES** INTERMITTENTS

2. **80-700 CONTACTS WITH LOW INSERTION FORCE**

3. **JACK-SCREW ECONOMY AND RELIABILITY**

...in test equipment



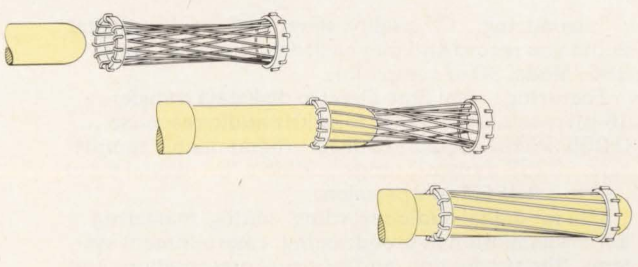
Only Hypertronics ends the compromise in multi-pin connectors—for heavy-duty power/signal applications—by replacing low wipe Zero Insertion Force (ZIF) contacts and expensive cams with low-force, high-cycle reliability.

Our N Series housing design accommodates 80 to 700 removable contacts, in a variety of types and terminations. And the wipe action of each Hypertac® contact maintains electrical continuity under corrosive conditions and extremes of shock and vibration...ending the problems of intermittents of ZIF contacts.

This design provides Low Insertion Force (LIF)—less than 45 pounds for a 700 contact connector—that eliminates the need for cams. A simple jack screw affords a more reliable and economical closure.

Now you can have it all...in connectors for power & signal applications in test equipment requiring up to 700 contacts. End the connector compromise by calling 1-800-225-9228, toll free.

HYPERTAC®:
Inserting pin into hyperboloid sleeve.



HYPERTRONICS CORPORATION

"New Horizons in Connectors"

16 Brent Drive, Hudson, MA 01749 (508) 568-0451 FAX (508) 568-0680

CIRCLE NO. 126

INTEGRATED CIRCUITS

Floppy-Disk Controller

- *Incorporates 765B floppy-disk-controller core*
- *Offers software and hardware power-down/reset capability*

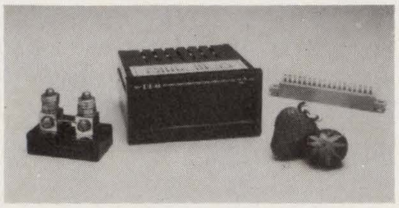
The FDC37C75 floppy-disk controller includes an IDE interface that performs the decode logic for IDE hard-disk drives. The 68-pin controller also includes a digital-data separator, an on-chip address decoder, and game-port decode logic. On-chip circuitry allows single-crystal-oscillator operation and generates a 1.8432-MHz output clock signal for direct drive of external I/O devices. A software- or hardware-selectable power-down mode suits low power applications. $3.95 (10,000).

Standard Microsystems Corp, Component Products Div, 35 Marcus Blvd, Hauppauge, NY 11788. Phone (516) 273-3100.

Circle No. 356

NEW PRODUCTS

COMPONENTS & POWER SUPPLIES



Ammeter Kit

- *Designed for remote monitoring applications*
- *Meter features 0.5% accuracy*

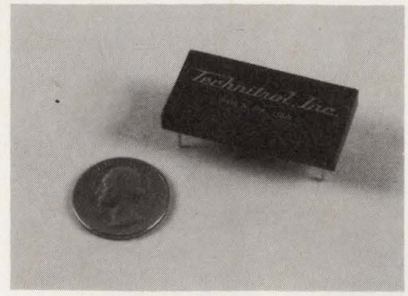
The model DP301-1S precision-digital-ammeter kit consists of a digital panel meter and an external shunt for monitoring dc current from a remote location. Monitoring distance can range to several hundred feet. Kits are supplied with external shunts of 5, 10, 50, 500, or 1000A. Measurement accuracy is better than ±0.5%, and resolution ranges from 0.001 to 1A, depending on current range. In the event of a reverse current flow, the 3½-digit LED readout will display a minus sign. A start/hold function allows the user to hold the current reading. The remote ammeter operates from a line voltage of 110 or 220V. From $90. Delivery, stock to six weeks ARO.

D1 International Inc, 95 E Main St, Huntington, NY 11743. Phone (516) 673-6866. **Circle No. 357**

Scott-T Transformers

- *Have a 0.01° accuracy*
- *Available in four versions*

Measuring 0.25 in. high, these Scott-T transformers are guaranteed to meet a ±0.01° accuracy specification. The units are available in synchro-resolver (LSR), resolver-synchro (LRS), resolver-resolver (LRR), and synchro-synchro (LSS) versions. The transformers meet the requirements of MIL-T-27. Standard frequency is 400 Hz ±20 Hz, and input and output voltages range to 11.8V. Standard power rating equals 30 mW. The devices are supplied in an epoxy-encapsulated package that measures 1.62×0.81 in. Custom designs are available on request. $60 (100).



Technitrol, 1952 E Allegheny Ave, Philadelphia, PA 19134. Phone (215) 426-9105. FAX (215) 426-2836. **Circle No. 358**

DC/DC Converters

- *Deliver 250W*
- *Feature redundant operation*

The μV 48 Series dc/dc converters deliver an output of 200 to 250W. Housed in a package measuring 0.5×2.4×3.6 in., they feature a $58W/in.^3$ power density. They accept an input of 36 to 72V and output 5V at 40A, 12V at 20A, 15V at 16A, 24V at 10A, or 28V at 9A. Converter features include n+1 redundancy with current sharing and hot plug-in capability. Nonshutdown overvoltage protection, logic on/off, and short-circuit and overtemperature protection are all standard. An optional ±10% output-good signal is available. The converters comply with MIL-STD-810D requirements and with UL 1950 and IEC 950. A sync-pin option allows you to control and synchronize the frequency of several converters externally. $225. Delivery, stock to eight weeks ARO.

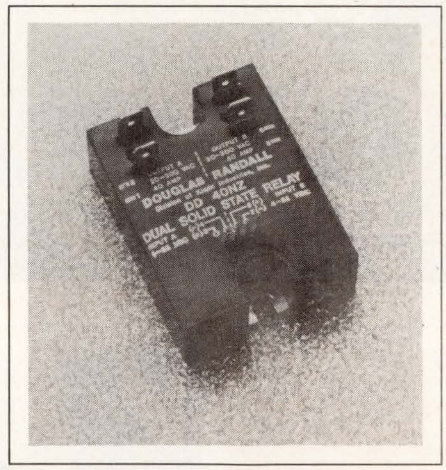
RO Associates Inc, 246 Caspian Dr, Sunnyvale, CA 94088. Phone (408) 744-1450. FAX (408) 744-1521.

Circle No. 359

Dual Relays

- *Provide two independent relay outputs in a single case*
- *Operate to 80°C*

DD Series solid-state relays provide two independent circuits in one standard hockey-puck case. The outputs are rated for 15, 25, or 40A, and the control voltage ranges from 3 to 15V dc. Load voltage measures 20 to 300V ac. Leakage current ranges from 10 to 20 mA, and the forward voltage drop at rated load equals 1.6V. The relays have reverse polarity protection on the input. Versions are available with



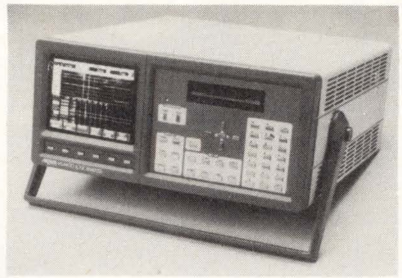
both zero-crossing and nonzero-crossing switching characteristics. Input-to-output isolation equals 2500V rms, and operating range spans −30 to +80°C. $15 to $25.

