

EDN[®]

SPECIAL ISSUE:
Analog Technology

Analog Spice models pg 61

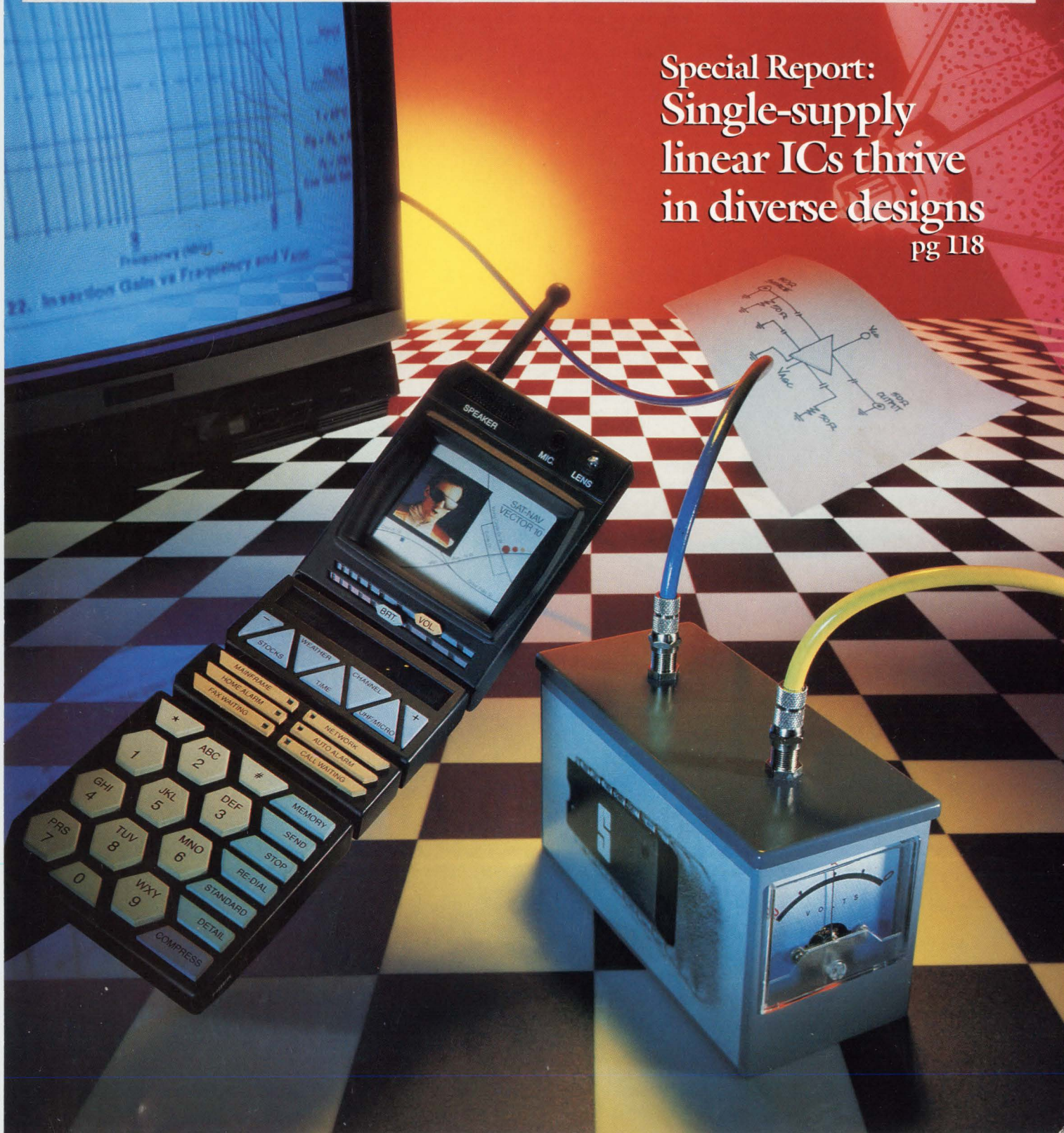
Switching regulators pg 79

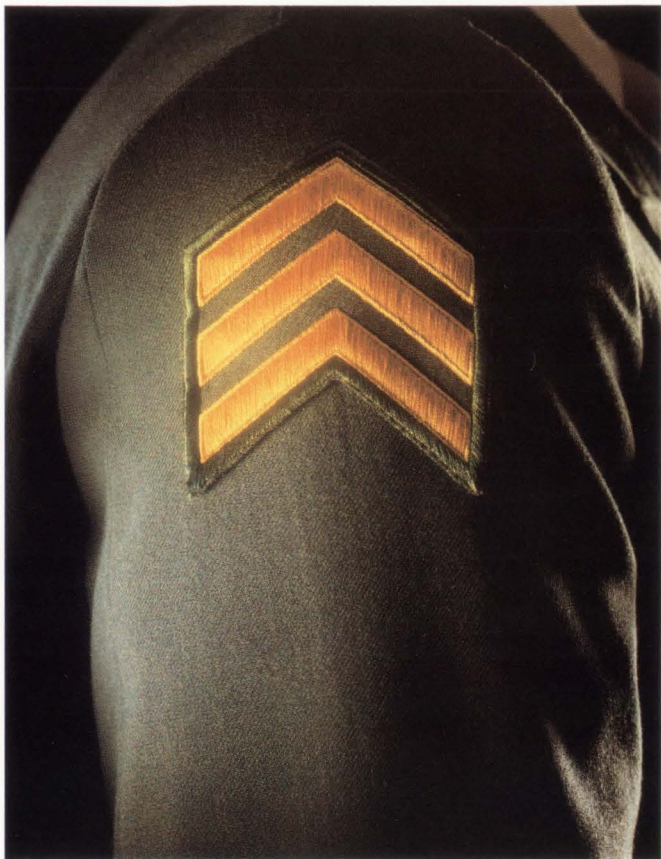
Spectrum analyzers pg 95

Designers' guide to subranging
A/D converters—Pt 3 pg 155

ELECTRONIC TECHNOLOGY FOR ENGINEERS AND ENGINEERING MANAGERS

Special Report:
Single-supply
linear ICs thrive
in diverse designs
pg 118





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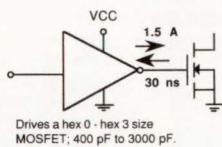
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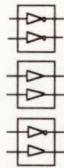
High Speed, High Current Low Side MOSFET Drivers



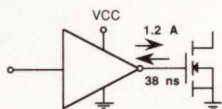
Drives a hex 0 - hex 3 size MOSFET; 400 pF to 3000 pF.

MIC426/7/8 (Original)

- 30 nS into 1000 pF
- 4.5 V to 18 V supply
- 1.5 A peak output
- 6 Ω output impedance
- Available in surface mount packages



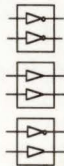
MIC426
MIC427
MIC428



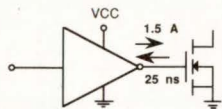
Drives a hex 0 - hex 3 size MOSFET; 400 pF to 3000 pF.

MIC1426/7/8 (Low Cost)

- Low cost predriver
- 38 nS into 1000 pF
- 4.75 V to 16 V supply
- 1.2 A peak output
- 8 Ω output impedance
- Available in surface mount packages



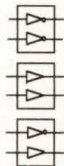
MIC1426
MIC1427
MIC1428



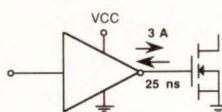
Drives a hex 0 - hex 3 size MOSFET; 400 pF to 3000 pF.

MIC4426/7/8 (Protected)

- Latch-up protected
- 25 nS into 1000 pF
- 4.5 V to 18 V supply
- 1.5 A peak output
- 7 Ω output impedance
- Withstands 5 V negative swing
- Available in surface mount and high temperature packages



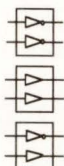
MIC4426
MIC4427
MIC4428



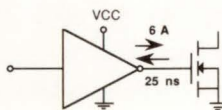
Drives a hex 4 - hex 5 size MOSFET; 6000 pF to 12000 pF.

MIC4423/4/5 (High Current)

- Latch-up protected
- 25 nS into 1800 pF
- 4.5 V to 18 V supply
- 3 A peak output
- 3.5 Ω output impedance
- Withstands 5 V negative swing
- Available in surface mount packages



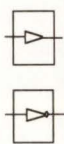
MIC4423
MIC4424
MIC4425



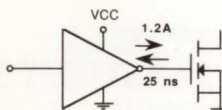
Drives a hex 6 - hex 7 size MOSFET; 15000 pF to 16000 pF

MIC4420/4429 (Singles)

- Latch-up protected
- 25 nS into 10,000 pF
- 4.5 V to 18 V supply
- 6 A peak output
- 2.5 Ω output impedance
- Withstands 5 V negative swing
- Available in surface mount packages



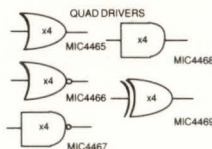
MIC4420
MIC4429



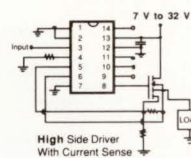
Drives a hex 0 - hex 3 size MOSFET; 400 pF to 3000 pF

MIC4465/6/7/8/9 (Quad)

- Latch-up protected
- 25 nS into 470 pF
- 4.5 V to 18 V supply
- 1.2 A peak output
- Available in surface mount packages
- Five logic choices



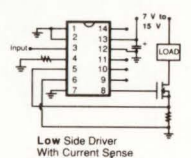
High Side, Protected MOSFET Drivers



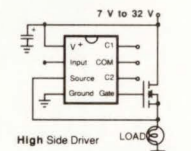
High Side Driver With Current Sense

MIC5010

- Full featured predriver
- Optional speed up caps
- 7 V to 32 V supply
- Internal charge pump
- 60 μ S into 1 nF
- Over current sensing
- Fault flag output
- Surface mount packages
- Dynamic sensing threshold



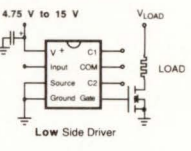
Low Side Driver With Current Sense



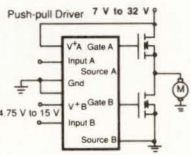
High Side Driver

MIC5011

- Minimum parts count
- Optional speed up caps
- 4.75 V to 32 V supply
- Internal charge pump
- 60 μ S into 1 nF
- Surface mount packages



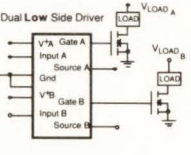
Low Side Driver



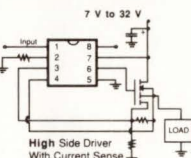
Push-pull Driver 7 V to 32 V

MIC5012

- Dual predriver
- Provides high and low side
- 4.75 V to 32 V supply
- Internal charge pump
- 60 μ S into 1 nF
- Surface mount packages



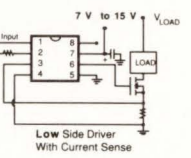
Dual Low Side Driver



High Side Driver With Current Sense

MIC5013

- Over current sensing
- 7 V to 32 V supply
- Fault flag output
- Internal charge pump
- 60 μ S into 1 nF
- Surface mount packages
- Dynamic sensing threshold



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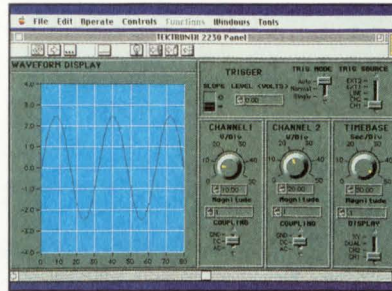
```

20 REM *****
30 OPEN "dev1" FOR OUTPUT AS #1
40 OPEN "dev1" FOR INPUT AS #2
50 REM *****
60 PRINT #1;"clear 1"
70 PRINT #1;"local lockout"
80 PRINT #1;"output 1:dev1 gml: wml gaff:"
90 REM *****
100 PRINT #1;"trigger 1"
110 PRINT #1;"enter 1"
120 INPUT #2;AS
130 REM *****
140 PRINT #1;"output 1:dat end:asc:curve1"
150 PRINT #1;"enter 1"
160 INPUT #2;AS
170 REM *****
180 PRINT #1;"op11 1"
190 INPUT #2;AS

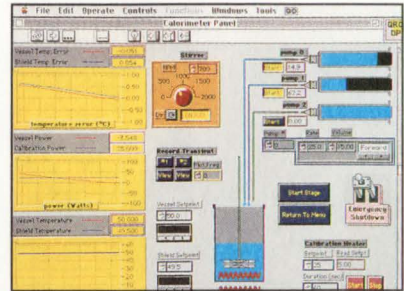
```

You can automate your system with 30-year old technology, or . . .

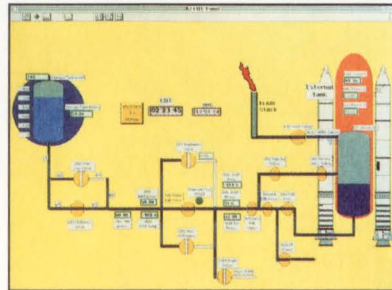
Automated Test



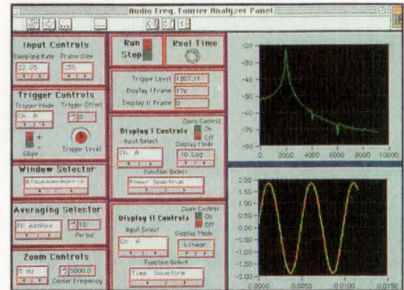
Analytical Chemistry



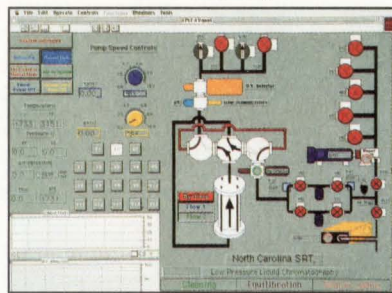
Process Control



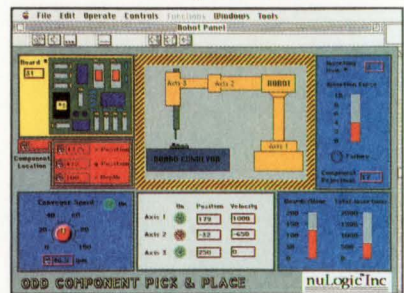
Audio and Vibration



Chromatography



Manufacturing and Production



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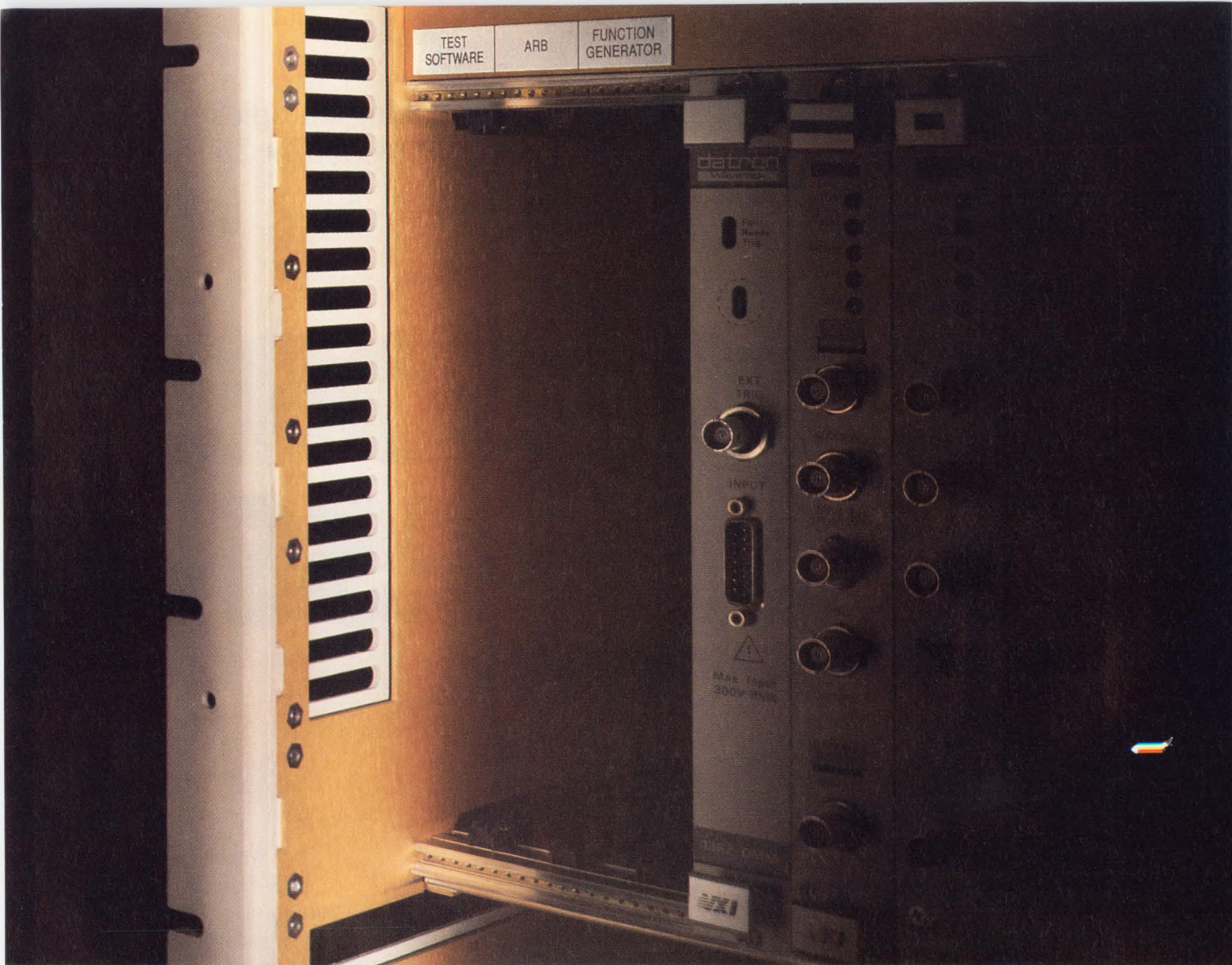


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Circle 88 for Literature

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On the cover: Because they are tailored to operate from a unipolar power supply, single-supply linear devices are gaining popularity over bipolar supplies for some applications. Primarily, these linear components are suited to systems that pose strict size and weight constraints, such as battery-powered equipment. See our Special Report on pg 118. (Photo courtesy Philips Signetics)

SPECIAL ISSUE: ANALOG TECHNOLOGY

SPECIAL REPORT

Linear components for single-supply designs 118

The number of linear ICs tailored to operate from a single power-supply voltage has dramatically increased in the last few years. Using these devices requires a conservation-of-signal mentality and a conscious choice of what to call "ground."—*Anne Watson Swager, Regional Editor*



DESIGN FEATURES

Patience and reason solve digital-system debugging problems 135

When a bug strikes your digital system, try to suppress panic and approach the task systematically. Deductive digital debugging can help you find and eradicate any digital bug infestation.

—*Ronald M Jackson, Fascinating Electronics*

Designers' guide to subranging A/D converters—Part 3 155

Part 1 of this 3-part series covered the architecture and operation of subranging ADCs. Part 2 covered the devices' parameters and specifications. Part 3 concludes the series with a discussion of testing high-speed subranging ADCs.—*Ray K Ushani, Datel Inc*

TECHNOLOGY UPDATES

Analog Spice simulation models: Accurate models mirror extremes of operation 61

Before you base design decisions on the results of a simulation, check that the pedigree of your models is fine enough to satisfy the needs of your application.—*Brian Kerridge, European Editor*

Continued on page 7

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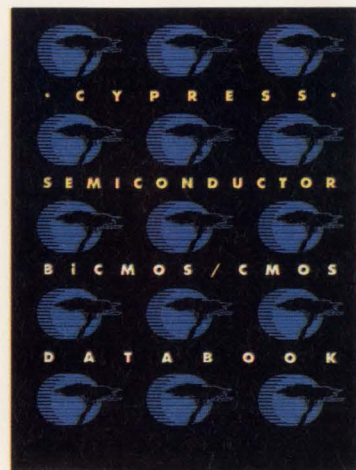
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TECHNOLOGY UPDATES (CONTINUED)

Switching regulators: Demo boards, software ease circuit design 79

For engineers not familiar with the intricacies of switching regulators, design aids help simplify the task of realizing a practical circuit.—*Dave Pryce, Associate Editor*

Spectrum analyzers: Modern instruments ease frequency analysis 95

Modern spectrum analyzers have come a long way. Improved RF performance and digital processing features open new vistas for viewing the frequency domain.—*John Gallant, Associate Editor*

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Panel-mount display package 114

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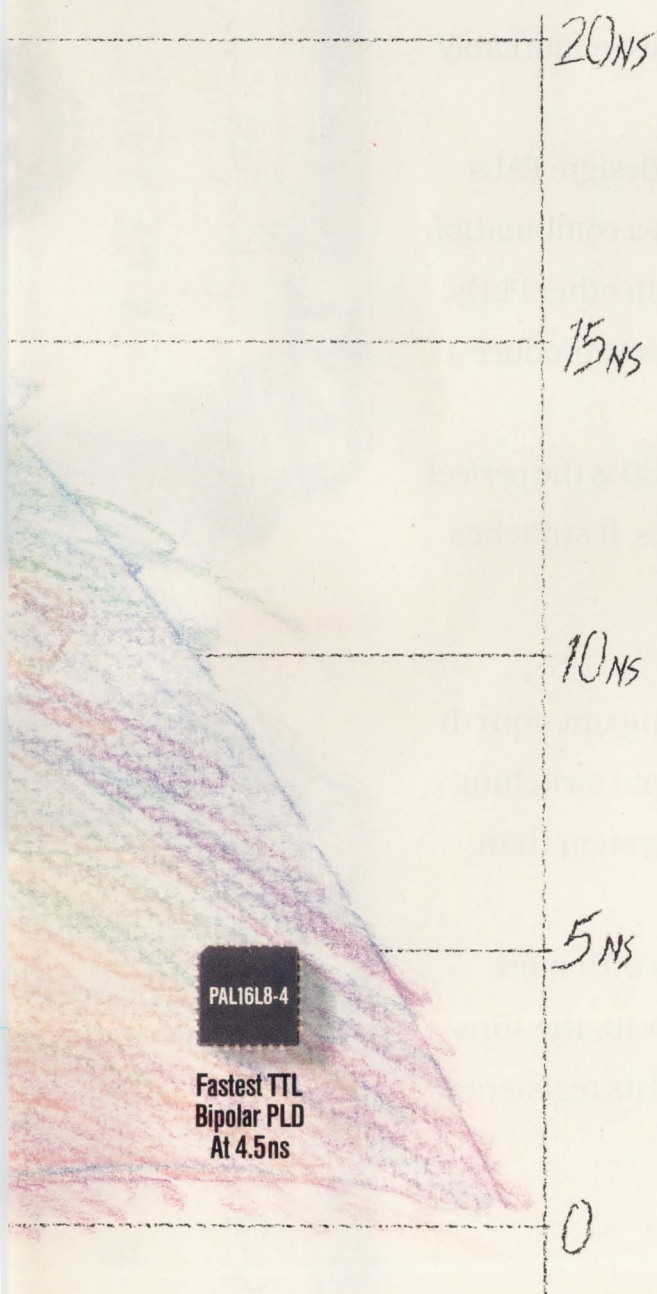
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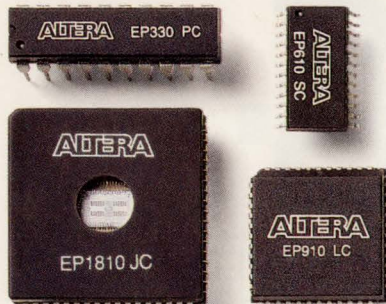
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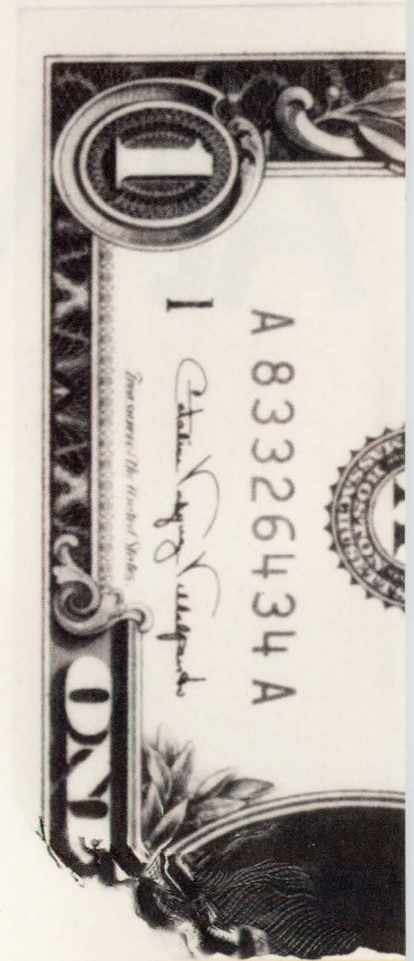
So now you can cut something from your design: PALs and GALs. Because our Classic parts give you a combination of speed, density and flexibility you won't find in other PLDs.

All of which helps you cut the time it takes to produce a superior design.

For example, our 20-pin, 8-macrocell EP330 is the perfect replacement for over 20 types of PALs and GALs. It stretches

counter frequencies to 125 MHz while sipping one-fourth the power of a standard PAL. And its quiet output switching circuitry allows the EP330 to run faster in-system than a 10ns 16V8.

Our 24-pin, 16-macrocell EP610 delivers 60% more logic density than a 22V10. And unlike a 22V10, the 15ns EP610 consumes a mere 20 μ A in standby. And its registers



MORE THAN LOGIC DELAYS.



can be programmed for D-, T-, JK- or SR-operation or for asynchronous clocks.

To replace multiple PALs and GALs with a single chip, try our 44-pin EP910 or 68-pin EP1810. Both offer superior logic density and greater I/O at a lower cost than any other mid-range CMOS PLD.

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What's more, we offer the industry's broadest, most flexible line of CMOS PLDs. With devices ranging from 20 to 100 pins, and logic densities from 8 to 192 macrocells, there's an EPLD for every logic design task.



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John Jorgensen, National's Director, Advanced Communications Business Group, talks about applying advanced VLSI technology to next-generation communications systems.

Setting the stage for connectivity.

"National has a definitive strategy for providing voice- and data-communications solutions in silicon.

"We have solutions for Ethernet, FDDI, and integrated-digital networks. And we're working on next-generation solutions for ultra-high-speed network applications.

"The key to building devices this sophisticated is our experience with advanced analog+ digital

integration. We have all the enabling technologies. BiCMOS, CMOS, and ECL processes. Powerful design tools. Experienced analog + digital designers.

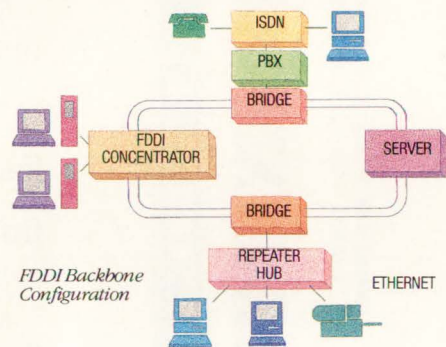
"It isn't easy. But we're doing it."

Linking LANs with FDDI.

"Our FDDI chipset provides the backbone that links Ethernet LANs at the workgroup level with integrated-digital networks, such as ISDN and SONET— and it provides the high-speed datapipe that links workstations directly.

"We're the first manufacturer to introduce a fully-integrated FDDI solution. It offers more network management features and consumes less power than any other solution.

"Our latest device, called the BSI, provides the system interface between our core FDDI chips and the host-system bus, such as VME,



AT, Microchannel, or EISA. It gives you the maximum available system bandwidth, with burst-mode transfers of 800Mbits/second through a 32-bit-wide data interface — without the need for an external processor.

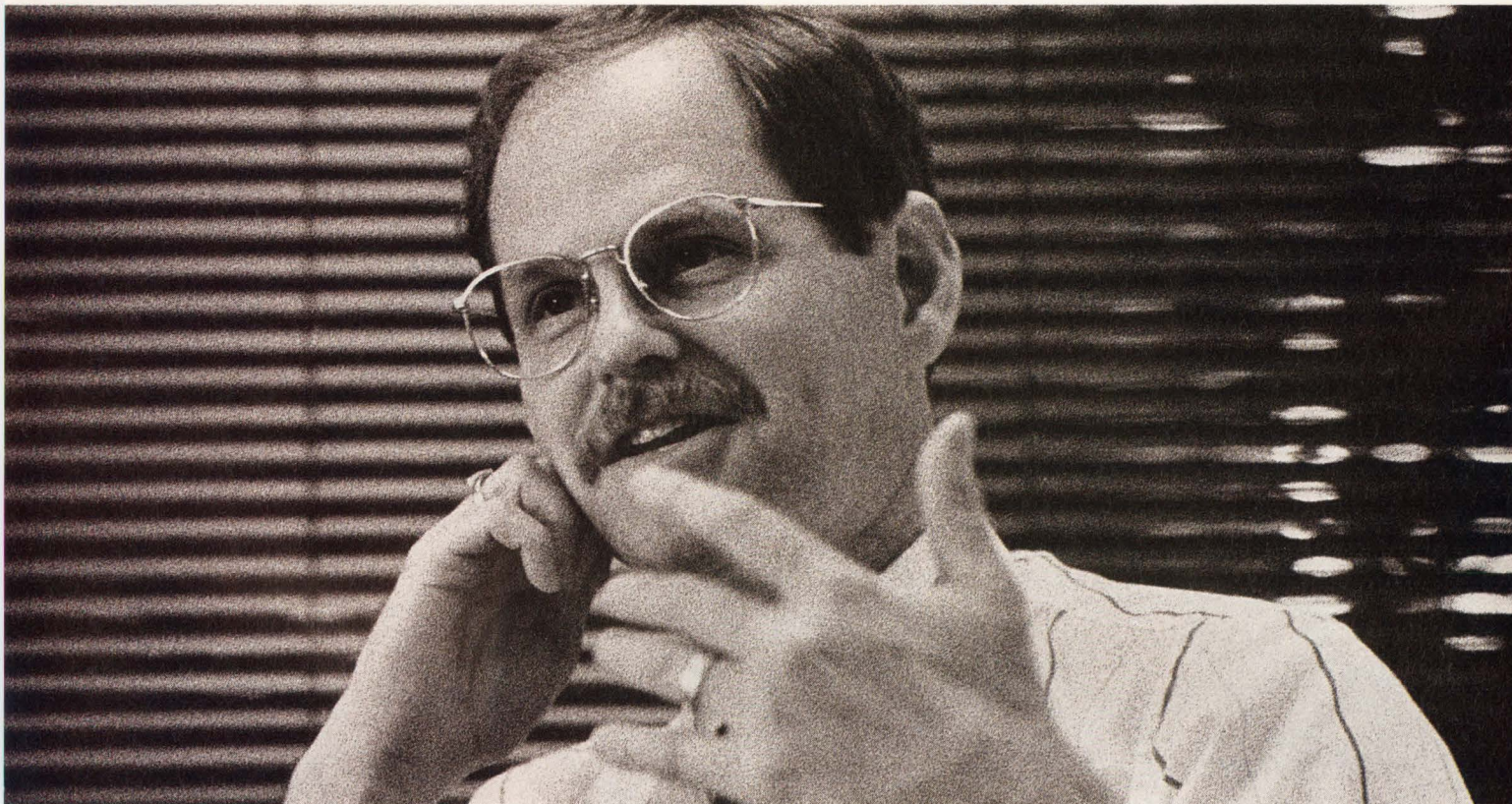
"So now you can develop products for highly-integrated FDDI networks, such as bridges, routers, and concentrators, or you can develop adapter cards for high-performance workstations and PCs — all from one supplier. National."

Linking the workgroup with Ethernet.

"Our SONIC — Systems Oriented Network Interface Controller — integrates, for the first time, a digital controller with a 10Mbit/second analog encoder/decoder.



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"It supports all IEEE 802.3 functionality in a single chip that goes right on the motherboard in 16- and 32-bit systems, providing full network management functions in hardware.

"And with a transfer rate of 50 Mbytes/second, it's 20 times faster than most other solutions, and cuts bus occupancy by up to 80%.

"The workgroup is linking itself with Ethernet. And we're making it happen faster, smaller, and more cost effectively. That's the standard, and we're setting it."