Douglas Randall, Box 506, Pawcatuck, CT 06379. Phone (800) 447-6799. FAX (203) 599-1754.

Circle No. 360

NEW PRODUCTS

INSTRUMENTS



Logic-Analyzer Support For LR33000 µP

- *Accepts data in every clock cycle or bus transaction*
- *Fully disassembles instruction and data cycles*

With the TGI-LR33K target-interface adapter, the vendor's ML4400 logic analyzer supports the LSI Logic's LR33000 reduced-instruction-set µP. The µP uses the MIPS Computer Systems architecture. The adapter plugs into the µP's pin-grid-array socket in the target system. The logic analyzer fully disassembles the instructions and data flowing to and from the IC. A disassembler supports the µP's complete instruction set and allows symbol tables to define as many as 10,000 symbols. The adapter permits processor clock speeds to 50 MHz. From $10,000.

American Arium, 14281 Chambers Rd, Tustin, CA 92680. Phone (714) 731-2138. **Circle No. 361**

68302 Emulator

- *Operates to 25 MHz*
- *By changing personality cards, emulates other µPs*

The Mime-700 in-circuit emulator (ICE) supports the MC68302 single-chip microcontroller. The ICE operates to 25 MHz; by changing its personality card, you can configure it to support other processors. The ICE supports debugging of applications that use the 68302's complex communications facilities. Pipeline


Killer Specs.
Panther® SCSI
Stalking system performance is your goal. That's why Maxtor's 1.2GB SCSI Panther was designed to perform a data seek in just 13ms. No other drive in its class features such lightning speed.
Panther's hunting prowess of 2ms track-to-track seek time stands out compared to Seagate's Wren 7 seek time of 2.5ms. And Panther outruns the competition with a 30Mb/sec. internal transfer rate.
Experience counts. Panther uses the reliable head disk assembly used in the Maxtor XT-8000, which boasts more than 300,000 units in the field. Panther shreds the competition with the widest range of available controllers, an MTBF of 150,000 hours, Novell certification and a highly competitive price.
Call about the full line of Panther drives that range from 1.2GB to more than 1.7GB capacity. If you're stalking performance, check out Panther's killer specs.
Call your nearest Authorized Maxtor Distributor.

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

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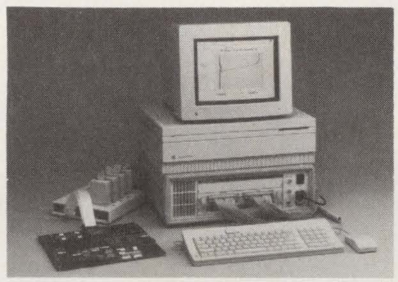
CIRCLE NO. 132

tracking logic allows qualifying breakpoints on instruction execution, so that prefetched but unexecuted instructions do not erroneously trigger ICE operations. $14,159.

Pentica Systems Inc, 1 Kendall Square, Bldg 200, Cambridge, MA 02139. Phone (617) 577-1101. FAX (617) 494-9162. **Circle No. 362**

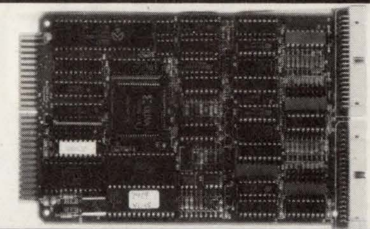


Software-Performance Analyzer

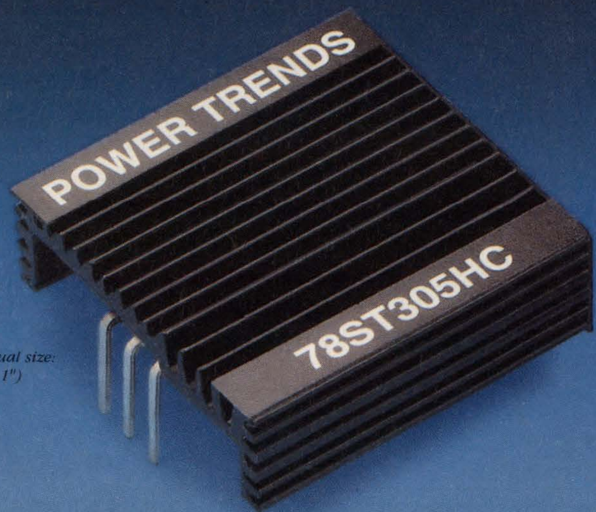
- *Captures and displays values of variables in memory*
- *Captures and time tags value changes 20 nsec apart*

The VVM-1 variable-value monitor is a hardware/software tool for analyzing software performance, especially in embedded systems. It captures the values of variables in a system's memory continuously, as they are stored, without adding bus cycles. It displays as many as 1000 values/sec in numeric form or in several graphic formats. It also replays recorded data. The displays let you determine what your code is doing; why it does what it does; and how well it does it. You can select the "watchpoints," that is, the variables and their values that the system looks for. The instrument time-tags each value it records. It can store changes separated by as little as 20 nsec. The vendor offers interfaces to µPs from five manufacturers. From $19,950. Delivery, twelve weeks ARO.

Biomation Inc, 19050 Pruneridge Ave, Cupertino, CA 95014. Phone (800) 538-9320; (408) 988-6800. **Circle No. 363**



THE POWER CHIPSET™ FOR NOTEBOOK COMPUTERS



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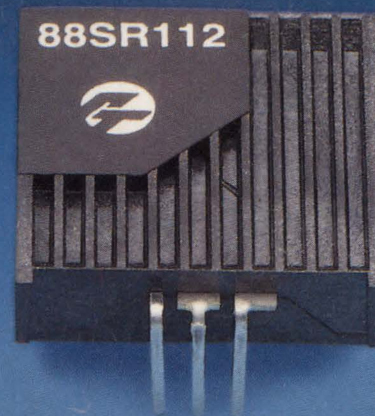
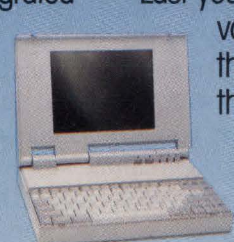
A fully self-contained 3 Amp, 1 MHz, step-down Integrated Switching Regulator



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

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



And, for those who require a +12 volt output for flash memory or other functions, the companion unit offered is a 1 MHz step-up Boost Converter.

Power Trends' *Power Chipset*™ drastically cuts component count and simplifies your design. **This means lower costs and shorter time to market!**

Last year, Power Trends' 1.5 Amp product was voted the power supply innovation of the year by EDN magazine. Recently, the *Power Chipset*™ has been recommended by Intel for use in their 386™SL Mustang Notebook Computer.

If you are designing notebook computers or other battery operated products, then Power Trends has the power conversion products for you. Call or write for more information about the *Power Chipset*™ for Notebook Computers from Power Trends. Samples are available now. Call today.

POWER TRENDS

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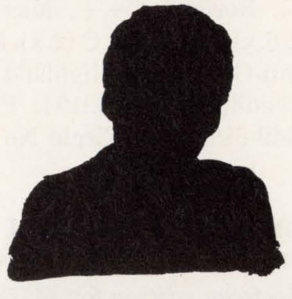
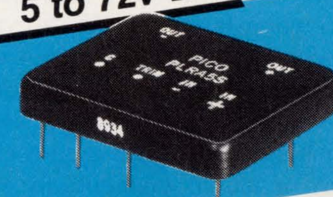




NEW PRODUCTS

CAE & SOFTWARE DEVELOPMENT TOOLS

PC Code Tool For Large Data Arrays

- *Supports virtual memory arrays*
- *Unlimited array sizes*

The Virtual Array/Numerical Analysis Toolbox provides very large array sizes. It can map arrays into lower memory, then extended memory (above 1 Mbyte), and finally to disk if there is not enough active memory. In this case, array sizes are limited only by available disk space. The package caches array or matrix elements for fast access. It also contains support routines for advanced analysis. These routines include functions for matrix math, large sets of linear equations (1000 × 1000 or larger), curve fitting, multiple and stepwise regression analysis, eigenvalues and eigenvectors, and statistical analysis. According to the vendor, you can calculate a 65,536-(2^{16})-point FFT in 54 sec, using a 33-MHz IBM PC/AT. The functions can be called from Turbo Pascal (5.x, 6.x), Turbo C (2.x), Borland C++, Microsoft C (5.x, 6.x) and Quick C (2.x). $300.

Quinn-Curtis, 35 Highland Circle, Needham, MA 02194. Phone (617) 449-6155. **Circle No. 366**

Interactive Development System For 8052 Systems

- *Full-screen editing for 8052AH-Basic*
- *Modular, symbolic Basic code*

Basikit provides a full PC-based, interactive development system for front-end embedded Basic running on 8-bit 8052s. Using this tool, you are no longer tied to the Basic interpreter's line-oriented, dumb-terminal interface. You can take advantage of the PC's processing power with a full-screen oriented interface, supplemented by any ASCII text editor. Using the software, you can build modern, symbolically labeled Basic code. You don't need line numbers. The software adds them for you and tracks them in conjunction with the 8052 interpreter execution for debugging. It also automatically converts old, line-oriented code as well. Using the code, you can download to RAM or build ROM-ready code for burn-in. Program output, memory dumps, and register dumps can be stored in files. The software also speeds up debugging: It can download and upload code at speeds as high as 38,400 bps. It enables you

CIRCLE NO. 136

CIRCLE NO. 137

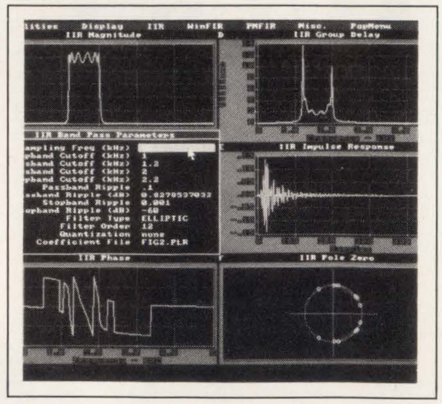
to speed up your application by inserting assembly-language code anywhere in the application. The software comes with a number of utilities to convert and manipulate source and execution files. $150.

MDL Labs, 15 Deerfield Rd, Chappaqua, NY 10514. Phone (914) 238-0416. **Circle No. 367**

Enhanced Filter-Design Package

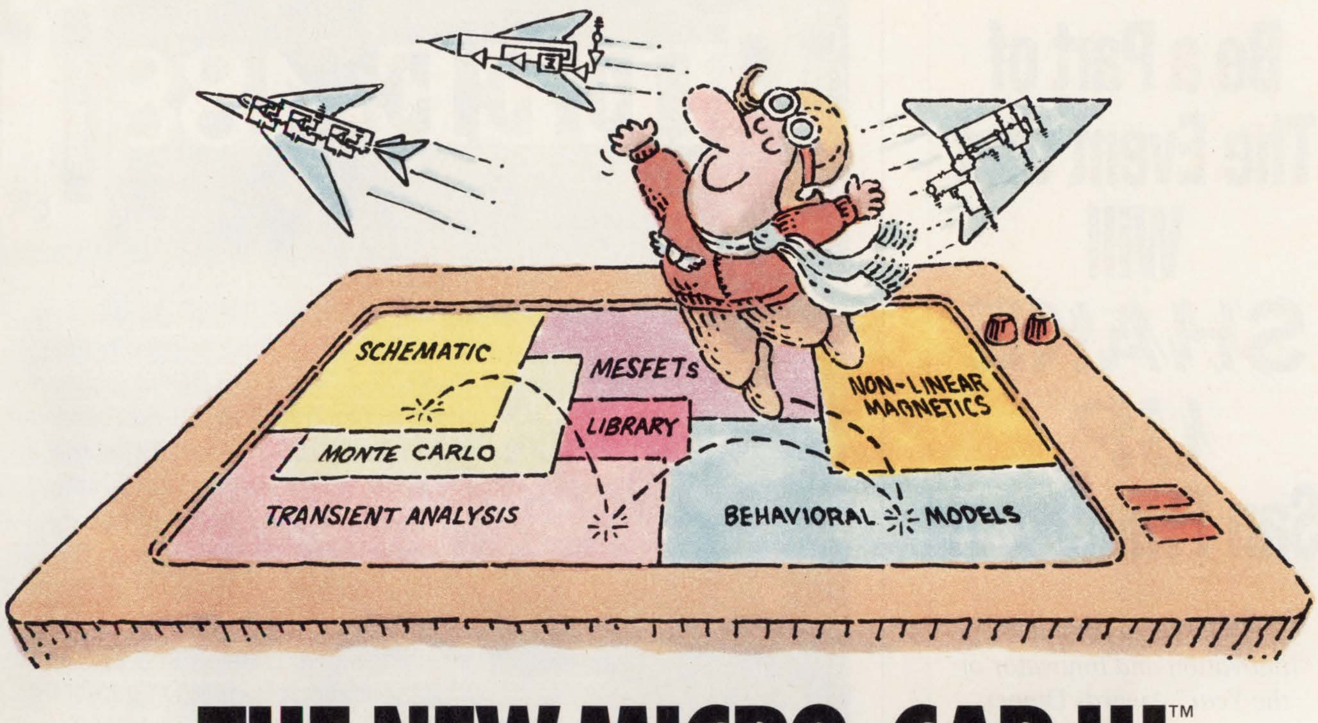
- *Designs filters for fixed DSPs*
- *Handles arbitrary size and phase IIR filters*

Using the DFDP/3plus filter design package, you can interactively design DSP filters without coding. You can graphically specify the filter parameters and build FIR or IIR filters, using prebuilt analysis and generation functions. This version interacts with mouse selection and a color graphics system. You can design magnitude and arbitrary-phase IIR filters, using a special iterative design technique. FIR filters can be designs using the Parks-McClellan, Kaiser Window, and Window FIR methods. The software supports many different IIR filter-design methods including frequency-selective filters, differentiators, Hilbert transforms, and pulse shaping filters. Filter performance is presented in easy-to-read color plots of magnitude, phase, group delay, impulse response, and a pole/zero plot. You can design Kaiser Window or Parks-McClellan filters to 3071 and 1280 taps, respectively. Signal-analysis functions for the time domain include convolution, correlation, and signal statistics. For frequency-domain analysis the package supplies short-term Fourier transforms (STFT), inverse STFT, cepstrum, linear predictive-analysis and spectral-estimation techniques, and power-spectrum estimation methods. The DFD3/plus package runs on a 640-kbyte PC, using DOS 3.1 or higher. $1045.