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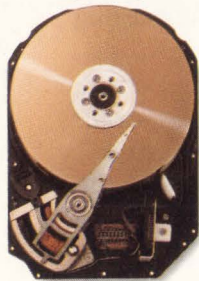
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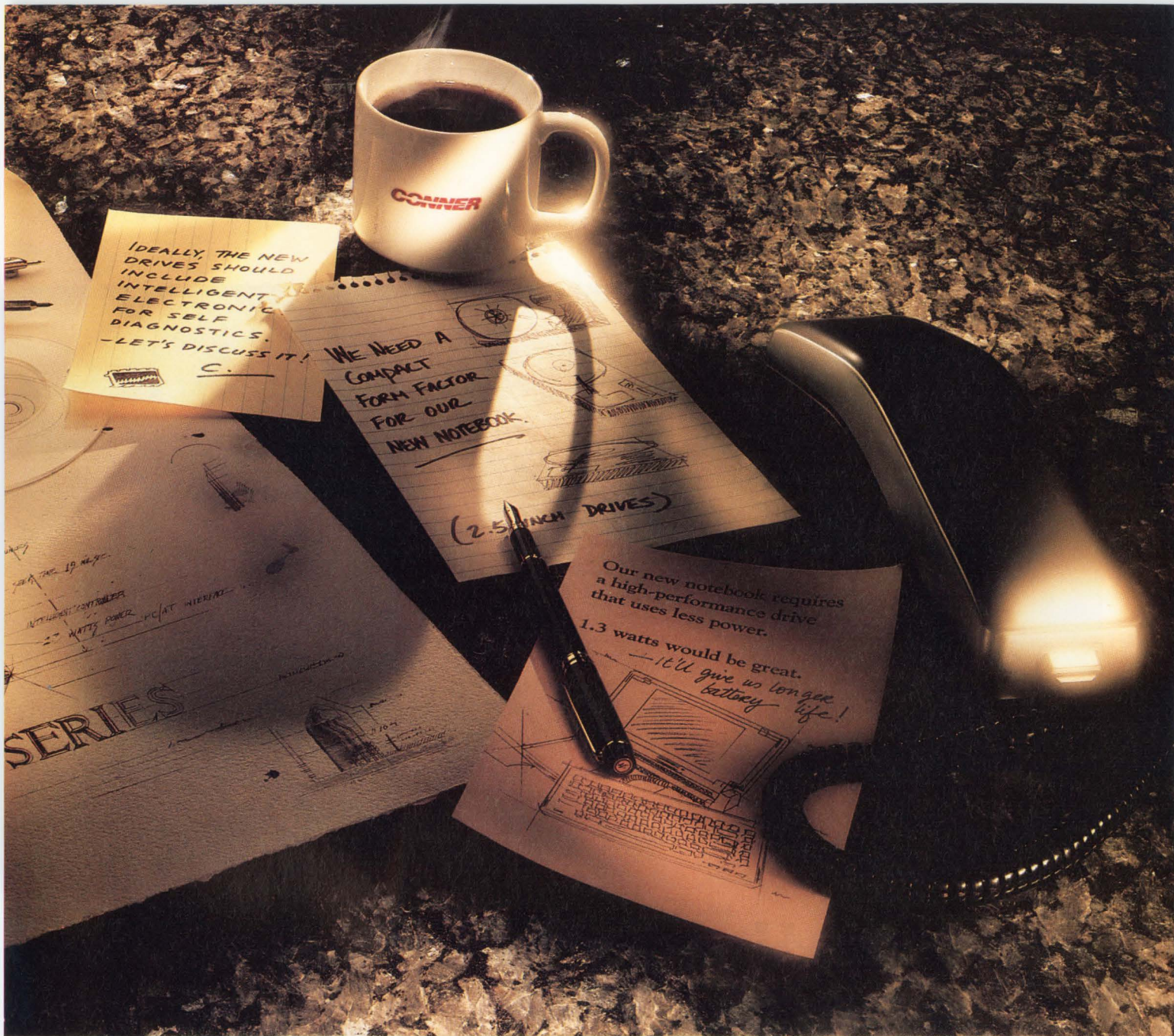
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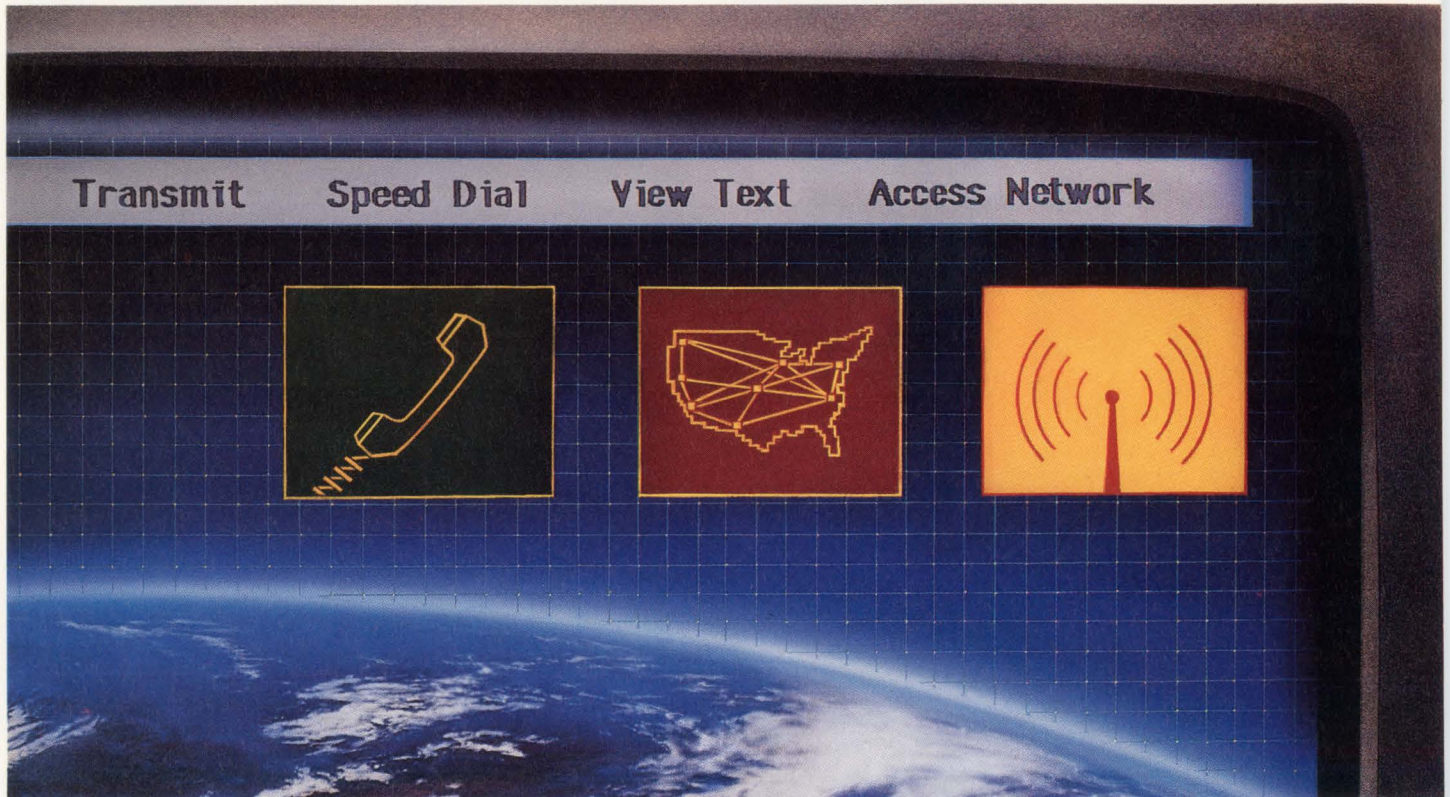
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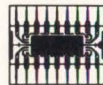
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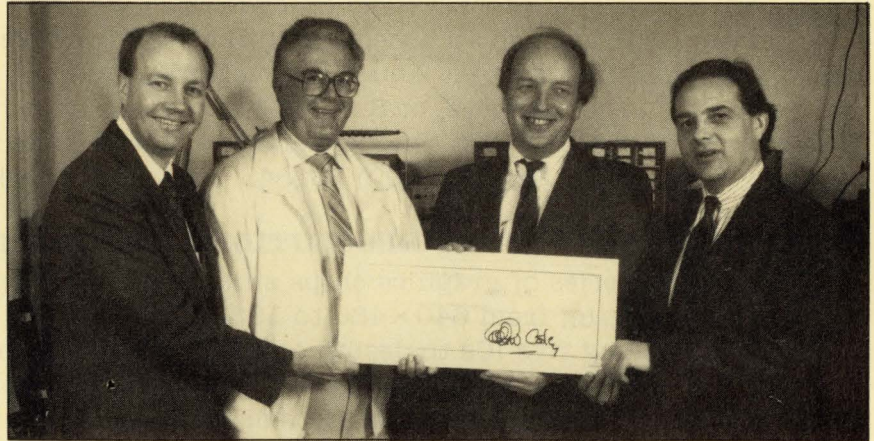
NEWS BREAKS

EDITED BY SUSAN ROSE

CAL TECH RECEIVES EDN'S \$10,000 INNOVATION GRANT

As part of its annual Innovation and Innovator awards program, EDN presented the 1990 \$10,000 Innovator grant to the Power Electronics Group at California Institute of Technology (Pasadena, CA) in April. The award was presented to Cal

Tech in the name of Dr. Klas Eklund who won EDN's Innovator award for 1990. Eklund received a plaque and the right to designate the grant's beneficiary at EDN's awards banquet at Wescon '90 in Anaheim, CA. Eklund garnered the Innovator award for work done in implementing power MOSFET transistors using a standard CMOS-logic semiconductor-manufacturing process. Eklund chose the Power Electronics Group for its innovative work



From left to right: Jon Titus, Dr David Middlebrook, Dr Klas Eklund, Mark Holdreith.

in switching power-supply topologies and in magnetic materials for power-supply circuits. Present at Cal Tech were Dr Eklund, Dr Middlebrook of Cal Tech's electrical engineering department, EDN's associate publisher, Mark Holdreith, and EDN's editorial director, Jon Titus. After the brief ceremony, several graduate students demonstrated research projects involving high-voltage switching supply circuits and magnetic-materials investigations.—EDN Staff

MIXED-LEVEL ANALOG TOOL SIMULATES CIRCUITS

Profile, a Spice-based analog simulation tool from Valid, lets you describe all or part of a circuit or system at the behavioral level. The software works with the company's Workbench II to let you mix ordinary Spice-level descriptions with a behavioral description for simulation. The software simulates many effects that are difficult or impossible to simulate with Spice macromodels, such as hysteresis, memory, state-variable, and conditional branching. You can easily model pulse-width modulators, multiplexers, and sample-and-hold circuits. The tool accepts user-programmable blocks for functions such as differential equations, Laplace domain transfer functions, and basic arithmetic. The \$15,000 software runs on Sun, DEC, and IBM workstations and will be available the second quarter of 1991. Valid, San Jose, CA, (408) 432-9400, FAX (408) 432-9430.—Doug Conner

DSP VMEBUS PROCESSOR CLOCKS UP TO 66M FLOPS

The DPV30 from Loughborough Sound Images is a VMEbus DSP board that employs two TMS320C30 processors. The twin processors operate independently, in parallel, or by pipeline multiprocessing. Each processor has a 64k × 32-bit-word zero-wait-state static RAM (SRAM), which is expandable to 256k × 32-bit words. Each processor shares 128k × 32-bit-word single wait-state SRAM or 1M × 32-bit-word dynamic RAM (DRAM), expandable to 512k × 32-bit words or 4M × 32-bit words, respectively. Further coupling is possible using a block of 2k × 32-bit-word dual-port SRAM, which

NEWS BREAKS

occupies the same address location of each processor. One processor shares a further $2k \times 32$ -bit-word dual-port SRAM with an expansion port, enabling up to three more DVP30 boards to function in the same system. A daughter board containing two channels of 16-bit ADC and DAC, sampling at 200 kHz, plugs into the main assembly. A proprietary 16-bit I/O port enables further off-board expansion. Two full-duplex synchronous serial ports transfer data as 8-, 16-, or 32-bit words at 8.3 MHz.

Software tools include an assembler/linker, a C compiler, debug monitors, and the SPOX DSP operating system. You can develop applications in DOS or Unix using IBM PC or compatible computers, or Sun SPARC workstations, respectively. DPV30 with basic memory costs £4395. Analog daughter board adds £600. Loughborough Sound Images, Loughborough, UK, (509) 231843, FAX (509) 262433.—Brian Kerridge

GRAPHICS ICs SUPPORT RESOLUTIONS AS HIGH AS 1920×1150

The GC1200 series of graphics chips suits 2- and 3-D applications and supports resolutions ranging from 640×480 to 1920×1150 pixels, respectively. You can pick and choose among five ICs to design a graphics subsystem that meets your needs. The vector raster processor can draw as many as 1.2M vectors/sec. One or more bitblt processors control frame buffers as deep as 32 planes. The video controller processes signals from as many as 24 planes and produces a video rate as fast as 120 MHz. You can add shading and depth cuing to a design with the depth buffer controller that handles the Z axis. Finally, the pixel accelerator speeds bitblt operations four fold. In evaluation quantities, a chip set for a basic 8-plane, $4k \times 2k$ -pixel design costs \$1000. You can add shading and pixel acceleration for \$1500. Yamaha Corp, San Jose, CA, (408) 437-3133, FAX (408) 437-8791.—Maury Wright

SWITCHED-INTEGRATOR IC SURPASSES DISCRETE DESIGNS

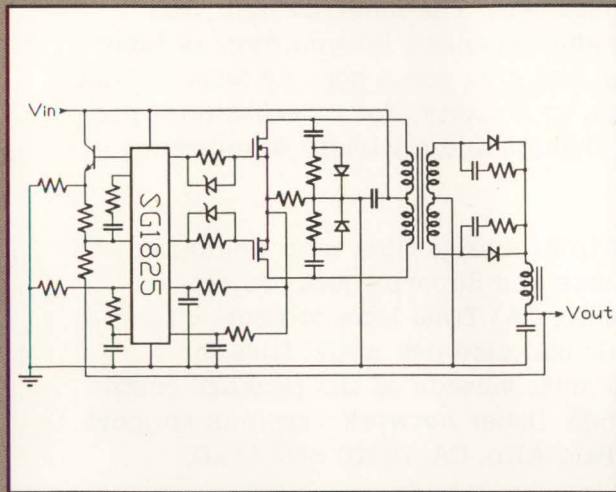
The ACF2101 from Burr-Brown Corp is a dual, monolithic switched integrator for precision applications. Each channel can convert a low-level input current of 0 to 100 μ A to an output voltage of -10 to $+0.1V$ by integration using either an internal or external capacitor. As a complete circuit on a chip, the device eliminates or minimizes many of the problems commonly encountered in discrete integrator designs: leakage-current errors, noise pickup, and charge injection. The integrator uses a minimum of pc board space. Key specifications are low noise, 10 μ V rms, low bias current, 100 fA, and dynamic range of 120 dB. The \$18 (100) device comes in 24-pin plastic DIP and SOIC packages. Burr-Brown Corp, Tucson, AZ, (800) 548-6132, FAX (602) 889-1510.—Anne Watson Swager

\$1995 VMEBUS CPU IS PC COMPATIBLE

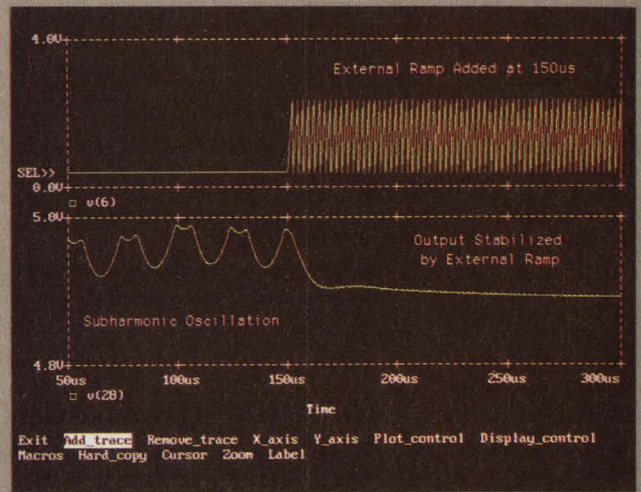
The EPC-6 VMEbus CPU board from Radisys can run IBM PC-compatible software because of its 20-MHz 80386SX processor, MS-DOS in ROM, as much as 4M bytes of RAM, and 512k bytes of Flash EPROM for program storage. The board targets embedded-control applications, and the control software lets you download software you develop on a PC into the Flash memory. Yet, the \$1995 board doesn't include standard PC features, such as graphic controller, modem, and disk interfaces—features often not needed in embedded applications. You can add peripheral functions necessary to your application via a local expansion bus. Standard features of the board include a math coprocessor socket, 8k bytes of battery-backed static RAM, two RS-232C ports, and a clock. Radisys Corp, Beaverton, OR, (503) 690-1229, FAX (503) 690-1228.—Maury Wright



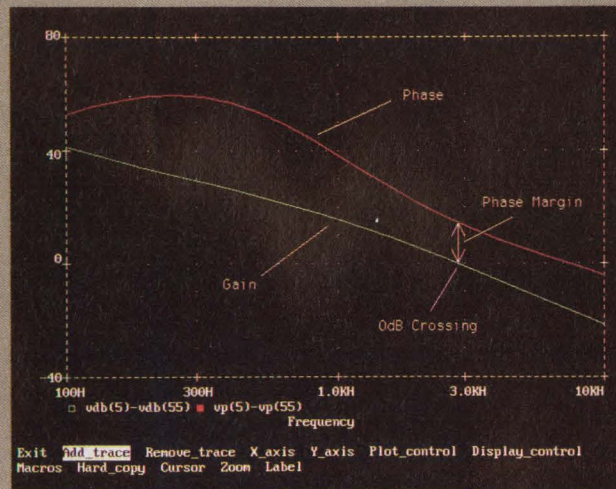
The Standard for Circuit Simulation Switch-Mode Power Supply Design



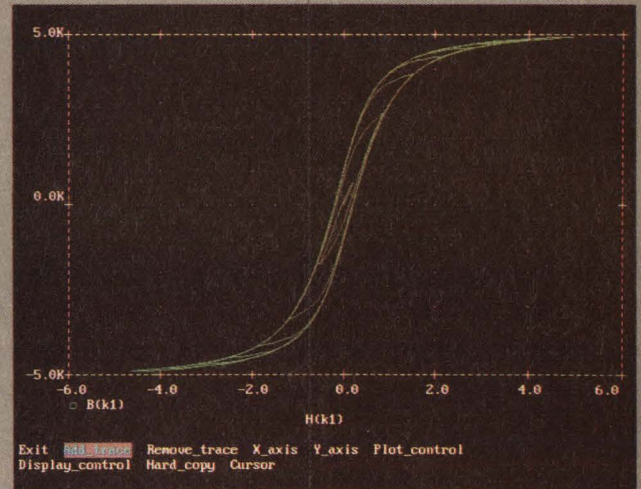
Current mode power supply schematic.



Power supply simulated using mixed analog/digital simulation. Plot shows subharmonic oscillation being suppressed by external ramp.



Simulation using the Vorperian switch model to examine the stability of a power supply.



Hysteresis curve of transformer.

A cycle by cycle simulation of switch-mode power supplies is recognized as a difficult simulation task for SPICE-based simulators, which must cope with timings that can span 4 orders of magnitude. This problem invariably results in very long simulation times, but is improved considerably by MicroSim's approach of building the controller macromodel chips so that a significant section is simulated in the digital domain. PSpice's behavioral modeling and mixed analog/digital simulation capability makes this possible.

PSpice is available on the IBM-PC (running DOS or OS/2); Macintosh II; Sun 3, Sun 4, and SPARCstation; DECstation 2100, 3100, and 5000; and the VAX/VMS families. In addition to the PWM macromodels, the PSpice library contains over 3,500 analog and 1,500 digital parts which can be used in a variety of applications. Our technical staff has over 150 years of combined experience in CAD/CAE, and our software is supported by the engineers who wrote it.

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NEWS BREAKS

SOFTWARE REVISION ADDS PROJECT-MANAGEMENT FEATURES

Major revisions to version 2.0 of Software Partners Inc's Time\$heet Professional time- and expense-tracking software package for IBM PC and compatible computers take the product into the realm of project management. The modifications add spreadsheet-like analysis of the tracked hours and expenses; let you display labor costs to date and estimates of completion costs; and give you a sorting feature that lets you examine project costs by project, client, or activity. For international projects, the package supports international date formats and a variety of currency symbols.

An import/export module allows the product to exchange files with Computer Associates' (Garden City, NY) accounting products and Superproject project-management software, and Symantec's (Cupertino, CA) Time Line project-management package. The import/export module can also use ASCII files for exchanging data with other programs. A single-user version of the package costs \$179.95, and a 5-user network version costs \$595. Other network versions support as many as 500 users. Software Partners Inc, Palo Alto, CA, (415) 857-1110, FAX (415) 949-3365.—Steven H Leibson

PLD EASES DESIGN OF VIDEO TIMING GENERATORS

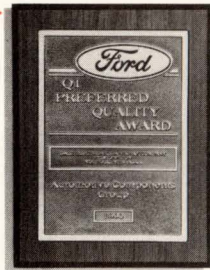
Altera Corp's function-specific PLD helps generate complex timing waveforms. The EPS464 synchronous timing generator offers the equivalent of 2500 gates in 64 macrocells. The macrocells include wide (>100) product-term logic, programmable register type (D, T, SR, or JK), and a selectable clocking source. The macrocells operate with system clocks as fast as 50 MHz, or with logic terms as the clock source. The device also features programmable I/O pins—configurable as input, output, or bidirectional signals—and input buffers having 250 mV of hysteresis.

You can design for the synchronous timing generator using the company's Max + Plus II software. The software lets you specify your design using waveforms, then uses logic synthesis to convert the waveform description to a fuse map. The company also offers a library of macro functions for the timing generator, including logic to generate NTSC, PAL, and SECAM waveforms, a digital phase-locked loop, and an oscillator. The synchronous timing generator is available in a windowed, ceramic J-lead chip carrier for \$35 (1000). It is also available in plastic 1-time-programmable packages. Altera Corp, San Jose, CA, (408) 984-2800, FAX (408) 435-1934.—Richard A Quinnell

FRAMEWORKS SUPPORT ASIC AND SYSTEM DEVELOPMENT

Visula ASIC Expert and System Expert from Racal-Redac provide tightly coupled frameworks with application software that you can select to meet your needs. The frameworks support schematic entry, architectural synthesis from VHDL (VHSIC hardware description language); simulation for logic, timing, and fault; automatic test pattern generation; mixed digital and analog simulation; hardware modeling; and PLD design tools. The frameworks are currently available for Sun, DEC, and HP-Apollo workstations. Individual products start at \$25,000. Racal-Redac, Mahwah, NJ, (201) 848-8000, FAX (201) 848-8189.—Doug Conner

What's the quality of our quality



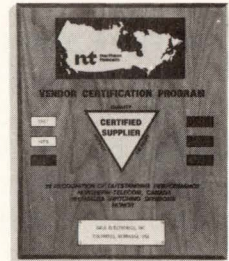
Ford



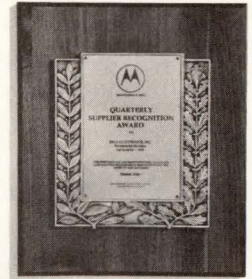
General Electric



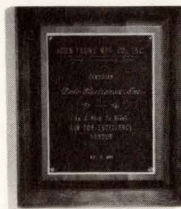
Rockwell International



Northern Telecom



Motorola Inc.



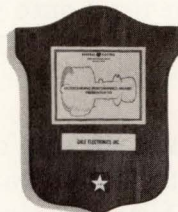
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Talk to any of the major manufacturers who, during the past three years, have recognized Dale's ability to meet their exacting quality standards. Then talk to us. We have a wall full of awards—perhaps as many as anyone in the industry—and we're always pleased to receive more. However, we'd much rather discuss what these awards represent: A soundly structured quality system able to quickly interface with your manufacturing process—and make you more competitive. That's the quality of our quality.

For more information on Dale quality procedures and systems, write Joe Matejka, Vice President of Quality Assurance, Dale Electronics, Inc., 1122 23rd Street, Columbus, Nebraska 68601-3647. Phone (402) 563-6511.



NEWS BREAKS

PRECISION OP AMPS SPEED UP

The LT1220 family of op amps from Linear Technology Corp combines slew rates of 250 and 150 V/ μ sec with offset voltages of 1 mV max, gains of 20,000 min, and input bias currents of 300 nA max. The family includes a unity-gain-stable amplifier with a 45-MHz gain-bandwidth product and a 250 V/ μ sec slew rate; an amplifier with a 150-MHz gain-bandwidth product and a 250 V/ μ sec slew rate, decompensated for closed-loop gains of 4 or more; and an amplifier with a 350-MHz gain-bandwidth product and a 150 V/ μ sec slew rate, decompensated for gains of 10 or more. The amplifiers use a single gain stage, which enables them to achieve respective settling times of 90 and 165 nsec to within 0.1% and 0.01% to a 10V step, along with gain-enhancement circuitry to increase the amplifiers' dc gain. The amplifiers are specified for operation with either $\pm 5V$ or $\pm 15V$ supplies, require 8 mA of supply current, and can drive unlimited capacitive loads. Wideband noise varies from 3 to 17 nV/ $\sqrt{\text{Hz}}$ for the three devices. The op amps are available in 8-pin plastic DIPs. Prices start at \$3.85 (100). Linear Technology Corp, Milpitas, CA, (800) 637-5545, (408) 432-1900, FAX (408) 434-0507.—Anne Watson Swager

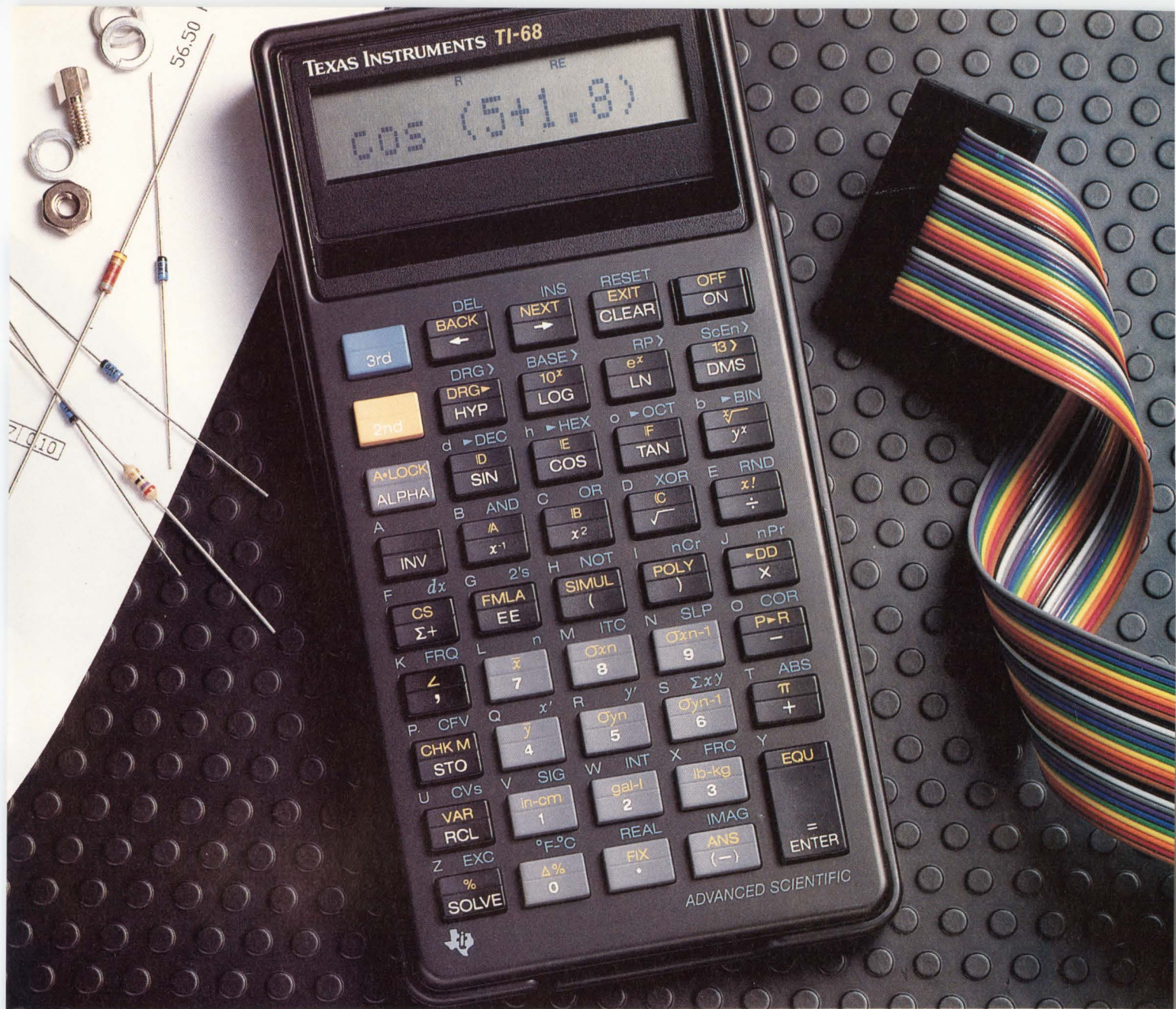
TRANSPUTER INCLUDES MULTIPROCESSING PROTOCOL

Inmos revealed the technical details of its second-generation transputer at the Transputing'91 conference in April. The 50-MHz device, named the H1, is code compatible with existing Transputers and extends their multiprocessing capabilities by adding hardware to facilitate interprocessor communications. These extensions let you program the device for multitasking without concern for which CPU executes each task. Both local and remote interprocessor communications appear identical at the instruction level. The device also offers a virtual channel processor, automatically multiplexing as many channels as you need onto the four physical channels the device provides. An external message-router IC directs traffic between processors.

The Transputer operates with an internal clock rate of 50 MHz max, derived from an external 5-MHz clock signal. Its serial links can transfer data as fast as 10M bytes/sec in each direction. It offers a 16k-byte combined instruction- and data-cache and can directly address 8M bytes of external dynamic RAM without additional logic. The cache's speed and the device's superscalar architecture combine for an execution of >60 MIPS sustained and 200 MIPS peak. Samples of the device will be available in the second quarter of 1991, with production slated for the fourth quarter. It will cost from \$300 to \$500 (100). SGS-Thompson/Inmos, San Jose, CA, (408) 452-9122, FAX (408) 452-0218.—Richard A Quinnell

600W MODULAR POWER SUPPLY INCORPORATES PFC

Omega 600 modular switched-mode power supplies from Coutant Lambda provide four outputs of nominal 5, 12, 24, or 48V. Power factor correction (PFC) circuitry produces a power factor of >0.9 to anticipate 1992 European standards for EMC. The unit complies with line harmonic-distortion standard IEC 555-2 and conducted RFI standard VDE 0871 curve B. The unit accepts a line supply of 85 to 265V, 47 to 63 Hz without adjustment. Overall dimensions are 64 \times 127 \times 303 mm. Price is £495 (100) depending upon configuration, and shipments commence third quarter of 1991. Coutant Lambda Ltd, Ilfracombe, UK, (271) 863781, FAX (271) 867185.—Brian Kerridge



There's a new standard for functionality, ease-of-use and price. The TI-68.

We set some tough goals for ourselves in designing the TI-68. It had to have the powerful functions that technical professionals need. It had to be easy to use. And it had to provide all of this at a substantially lower price than the competition.

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rectangular forms for entries and results.

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binary. And it does Boolean logic operations, too.

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

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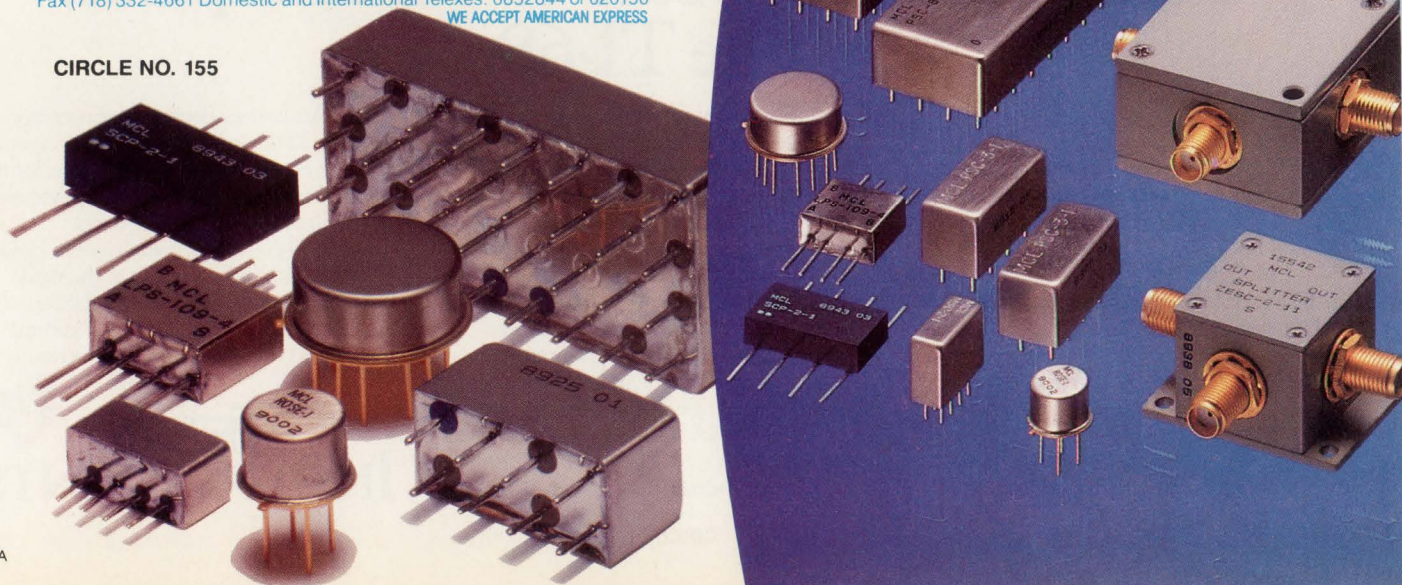
For detailed specs and performance data, refer to the *MicroWaves Product Directory*, *EEM* or *Mini-Circuits RF/IF Signal Processing Handbook*, Vol. II. Or contact us for our free 68-page *RF/IF Signal Processing Guide*.