Atlanta Signal Processors Inc, 770 Spring St, #208, Atlanta, GA 30306. Phone (404) 892-7265. FAX (404) 892-2512.

Circle No. 368



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

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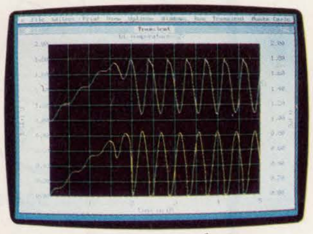
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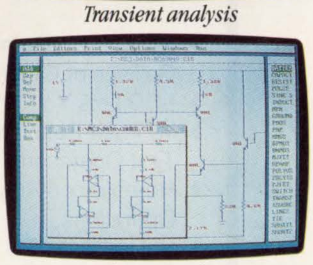
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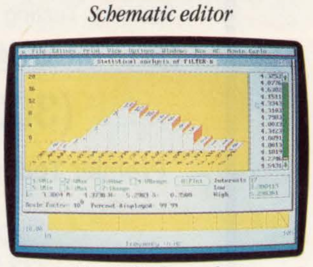
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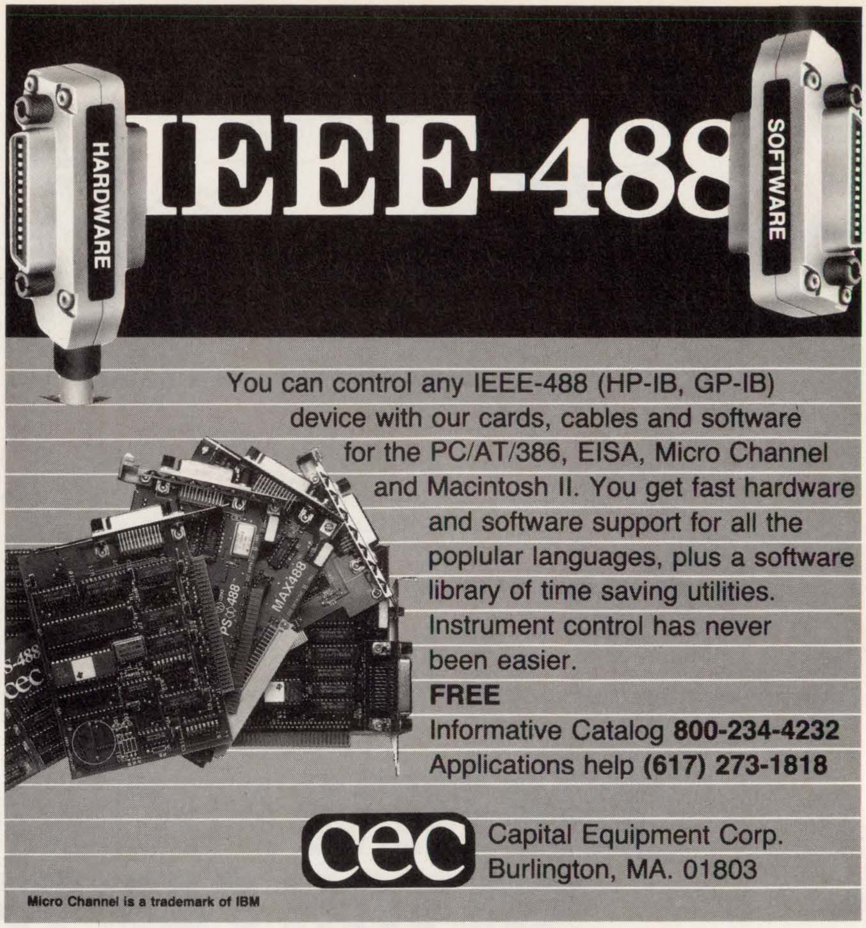

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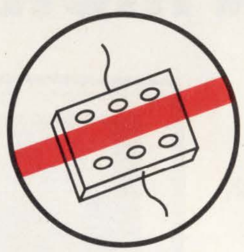