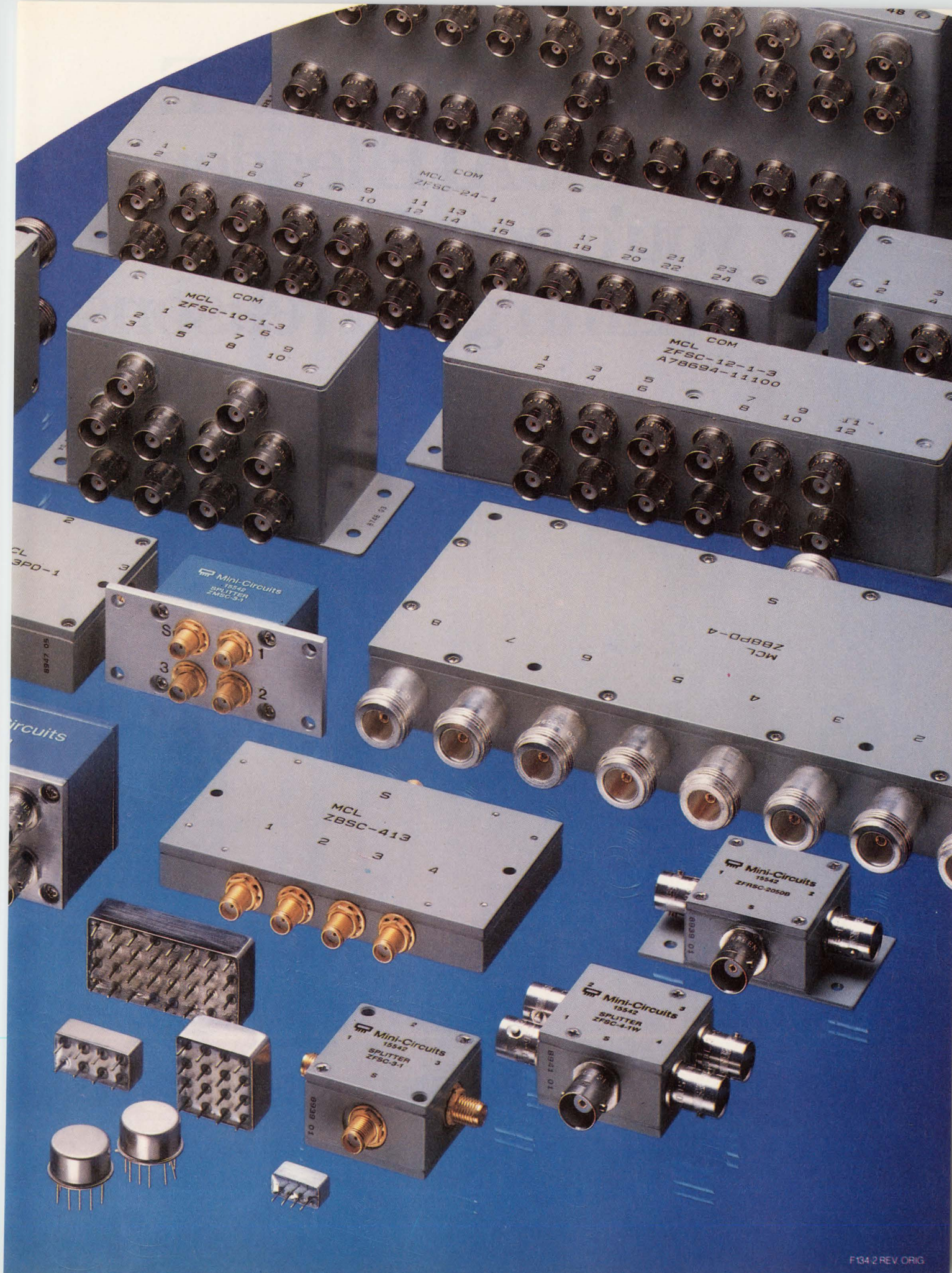
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Gary Oehrle,
Implementation Manager
AMCC

“A Stardent 1000 system has more than 60 CMOS ASICs, a total of more than 2 million gates. Using AIDA, we were able to achieve virtually 100% fault coverage with the test vectors we generated for our ASIC supplier, LSI Logic. When we received first silicon, all the ASICs worked the first time. We had the whole system up and running in three days.”

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Ed Faller,
Senior Engineer
General Electric Company



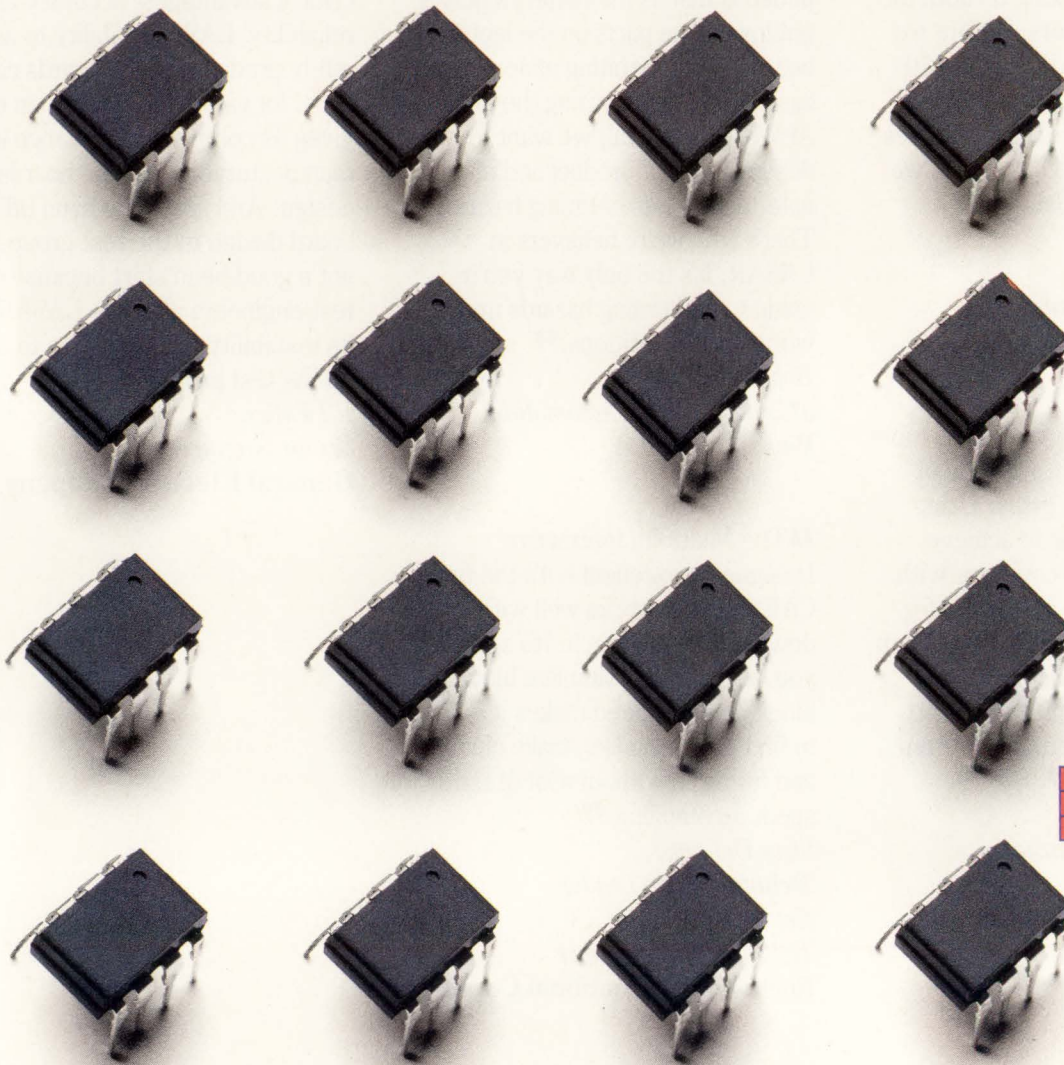
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Saga of a "defense engineer"

After reading "The Job-Hunting Blues" by Julie Anne Schofield (EDN, January 21, 1991, pg 230), I believe it's time we laid to rest some myths about the so-called "defense engineer."

Most of today's defense contracts are known as "firm fixed-price" contracts. These contracts will pay only a predetermined, negotiated unit price for the product. The total profit negotiated into the unit cost is limited by the federal government. Unit cost overruns are borne completely by the contractor.

Other costs not associated with the unit product cost also affect the "product" cost. Most defense-related items are sold on a "lot" basis. A predetermined number of units will be pulled from this lot and tested, often destructively, to determine if the entire lot is acceptable. Passing this lot-acceptance test often results in an incentive being paid to the contractor. These incentive payments usually increase as the number of contiguous acceptable lots increase.

Knowing that a failure, due to the random combination of parts characteristics assembled on a circuit board may cause a failure in 1 of 100,000 units, I may specify one part to have tighter tolerances, pushing the failure rate to 1 in 125,000 units. Doing this may cause my unit price to rise \$0.05/unit, but is acceptable in the defense world where higher product reliability is top priority.

Another way that the defense engineer reduces cost is through a process known as a VECP (value engineering change proposal). The defense contractor will write a VECP and submit it to the government. If it is accepted, the change is implemented, and the unit product cost is reduced by the amount specified in the VECP; the government and defense contractor share the savings—50/50. Note that both

incentive payments and VECP savings represent revenue beyond that generated by the actual sale of the product.

I am no longer employed as a defense engineer. I'm working as a consulting electrical engineer at the same start-up company that laid me off after only three months of employment during a general downsizing. Curiously enough, they hired me because of my defense background.

Steven Hum
Minnetonka, MN

Hobbies had lasting influence

Jon Titus's editorial, "Where are the experimenters?" (EDN, February 4, 1991, pg 29), rang sympathetic chords in my own recollections. When I was in the fourth grade, an uncle gave me a copy of Audel's *Radioman's Handbook* and a copy of *Radio for the Millions*, I earned my novice-class amateur-radio license when I was in the seventh grade. For every early experiment that did work, there were probably three that didn't. But that early training gave me solid foundations for future endeavors; the most useful lesson was developing the attitude that if you can't buy it, then build it.

My hobby activities won me a job at Boeing as an electronics technician straight out of high school. My most pleasing achievement was being promoted to supervisor of the electrical/avionics group of the GP-180 project at Lear-Jet. In that position, I had six engineers—all with degrees—working for me. I am presently general manager of a firm that pioneers techniques for illustrating and demonstrating factual evidence in court.

I'm planning to start a science club in Benton, KS, a suburb of Wichita. Everyone will be welcome, but the kids will be the target of the program material. The goal will

be to stir the imagination of any kid who rises to the invitation. We already have members in the community who can serve as mentors in aviation, electronics, amateur radio, computer science, photography, astronomy, and the mechanical arts such as woodworking, machining, and welding. The local Lions Club will be tapped for funds to support National Science Fair projects.

In answer to Jon's question, "Where are the experimenters?" I say, "They're all around us just waiting for the opportunity to grow."

Robert L Nuckolls, III
Videmotion Inc
Wichita, KS

Omission

Anne Watson Swager's article on Semicustom analog ASICs (EDN, February 4, 1991, pg 35) did not include Sipex. The company manufactures a number of dielectrically isolated complementary bipolar arrays and full-custom ICs. It accepts projects with customer, joint, and turnkey designs with nonrecurring engineering costs from \$19,000. The typical turnaround time is six to eight weeks from an approved layout.

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Sipex Corp's address is 491 Fairview Way, Milpitas, CA 95035. (408) 945-9080. FAX (408) 946-6191.

Revise criteria for hiring software engineers

"Software crisis" is a term in perpetual vogue, it seems. Yet the software industry, which has so many problems in development that

SIGNALS & NOISE

it is virtually unable to produce quality products in a timely manner, appears willing to perpetuate a myth. This myth is that expertise in a programming language and with a specific piece of hardware is necessary to be a successful programmer and applicant for a programming position. Today the myth

extends to the need for experience with CASE (computer-aided software engineering).

Experience with a programming language makes for a good "coder," but says little about analytical and design abilities. Experience with a specific hardware set and a related operating-system/control-program

set makes for a good "operator," but says nothing about analytical and design abilities. Experience with CASE is so vague as to be meaningless nonsense.

There is only one universal expressive language, and it governs the underlying machine—state-machine theory. It addresses many of the issues that face software engineering, specifically, and computer science, generally.

Electronics engineers are not hired on the basis of being able to use a specific CAD program. Why then hire software engineers on the basis of years of experience programming a specific language on a specific machine under a specific operating system or control-program set?

The tail still wags the dog!

Charles F Sauerbier
Senior Project Coordinator
Information Systems Service
Salem, OR

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Courts should research programming interchange

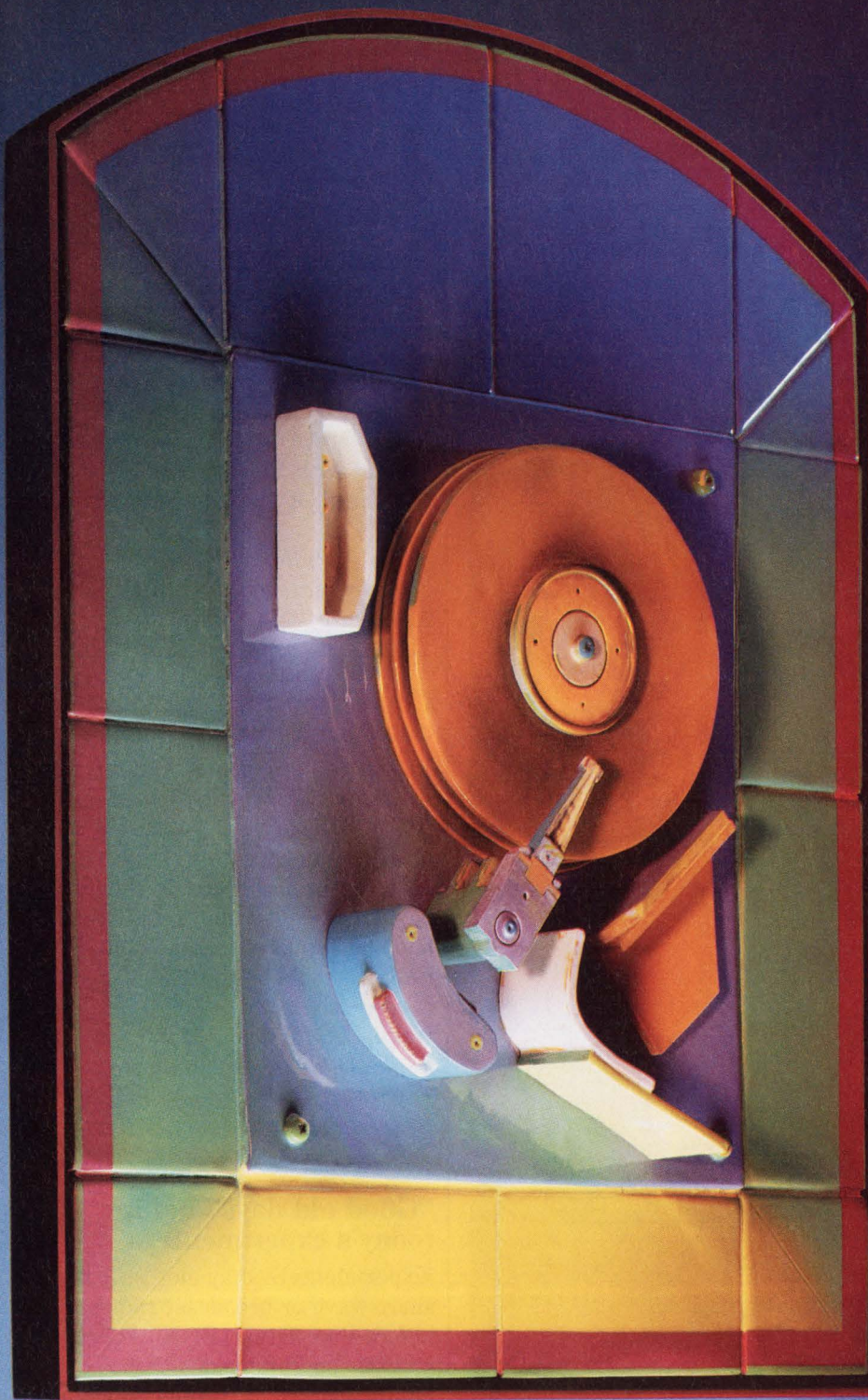
In the December 6, 1990, issue of EDN, pg 252, Joseph S Iandiorio, attorney at law, refers to the federal district court's considerations of "Supercode 4 . . . electronic spreadsheet." According to my research and recollection, there never was a microcomputer spreadsheet with that name. There was a code generator and a database. Perhaps he should have referred to Supercalc 4, which was quite successful.

The above is only one example of careless research and limited understanding of the issues involved in Lotus vs Paperback. It's no wonder that the court and the lawyers have reached a conclusion so much at variance with common sense and the history of free information interchange for computer programming!

Harvey Nice
Actinics
Research & Development
Addison, IL

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*Ceramic Sculpture by
Steven Donegan
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Continue Irwin Feerst's work for engineers

In memory of Irwin Feerst, several of us are taking action that we hope will lead to the continuation of Irwin's work. He has done the basic work by forcing leading individuals in the IEEE hierarchy to realize that some real problems exist for

the members of the IEEE and other branches of the engineering profession.

We must continue to place emphasis on portable pensions so that companies can no longer lay off engineers who are just short of being vested. We must find an effective way to prevent undercutting of our

people and underpaying for engineering services. Another problem I've encountered is the rejection of papers that I could prove contained new technology.

Tentatively, our group is called "Society of Concerned Engineers." Anyone who's interested write to me or to Richard Lowrie, 101 Lowrie Lane, Dade City, FL 33525.

We expect that the IEEE will cooperate with us in this endeavor. A check for \$10 made out to the Society of Concerned Engineers would be helpful. Richard Lowrie will deposit the money in a special account, which I'm sure will be subject to audit. We have also been in contact with Richard Tax and other recipients of the final CCEE bulletin.

*Keats A Pullen, PE
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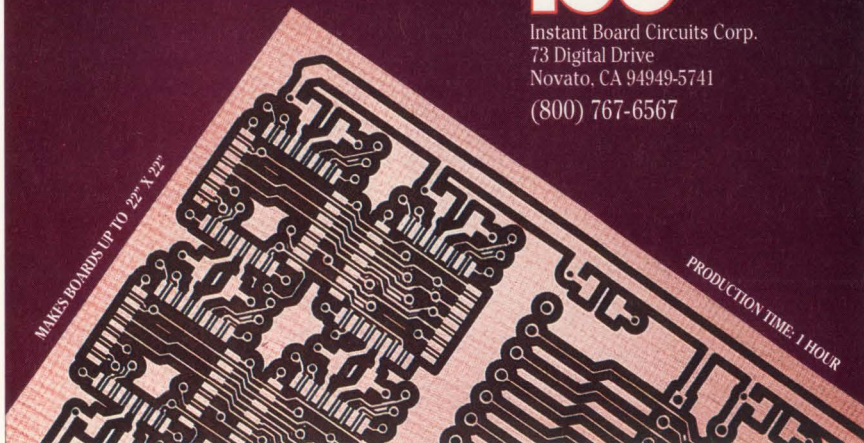
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Correction for logic-analyzer table

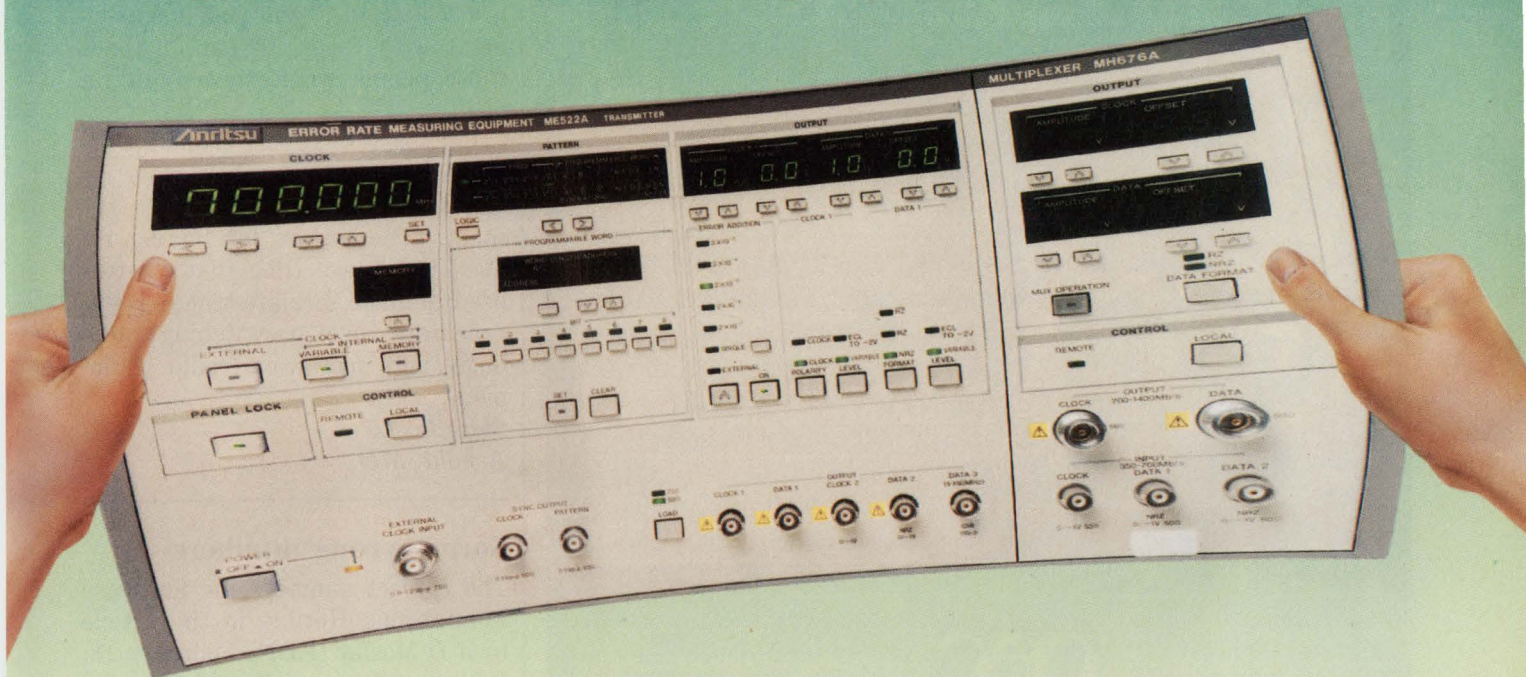
In the table of logic-analyzer support for 32-bit CISC processors (EDN, December 20, 1990, pg 139), the information for Tektronix's DAS9200 is incorrect; it should include the Motorola 68020, 68030, and 68040 microprocessors, and the i386SX should be the i386. [The i486 is correctly listed.]

*Wendy L Morrison, Manager
Logic Analyzer Div Marcom
Tektronix Inc
Beaverton, OR*

"Good old days" befog today's experimenters

Experimenters may not still build short-wave or broadcast radios, but before Jon Titus (EDN, February 4, 1991, pg 29) decides that nobody builds electronic things anymore, three general electronics hobby magazines are available on the stands. There are also several computer magazines, with new ones being added every day. Computers

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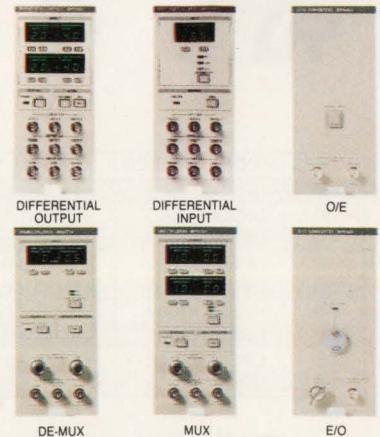
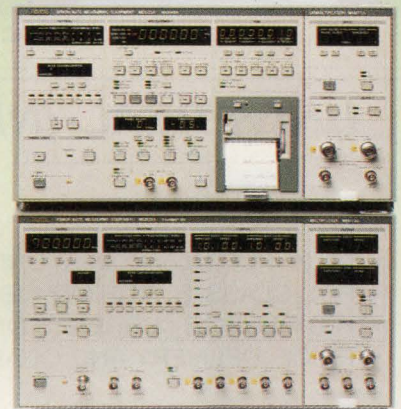
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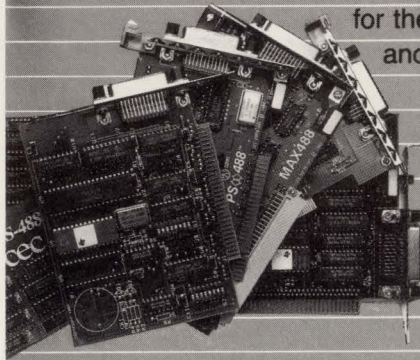
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are "electronic," and people experiment with them. In earlier times these people would have built radios.

I'm sorry to report that kids today are not building short-wave radios as they used to; now they buy them. [The reason for buying radios] is to save time that's better used to make satellite transceivers, repeaters, packet-switching radio links, and microwave radio equipment.

Steve Loska
Arnold, MD

Sorry, wrong numbers

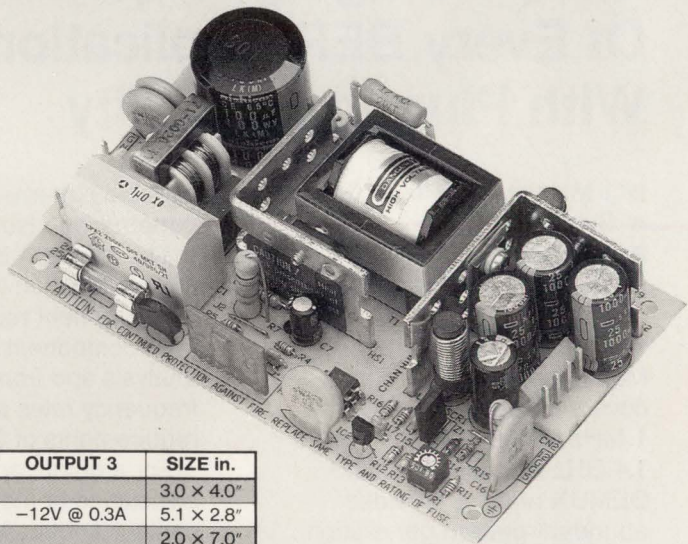
The correct numbers for Software Publications Hotline in the article by J D Mosley (EDN, February 18, 1991, pg 114) are (800) 426-7763 and (407) 982-6178.

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40	UPS40 - 1002	+5V @ 3.0A	+12V @ 2.0A (4.5)		2.0 x 7.0"
40	UPS40 - 2002	+5V @ 3.0A	+12V @ 2.0A (4.5)		3.0 x 5.0"
40	UPS40 - 2003	+5V @ 3.0A	+12V @ 2.0A (4.0)	-12V @ 0.3A	3.0 x 5.0"
50	UPS50 - 1002	+5V @ 3.0A	+12V @ 3.0A (5.5)		2.0 x 7.0"
50	UPS51 - 2002	+5V @ 4.0A	+12V @ 3.0A (5.5)		3.0 x 5.0"
65	UPS65 - 1002 - X	+5V @ 3.5A	+12V @ 4.0A (7.0)		3.5 x 6.0"
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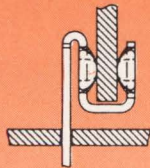
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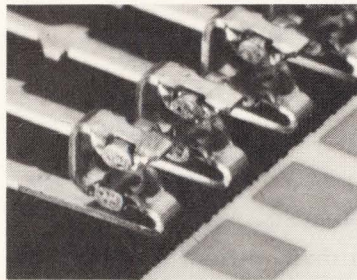
...and improve product reliability

When you use NAS solder and flux bearing edge clips, rework is virtually eliminated. Steps that yield high rates of rejects in other circuits assembly methods — solder paste, dipping and board clean-up — are replaced by simple, one-step lead attachment and reflow operations that consistently produce 100% solderability. Also, NAS clips can be bonded to conductor pads without raising the temperature of pre-populated boards to reflow levels and causing damage to existing connections. Most — or all — of the inspection procedures required by other methods are unnecessary, and expensive rework becomes a thing of the past.

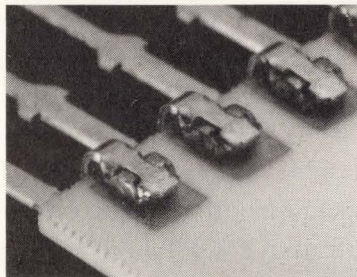


Preforms on edge clip terminals contain precisely the right amounts of the proper solder and flux for each application, and the exclusive NAS "Claw" grip holds each preform. This unique grip design provides direct contact between solder and conductor pads, a beneficial wiping action as clips are attached, and positive control of solder flow.

The simple, efficient method of applying NAS solder and flux bearing edge clips:



Direct contact between solder preforms and conductor pads produces a beneficial wiping action as clips are attached, either manually or with a lead attachment machine.



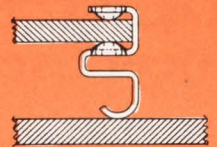
Interference fit holds clips firmly in position for reflow. Top and bottom preforms are reflowed in one operation using any method that raises temperatures to reflow levels.



Precise amounts of the right solder and the shape of the "Claw" grip provide control of solder flow without a solder stop. This assures perfect mechanical and electrical bonding without wicking or bridging.

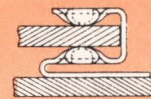
Unretouched Macro Photography

A single reflow operation for top and bottom preforms — using any method that raises temperatures to reflow levels — produces perfect solder joints every time.



With no specialized labor skills to acquire and very little capital investment, you can quickly and easily convert to the NAS solder and flux bearing edge clip method. The immediate result will be a faster, far less costly circuits assembly process, and more reliable, better performing products.

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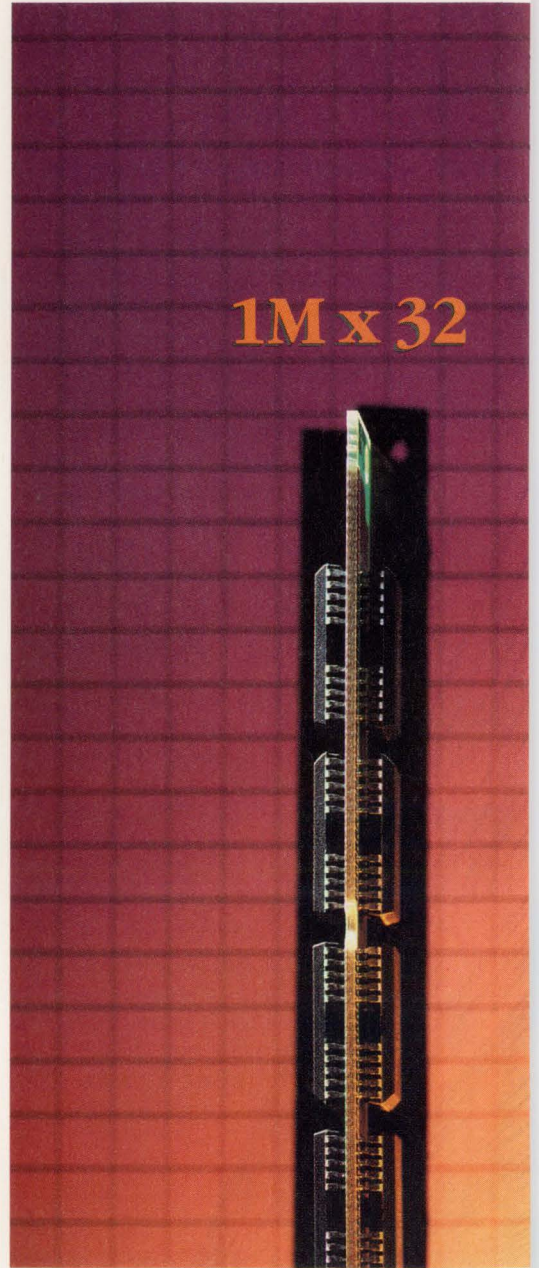
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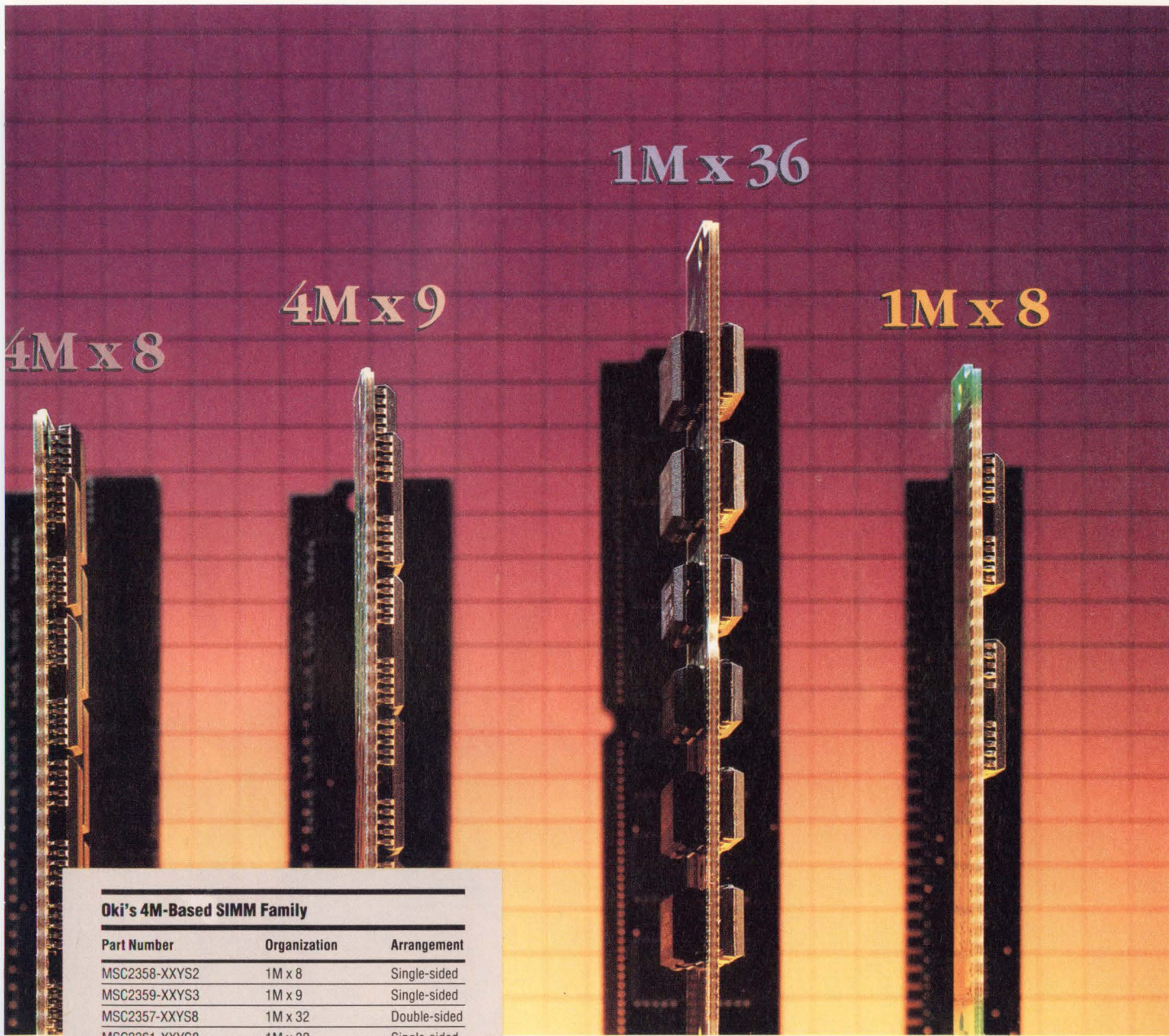
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Part Number	Organization	Arrangement
MSC2358-XXYS2	1M x 8	Single-sided
MSC2359-XXYS3	1M x 9	Single-sided
MSC2357-XXYS8	1M x 32	Double-sided
MSC2361-XXYS8	1M x 32	Single-sided
MSC2355-XXYS12	1M x 36	Double-sided
MSC2360-XXYS12	1M x 36	Single-sided
MSC2353A-80YS10	1M x 40	Single-sided
MSC2362-XXYS16	2M x 32	Double-sided
MSC2356-XXYS24	2M x 36	Double-sided
MSC2352A-80YS20	2M x 40	Double-sided
MSC2341-XXYS8	4M x 8	Single-sided
MSC2340-XXYS9	4M x 9	Single-sided

All the above listed SIMMs operate in fast page mode.

Speed options (XX) include:

70 = 70ns (^tRAC)

80 = 80ns (^tRAC) 20ns (^tCAC)



OKI
Semiconductor

785 North Mary Avenue
Sunnyvale, CA 94086-2909

FILTERS



dc to 3GHz from \$11.45

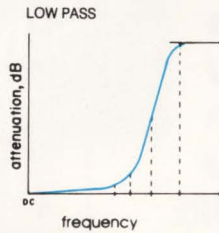
lowpass, highpass, bandpass, narrowband IF

- less than 1dB insertion loss • greater than 40dB stopband rejection
- 5-section, 30dB/octave rolloff • VSWR less than 1.7 (typ) • meets MIL-STD-202 tests
- rugged hermetically-sealed pin models • BNC, Type N; SMA available
- surface-mount • over 100 off-the-shelf models • immediate delivery



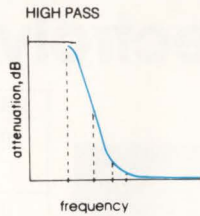
low pass dc to 1200MHz

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



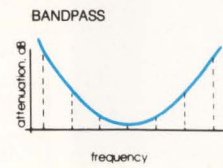
high pass dc to 2500MHz

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



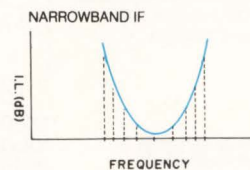
bandpass 20 to 70MHz

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



narrowband IF

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



CIRCLE NO. 113

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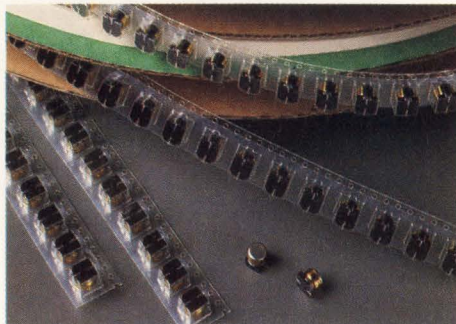
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UZ	5,000 hr. life/6mm ht./4~50V -55~+105°C/0.1~200 μF
WX	2,000 hr. life/5.5mm max. ht. -40~85°C/0.1~220, μF/4~50V
UT	2,000 hr. life/6mm ht. -55~105°C/0.1~100, μF/4~50V
UP	1,000 hr./6mm ht./Non-polarized -40~+105°C/0.1~47 μF 6.3~50V
UK Muse	2,000 hr./6mm ht./For audio -40~+85°C/0.1~220 μF 4~50V

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One good idea after another.

CIRCLE NO. 90

EDN May 9, 1991

ASK EDN

EDITED BY JULIE ANNE SCHOFIELD

Mysterious reader has scoop on discontinued parts

Regarding the January 21, 1991, question on obsolete National Semiconductor parts: I don't know if the following companies have the needed parts, or if they're even still around, but here are some places that have specialized in discontinued devices:

Rochester Electronics
10 Malcolm Hoyt Dr
Newburyport, MA 01950
(508) 462-9332
FAX (508) 462-9512

American Microsemiconductor Inc
133 Kings Rd
Madison, NJ 07940
(201) 377-9566
FAX (201) 377-3078

Lansdale Semiconductor Inc
2929 S 48th St, #2
Tempe, AZ 85282
(602) 438-0123
FAX (602) 438-0138

If you print this letter, please withhold my name.

We checked up on these companies, and all three still exist and continue to specialize in discontinued parts.

Antique-radio collector seeks same

I collect World War II military radios and specialize in German Wehrmacht and resistance (suitcase) equipment. Who in the USA deals with this kind of antique equipment?

Ragnar Otterstad
Holte, Denmark

John Terrey, editor and publisher of the *Antique Radio Classified* (Box 2-V22, Carlisle, MA 01741), recommends several individuals who collect antique radio equipment. One of these

people claims to have the largest collection of spy-related equipment in the world and has already corresponded with the reader. Rather than having Ask EDN serve as a classified section, we recommend that hobbyists use either the EDN bulletin-board system (BBS) at (617) 558-4241, 300/1200/2400,8,N,1 or specialty publications such as the *Antique Radio Classified*, which will send an evaluation copy upon request.

Reader suggests urgent data request

In the October 1, 1990, issue of EDN, David Fors of the Naval Weapons Center in China Lake, CA, requested a vendor for an IRIG-B converter. I would suggest he try sending out an urgent data request through the Government Industries Data Exchange Program (GIDEP). Most large companies, including military IC manufacturers, have a GIDEP representative.

Mark Monroe
Grumman Corp
Bethpage, NY

Sensitive-sensor suggestion

I hope your department can help us search for a particular sensor. We are looking for vendors of sensors to measure the blast/light intensity of a military fuse. We would prefer an explosion-proof sensor with an ultrahigh response time and an analog output.

Arthur Rangel
Senior Engineer
Engineering/Documentation
Systems Inc
Corona, CA

EDN Editor Jon Titus suggests that you try a photomultiplier tube. They are extremely sensitive and fast, and they provide an analog output. A couple of inches of clear Lexan in front of the tube's face should provide

enough protection from an exploding fuse. Three companies that sell photomultiplier tubes are

Antique Electronic Supply
688 W First St
Tempe, AZ 85281
(602) 894-9503
FAX (602) 894-0124

Daily Elecs, Div E
Box 5029
Compton, CA 90224
(213) 774-1255
FAX (213) 603-1348

International Components Corp
105 Maxess Rd
Melville, NY 11747
(516) 293-1500
FAX (516) 293-4983.

Alternate APU found

We are using the AM9511 arithmetic processing unit (APU) from Advanced Micro Devices for trigonometric functions and roots in several systems with different microprocessors. This device was easy to configure as an I/O peripheral.

The AM9511 became obsolete. We are looking for a similar 8- or 16-bit APU. Can you help?

Robert Fesler
Brussels, Belgium

By using the CAPS (Computer-Aided Product Selection) system, which is available from Cahners Technical Information Services, we discovered that Intel makes an 8-bit part similar to the AM9511. The APU's generic part number is 8231.

Intel Corp
3065 Bowers Ave
Santa Clara, CA 95051
(408) 765-8080
FAX (408) 765-2633

EDN

Ask EDN solves nagging design problems and answers difficult questions. Address your letters to Ask EDN, 275 Washington St, Newton, MA 02158. FAX (617) 558-4470; MCI: EDNBOS. Or send us a letter on EDN's bulletin-board system at (617) 558-4241; leave a letter in the ask_edn Special Interest Group.



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Compatible with the bus system built in your test programs, the PM 2200 Family provides a complete GPIB system solution. It includes a GPIB interface, a GPIB controller, and a GPIB-to-serial converter. The GPIB-to-serial converter allows you to use any GPIB controller you prefer. This is the only GPIB-to-serial converter that can be used with any GPIB controller.

The GPIB-to-serial converter is a standard 16-bit microprocessor. It can be used with any GPIB controller. It can be used with any GPIB controller. It can be used with any GPIB controller.

Writable power modes

The PM 2200 Family has 16 around three types of power supplies:

- 20V, 10A, 100W
- 10V, 10A, 100W
- 5V, 10A, 100W

Extensive protection features

An advanced set of features provide strong protection for your test in three under-test. Over-voltage and over-current protection levels are fully programmable. 5A, 10A and 20A current limiting is built-in and includes variable sense lines for compensation for voltage drops in the power distribution lines.

The equipped protection mode ensures that all outputs are switched off if a fault occurs or an over-current condition is detected. Programmable protection levels can be used to operate above the maximum that can occur. This is the only power supply that can be used to operate above the maximum that can occur. This is the only power supply that can be used to operate above the maximum that can occur.

The operating modes

The power supplies can operate in voltage source constant voltage or in current source constant current. With optional case calibration a calibrated multimeter is all that is required. The power supply does not have to be removed from the rack. We can access the calibration mode and the instrument firmware from the rack.

Reliability for design

1000 average mean time between failure (MTBF) over 30,000 hours. Fluke/Philips programmable power supplies are designed to give years of trouble-free service. One for your power needs provides a tremendous amount of loading for even the most demanding applications. These supplies are designed for a broad operating temperature range of 0-50°C.

Programmable Power Supplies

Model	Output	Current	Power	Price
PM 2200	20V	10A	100W	\$1500
PM 2201	10V	10A	100W	\$1200
PM 2202	5V	10A	100W	\$1000
PM 2203	20V	5A	100W	\$1000
PM 2204	10V	5A	100W	\$800
PM 2205	5V	5A	100W	\$700



FOR MORE INFORMATION CALL 1-800-44-FLUKE

GPIB SYSTEMS SOFTWARE

Get on the bus for instrument control—PM 2200 Family GPIB Controller

Here are the convenient and economical ways to connect your GPIB (PM 2200) or GPIB (PM 2200) computer into a complete controller for GPIB instruments.

Build into a program to read and include data for GPIB instruments.

Fluke/Philips offers support for the new IEEE 488.2 protocols so your software is easier to write, and is portable. Full-time interaction is compatible with all the GPIB software packages in the library—whether you're using automatic instruments for DUTs, making data from sources, or designing arbitrary waveforms. They also work with packages such as National Instruments, LabMaster, LabView, ADVANTAGE, LabMaster, and more.

Basic GPIB programs

PM 2200 Software Library

Software gives you a complete, easy-to-use GPIB program development environment. You can use it to write, test, and debug your programs. It includes a library of test programs, which can be used to test your programs. It includes a library of test programs, which can be used to test your programs. It includes a library of test programs, which can be used to test your programs.

Do you need to test—PM 2200 Family GPIB Controller

One minute it takes the software configuration utility to set up your system. The software automatically determines the GPIB system configuration. It recognizes the type of instrument and its address and assigns a user-defined name. All in less than a minute.

Included across the instrument control software. Software controls your GPIB programming software. The software takes care of the details for you.

Choice of programming environments.

Fluke and Philips instruments are available for BASIC/SIMPLIB, Microsoft QUASIC, and C.

Compatible systems for calibration

Fluke software can help you maintain your calibration equipment. Use METCAL, automatic calibration, when METTRACK keeps track of your requirements.



FOR MORE INFORMATION CALL 1-800-44-FLUKE

SIGNAL SOURCES

New wave solutions—PM 5200 Series Function Generators

These three general-purpose function generators offer a lot of versatility for the lab.

Adding waveform generators

In addition to the wide choice of standard waveforms, the arbitrary waveform generator can generate your own customized waveforms. Whether it's a waveform that's difficult to reproduce, such as a sine wave, or one that's not available in your library, you can generate it with the arbitrary waveform generator.

Wide choice of waveforms and modulation modes

The PM 5200 Series offers the widest choice of waveforms, including sine, square, triangle, and more. It also offers a choice of modulation modes, including AM, FM, PM, and more. It also offers a choice of modulation modes, including AM, FM, PM, and more.

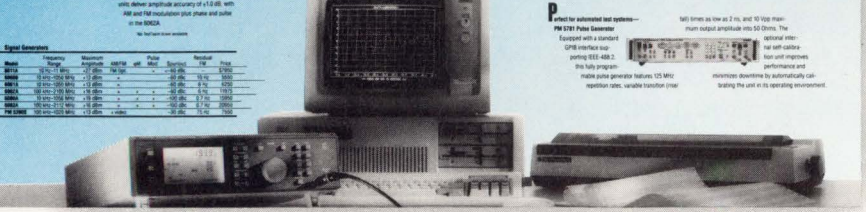
Precision performance at 10 MHz—PM 5200 Series Function Generator

The PM 5200 offers much higher performance than a standard function generator. It's a standard function generator for about the same price. It covers a 10 MHz range of frequencies—100 Hz to 10 MHz—with 10-bit resolution.

It also offers you a choice of eight waveforms, including sine, square, triangle, and more. It also offers a choice of modulation modes, including AM, FM, PM, and more.

Design your own waveforms with WaveCAD Software

Visual interface WaveCAD software gives you precise control of your waveforms. With the built-in waveform editor, you can create your own waveforms. You can create your own waveforms. You can create your own waveforms.



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COUNTERS AND TIMER/COUNTERS

A counter resolution—PM 6800 Series

For frequency or time interval measurements, the PM 6800 Series is the most cost-effective answer for the market. It offers a choice of resolution, including fully programmable 100 MHz resolution, high resolution (down to 100 ns), and more.

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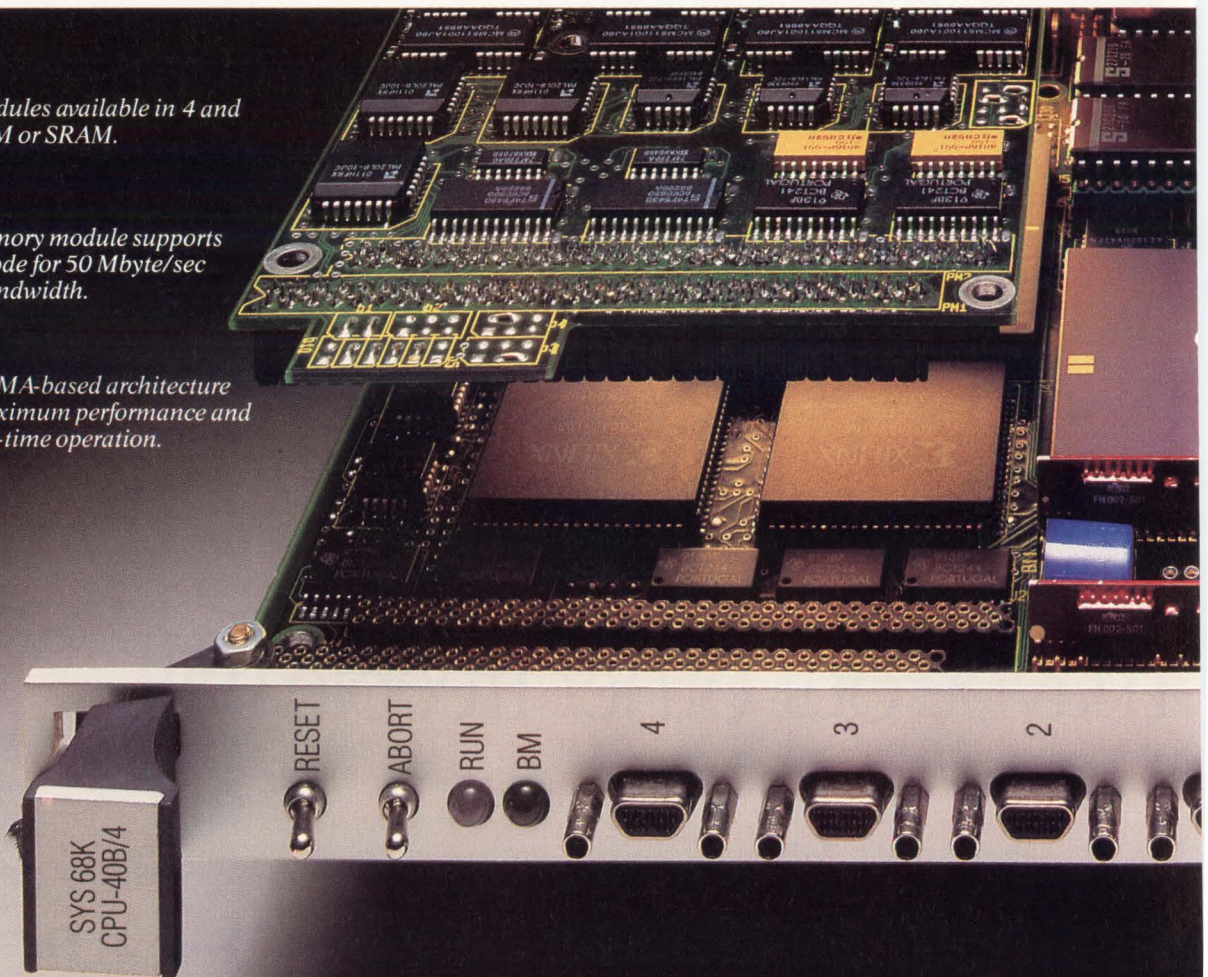
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Data from	CPU	CPU	CPU	CPU	VMEbus	SCSI*	Floppy Disk*	Ethernet*	Shared RAM*	VMEbus*
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Transfer Speed	53.7 MB/sec	16 MB/sec	2 MB/sec	2 MB/sec	5 MB/sec	4 MB/sec	500 KBit/sec	10 MBit/sec	15 MB/sec	15 MB/sec
Local 68040 CPU Operation	100%	100%	100%	100%	70%	80%	100%	100%	75%	100%

*DMA x FPS

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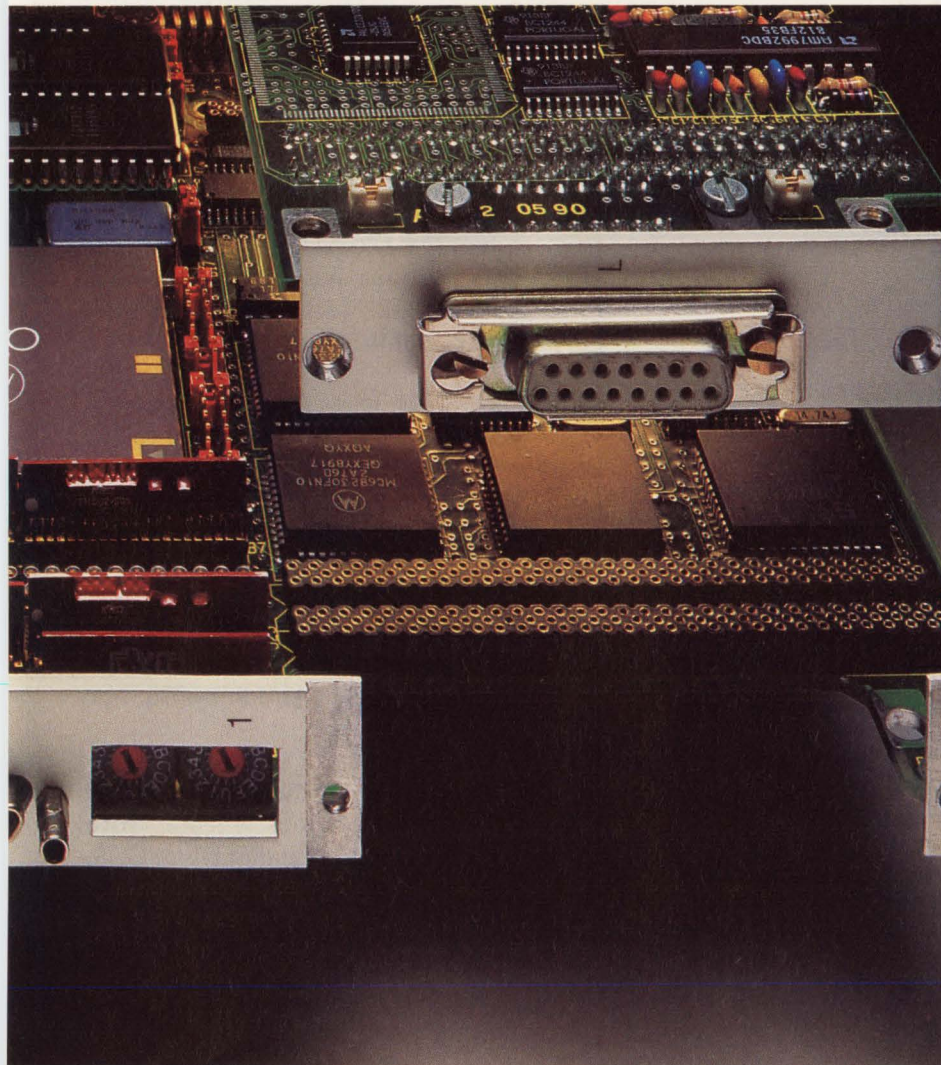


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CIRCLE NO. 91



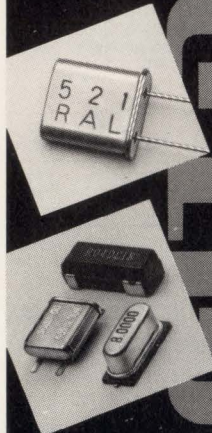
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Project Management: Skills For Success (short course), San Francisco, CA. Learning Tree International, Box 45028, Los Angeles, CA 90045. (800) 421-8166; in Canada, (800) 267-1824. May 14 to 17.

Spin-On Dielectrics for VLSI Applications (short course), San Francisco, CA. Continuing Education in Engineering, University Extension, University of California, 2223 Fulton St, Berkeley, CA 94720. (415) 642-4151. FAX (415) 643-8683. May 18.

American Consulting Engineers Council Annual Convention, Baltimore, MD. ACEC, 1015 Fifteenth St NW, Washington, DC 20005. (202) 347-7474. May 19 to 23.

International Semiconductor Manufacturing Science Symposium (ISMSS), Burlingame, CA. SEMI, 805 E Middlefield Rd, Mountain View, CA 94043. (415) 964-5111; (415) 940-6901. May 20 to 22.

ANSYS International Conference And Exhibition, Pittsburgh, PA. Jennifer D'Orazio, Swanson Analysis Systems Inc, Box 65, Houston, PA 15342. (412) 746-3304. FAX (412) 746-9494. May 20 to 24.

Midwest Electronics Exposition, Minneapolis, MN. Leslie Tolworthy, Miller Freeman Expositions, 1050 Commonwealth Ave, Boston, MA 02215. (617) 232-3976. May 21 to 23.

Semicon/West, San Mateo, CA. SEMI, 805 E Middlefield Rd, Mountain View, CA 94043. (415) 940-6961. FAX (415) 967-5375. May 21 to 23.

Embedded Processor Design Seminar, Various Cities. Intel Corp, 5000 W Chandler Blvd, Chandler, AZ 85226. (800) 548-4725; in AZ, (602) 941-3000. May 21 to June 27.

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— CXK581000M	100/120/150	SOP 525mil	L/LL	B/X	Now
— CXK581100TM	100/120/150	TSOP	L/LL	B/X	Now
— CXK581100YM	100/120/150	TSOP (reverse)	L/LL	B/X	Now
— CXK581001P	70/85	DIP 600mil	L/LL		Now
— CXK581001M	70/85	SOP 525mil	L/LL		Now
— CXK581020SP	35/45/55	SDIP 400mil			Now
— CXK581020J	35/45/55	SOJ 400mil			Now
128Kx9 — CXK77910J	20	SOJ 400mil		Sync ASM	2H '91
256Kx4 — CXK541000J	25/30/35	SOJ 400mil			2H '91

L = Low LL = Low, Low B = 3 Volt X = Extended Temperature

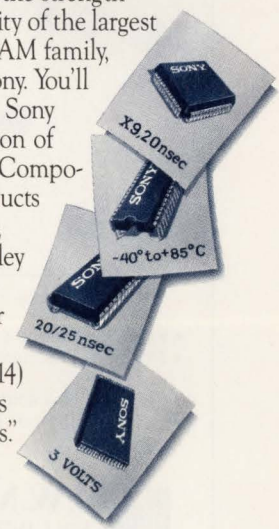
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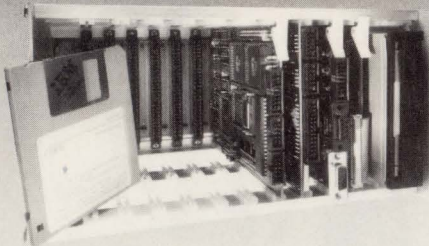
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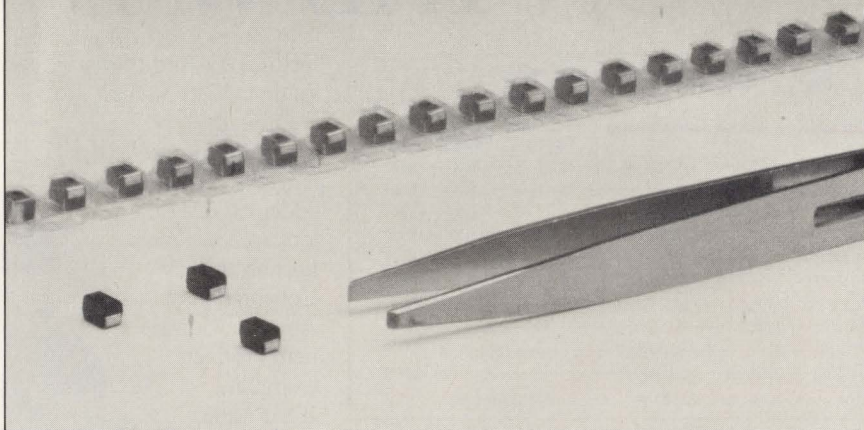
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Troubleshooting and Maintaining IBM & PS2 (short course), St. Louis, MO. Center for Advanced Professional Development, 1820 E Garry St, Suite 110, Santa Ana, CA 92705. (714) 261-0240. May 22 to 23.

International Symposium on Computer Architecture, Toronto, ON, Canada. Prof Z G Vranesic, Dept of Electrical Engineering, University of Toronto, Toronto, ON, M5S 1A4, Canada. (416) 978-5032. May 25 to 30.

IEEE-UFFC Frequency Control Symposium, Los Angeles, CA. Clark Wardrip, Box 6147, Vandenberg AFB, CA 93437. (805) 865-3214. May 29 to 31.

Unix System V.4 Developers' Conference, Universal City, CA. Interactive Corp, 2401 Colorado Ave, Santa Monica, CA 90404. (800) 753-3400; outside US, (818) 707-0102. FAX (805) 373-7357. June 2 to 5.

International Communications Association Conference & Exposition, Anaheim, CA. Naomi Sokol O'Sullivan, 12750 Merit Dr, Suite 710, LB-89, Dallas, TX 75251. (214) 716-4143. FAX (214) 233-2813. June 2 to 7.

Open Distributed Computing Exhibition, San Jose, CA. ICS Inc, Xhibition 91, 201 Broadway, Cambridge, MA 02139. (617) 547-0510. FAX (617) 547-0758. June 3 to 6.

Nepcon East, Boston, MA. Cahners Exposition Group, 1350 E Touhy Ave, Des Plaines, IL 60017. (708) 299-9311. FAX (708) 635-1571. June 10 to 13.

ISS Europe 91, Budapest, Hungary. SEMI, 805 E Middlefield Rd, Mountain View, CA 94043. (415) 964-5111. FAX (415) 940-6901. June 19 to 21.

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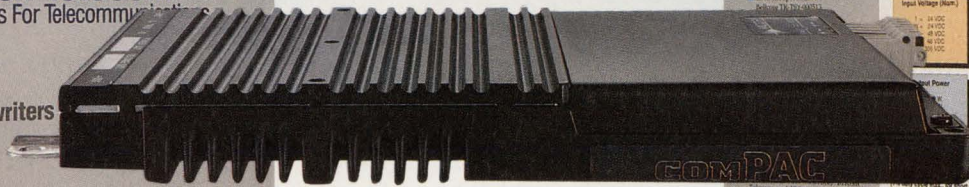
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Single Output: V1-OC	48 VDC	100-400W	8.6" x 4.9" x 0.99"
Single Output: V1-OC	300 VDC	300-600W	8.6" x 7.3" x 0.99"
Dual Output: V1-OC, V2-OC	24 VDC	100-400W	8.6" x 4.9" x 0.99"
Dual Output: V1-OC, V2-OC	48 VDC	150-600W	8.6" x 7.3" x 0.99"
Triple Output: V1-OC, V2-OC, V3-OC	24 VDC	150-600W	8.6" x 7.3" x 0.99"

Input Voltage (V_{IN})

Input Voltage (V _{IN})	Output Voltage (V _{OUT})	Product Grade
24 VDC	2-15 V	C = -20°C to 85°C
48 VDC	2-15 V	T = -40°C to 85°C
48 VDC	16-24 V	M = -55°C to 85°C
48 VDC	1-28 V	
300 VDC	1-48 V	

Output Power

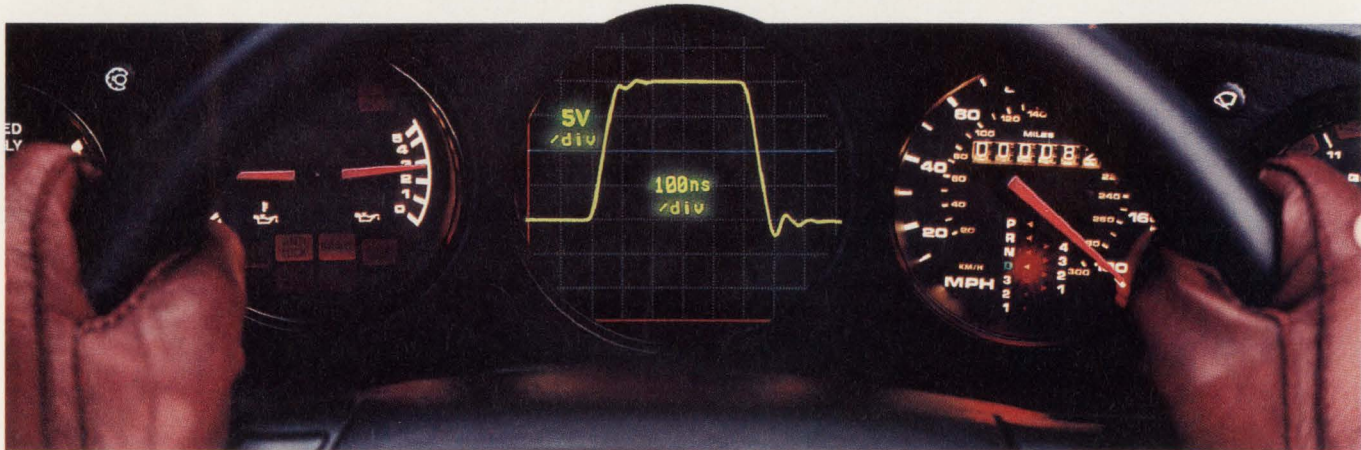
Output Power	Output Power
3-200 W	3-200 W
3-400 W	3-400 W
3-600 W	3-600 W
3-600 W	3-600 W

Operating Area Curves:

Normal Operating Area

High Surge Withstand (no duration of performance) Peak Load

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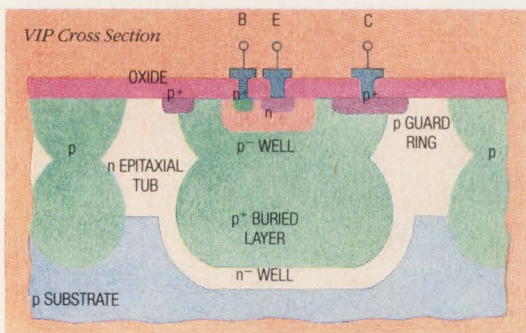
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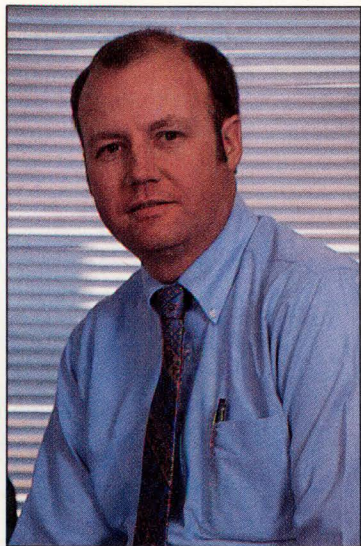


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EDITORIAL

Leave Microsoft alone



Some members of the computer industry press have been overindulging in their coverage of the Federal Trade Commission's investigations of Microsoft for anticompetitive practices. Because Microsoft is the largest personal-computer (PC) software company, and because it sells both operating systems and applications programs, it's the company that many self-proclaimed software experts love to hate. We say, "Leave Microsoft alone."