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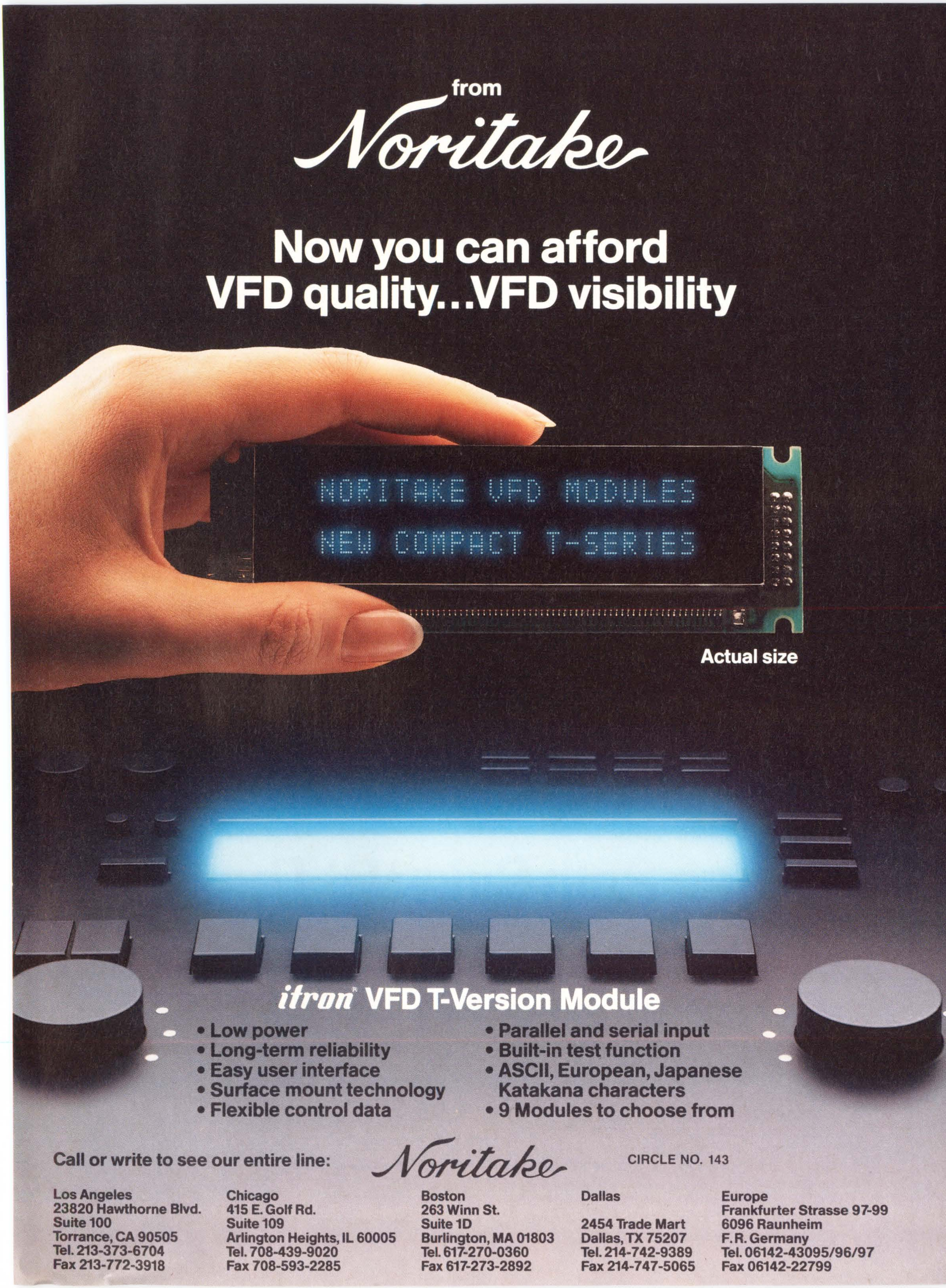
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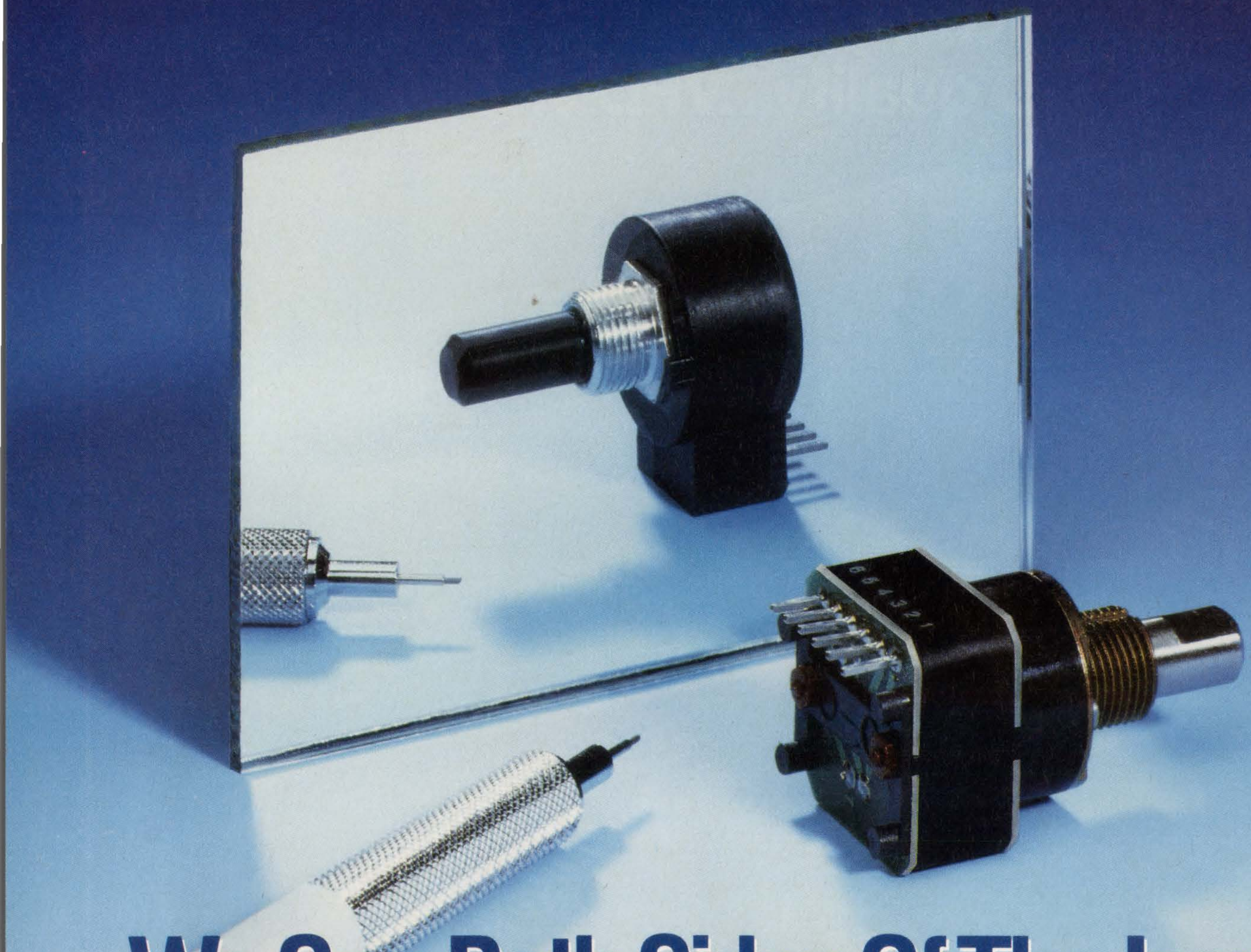

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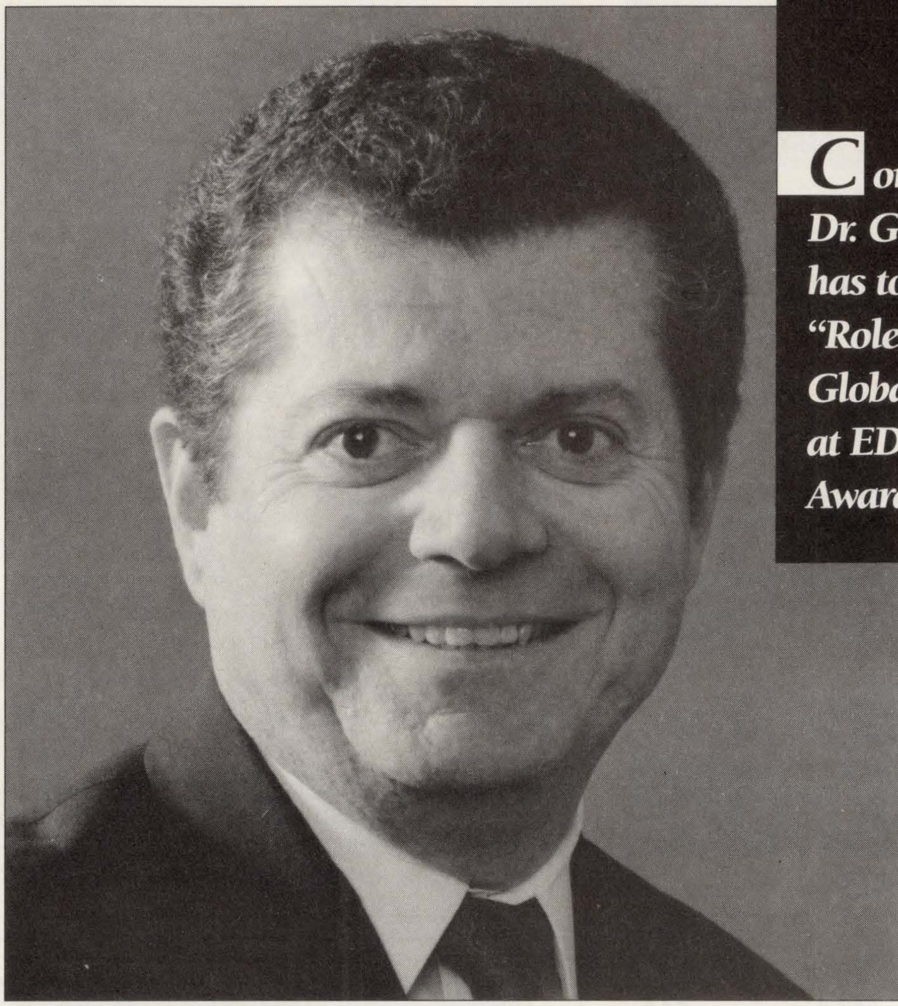