Microsoft isn't anticompetitive. Although it sells the MS-DOS and Windows operating-system programs as well as many application programs, I've never felt any pressure to buy both types of software from Microsoft. The company certainly has never forced anyone to buy its Word or Quickbasic as a prerequisite for purchasing MS-DOS. Microsoft doesn't have a lock on the operating systems market, nor does it enjoy preeminence among application-program suppliers.

In the PC operating-system domain, you can get DR DOS from Digital Research, and lesser-known operating systems from other companies. Granted, most PC manufacturers don't bundle those alternate operating systems with the PCs they sell, but alternatives are available if you want them. You may think that Microsoft's application-software people have an advantage in being so close to their MS-DOS and Windows developers, but sales figures don't seem to agree. If there's an advantage to Microsoft, it's not obvious. In the language arena, Borland's language packages come out about even with Microsoft's, and Wordperfect still beats Word in word-processing package sales. Also, Microsoft lags badly in network operating systems. So much for the uncompetitive, innovation-stifling monopoly argument.

Since I've mentioned PCs . . . Maybe the software industry's stuffed shirts ought to examine the hardware side of the PC business and consider the "monopoly" that Intel has had on the PC market for about a decade. There are few PCs that use anything but Intel's 80X86 microprocessor chips. However, without that "monopoly," the PC market would have shattered into uninnovative niche markets years ago.

The same sort of "monopoly" appears in the workstation market, too. Even small companies are selling Sun-workstation clones now, but all clone makers still must license compilers, programming toolkits, and other software from their archrival: Sun Microsystems. Consider CAE software supplier Cadre, too. If its CAE framework becomes successful, will the US government try forcing the company to split into independent framework and application-software suppliers?

A monopoly exists only when one company forces its competitors out of business and exerts clear control over a market. That's not taking place in the computer industry. We don't think that anyone gains from attacking so-called monopolies that are actually just prosperous companies thriving through good business sense, smart marketing, and a dash of luck.



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

A handwritten signature in black ink that reads "Jon Titus". The signature is fluid and cursive, with a long horizontal stroke extending to the right.

Jon Titus
Editor

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.

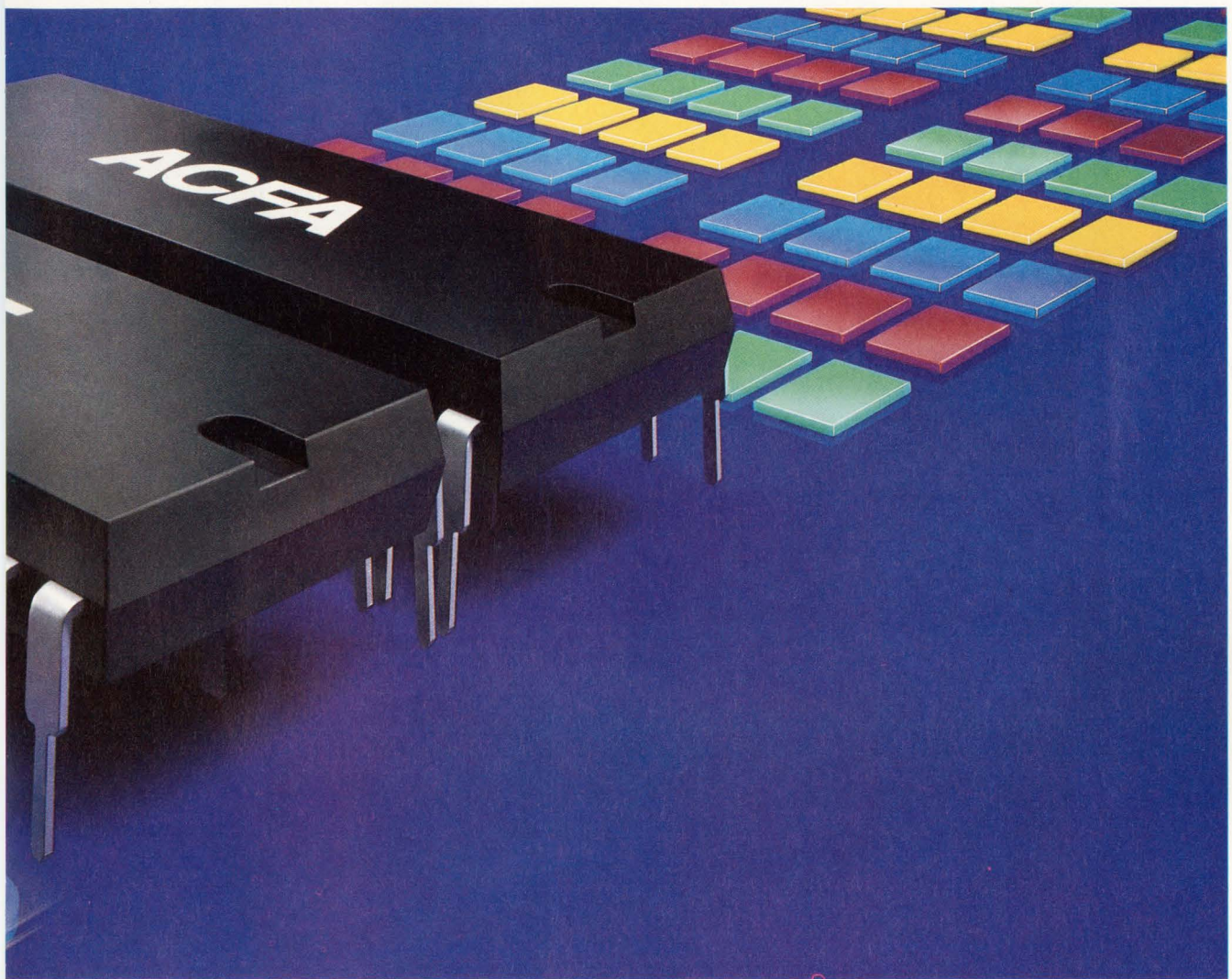


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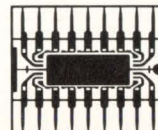
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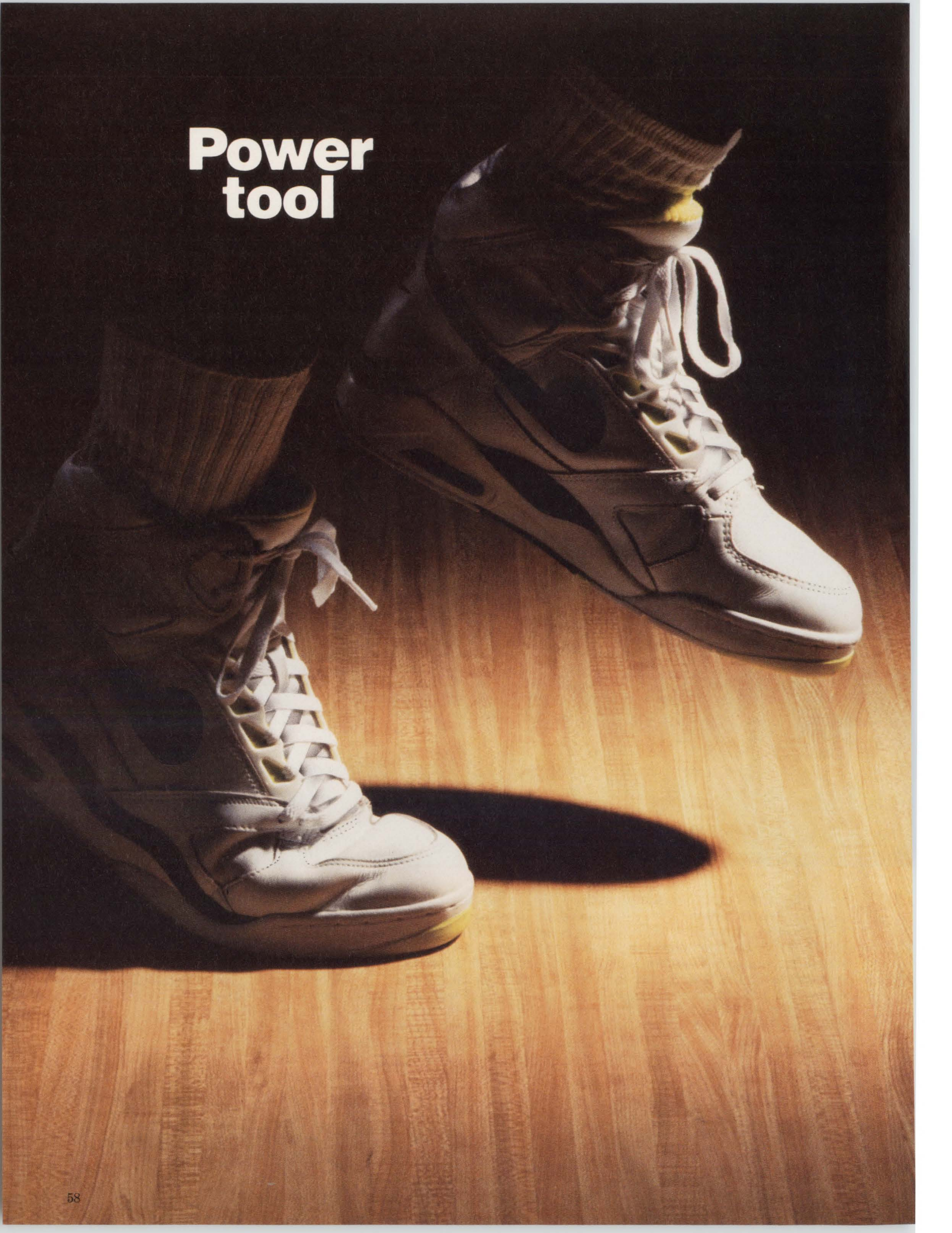
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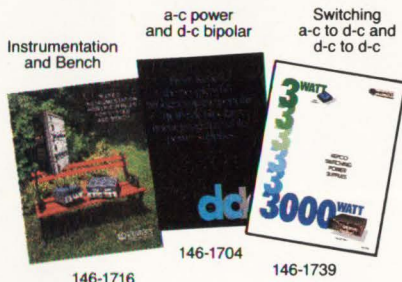


Power tools

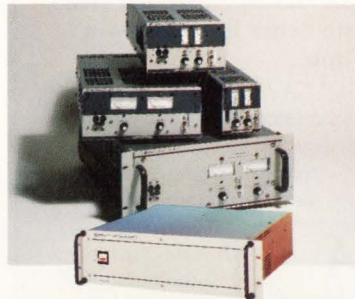
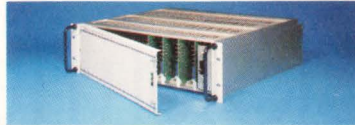
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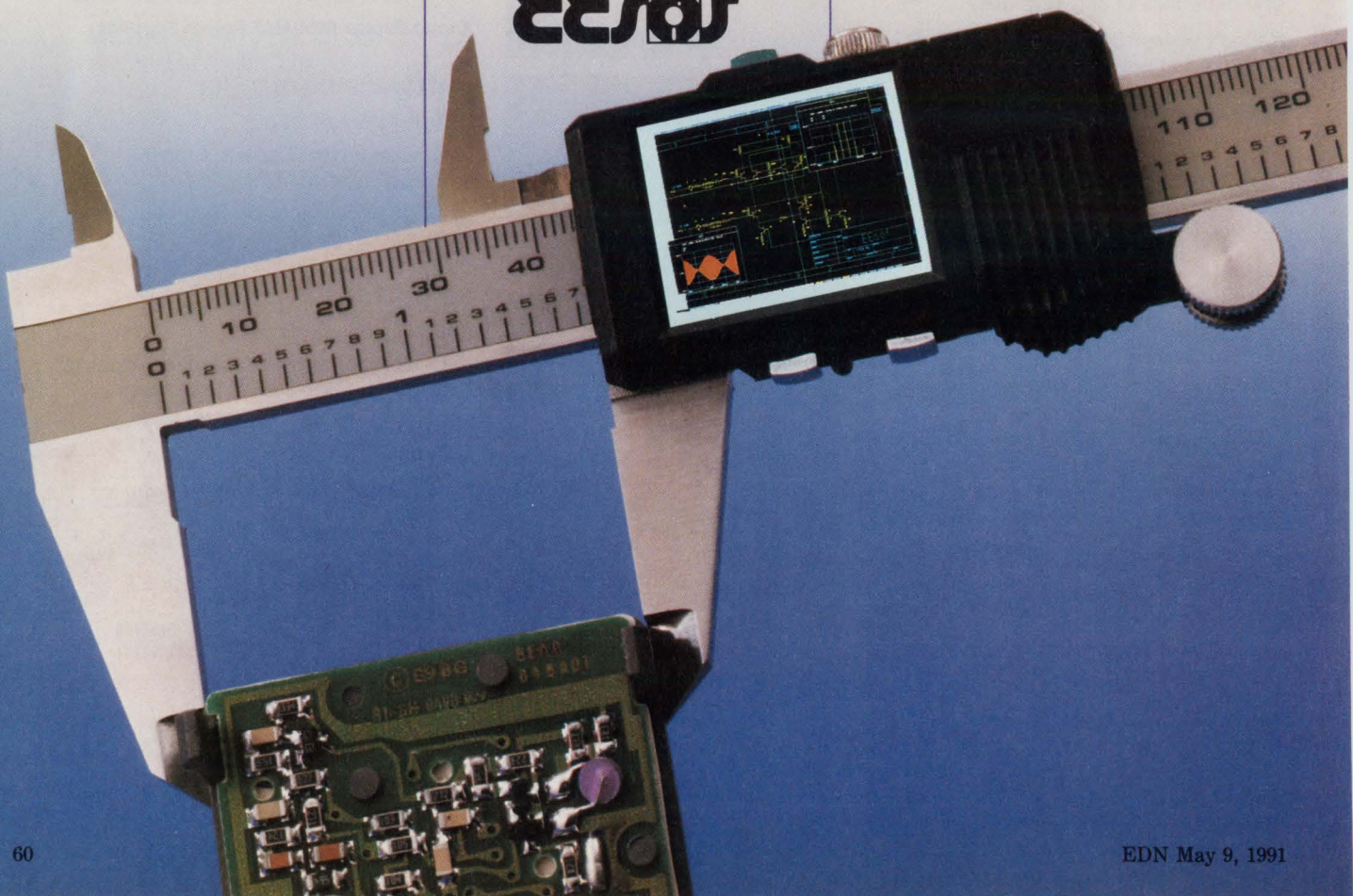
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*Brian Kerridge,
European Editor*

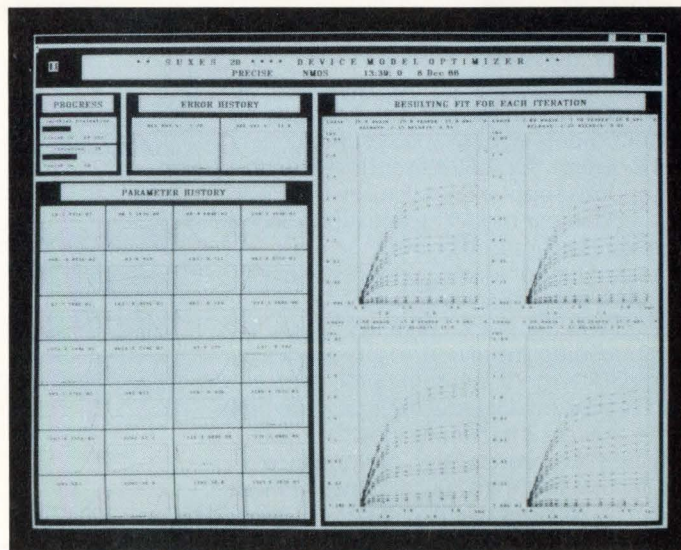
You can use just about any generic Spice (Simulation Program with Integrated Circuit Emphasis) semiconductor model to run a simulation if you only need to prove that a circuit functions. But most of the time you'll be using simulation for something more. You may wish to examine performance when power supplies are operating at their upper limits, transistors are in saturation, and components' ambient temperatures are reaching the end-stops. At these times, you'll need accurate models if you plan to produce meaningful results.

Semiconductor designers already employ analog Spice simulation tools when developing new components. But, as circuit designers also rely increasingly on simulation to develop their products, demand for accurate models is growing.

You can produce accurate models using the software tools in **Table 1**. These tools have two functions. First, they derive characteristic performance curves from measurements made on a hardware sample of your device. Second, using the measured data as a starting point, they assign initial model-parameter values. When the parameter-extraction tools are finished, you can then have a Spice simulator optimize the parameters until simulated results and measured results tally.

However, as **Table 1** shows, Spice model parameter extraction tools cost \$10,000 or more. When you add to that figure the cost of the computer and the test instruments, your total bill will exceed \$50,000. If you can't justify that expense, but still need an accurate model, all is not lost. A number of vendors are dedicated to offering comprehensive modeling services utilizing this type of set-up. If you buy from one of these vendors, a bipolar junction transistor (BJT) model, for example, will cost you \$350 or more depending on your requirements.

The question arises: How do you specify the level of accuracy you need for a particular application? You have to make some sort of assessment to put the cost of models and simulation into context with alternative development



You can supervise optimizing and ensure that parameters adopt sensible values using Electrical Engineering Software's SuXes 20 package.

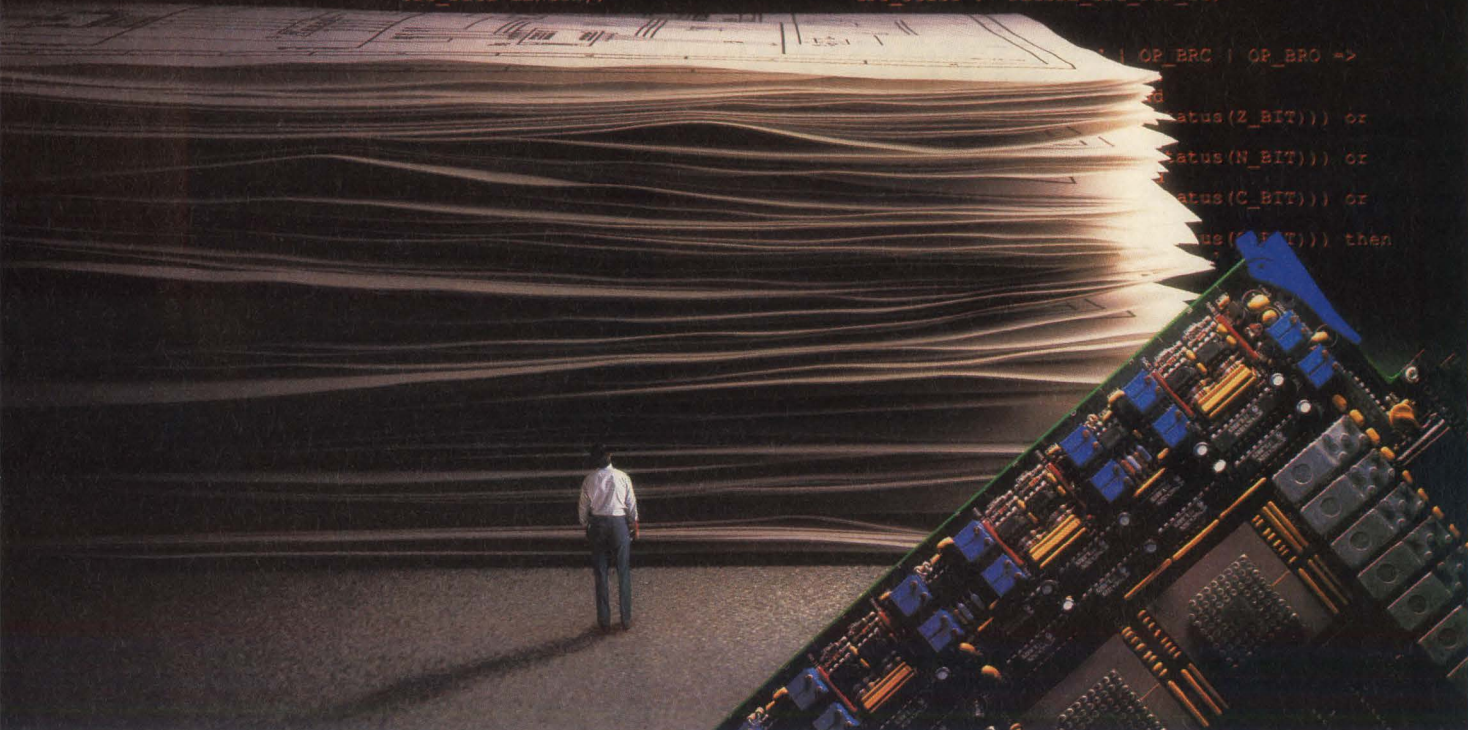
SIX SUBMICRON ASICs, 100 SCHEMATIC PAGES, 5000 LINES OF VHDL AND A 50 MHz BOARD. WELCOME TO THE FUTURE.

```

Src_Reg := DLV_To_Natural(IR_Src_Reg);
case Src_Reg is
when 0 to MAX_GEN_REG =>
  Src_Data := GEN_REG(Src_Reg);
when PC_REG =>
  Src_Data := Natural_To_DLV(PC,
                             Src_Data'LENGTH);
end case;

CPU_State := DECODE_OP1_OF_1;
when OP_NOT | OP_INCR | OP_DECR |
OP_PUSH | OP_POP =>
CPU_State := DECODE_OP1_OF_1;
when OP_OSTR | OP_OINT | OP_IINT =>
CPU_State := DECODE_OP1_FOR_IO;
when OP_BRC | OP_BRO =>
  Status(2_BIT)) or
  Status(N_BIT)) or
  Status(C_BIT)) or
  Status(F_BIT)) then

```



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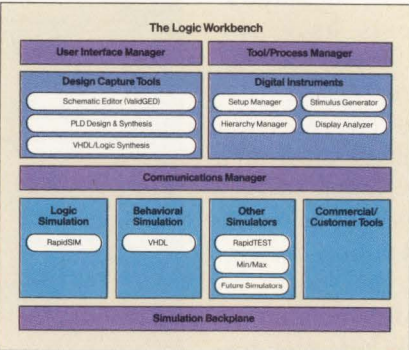
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TECHNOLOGY UPDATE

Analog Spice simulation models

methods. The box, "Appraising BJT Spice models," introduces some ideas you can adopt to check the validity of your models.

Tools adopt various forms

All of the software tools in Table 1 will run with the typical setup for extracting model parameters from hardware in Fig 1. These tools can output models in a range of formats to suit standard Spice and other Spice-based simulators. Only Meta-Software steers you to its own HSpice simulator.

Take care when comparing prices—there is no commonality in the way vendors offer their products. Program sections appear as standard in some products, but as options in others. Also, with some vendors, options depend on the semiconductor device you wish to model.

Time-domain analysis software is commonly offered as an option, although without it you can't establish the parameters necessary to model ac and transient performance. This option often comes bundled with a macro-modeling program to enable you to construct

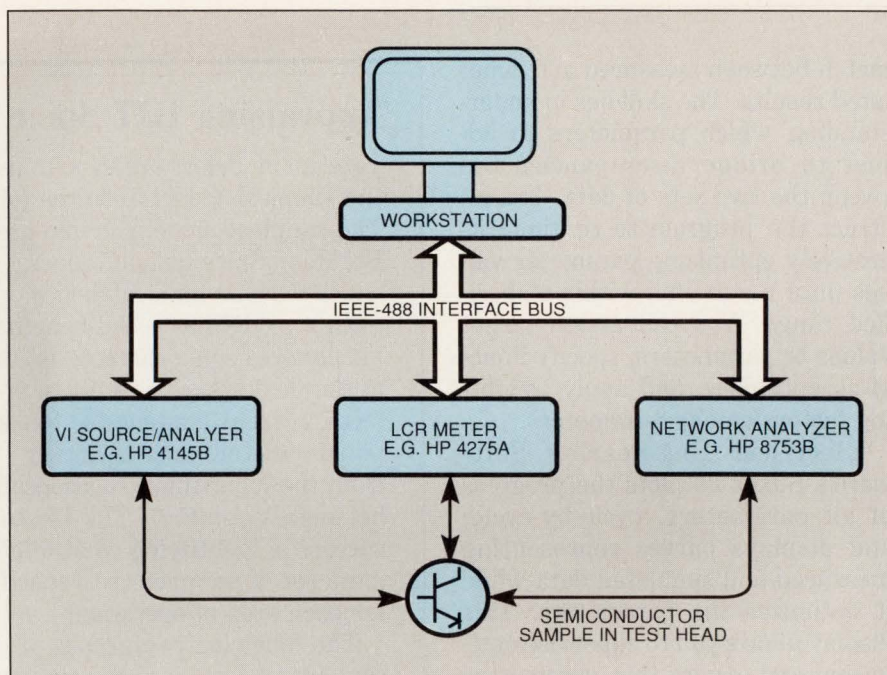


Fig 1—This diagram shows a typical setup for extracting model parameters from a hardware sample of a semiconductor.

sub-circuit models by using Spice primitive elements.

If you find macro-modeling a bore, then consider the model-definition software that Electrical Engineering Software, Hewlett-Packard, and Sencad offer. Only for the real enthusiast, this toolkit soft-

ware allows you to tinker with equations that form the very basis of Spice primitive models.

Producing accurate models results from the modeler skillfully intervening during the parameter-optimizing phase. In this phase, you guide the software to produce a

Table 1—Representative software for Spice-model parameter extraction

Vendor	Product	Computer platform	Price ¹	Options/comments
Electrical Engineering Software	Suxes 20	Apollo, HP 9000, Sun, VAX	\$25,000	Plus—instrument drivers, \$5000; EXModeler—time-domain and macro modeling, \$10,000. (Single purchase of three programs, \$35,000.)
Hewlett-Packard	Tecap	HP 9000 series 300 (Pascal)	\$24,720	Essential modules dependent upon semiconductor type: BJT ² , \$7210; MOS, \$4120; BSIM ³ , \$4120; GaAs, \$7210.
	IC-Cap	HP 9000 series 300	\$22,000	Essential modules dependent upon semiconductor type: BJT ² , \$9000; MOS, \$6000; BSIM ³ , \$6000; GaAs, \$9000. Instrument drivers (four modules—dc, ac, LCR, and time-domain) \$17,000.
Meta-Software	Atem	Apollo, HP 9000, MIPS, Sun, VAX	\$10,000	Provides initial parameter values that require optimizing with HSpice; emphasis on process modeling.
Sencad	Model Station II	Apollo, Sun, HP	\$15,000	Instrument drivers, \$7500; macro-modeling tool kit, \$7500; HP4145 data link, \$1000.
Silvaco	Utmost II	Apollo, HP 9000, Sun, VAX	\$30,000	Product exists as three modules for modeling BJTs, ² MOS, or GaAs devices. Each module costs \$30,000. All modules include modeling of diodes, JFETs, and macro modeling. Time-domain modeling option, \$15,000.

Notes: 1. Price includes instrument drivers unless shown separately.

2. BJT—Bipolar junction transistor.

3. BSIM—Berkeley short-channel insulated-gate MOSFET.

TECHNOLOGY UPDATE

Analog Spice simulation models

match between measured and simulated results. The skill lies in understanding which parameters to adjust to bridge discrepancies between the two sets of data. You instruct the program to continue iteratively optimizing parameter values until results fall within a specified range. You can assign target values to parameters, specify limits of acceptability, and apply weighting factors among parameters.

Electrical Engineering Software's Suxes 20 plots the progress of all parameters, cycle-by-cycle, and displays curves representing measured and simulated data while it optimizes the parameters. This display allows you to supervise optimizing and ensure that parameters adopt sensible values.

Sancad's Model Station II doesn't require an overly skilled user to identify which parameter is likely to narrow differences between measured and simulated display curves. Using what the company calls "rubber-banding," you use a mouse pointer to grab a section of simulated curve and drag it toward the measured curve. The software recognizes this movement as an instruction to adjust certain model parameters when optimizing begins. In addition to assigning individual target values to a set of model parameters, you can enter mathematical relationships between parameters that must hold as optimizing progresses.

Such intelligent software can be invaluable in helping to avoid situations when, although measured and simulated results match, some of the underlying parameters end up with physically impossible values—a possible outcome with earlier generations of this type of software tool.

If you resort to the services of a dedicated hardware modeler, your

Appraising BJT Spice models

Veteran modelers urge you to use the simplest model to do the job. The simplest model possible uses Berkeley Spice default values, which assume an ideal device. Such a model has speed benefits but ignores some characteristics of the device such as storage effects, current limiting due to terminal resistors, and deviation from the logarithmic relationship between V_{BE} and I_C . The key to success is identifying what minimum set of parameters to specify for each area of operation.

The following paragraphs present just a few ideas to help you assess the suitability of a BJT model. The checks are not exhaustive, but they draw attention to the significance of appraising models—a point to ponder the next time you base important design decisions on simulation results.

Table 2 shows parameter values for the default BJT and two versions of a BC107. The BC107 basic and hardware-derived versions are typical of models from low-cost simulator and modeling vendors respectively. The first point to check is that critical parameters do not have default values. Essential parameters are IS, BF, VAF, IKF, VAR, RB, IRB, RBM, RE, RC, CJE, TF, CJC, and TR. If VAF or VAR is at default, use the model only in applications with constant V_{CE} . If any reverse parameter is at default, avoid use in applications where reverse biasing occurs (eg, with an inductive load). If either TF or TR is at default, restrict use of the model to steady-state dc simulation.

The values shown for the BC107 basic model indicate that the model should perform adequately for functional dc and ac simulations.

For a model to perform well in the saturation region, the parameters—RB, IRB, RBM, RE, and RC—must be set. When you wish to mirror V_{BE} accurately and the transistor is saturated, the IRB and RBM parameters will be the most significant. RBM dominates at low currents.

In an attempt to achieve model conformity at low current, values set for RE and RC are often too high. Check that a voltage drop across the addition of RE and RC does not exceed specified $V_{CE(sat)}$ at the corresponding I_C . A Gummel-plot simulation of I_C and I_B vs V_{BE} , at constant $V_{CE(sat)}$, will soon show up deficiencies in RE and RC. Both current plots should rise steadily and round off smoothly to the upper limit. Any sudden flattening off of I_C , or rapid increase in I_B , indicates RC is set too high.

A further simple simulation test indicates likely ac and transient accuracy. Set up the switching circuit commonly shown in data books to test storage time. If the simulated storage time measurement deviates by more than $\pm 30\%$ from the data sheet value, suspect the accuracy of TR.

Acknowledgment

Thanks go to Steve Webb at Device Modeling and Characterization Center, Thorn-EMI, for suggesting many of the points in this box.

TECHNOLOGY UPDATE

Table 2—Comparison of bipolar-junction-transistor (BJT) model parameter values

Parameter symbol	Parameter description	Parameter value			Units
		BJT default model	BC107 basic model	BC107 hardware-derived model	
IS	Saturation current	1E-16	2.27E-16	1.38E-14	A
BF	Ideal maximum forward Beta	100	307.00	362.58	
NF	Forward-current emission coefficient	1.0	Default	0.992	
VAF	Forward Early voltage	Infinite	121.00	55.61	V
IKF	High-current Beta roll-off	Infinite	0.50	0.07057	A
ISE	Base-emitter leakage saturation current	Zero	5.19E-13	2.17E-14	A
NE	Base-emitter leakage emission coefficient	1.5	2.00	1.37	
BR	Ideal maximum reverse Beta	1.0	4.00	8.78	
NR	Reverse current emission coefficient	1.0	1.00	0.993	
VAR	Reverse Early voltage	Infinite	24.00	9.21	V
IKR	High current reverse Beta roll-off	Infinite	Default	0.01718	A
ISC	Base-collector leakage saturation current	Zero	Default	1.60E-14	A
NC	Base-collector leakage emission coefficient	2.0	Default	1.13	
RB	Zero-bias base resistance	Zero	1.70	91.68	Ω
IRB	Current where RB falls to half minimum	Infinite	Default	1.50E-04	A
RBM	Minimum base resistance	RB	Default	0.05673	Ω
RE	Emitter series resistance	Zero	0.41	0.555	Ω
RC	Collector series resistance	Zero	0.17	1.18	Ω
CJE	Base-emitter zero-bias depletion capacitance	Zero	9.00E-12	1.337E-11	F
VJE	Base-emitter built-in potential	0.75	Default	0.658	V
MJE	Base-emitter junction exponential factor	0.33	Default	0.31	
TF	Ideal forward transit time	Zero	4.50E-10	3.44E-11	Second
XTF	Coefficient for bias dependence of TF	Zero	Default	178.03	
VTF	Voltage describing VBC dependence of TF	Infinite	Default	10.56	V
ITF	High-current parameter for TF	Zero	Default	1.0	A
PTF	Excess phase at f_T	Zero	Default	120.08	Degree
CJC	Base-collector zero-bias depletion capacitance	Zero	7.70E-12	7.88E-12	F
VJC	Base-collector built-in potential	0.75	Default	0.455	V
MJC	Base-collector junction exponential factor	0.33	Default	0.271	
XCJC	Fraction of CJC connected to internal base node	1.0	Default	Default	
TR	Ideal reverse transit time	Zero	6.20E-08	3.4415E-10	Second
CJCS	Zero-bias collector-substrate capacitance	Zero	Default	Default	F
VJS	Substrate junction built-in potential	0.75	Default	Default	V
MJS	Substrate junction exponential factor	0.33	Default	Default	
XTB	Forward and reverse Beta TC	Zero	Default	Default	
EG	Energy gap for temperature effect on IS	1.11	Default	Default	eV
XTI	Temperature exponent for effect on IS	3.0	Default	Default	
KF	Flicker noise coefficient	Zero	Default	Default	
AF	Flicker noise exponent	1.0	Default	Default	
FC	Coefficient for forward-depletion capacitance	0.5	Default	Default	

TECHNOLOGY UPDATE

Analog Spice simulation models

choice of vendors is limited, but the service is not. Companies such as ERA, Sancad, Silvaco, and Thorn-EMI have the setups and experience to carry out as much modeling as you care to finance. As a guide, expect to pay between \$350 and \$1500 for one BJT model from their libraries of standard models. The price spread allows for the range of model parameters that you may or may not want defined. At \$350, temperature coefficient parameters will almost certainly have default values and not be the result of a temperature sweep on the device. For a complete library, you can pay \$5000 or more, depending on size and semiconductor type. If the component type you want is not in the library, or if you want to model a particular hardware sample, then expect to pay around double the price of a standard library part.

For a nonstandard service, all modelers emphasize their ability to model as intensively as you instruct. In this situation, you need a very clear idea of what you expect

from a model and its application. Generally, you need to provide approximately five device samples, from which the modeler selects one for the tests.

At Thorn-EMI's Device Characterization and Modeling Center (DMCC), the emphasis is on accuracy right up to extremes of operation. Steve Webb, DMCC Manager, says the objective is for robust models accurate to a few percent across all areas. Webb says users expect models to work under all conditions, instead of being spot-on in one region. Anyone can fit parameter values in the lower current region, but then quoting tight specifications for mean or rms curve fit is meaningless. Thorn-EMI's increased accuracy comes at a proportionally increased cost; a BJT model costs £750.

For dc characteristics of a BJT model, DMCC optimizes parameters from sets of measurements at different levels in fourteen areas of operation. The resultant spread of optimized parameters leads to an

optimal parameter value that covers the entire operational range.

When establishing capacitance values for ac characteristics, DMCC employs a 3-terminal measurement. This method guards against stray interelectrode capacitance, yielding only the capacitance value of interest.

Webb adds two points as further examples of DMCC's desire to achieve model accuracy. First, all parameter-extraction routines in the simulator compensate for dynamic self-heating in the semiconductor sample. Second, Webb believes the company is unique in its ability to routinely isolate RE from other parameters: RB, IRB, and RBM of the base-emitter circuit of a BJT. These parameters are critical for accurately describing the upper-end "knee" of a Gummel curve.

Don Peddar, ERA's modeling-service manager, expects users to recognize limitations of models in the same way that component vendors assume you understand the real parts. For around \$500, ERA's

For more information . . .

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

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TECHNOLOGY UPDATE

Analog Spice simulation models

standard service will provide you with a full list of, for example, BJT parameter values, showing which values are set and which remain at default values. For a small-signal BJT, the accuracy of the curve fit has a mean error between measured and characterized values of less than 2%. Accuracy for reverse characteristics is less than 6% typical, and less than 1% maximum for capacitance. Peddar states it's all a matter of cost. If you need to model components working at the edge of their capabilities, that's OK, but expect to pay significantly more for the model.

Paul Gunther, Sales and Marketing Manager with Silvaco Data Systems, also assumes users have a certain level of knowledge. He says if customers ask no questions or state no specific requirements, then

they automatically receive standard model service. In most cases, users do not query the accuracy of these models. When a customer starts asking questions about the models, that's the time to investigate the application, and if necessary, bring the full modeling service into play.

Data sheets open low-cost path

Although modeling from hardware samples provides the most accurate—and most expensive—result, circuit designers have other, lower-cost options. Some designers argue that if component data sheets provide enough information for you to design-in a part with confidence, then the same information should be adequate for specifying a model. In the case of op amps, this assertion is valid.

For this reason, even model ven-

dors with hardware-modeling equipment develop op-amp models directly from data sheet information. But op amps are the exception; and anyway, almost all op-amp vendors now offer free Spice models of their preferred types (Ref 1). It is unfortunate that semiconductor component vendors are not so forthcoming. With intimate knowledge of their products, they occupy a unique position from which to offer the best Spice simulation models.

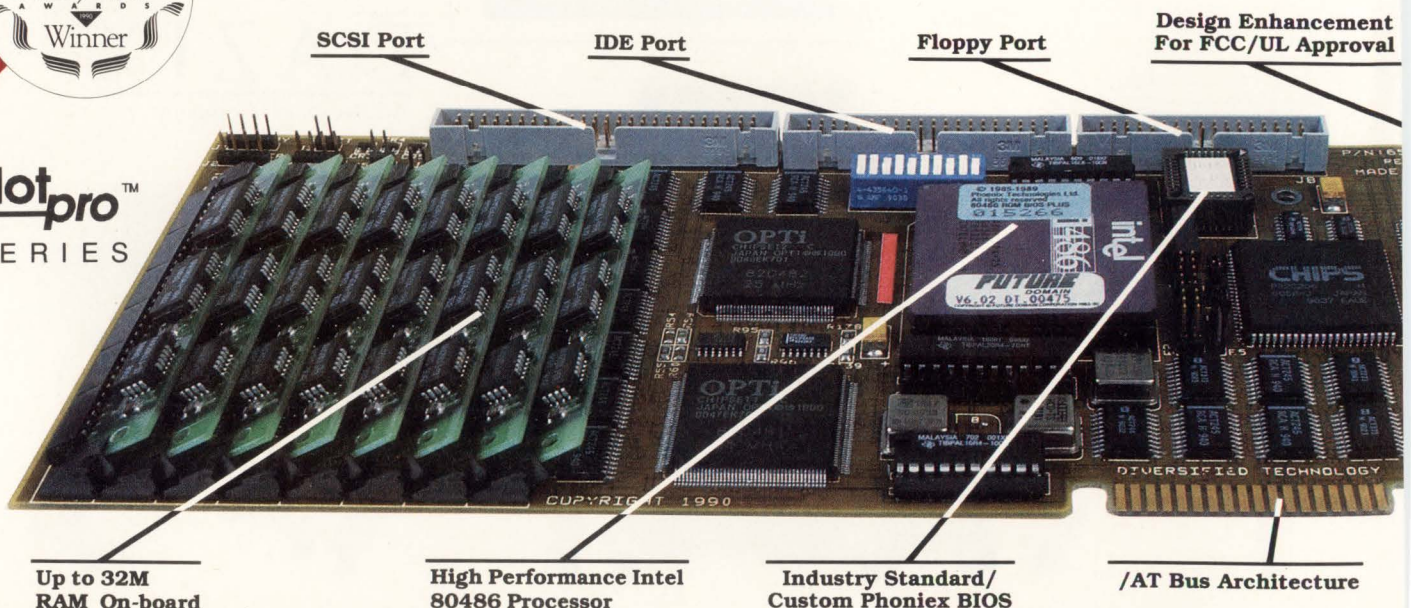
Several low-cost, PC-based software tools exist for extracting Spice-model parameters from data-sheet information, although some are inseparable from simulator programs. Intusoft's Spicemod (\$199) is a stand-alone modeling program that produces strictly Spice-compatible models. The program provides parameters of models for di-

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TECHNOLOGY UPDATE

odes, BJTs, junction FETs (JFETs), and MOSFETs; and macro-models for power transistors, Darlingtons, and two levels of power MOSFETs. In operation, you enter essential specifications (16 in the case of a BJT) from the component's data sheet, and a table of most significant Spice parameters updates on each entry.

MicroSim's Parts program (\$450) performs a similar function but outputs model files compatible with the company's PSpice simulator program. As you enter the series of data sheet values, a display of characteristic curves developed from model parameters allows you to compare performance with original data.

The snag with modeling from data sheets is that they can be inadequate and misleading. Missing

information can limit the accuracy of the model, or the data may be wrong or simply out of date. Consequently, these low-cost tools attempt to determine only those parameter values that play a significant role in molding a component's performance. Other parameters remain at Spice default values.

This approach may work fine while you simulate a semiconductor's dc and small-signal performance, but if semiconductor junctions see reverse bias voltage or ac signals, failure to assign a wider set of parameter values may cause errors in simulation.

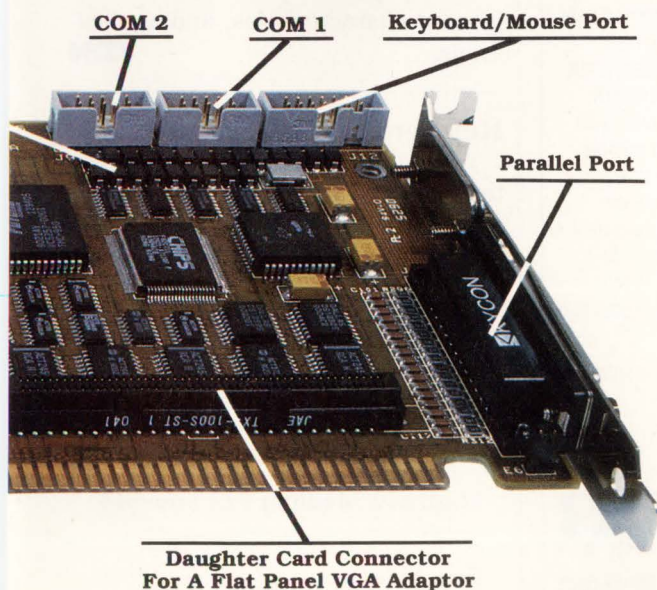
You can also have vendors produce data-sheet-based models for you. Companies such as Analog and RF Models, Contec, and Intusoft offer a modeling service using only data-sheet information. Bill Sands,

President of Analog and RF Models, emphasizes the economy of this approach—a typical model costs \$75. The company specializes in models with good RF performance and can also parameterize MMICs (monolithic microwave ICs). According to Sands, if three sets of s or Y parameters are available, his in-house software tools can even assign values to package parasitics.

Charles Hymowitz, Chief Applications Engineer with Intusoft, offers a pragmatic view of modeling. Modeling is such a complex subject, it is impossible to generalize on the merits of using hardware or data sheets. The good and bad points in each method not only vary with the type of component being modeled, but also with the Spice parameter being extracted. Modeling from hardware produces accurate data

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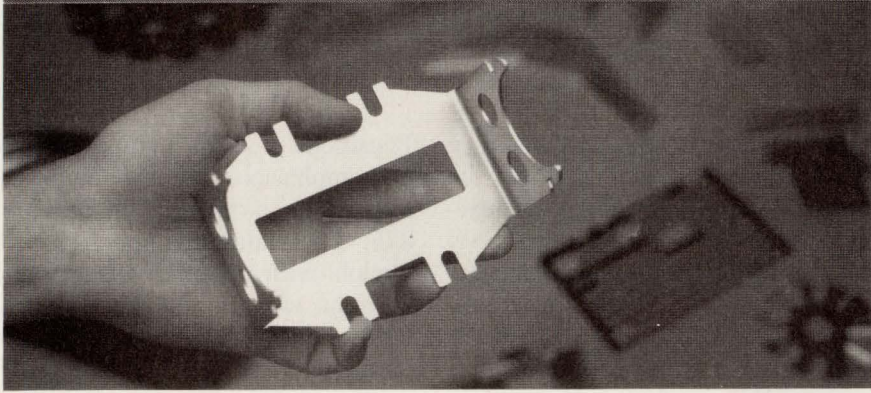
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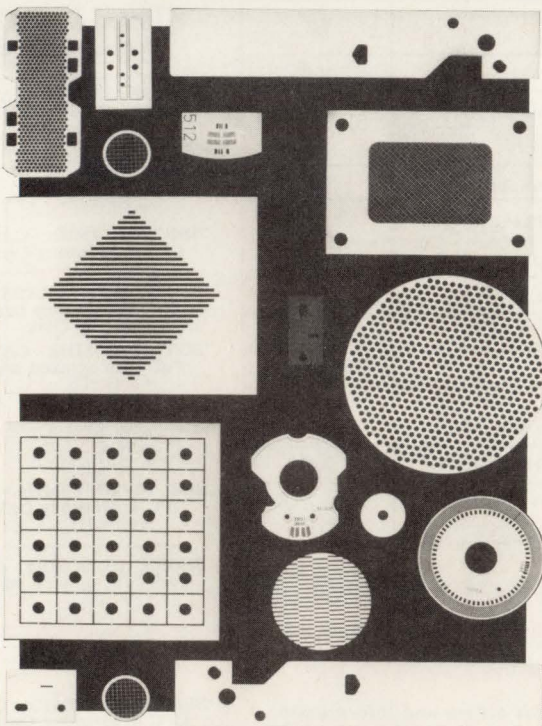
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UPDATE

Analog Spice simulation models

for a specific sample, but you can never be sure if the part exhibits maximum, typical, or minimum behavior. In general, hardware-generated data must be combined with data-sheet information to gauge limits of performance. For example, some hardware modeling programs waste time optimizing the heck out of dc response curves—resolving Spice parameters from semiconductor characteristics that typically vary 4:1 from sample to sample.

Another limitation on the accuracy of hardware modeling is the uncertain effects of package parasitics (resistors, inductors, and capacitors) on collected performance data. If modeling software ignores these elements, then its Spice parameters adopt invalid values. The effects of ignoring parasitics show up particularly at RF and must be overcome by extending the model by adding Spice primitive elements—macro-modeling. The question of when to consider modeling in the parasitics is left to the judgment of the person controlling the modeling. As Hymowitz points out, macro-modeling in general is an extremely skillful exercise, requiring a rare combination of experience in device physics, Spice models, component characteristics, and applications. **EDN**

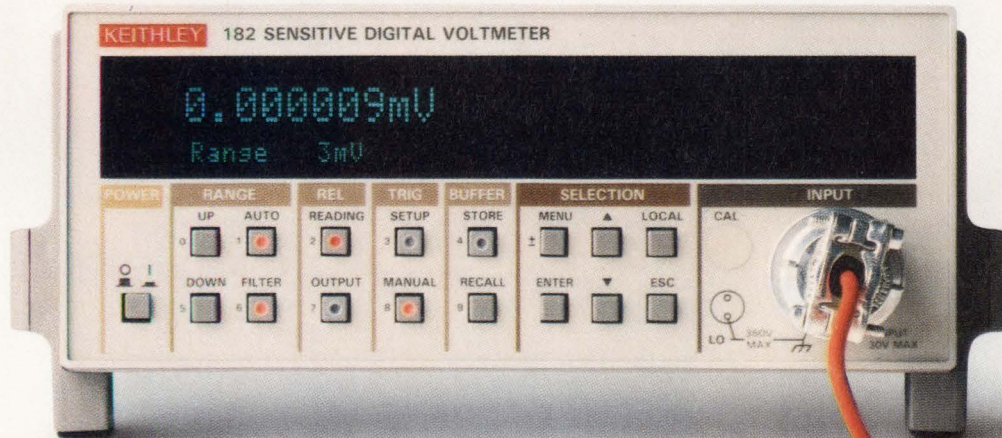
References

1. Kerridge, "Spice models enjoy multiple sources," *EDN*, September 3, 1990, pg 79.
2. Antognetti and Massobrio, "Semiconductor Device Modeling with Spice," McGraw-Hill Company.
3. Meares and Hymowitz, "Simulating with Spice," Intusoft, 1988.

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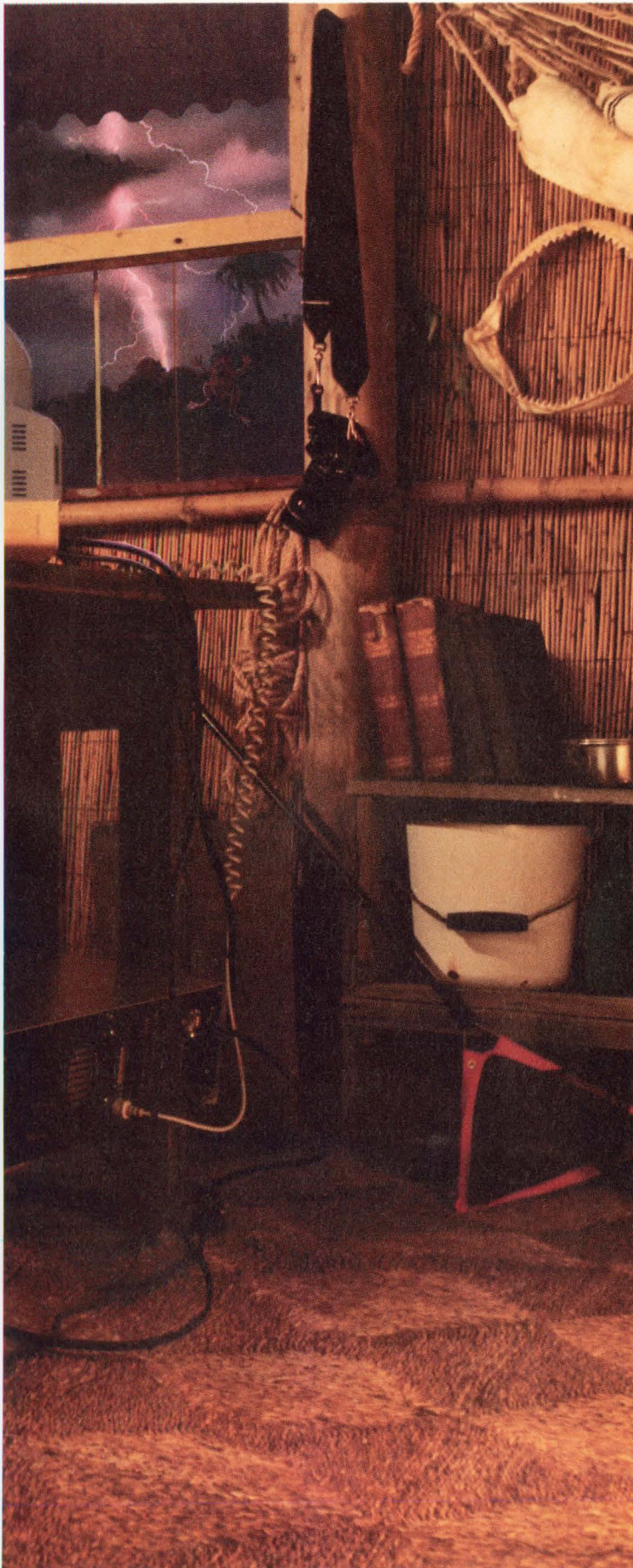
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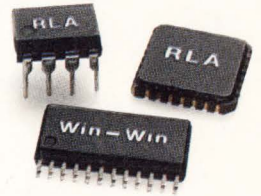
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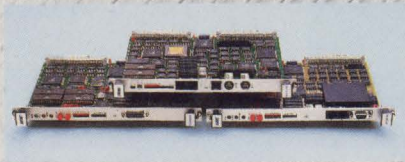
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SWITCHING REGULATORS

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ISSUE

For engineers not familiar with the intricacies of switching regulators, design aids help simplify the task of realizing a practical circuit.

*Dave Pryce,
Associate Editor*

When confronted with the task of designing a switching power supply, many systems engineers become apprehensive. Accustomed to a building-block approach to circuit design, these engineers often view designing switching-regulator circuits and switching power supplies as a form of black magic. Determining the correct value for an inductor, the required primary inductance and turns-ratio for a transformer, or even the values for the input and output capacitors can be intimidating to anyone who isn't a specialist. Recognizing the problem, several vendors of switching-regulator ICs have come to the assistance of the neophyte with aids that simplify the design task.

These design aids usually take the form of a demo board containing the company's switching regulator or dc/dc converter as well as most, if not all, of the additional active and passive components needed to complete a representative circuit. The manufacturers also provide data sheets that describe the circuit options. For example, data-sheet information typically includes charts and graphs that provide guidelines for selecting the proper inductor, the value of which depends on the input voltage and load current. Where appropriate, manufacturers also provide detailed application notes and assembly manuals.

Although these design kits are usually application-specific, they can often provide a starting point for other applications. In many cases, you can use the board as a test bed to evaluate your circuit's performance as you change components. Moreover, the application notes and design guides often provide helpful information about how these sometimes perplexing switching-regulator circuits actually work.

Most manufacturers of monolithic switching-regulator ICs have, at various times, offered demo boards to assist the designer in applying the company's particular type of pulse-width modulator, resonant-mode controller, or dc/dc converter. Included among the suppliers of demo boards and design kits are Linear Technology, Maxim, Gennum, Cherry Semiconductor, and National Semiconductor. In addition to a demo board, Na-

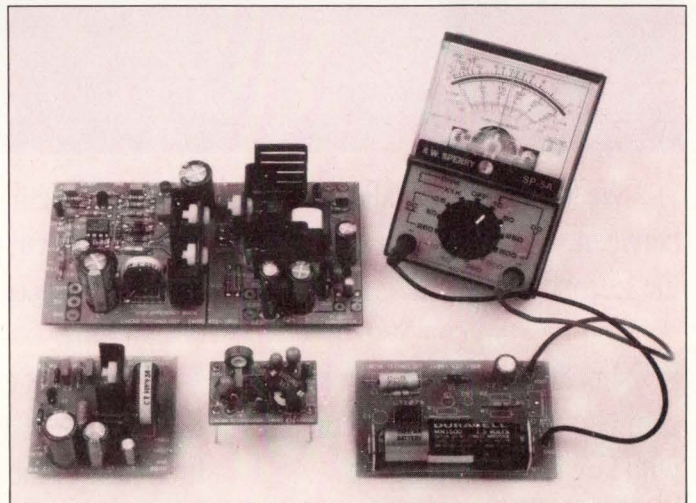
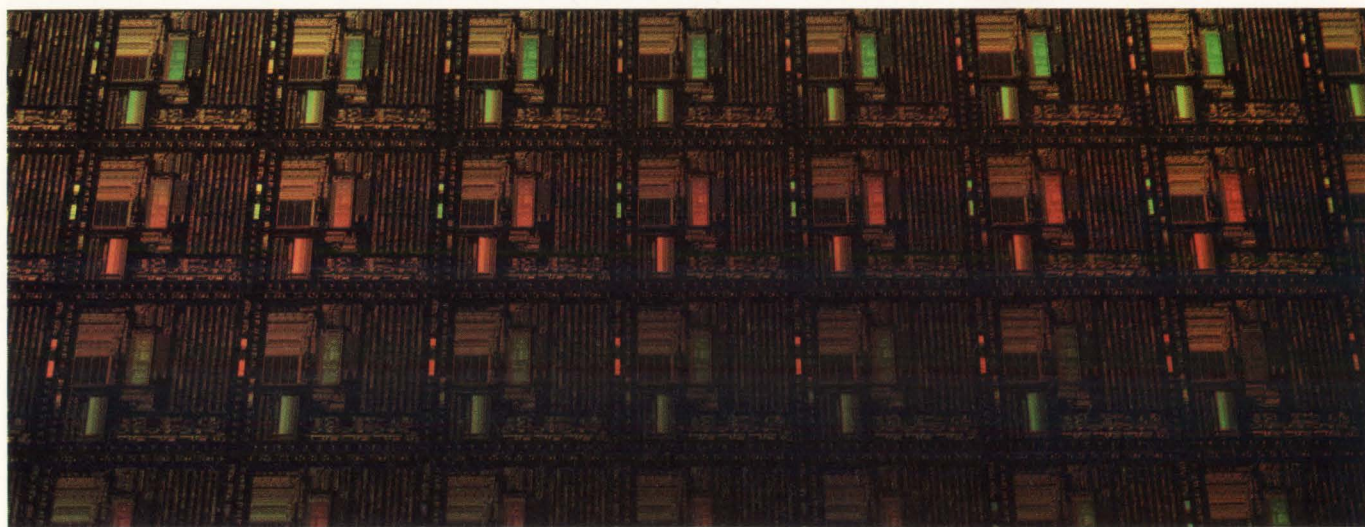


Fig 1—Typical of the switching-regulator demo boards are these boards from Linear Technology. The largest contains a buck converter and a flyback converter. The board with the meter attached contains a micropower regulator. The other two boards demonstrate regulator ICs for use in telecomm and LAN applications.

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TECHNOLOGY UPDATE

Switching regulators

tional offers a floppy-disk-based software program for use with three of its families of switching-regulator circuits.

Typical of the demo boards are four offered by Linear Technology (Fig 1). The largest of the four pc boards demonstrates the use of the LT1070 5A switching regulator. This board, which operates from a 6 to 16V input, contains a buck converter with a 5V output and a flyback converter with -5 and 12V outputs. The board with the test meter attached demonstrates the use of the LT1073 micropower voltage regulator. The LT1073 circuit, which delivers a 5V output from one 1.5V battery, needs only 130 μ A of supply current and can work from an input as low as 1V. Moving from left to right in Fig 1, the other two boards demonstrate the use of the LT1171 as a -48 to -5V converter in a telecomm application, and the LT1072 in a 5 to 9V LAN application, respectively.

Roll-your-own or ready-made

In support of its Max743, a 3W dual-output switching regulator, Maxim Integrated Products offers an evaluation board and a production kit. The \$20 evaluation board is actually a kit of parts in a static-proof plastic bag. In addition to the Max743, the kit includes a small pc board, two 1N5817 Schottky diodes, two 100- μ H inductors, three 150- μ F capacitors, and several resistors.

The Max743 is a dc/dc converter that generates ± 15 V at 100 mA or ± 12 V at 125 mA from a single 5V supply. In addition to two power MOSFETs and the usual converter circuitry, the device contains a few bells and whistles in the form of current limiting, undervoltage lockout, thermal shutdown, and soft-start.

If you don't want to play with the evaluation board and simply need

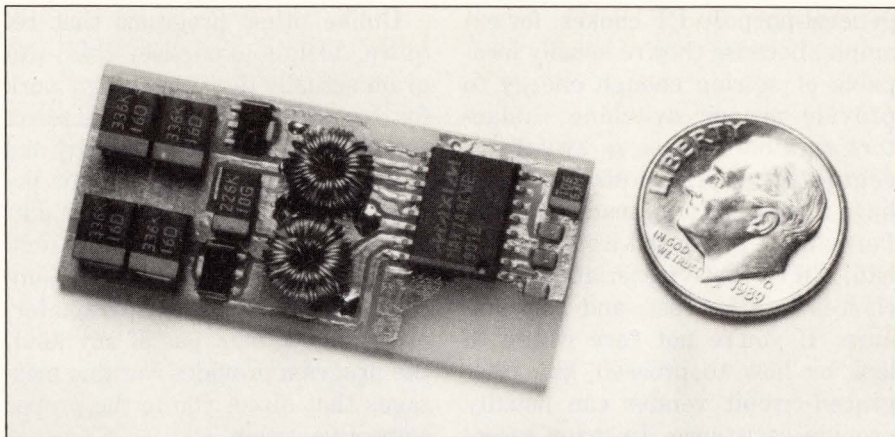


Fig 2—This 3W converter is available as a production kit. Using Maxim's Max743 dc/dc converter, the board delivers ± 15 V at 100 mA from a single 5V supply.

a plug-in module, Maxim accommodates this with its \$8.18 (1000) production kit (Fig 2). The kit, which features a proven board layout and an in-circuit-tested Max743, gives you a 3W converter with a guaranteed output voltage tolerance of $\pm 4\%$. The Max743 production kit has a typical efficiency of 78% with a 100-mA load and 70% with a 10-mA load—good numbers for a low-power dc/dc converter.

Many of the demo boards described thus far use devices that lend themselves to the construction of relatively simple circuitry. For example, the LT1073 micropower regulator from Linear Technology includes an on-chip power switch, which simplifies designing by reducing the number of necessary external components. Moreover, by operating at a fixed frequency, the LT1073 simplifies the design of the magnetic components. As is the case with many similar devices, the LT1073 needs only a single inductor as the magnetic element.

Despite the hand-holding simplicity provided by these demo boards, you may want to use them as just a starting point for your particular circuit application. If you're going to deviate from the components used on the demo board or charted

in the data sheet, you should consider a few important points. Apart from any variations in circuit layout, the foremost point you should consider is which capacitors and inductors you can use.

Because most switching regulators and dc/dc converters operate at frequencies in the 20- to 100-kHz range, a capacitor suitable for filtering the 120-Hz ripple from a full-wave-rectified 60-Hz line simply won't work in these devices. You need to choose a capacitor with a low equivalent-series-resistance (ESR). In general, standard wet electrolytics are questionable choices; you may find one that works in your breadboard, but don't count on being able to repeat the performance in production. Your best choice is either a tantalum capacitor specifically designed for switching power supplies (not all types are suitable), or a capacitor made from organic semiconductor material. The latter type has a very low ESR and is also smaller than an equivalent-value wet electrolytic.

When putting together a switching power supply, you must choose inductors that can handle dc current while maintaining their inductance value. You wouldn't want to choose

TECHNOLOGY UPDATE

Switching regulators

general-purpose RF chokes, for example, because they're usually incapable of storing enough energy to provide proper switching. Inductors suitable for use in switching-regulator applications typically have a core material made of Moly-Permalloy, powdered-iron, or ferrite. All of these materials present choices in size, cost, and performance. If you're not sure where to look or how to proceed, the integrated-circuit vendor can usually provide assistance. In many cases, the vendor's data sheet includes information detailing suitable types and sources.

Software program eases design

If a design kit or a completed module doesn't suit your objective, National Semiconductor's Simple Switchers software program may be just what you need. The program comes on a single 5 $\frac{1}{4}$ -in. floppy disk and is compatible with MS-DOS 2.0 or higher versions. Designed specifically for use with the company's LM2575 (1A), LM2576 (3A), and LM2577 (3A) families of switching regulators, the program provides several options. It helps you design buck and buck-boost (invert) regulators that use the LM2575/76, and boost and multiple-output flyback regulators that use the LM2577.

Apart from its ability to handle most of the commonly used regulator topologies, the best thing about the program is its ease of use. Even a novice—a category befitting this writer—will have no trouble following the program's menu-structured directions. However, if you do need help, take a look at the program's README.DOC file. The file presents various warnings you should heed as well as about nine pages of supplemental information concerning the operation of the program.

Unlike other programs that require design expertise, this program actually does the design work for you. All you need to do is select the appropriate circuit topology and enter the desired input-output parameters such as input voltage, output voltage, load current, and temperature range. If you enter an unacceptable value for any parameter, or commit a faux pas of any kind, the program provides warning messages that direct you to the proper corrective action.

The program then calculates and provides a list of the values for all components, including the part number and manufacturing source for the component where appropriate. The program also provides a

summary of miscellaneous calculations such as the peak switch current, ripple voltage, crossover frequency, and phase margin. If you wish, the program can generate a circuit schematic showing the input-output parameters and the values for all components. To print the schematic, you'll need an Epson-dot-matrix- or HP-Laserjet-compatible printer.