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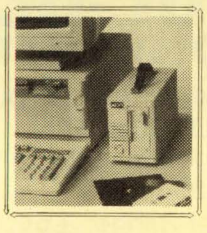

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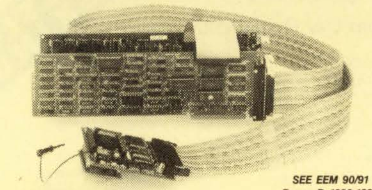

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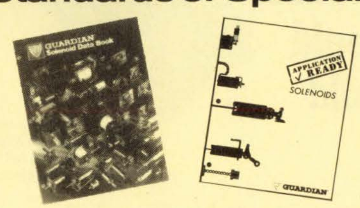

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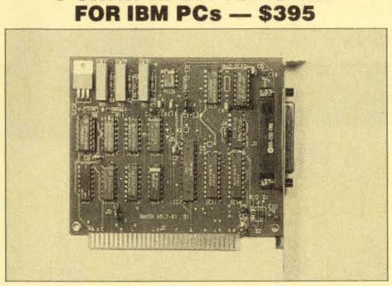

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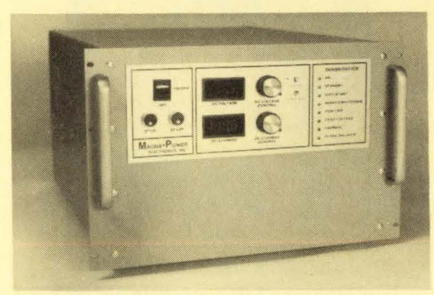

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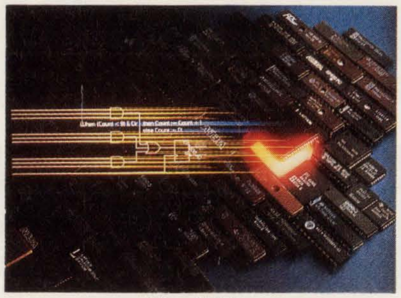

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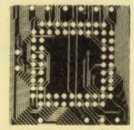

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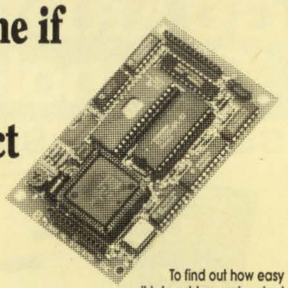

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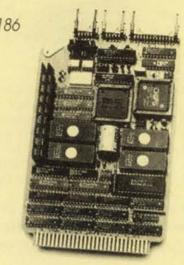

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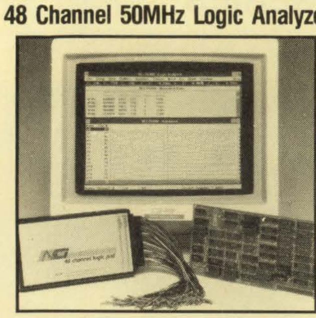

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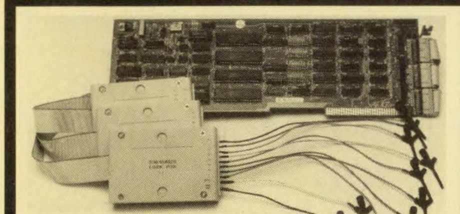

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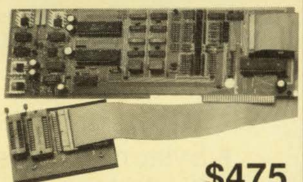

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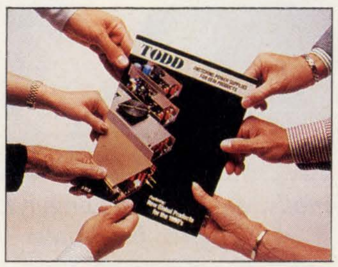

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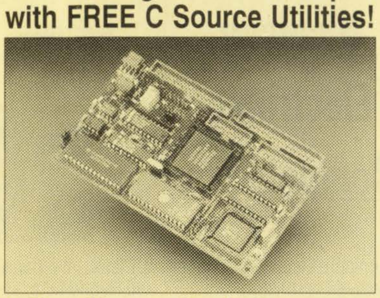

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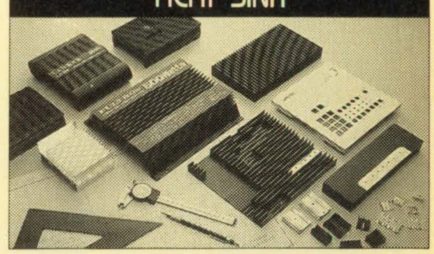

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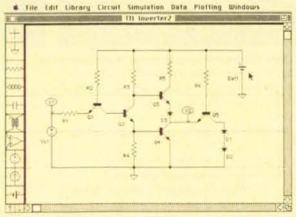

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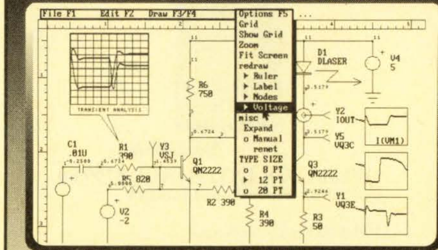

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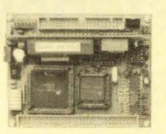

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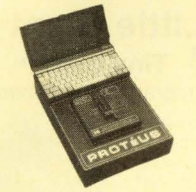

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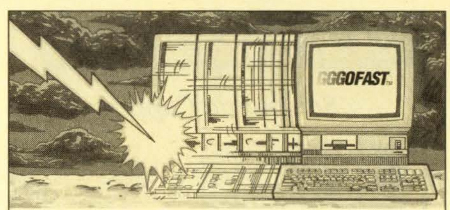

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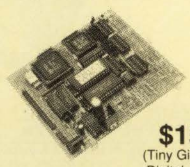

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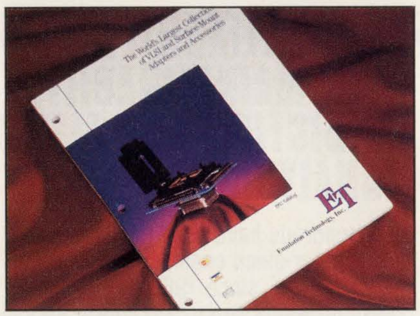

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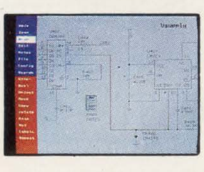

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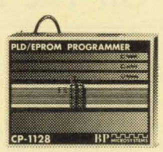

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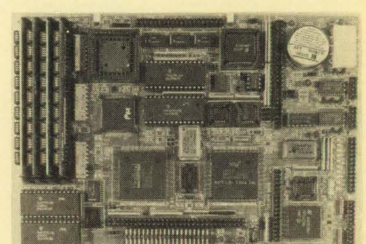

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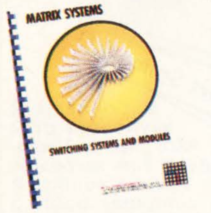

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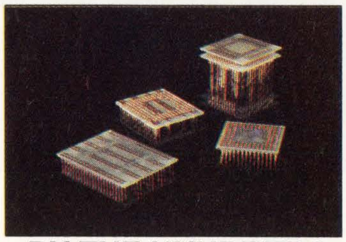

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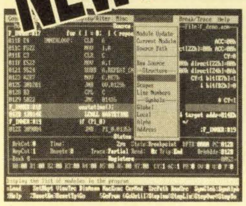

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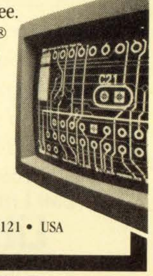

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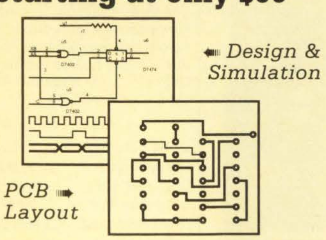

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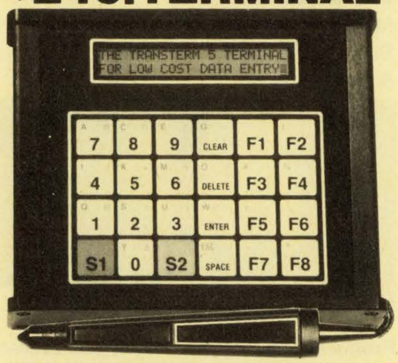

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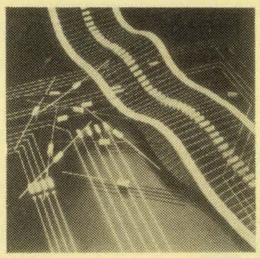

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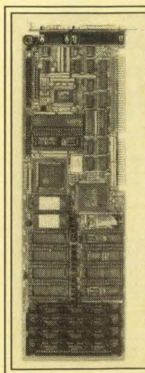

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Issue	Issue Date	Ad Deadline	Editorial Emphasis
Magazine Edition	Nov. 7	Oct. 17	High Performance DSPs • CAE/ASICs, Computers & Peripherals/ Communications, Software, Wescon Show Issue
News Edition	Nov. 14	Oct. 25	Telecommunications**, Wescon Show Issue
Magazine Edition	Nov. 21	Oct. 31	18th Annual Microprocessor Directory • Test & Measurement, CAE/ASICs, ICs & Semiconductors
News Edition	Nov. 28	Nov. 8	PC Cards, Board Level**, Regional Profile: Wisconsin, Illinois, Michigan**, EDN's Innovator/ Innovation Awards Coverage •
Magazine Edition	Dec. 5	Nov. 14	Product Showcase—Volume I • ICs & Semiconductors, Microprocessors, Power Sources, Hardware & Interconnect, Software
News Edition	Dec. 12	Nov. 20	DSP**, Regional profile: DC, Maryland, Virginia**
Magazine Edition	Dec. 19	Nov. 26	Product Showcase—Volume II • Test & Measurement, Components, Components & Peripherals, CAE/ASICs

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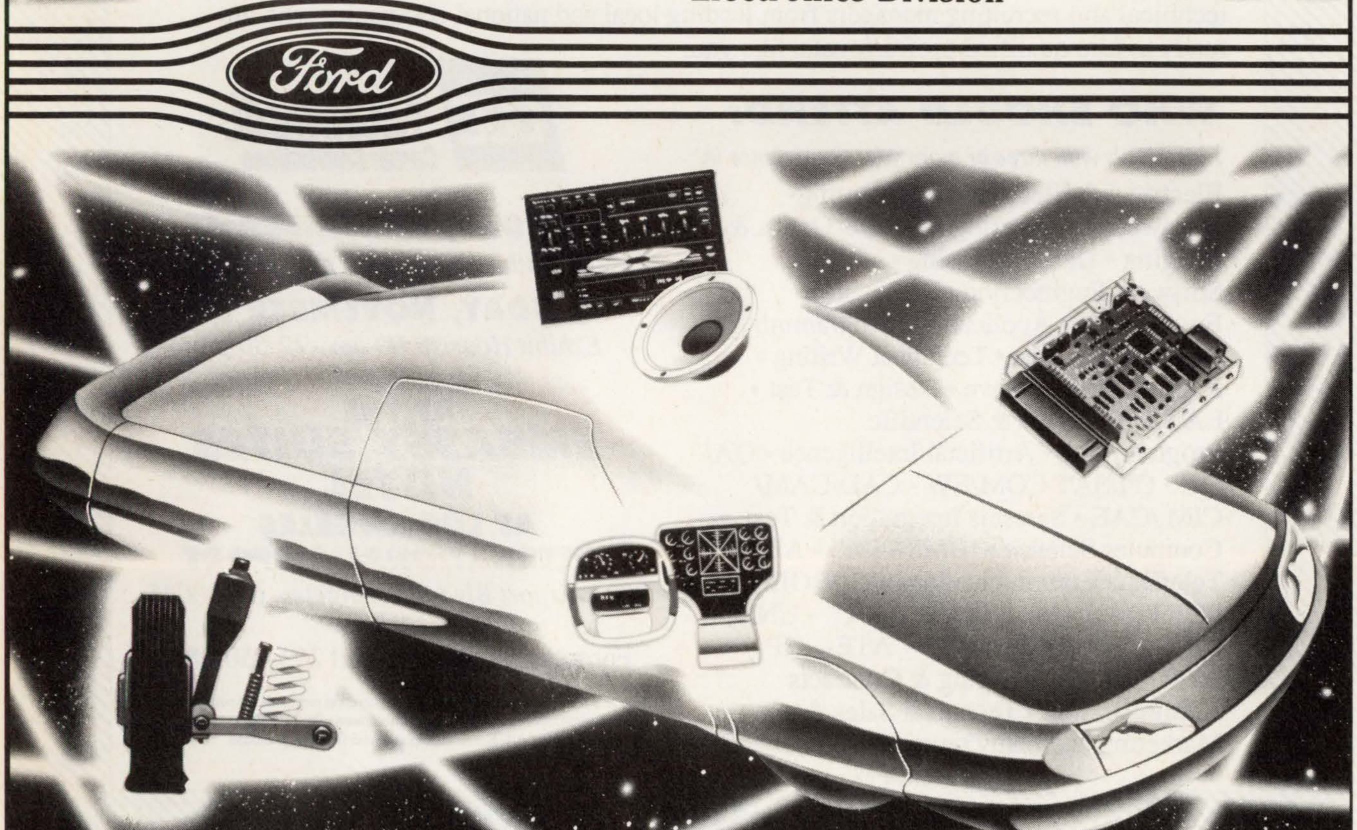