Examine the two sample designs in Fig 3. The first design (Fig 3a) is a boost converter with an input voltage between 4.5 and 5.5V, an output voltage of 15V, and a load current of 0.2A. The second design (Fig 3b) is a 2-output flyback converter with an input voltage between 25 and 30V. The first output

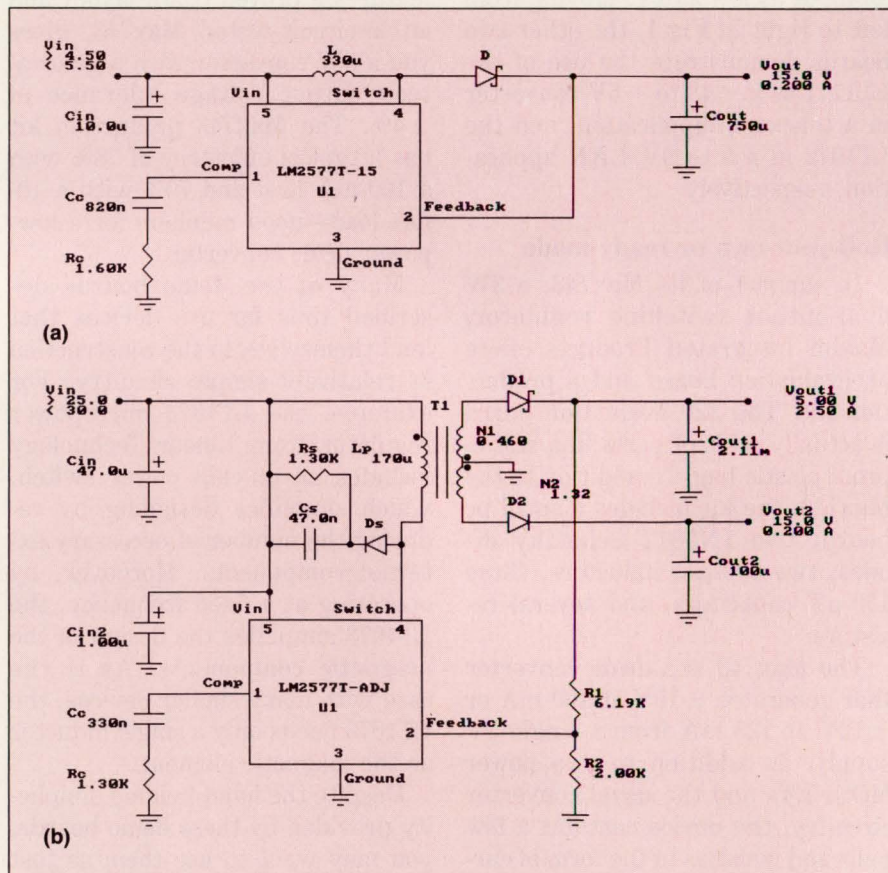
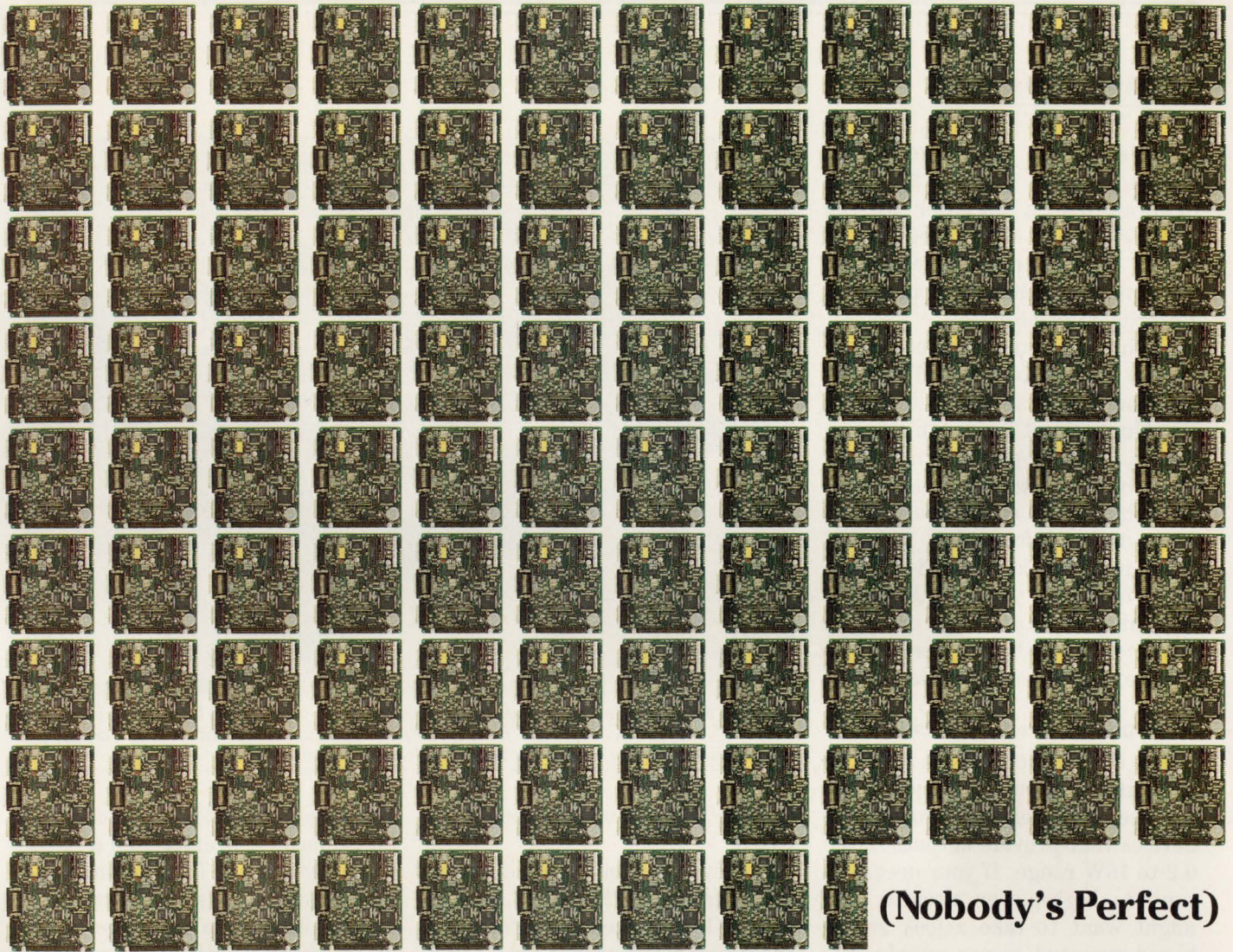


Fig 3—These converter designs were generated using a software program available from National Semiconductor. As reproduced by a laser printer, a shows a boost converter with a nominal input of 5V and an output of 15V at 0.2A. Circuit b is a 2-output flyback converter, which provides 5V at 2.5A and 15V at 0.2A.

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Switching regulators

provides 5V at 2.5A; the second output provides 15V at 0.2A. Both designs use a member of the LM2577 family of 3A regulators. Fig 3 shows the actual output of the sample schematics from an HP Laserjet II printer.

Within the limitations of the devices it applies to, National's Simple Switchers program fulfills its promise. Moreover, it does so in an easy-to-use, mistake-proof manner. Although National provides device data sheets that supply much of the same design information, the software program is so good—and so much fun—that you probably won't look at the data sheets until you need to know the pin connections for the recommended device.

High-power assembly kits

The design kits and the software program previously discussed are for use with relatively low-power devices that provide outputs in the 0.2 to 15W range. If your needs extend to high-power circuits, you might want to take a look at the board-mounted power supply kits from Cherry Semiconductor or Gennum Corp. Although differing in their respective circuitry, both of these boards use resonant-mode control for power conversion. Capable of operating at high frequencies while exhibiting low switching losses, resonant-mode control is becoming increasingly popular as a means to achieve high efficiency and high power density in switching power supplies.

Designed around its 1-MHz CS-360 monolithic controller chip, Cherry offers a complete half-bridge resonant converter. Operating in the series-resonant, parallel-loaded mode at 700 kHz, the converter outputs 28V at 5A from either a 90 to 132V or a 180 to 264V ac input. Other performance specifications include 85% efficiency, 0.1%

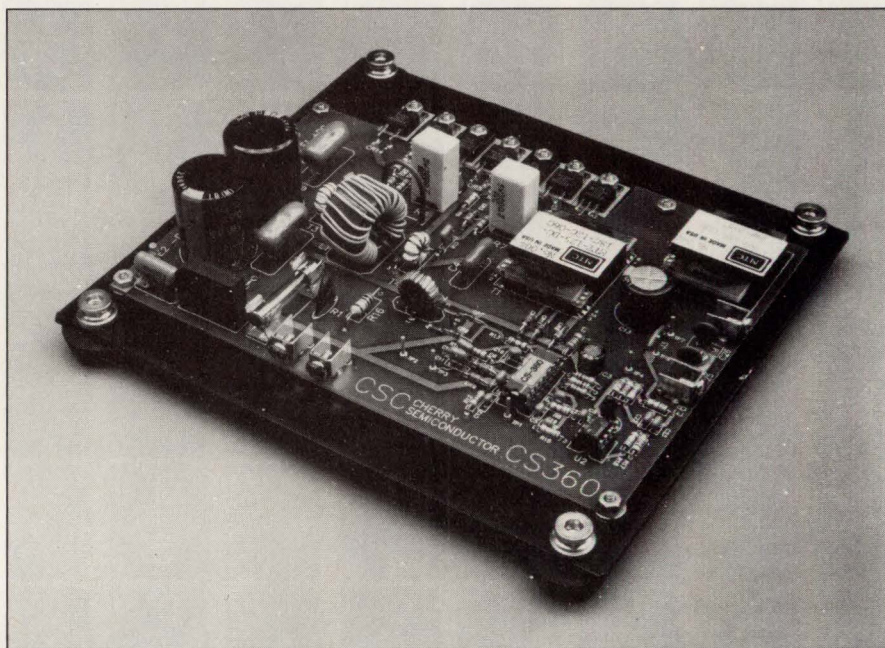


Fig 4—This converter kit operates from either a 110V or 220V ac line and delivers an output of 28V at 5A. Available from Cherry Semiconductor, the kit includes all of the components needed to assemble a 140W resonant-mode converter.

line regulation, and 0.5% load regulation.

Mounted on an anodized aluminum heat sink, the 7.5×3.5-in. pc board (Fig 4) accommodates all of the components needed for a 140W converter. The \$200 kit contains over 130 unmounted components. Cherry plans to make 250 kits available on a first-come, first-served basis. Included with the kit is a data sheet for the CS-360, a 24-pg appli-

cation note describing the design of the resonant converter, and a 16-pg assembly manual. In addition to detailed instructions, the assembly manual includes a complete parts list, a schematic, a board-layout diagram, and a picture of the fully assembled converter.

If you're heavily into Laplace transforms, you'll want to take a close look at the above-referenced application note. The note takes you

Basic switch-mode topologies

For the benefit of the newcomer to switching-regulator circuits, following is a brief description of the four basic topologies.

Boost: Used to step up the input voltage, eg, $V_{IN} = 5V$, $V_{OUT} = 12V$.

Buck: Used to step down the input voltage, eg, $V_{IN} = 10V$, $V_{OUT} = 5V$.

Buck-Boost: Used to generate a negative voltage from a positive voltage without isolation, eg, $V_{IN} = 5V$, $V_{OUT} = -5V$.

Flyback: Used for multiple output voltages, positive or negative, with the possibility of isolation. This topology requires the use of a transformer instead of an inductor. High output voltages are possible. Both step-up and step-down modes are possible. eg, $V_{IN} = 5V$, $V_{OUT1} = 15V$, $V_{OUT2} = -15V$.

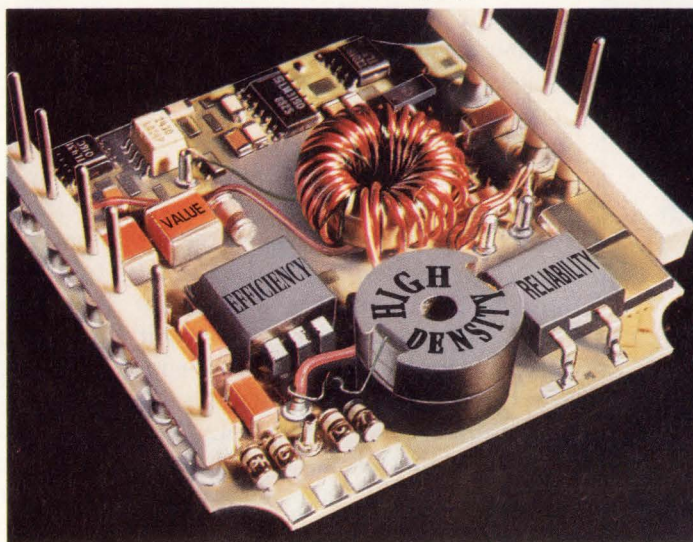
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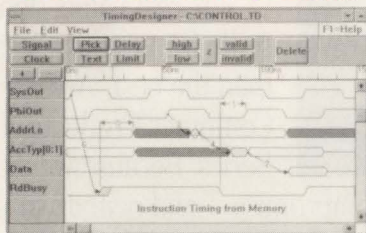
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on a mathematical excursion into the design of a half-bridge resonant converter using the CS-360 controller. Apart from its math orientation, the application note provides numerous graphs, photos of scope traces, and timing diagrams that provide a good understanding of circuit operation.

Using the same basic approach as Cherry, Gennum Corp offers its X485, a 100W dc/dc converter kit in unassembled form. Designed around the company's GP605 resonant-mode controller, the circuit uses a single-ended, forward-converter topology operating at a switching speed of 500 kHz. The converter delivers an output of 5V at 20A from a dc input of 48V (the input range is 36 to 60V). Other specifications include a typical efficiency of 82%, line regulation of 0.1%, load regulation of 0.5%, and a p-p output ripple of 50 mV.

Gennum's \$225 kit contains all of the active and passive components needed for an operating converter. You mount the components on the 5.25 x 3.5-in. pc board, which you then attach to an aluminum heat sink. Included with the kit is a data sheet, a 12-pg application note, and a 14-pg assembly and troubleshooting manual. The manual includes a

complete parts list, a schematic of the circuit, and a board-layout diagram.

Gennum also offers an evaluation kit, the X486, for use with its GP6040 resonant-mode controllers. This kit, which contains only a pc board and the GP6040 IC, sells for \$15. You can use the X486 kit in two ways. One-third of the board contains space for all the components needed to build an open-loop test circuit and evaluate the GP6040. The remaining two-thirds of the board allows you to build various types of resonant-mode converters. Included with this kit is an information note containing a schematic and layout diagram for the test circuit and a parts list.

Although not a panacea for all of the ills and pitfalls that often confront the designer of switching regulator circuits, the design aids described here can often provide the assistance needed to point a novice in the right direction. In some cases, the design kits might even provide a drop-in answer to your design problem. **EDN**

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High 509 Medium 510 Low 511

For more information . . .

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

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UC1843	*UC1843A	UC3843	*UC3843A
UC1844	*UC1844A	UC3844	*UC3844A
UC1845	*UC1845A	UC3845	*UC3845A
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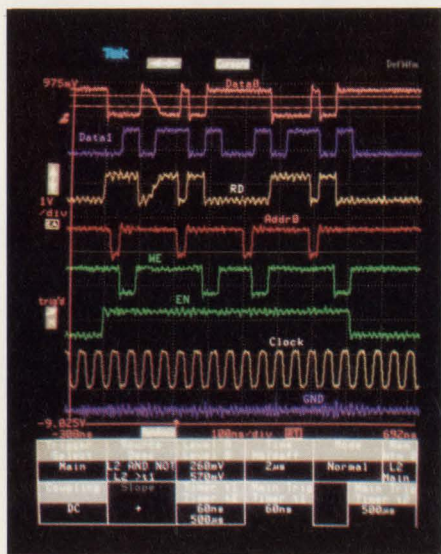
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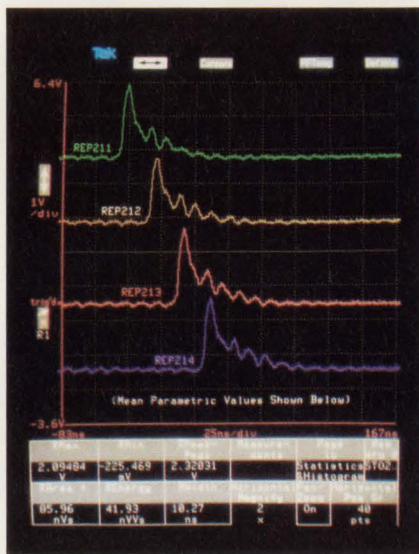
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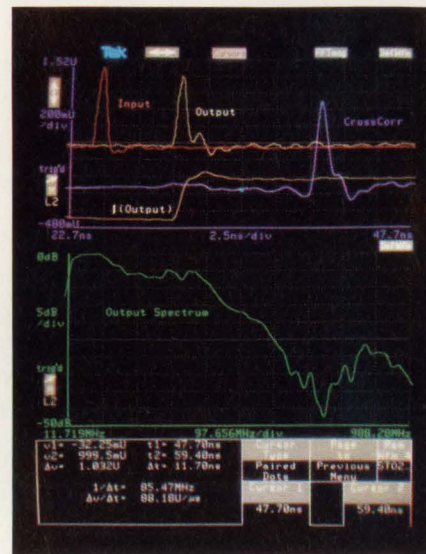
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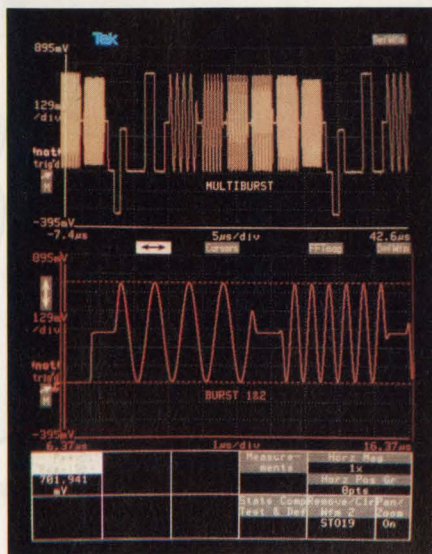
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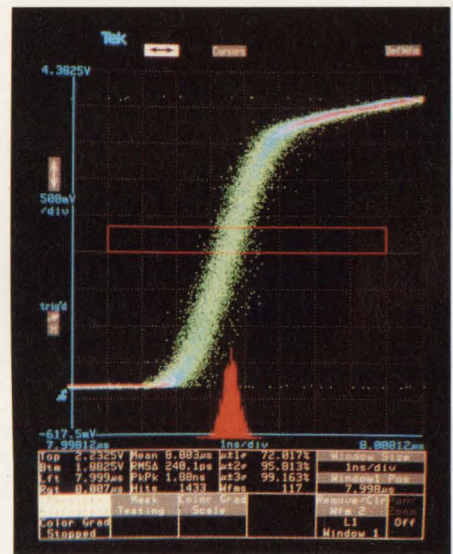
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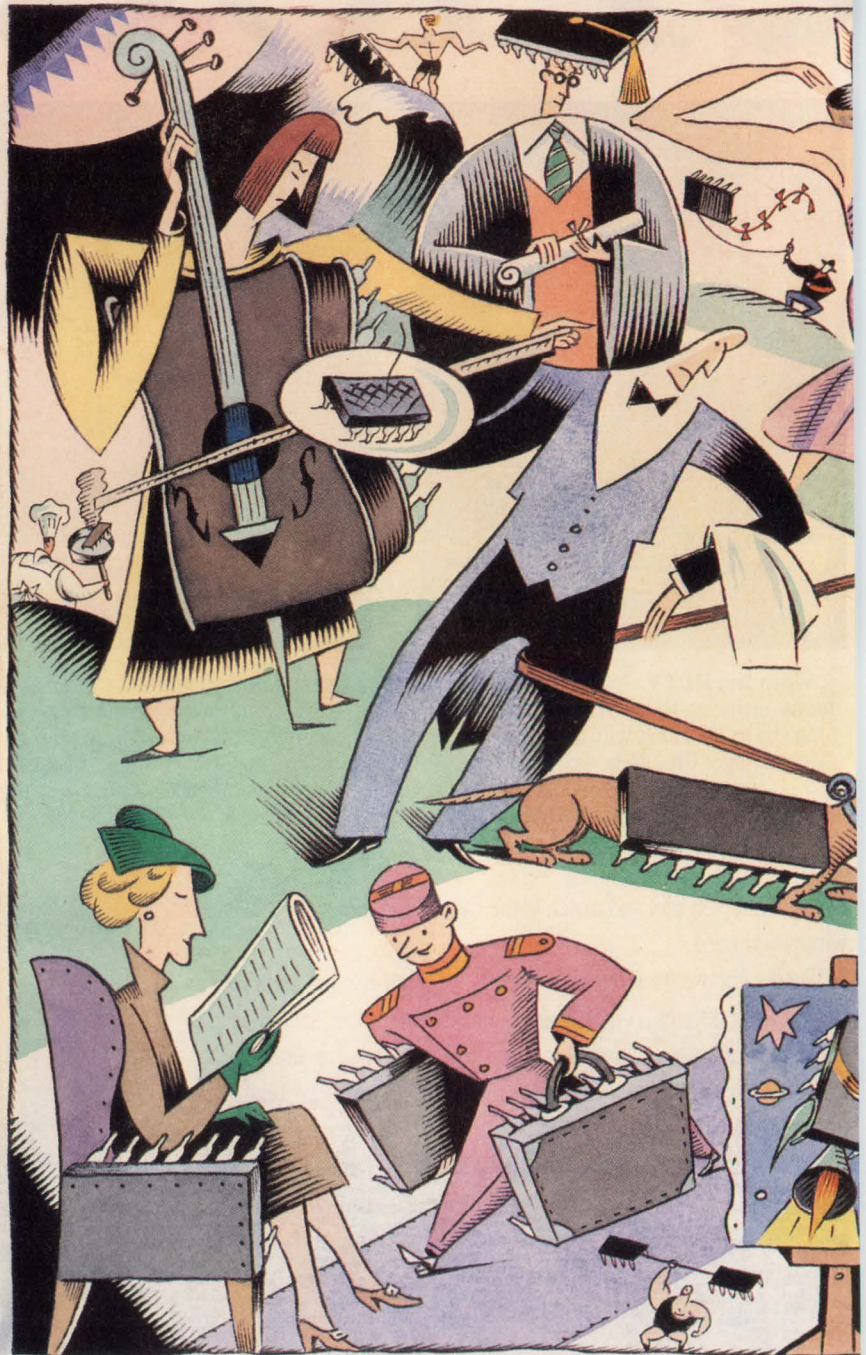
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KM28C17	2Kx8	Parallel	150	Data polling, ready/busy
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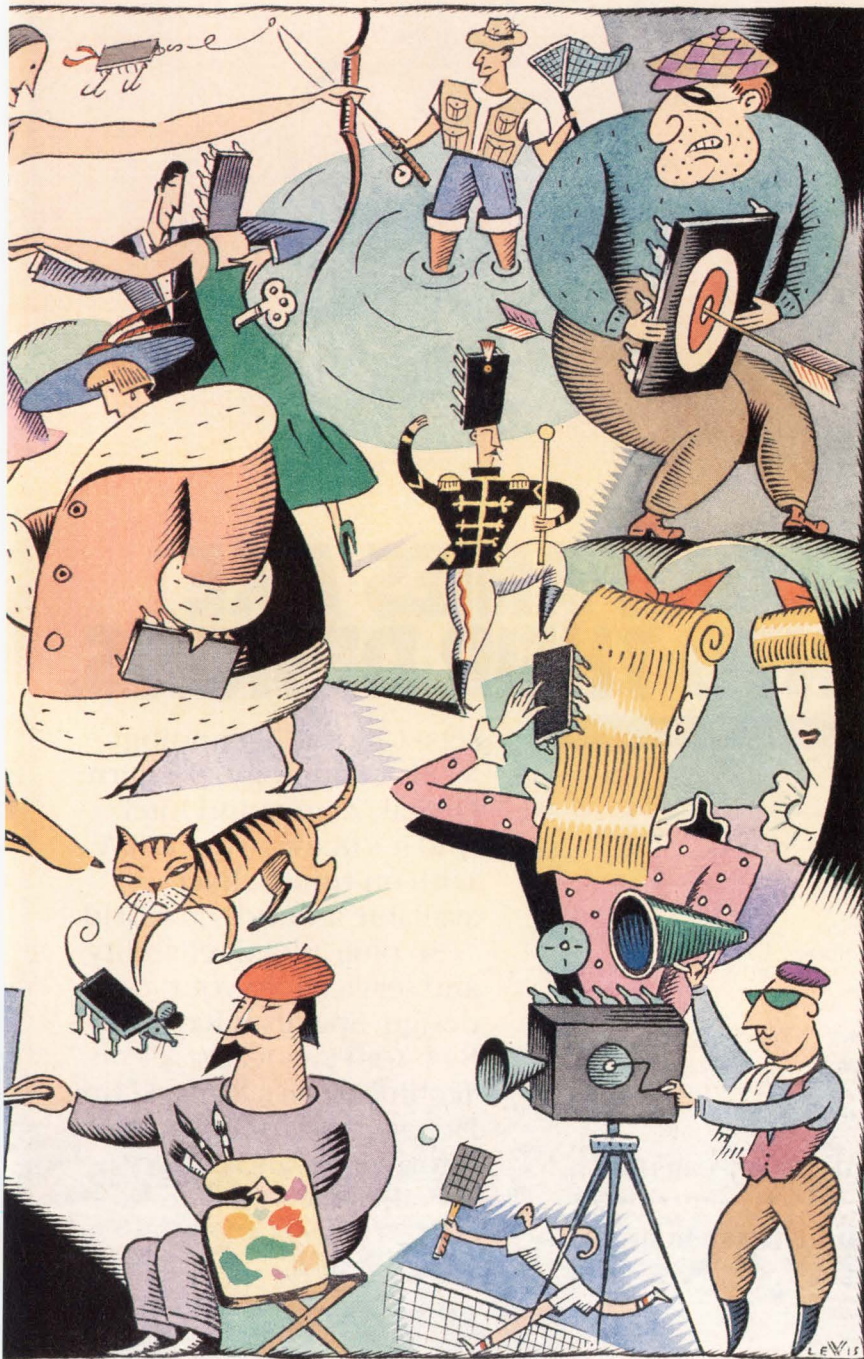
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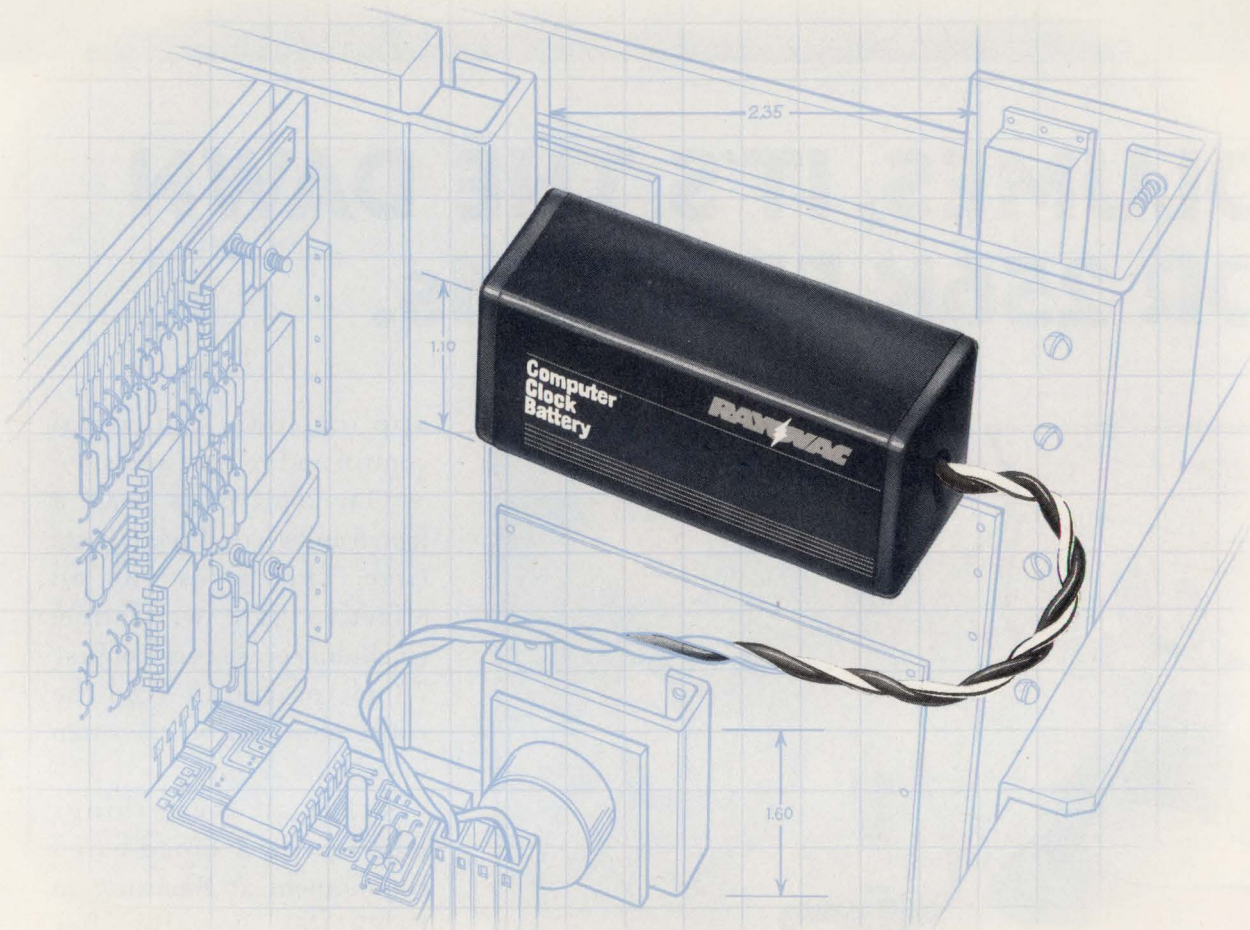
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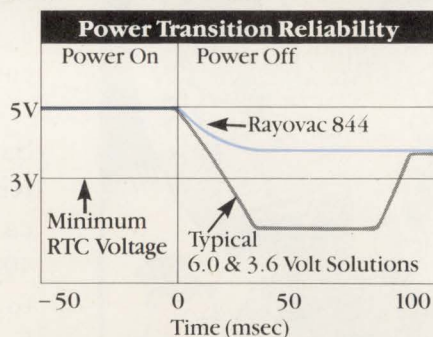
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SPECTRUM ANALYZERS

Modern instruments ease frequency analysis

Modern spectrum analyzers have come a long way. Improved RF performance and digital processing features open new vistas for viewing the frequency domain.

John Gallant,
Associate Editor

Pure mathematical spectral analysis, such as the Fourier analysis, can carry you only so far. Engineers need tools and instruments that can actually measure spectral-analytical results to quantify data. Tools, such as the oscilloscope, that measure the time response of a waveform are most familiar to engineers. However, their frequency-domain counterpart, the spectrum analyzer, is equally important for spectral analysis measurements, if less understood.

Spectrum analyzers can make frequency and amplitude measurements, and they operate over a larger dynamic range than time-domain tools. Because spectrum analyzers have narrow bandwidths, they are more sensitive than oscilloscopes.

Today's spectrum analyzers are more accurate and easier to use than older models, such as HP's Model 141T. Vintage engineers will recall not only the limitations of these "Model Ts," but will also recall the high degree of skill required to use them effectively. Although the 141T is still an effective tool, modern spectrum analyzers are more accurate and perform a broader range of functions.

Spectrum analyzers are classified in three categories: low-frequency, communications, and microwave analyzers. Low-frequency, or audio-frequency analyzers employ

DSP techniques to perform an FFT on signals in the 0- to 1-MHz range.

Spectrum analyzers for the communication frequency range of 10 kHz to 2 GHz operate similarly to heterodyne radio receivers. These analyzers employ the fundamentals of the first local oscillator as the mixing agent in the input mixer. Microwave spectrum analyzers, which operate from 2 to 18 GHz, are also heterodyne receivers. However, they use harmonic mixing to convert the high frequency range to the first IF.

Of the three types of analyzers, communications frequency-range analyzers best illustrate some of the advances that have occurred in the past 10 to 15 years. (For a broader look at spectrum analyzers, see **box**, "What you call a basic spectrum analyzer.")

Modern spectrum analyzers for the communication range have options for quasipeak detectors, antennas, and preamplifiers that conform to the CISPR



Low residual FM enables narrow resolution bandwidths. The Tektronix 497P portable spectrum analyzer has less than 5-Hz p-p residual FM, thereby permitting a 10-Hz bandwidth filter.

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Spectrum analyzers

(Comite International Special des Perturbations Radioelectriques) standards for measuring electromagnetic interference (EMI). The quasipeak detectors are standard for Anritzu's MS2601 series and Advantest's R3261 and R3361 series. By conforming to CISPR standards, a spectrum analyzer qualifies as a dedicated EMI receiver and can make prequalification tests on equipment to meet FCC and VDE EMI emission standards.

In addition, some communication frequency analyzers can perform specialized tests on CATV systems and mobil-radio systems. HP's 8590 series offers either 50 or 75 Ω input impedances and can perform time-

gated spectrum analysis. The Pan-European digital cellular-radio system, as defined by Groupe Speciale Mobile, uses time-division multiplexing to increase capacity. An option for the 8590 series provides a 1- μ sec to 65-msec gate, which is triggered by an external signal, to turn only the analyzer on and make measurements on a signal at specific time intervals.

The frequency accuracy of a modern spectrum analyzer has the resolution of a good frequency counter. All of the fixed local oscillator frequencies in modern analyzers are multiples of a stable crystal reference oscillator. The reference oscillator's stability is specified over

time and temperature. Typical reference oscillator aging rates range from 1 to 0.1 ppm/year. The tunable first local oscillator also uses the crystal oscillator as a reference in a phase-locked loop or frequency synthesizer.

Further, many modern analyzers, such as HP's 8590 series, Rohde and Schwarz's FSA and FSB analyzers, and Marconi's 2383, use a YIG-tuned oscillator for the first local oscillator. The oscillator has two tuning coils—a coarse-frequency control coil and a fine-grain tuning coil. The span generator drives the tuning coil to establish the specified frequency span. The precise linearity inherent in the

What you call a basic spectrum analyzer

Spectrum analyzers provide a visual representation of the amplitude of the frequency components in a waveform vs a specified frequency range. However, all phase relationships between components are lost. **Fig A** shows a simplified spectrum-analyzer block diagram for the communication frequency range.

The spectrum analyzer consists of a heterodyne receiver that has a tunable first local oscillator, which converts an input frequency range to a fixed

first IF frequency. Practical analyzers have as many as four IF stages to reduce spurious responses caused by image frequencies and local oscillator leakages. (The fixed local oscillators for the subsequent IF stages aren't shown in **Fig A** because they aren't essential to explain the analyzer's operation.) Spectrum analyzers also have an RF step attenuator to adjust the RF level into the input mixer and an IF step attenuator to adjust the display dynamic range.