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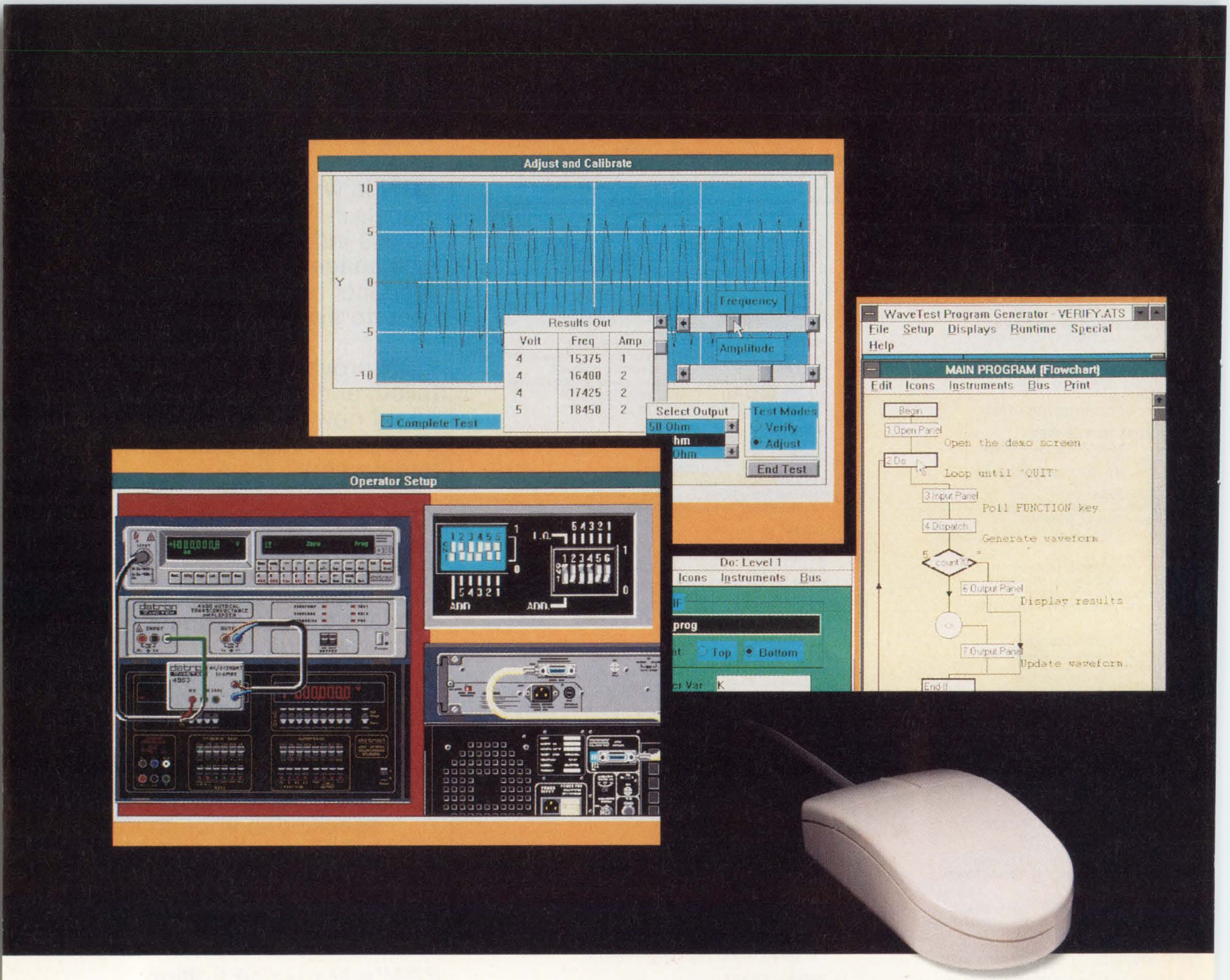

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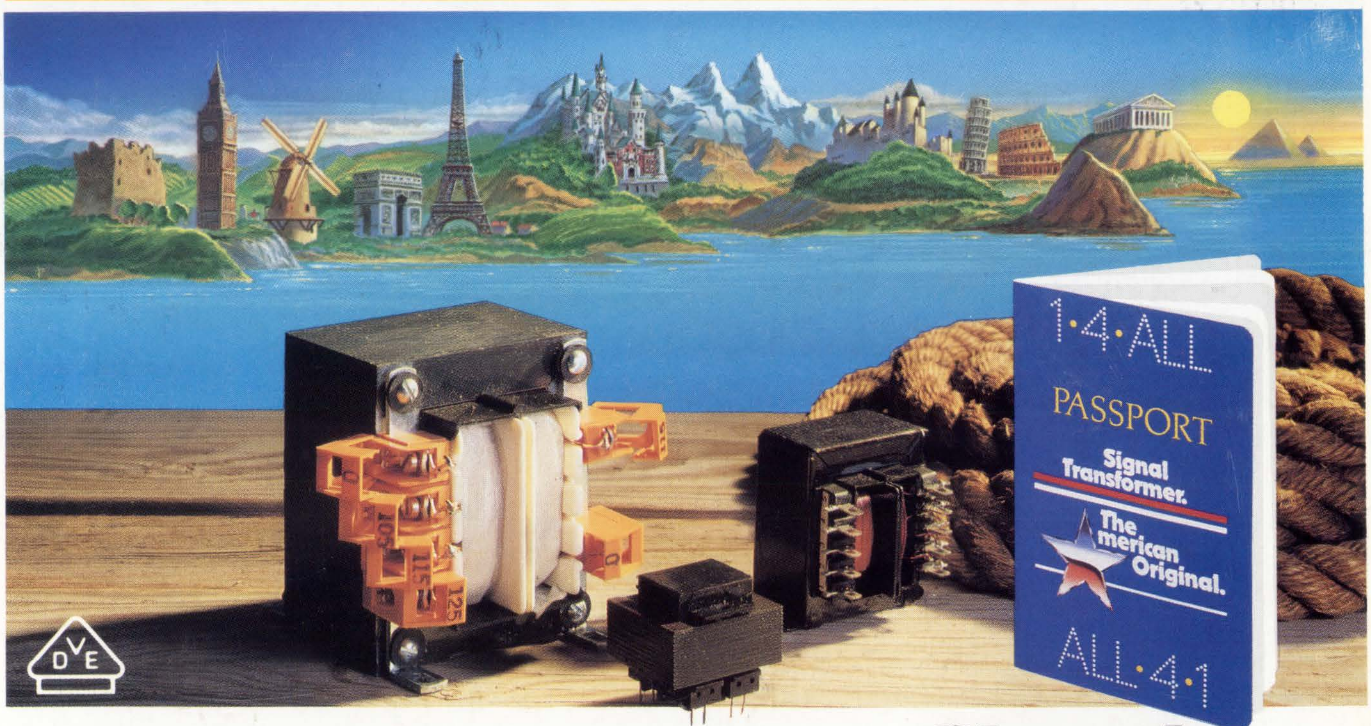

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