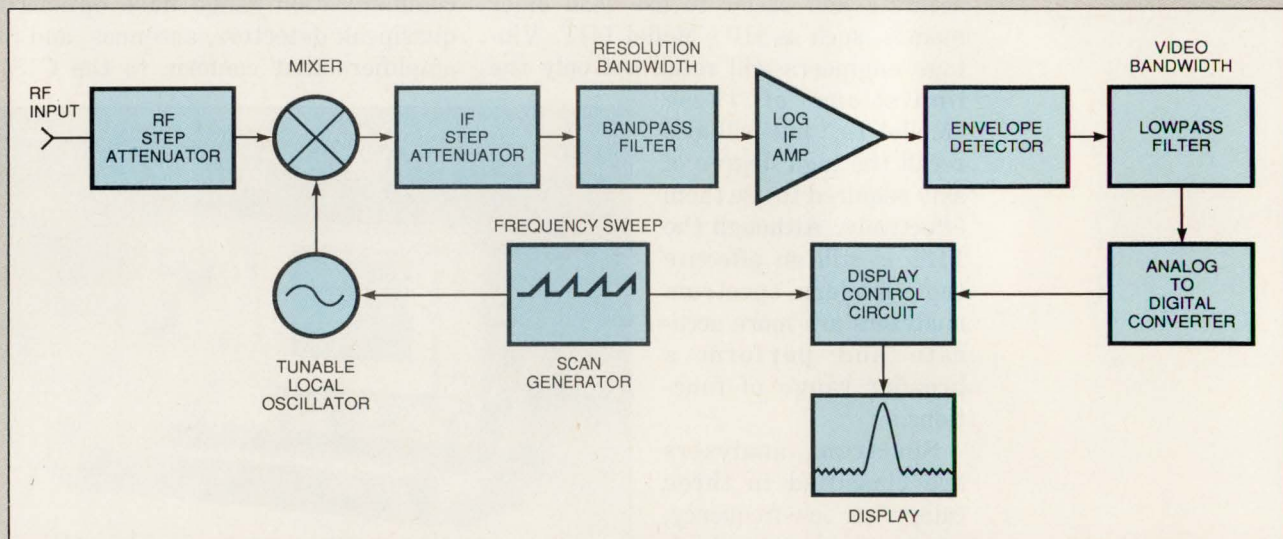


Fig A—This communications spectrum analyzer has a frequency-swept receiver whose display is synchronized to the sweep rate. A log-IF amplifier compresses the dynamic range of input signals for display.

TECHNOLOGY UPDATE

tuning characteristics of the YIG oscillator is another factor in the frequency readout accuracy.

Improvements in oscillator accuracy have allowed manufacturers to guarantee a frequency readout using a formula that typically depends on the reference oscillator's stability and the span accuracy. For example, Advantest specifies the following center-frequency readout accuracy formula for its R3261 and R3361 series:

$$\begin{aligned} \text{Readout Accuracy} = & \pm (3\% \times \text{span} \\ & + \text{central frequency} \\ & \times \text{reference oscillator stability} \\ & + 20 \text{ Hz}). \end{aligned}$$

Using this formula and the specified aging stability ($1 \times 10^{-7}/\text{year}$) of the reference to calculate the readout accuracy for a 1-GHz signal at a 1-kHz span yields

$$\text{Readout accuracy} = 150 \text{ Hz/year.}$$

Compare this number with the specification for a plug-in module (8554B) for measuring a 1-GHz signal on the 141T, which only guarantees that the dial indicates the display center frequency within 10 MHz. All modern spectrum analyzers have readout accuracy formulas similar to the Advantest formula. In fact, HP's 8590 series, Advantest's R3261 and R3361 series, and

Anritzu's MS2601 series can measure the frequency of a marker placed anywhere on the display with 1-Hz accuracy.

Because all oscillators wobble in frequency, all spectrum analyzers have an overall residual FM specification. In fact, the residual FM of the reference level, which is the feed-through signal from all of the local oscillators, determines the minimum bandwidth resolution of the analyzer. In order to make any meaningful measurements, the residual FM must be less than the minimum resolution bandwidth. The specification stipulates a measurement time, which usually ranges from .1 to less than 10 sec and

The selectable bandwidth of the bandpass filter that precedes a log-IF amplifier in the final IF stage determines the frequency resolution of the analyzer. The log-IF amplifier compresses the signal's dynamic range into the detection range of an envelope detector. Spectrum analyzers also have selectable post-detection video filters for averaging noise on the detected dc voltage. All modern spectrum analyzers digitally process the detected voltage using an A/D converter. The analyzer uses the digital data to control the vertical deflection on the display and also can store the data in onboard memory for a local μP 's use.

The sawtooth ramp generator, called the scan generator, provides the capability of displaying amplitude vs frequency. The analyzer provides spectral analysis by synchronizing the display's horizontal deflection to the scan generator, which also linearly sweeps the first local oscillator in frequency. You can select the amplitude of the scan generator, which determines the displayed frequency range, called the frequency span. Because the display's horizontal graticule is usually 10 divisions long, you can divide the frequency span by 10 to obtain the span/div. You can also select the scan generator's period, determining the time for one frequency span on the display—the sweep time.

The swept-frequency response of a filter depends on how long a signal dwells in the filter's passband.

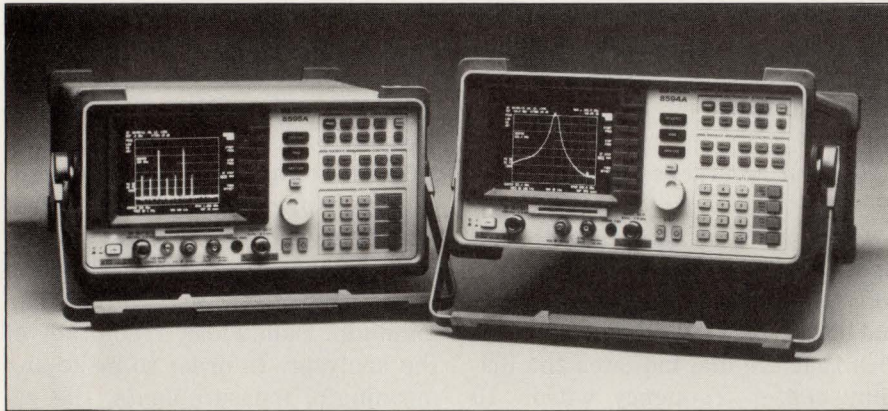
Therefore, a relationship between the frequency span, the resolution bandwidth, and the sweep time must be maintained to achieve the instruments calibration accuracy. Spectrum analyzers also let you select the start, stop, and center frequency for the display; they also generate frequency markers to designate specific points to make measurements.

You can also select a zero-span mode that displays the time-domain response of a signal tuned to the receiver's center frequency. The zero-span mode basically gives you an oscilloscope presentation of the input waveform having the frequency resolution of the attached receiver. In addition, modern spectrum analyzers can measure time periods and frequencies with the accuracy of a frequency counter.

Spectrum analyzer vendors have a variety of application notes that can acquaint you with these invaluable tools. Once you've mastered the controls, the analyzer not only lets you measure the amplitude and frequency of a waveform's spectral components, but it lets you determine distortion products, noise levels, frequency wobble, and the amplitude of any modulation sidebands. You can also measure the coarse and fine-grain frequency response of a system transfer-function and identify unwanted signals due to electromagnetic interference. The list of applications extends as far as your imagination allows.

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Spectrum analyzers



Some communication spectrum analyzers can perform specialized measurements. HP's 8594 and 8595 perform time-gated spectral analysis on mobil-radio and CATV signals.

distinguishes this specification from long-term drift in the oscillators.

Modern spectrum analyzers have RF sections with low enough residual FM to permit bandwidth resolutions as low as 3 Hz. For example, Marconi's 2380 series has a resolution bandwidth of 3 Hz min. Rohde and Schwarz's FSA and FSB have resolution bandwidths of 6 Hz min, and Advantest's R3265 and Tektronix's 497P have resolution bandwidths of 10 Hz min. In contrast, the communication-range plug-in module for the 141T has a

Table 1—Spectrum analyzers for the communications frequency range

Vendor	Model	Frequency range (Hz)	Resolution bandwidth (Hz)	Selectivity (60 to 3 dB bandwidth)	Frequency Span (Hz)	Amplitude Range (dBm)	Third-order intermodulation (dBC)	Reference oscillator stability (per year)	Nonharmonic response
Advantest	R3261A and R3361A series	9k to 3.6G	30 to 1M	15 to 1	1k to 3.6G	+25 to -130	-70 at -30 dBm	$\pm 2 \times 10^{-7}$	-70 dBC (at -30 dBm)
	R3265	100 to 8G	10 to 3M	20 to 1	200 to 8.0G	+30 to -140 (1 MHz to 3.6 GHz)	-60 (at -30 dBm) (10 MHz to 3.6 GHz)	$\pm 1 \times 10^{-7}$	-70 dBC (10 MHz to 8 GHz) (at -30 dBm)
Anritzu America	MS2601A	9k to 2.2G	30 to 1M	15 to 1	1k to 2.2G	+20 to -130	-75 (at -30 dBm) (5 to 800 MHz)	$\pm 2 \times 10^{-7}$	-75 dBC (at -30 dBm) (5 to 800 MHz)
Hewlett-Packard	8594A	9k to 2.9G	1k to 3M	15 to 1	10k to 2.9G	+30 to -112	-70 (at -30 dBm)	$\pm 2 \times 10^{-6}$	-65 dBC (at -30 dBm)
	8595A	9k to 6.5G	1k to 3M	15 to 1	10k to 6.5G	+30 to -114	-70 (at -30 dBm)	$\pm 2 \times 10^{-6}$	-65 dBC (at -30 dBm)
IFR Systems Inc	A-8000	10k to 2.6G	300 to 3M	Not specified	10k to 2.5G	+30 to -120	-70 (level not specified)	$\pm 0.5 \times 10^{-6}$	Not specified
Marconi	2383	100 to 4.2G	3 to 1M	11 to 1	100 to 4.2G	+30 to -150	-90 (at -40 dBm)	$\pm 1 \times 10^{-6}$	-70 dBC (at -40 dBm)
	2382	100 to 400M	3 to 1M	11 to 1	100 to 400M	+30 to -150	-95 (at -42 dBm)	$\pm 1 \times 10^{-6}$	-75 dBC (at -42 dBm)
Rohde and Schwarz	FSA	100 to 1.8G	6 to 3M	12 to 1	10 to 2G	+30 to -150 (>20 MHz)	-75 (at -30dBm)	$\pm 1 \times 10^{-7}$	-75 dBC (>20 MHz) -70 dBC (<20 MHz) (at -40 dBm)
	FSB	100 to 5.0G	6 to 3M	12 to 1	10 to 2G	+30 to -145 (>40 MHz)	-70 (at -30 dBm)	$\pm 1 \times 10^{-7}$	-75 dBC (>40 MHz) -70 dBC (<40 MHz) (at -40 dBm)
Tektronix	2712	9k to 1.8G	200 to 5 MHz	7 to 1	10 to 1.8G	+20 to -127 (-139 using built-in preamp)	-70 dBC (at -30 dBm)	1×10^{-7}	Not specified
	2710	10k to 1.8G	3k to 5M	7 to 1	10k to 1.8G	+20 to -129	-70 dBC (at -30 dBm)	$\pm 10 \times 10^{-6}$	Not specified
	497P	100 to 7.1G	10 to 3M	7.5 to 1	100 to 500M	+30 to -120	-70 dBC (at -27 dBm)	$\pm 1 \times 10^{-6}$	Not specified

TECHNOLOGY UPDATE

resolution bandwidth of 100 Hz min.

The resolution filter's shape factor also plays an important part in spectral analysis. The filter's selectivity determines the analyzer's ability to distinguish between spectral components that are close in frequency but broadly separated in amplitude, such as "hum" sidebands produced by power line frequencies. If the resolution filter rolls off slowly in frequency, the analyzer may not recognize frequency components close to the carrier frequency. A ratio of the 60-dB to the

3-dB bandwidths specifies the filter shape factor. Ratios of better than 11:1 are common in today's analyzers. The resolution filters in Advantest's 3265 are better than 20:1.

The maximum dynamic range of the spectrum analyzer hasn't changed much over the years. Minimum sensitivity is determined by nature and the analyzer's noise figure. Because spectrum analyzers don't have a preamplifier, the noise figure of the first mixer and the noise figure of the first IF amplifier determine the analyzer's overall

noise figure, and subsequently its minimum sensitivity.

Spectrum analyzers have overall noise figures between 20 and 25 dB. Since nature dictates that the noise floor of the universe is -174 dBm/Hz at room temperature, a spectrum analyzer with a 20-dB noise figure and a 1-kHz resolution bandwidth has a sensitivity of -124 dBm min. Spectrum analyzers have an upper power limit, which you must observe to avoid damaging the RF attenuator or the first mixer. The power level ranges between 20 and 30 dBm max.

Another factor that degrades the analyzer's sensitivity is noise imposed on the detected signal caused by noise sidebands on the conversion of local oscillators. These noise sidebands can appreciably add to the system noise and mask signal components that are close in frequency to the detected signal. You estimate this degradation on state-of-the-art spectrum analyzers by specifying the amplitude of the noise sidebands in dBc/Hz (dB below the carrier in a 1-Hz bandwidth) at a specific offset frequency. Vendors provide a curve of the noise sideband levels in dBc/Hz vs offset frequency. As recently as a few years ago, you had to measure the noise sidebands yourself.

Nonlinear distortion components also limit the analyzer's ability to identify signals. Harmonic distortion, nonharmonic distortion, and third-order intermodulation distortion products all affect the analyzer's spurious-free dynamic range. The third-order intermodulation products are the most vexing because two input signals can generate in-band spurious responses within the analyzer's resolution bandwidth. Third-order-product terms for a particular power level are specified into the first mixer, generally -30 dBm.

Scale settings	Price	Other features
10, 5, 2, and 1 dB/div, linear	\$12,900 (R3261A) \$18,500 (R3361A)	R3361A has an internal tracking generator, standard quasipack detector; preselector option; 12 division display; ± 1 dB total accuracy; log sweep 1, 2, or 3 decades from 10 kHz to 1 GHz. Device weighs less than 37 lbs.
0.1 to 10 dB/div, linear	\$27,000	AM/FM demodulators; standard quasipeak detector; time-gated sweep; log sweep 1, 2, or 3 decades from 1 kHz to 1 GHz. Device weighs 48.5 lbs.
10, 5, 2 and 1 dB/div, linear	\$11,995	± 10 overall accuracy; plug-in memory cards; zone sweep and measurements between markers; standard quasipeak detector; log sweep (3 decades). Device weighs 41 lbs.
0.1 to 20 dB/div, linear	\$14,995	Tracking generator; AM/FM demodulator; time-gated sweep; quasipeak detector; memory card. Device weighs 35 lbs.
0.1 to 20 dB/div, linear	\$19,760	Tracking generator; AM/FM demodulator; time-gated sweep; quasipeak detector; memory card. Device weighs 35 lbs.
10 dB/div, 2 dB/div, linear	\$11,595	Tracking generator; quasipeak detector; 75 Ω input impedance; RS-232C port. Device weighs 34 lbs.
10, 5, 2, 1, and 0.5 dB/div, linear	\$46,000	Total accuracy= ± 1 dB; standard tracking generator; overload protection; 10-division display; AM/FM demodulators. Device weighs 50 lbs.
10, 5, 2, 1, and 0.5 dB/div, linear	\$27,950	Total accuracy= ± 1 dB; standard tracking generator; overload protection; 10-division display; AM/FM demodulators; 75 Ω option. Device weighs 38 lbs.
10 dB/div, 0.1 \times measurement range, linear	\$42,800	10-division display; AM/FM demodulator; color monitor. Device weighs 128 lbs.
10 dB/div, 0.1 \times measurement range, linear	\$64,200	10-division display; AM/FM demodulator; color monitor. Device weighs 128 lbs.
1, 5, 10 dB/div, linear	\$11,950	Standard quasipeak detector; nonvolatile memory; AM/FM demodulator; tracking generator. Device weighs 21 lbs.
10, 5, and 1 dB/div, linear	\$8750	AM/FM demodulator; views TV picture on display; nonvolatile memory; switchable internal preamp. Device weighs 21 lbs.
1 to 15 dB/div, linear	\$26,250	Automatic unit conversion; nonvolatile memory; help menu. Device weighs 45 lbs.

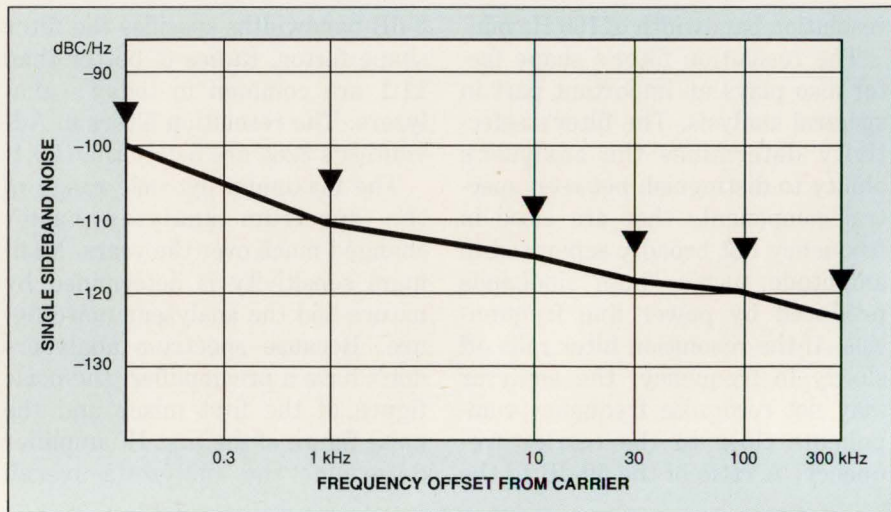
TECHNOLOGY UPDATE

Spectrum analyzers

You can find considerably lower nonharmonic distortion products for state-of-the-art spectrum analyzers than older models. Modern spectrum analyzers have a lowpass filter preceding the first mixer that attenuates out-of-band signals, which generate these products. (An example of this is a signal at the image frequency for the input mixer.) Some analyzers, such as Advantest's R3261 and R3361, have an optional preselector that tracks the first local oscillator in frequency.

In contrast, the 141T has a broadband input section. Therefore, it isn't always clear whether you've tuned the display frequency to the desired response or tuned the image response of equal magnitude. Engineers who have been around for 15 years will remember the signal identifier switch on the 141T, which identifies image responses.

The lowpass filter in the RF section of HP's 8590 series reduces the image response to at least 65 dB below the desired response for a -30-dBm input signal. Distortion specifications depend on the amplitude levels, so it is important to compare specifications with consistent input power levels. Because



Noise sidebands can degrade the minimum sensitivity close to a detected signal. The curve shows the typical single sideband noise for the Rohde and Schwarz FSB analyzer. The triangles are the guaranteed specification.

these specifications depend on the second and third order intercept points for the first mixer, they are sensitive to the measurement's power level.

Thank God for calibration

The amplitude accuracy of a spectrum analyzer depends on a wealth of factors. Some sources for error include attenuator accuracy, gain variations vs frequency, bandwidth accuracy, log-IF linearity, detector linearity, and the fidelity of the de-

flection circuitry for the display. Because total uncertainties can measure ± 6 dB, you need to calibrate the instrument if you want to measure amplitude with ± 1 -dB min accuracy. Calibrating older instruments requires a host of expensive peripheral equipment.

Because modern analyzers digitally process data, they can store calibration data internally. The μ P's ability to manipulate and store internal data and perform automatic calibration is the most distin-

For more information . . .

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

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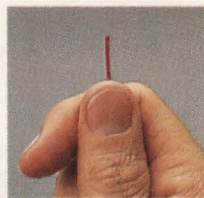
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Illustration of cross-section of typical coil winding using round magnet wire.

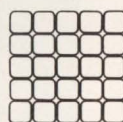


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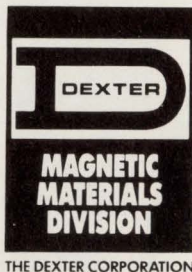
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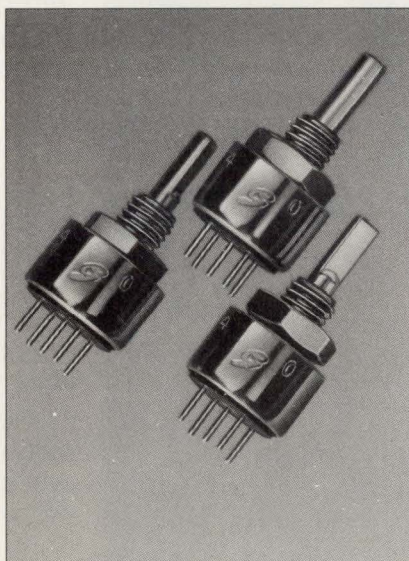
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UPDATE

Spectrum analyzers

guishing aspect of the modern analyzer. Some instruments, such as Advantest's R3361 and Marconi's 2382 and 2383, contain accurate built-in tracking generators for calibration. In fact, these instruments claim an overall accuracy of better than ± 1 dB after calibration.

Digital processing provides a gaggle of other features. For example, modern analyzers have digital display storage. This feature counters the difficulties in setting the phosphor persistence used in older analyzers. They can also automatically adjust the resolution bandwidth, video bandwidth, and sweep time. This ability ensures sufficient dwell time of the signal within the analyzer's passband during a specified frequency span.

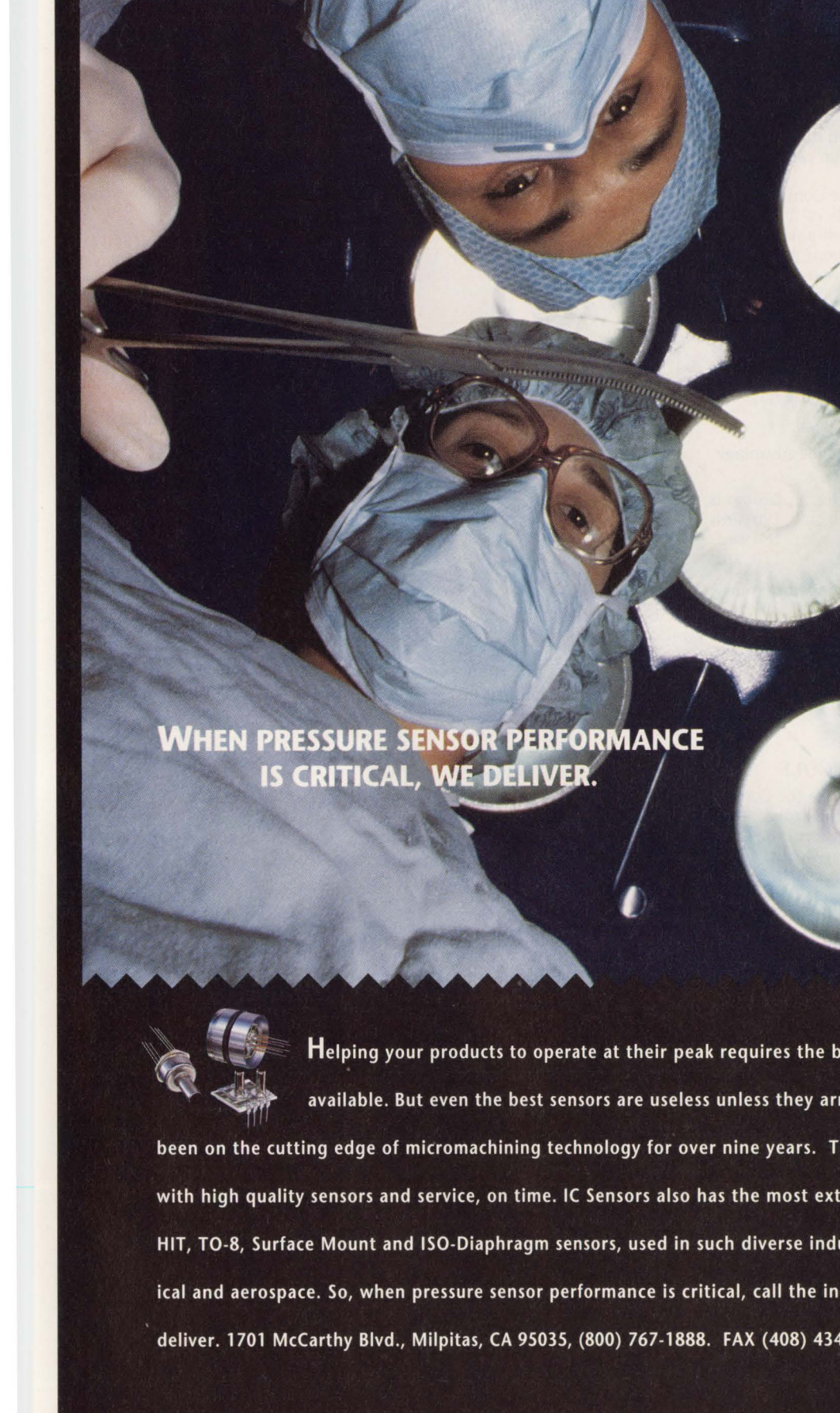
In addition, digital processing allows built-in diagnostics, direct-plot capability on printers and plotters, programming of custom measurement routines, and frequency-settable markers to make accurate measurements at or between display settings. Digital processing also allows simultaneous comparison of stored data at different display settings, automatic pass/fail tests, storage of data on memory cards, and automatic readout of display settings.

Advantest's R3261 and R3361 analyzers can display a 120-dB dynamic range and have a log sweep feature that produces a semi-log display for as many as three frequency decades. In fact, the number of gaggles on modern analyzers is mind boggling. Of course, any modern spectrum analyzer would lose respectability without incorporating an IEEE-488 interface, which allows remote software control.

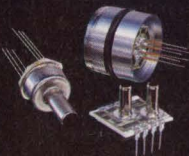
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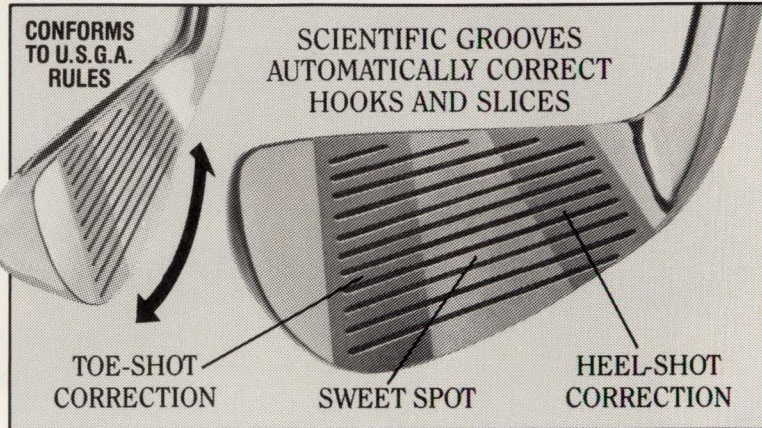
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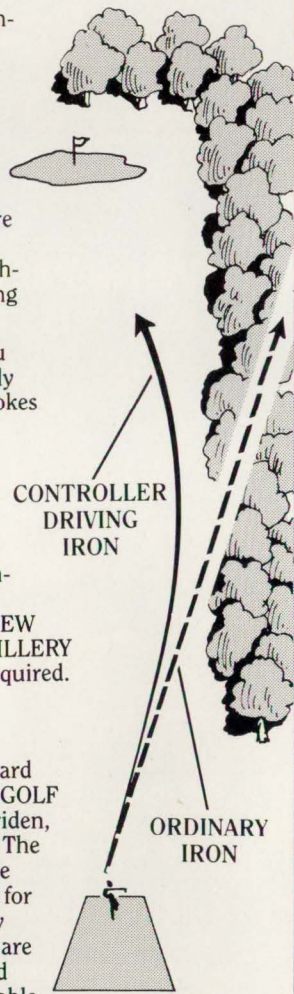
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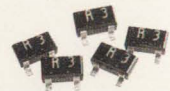
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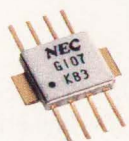


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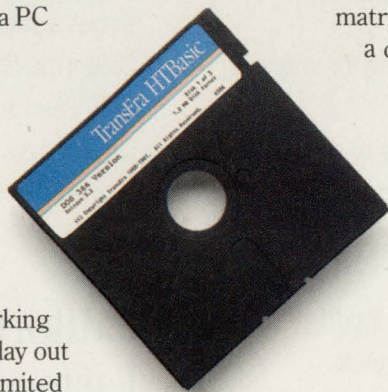
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Icon-based workstation software handles mathematics and instrument-control chores

HP VEE (Visual Engineering Environment) is a software package that in its basic form, called VEE Engine, lets engineers and scientists manipulate and display data without programming. You make the software do your bidding by interconnecting icons on the screen. An optional version, called VEE Test, also controls instruments and gathers data from them.

The software runs on the vendor's HP 9000 Series 300 and 400 workstations under the HP/UX operating system. It operates in an interpreted mode, it is not a code generator, and it requires no compilation.

One of the more obvious differences between this software and other visually oriented problem solvers is the quality of the graphics. Like those produced by many workstation-based products, its graphics are highlighted and shaded to suggest three dimensions. Generally speaking, software that runs on IBM PCs and even on the Apple Macintosh does not produce such displays.

But impressive graphics and genuine usefulness are two different matters. A shortcoming of other interpreted data-manipulation packages has been speed of operation. Although HP is not yet providing performance data, the package's speed in running demonstrations seems to be quite fast.

The software's developers point out that one of the most frustrating aspects of writing data-manipulating software is that of dealing with

data types. Although the software recognizes nine data types, it usually shields users from concern about types. When necessary, the software will automatically convert a waveform into a spectrum by performing an FFT.

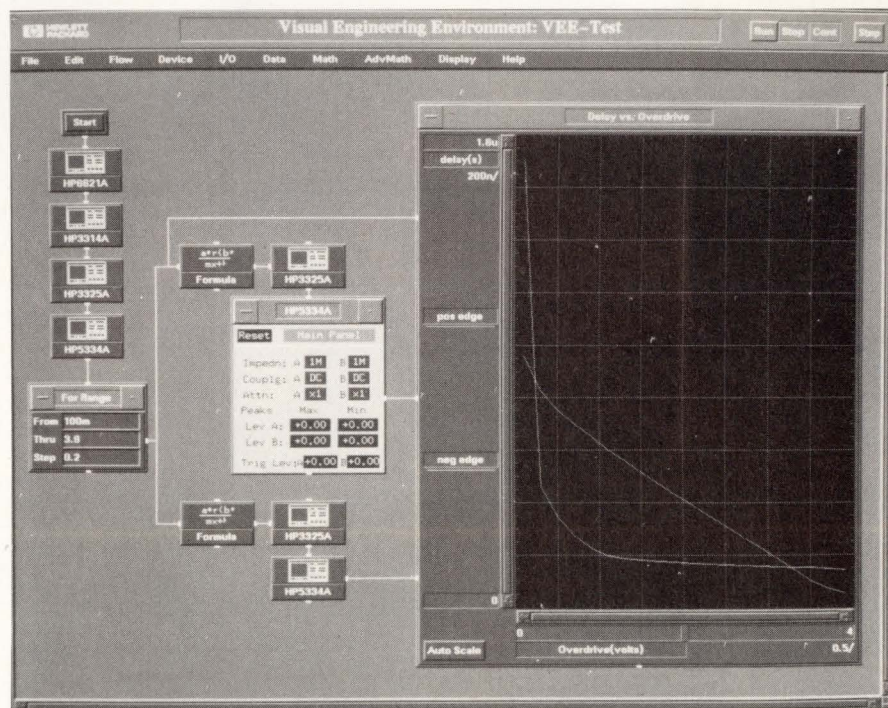
Approximately 150 objects manipulate data (analysis objects). A few categories of analysis objects are trig, array, matrix, calculus, regression, filtering, probability, statistics, and signal processing.

Although icon-based block diagrams are to a large degree self documenting, they often can't do a complete job of describing an experiment. Users of other instru-

ment-controlled software have usually had to maintain lab notebooks to hold vital information. In VEE, a notepad icon acts as a repository for such textual material. The number of such notepads is unlimited.

Even when you avoid programming by describing your procedure graphically, you don't guarantee that everything will work perfectly the first time. Most of the time, you'll have to do some debugging. A line-probe feature shows which objects are connected by a specific line. In addition, debugging tools let you insert breakpoints and show data and execution flow.

One of the beauties of conven-



Linking icons allows you to control instruments and manipulate and display the data the instruments produce. HP's VEE avoids programming yet does not sacrifice the control and flexibility normally associated with it.

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EDN EDITORS' CHOICE

tional programming is that it allows you to use constructs that control the flow of your program. Often, when you replace program statements with a graphical flowchart, you automatically and intuitively answer questions about program flow—but not always. The software recognizes that flow-control constructs are still needed and provides a group of objects for the purpose. Included are several if/then conditional objects as well as objects to control looping and repetition.

The software requires a color display; the vendor recommends one with at least six color planes. Although the software will run on a workstation with 8M bytes of RAM, the vendor recommends 12M to 16M bytes and a hard disk of at least 200M bytes. VEE Engine costs \$995; VEE Test, including VEE Engine, costs \$5000.

—Dan Strassberg

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EDN's Editors' Choice

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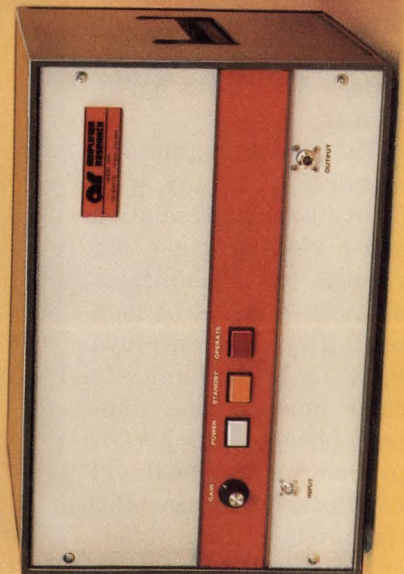
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Compact panel-mount package accommodates 80386 PC, EL display, and touchscreen

You can now buy a panel-mount EL-display package that includes a CPU and measures only 10.5 × 6.875 × 3 in. The Displaypac-EL includes a choice of IBM PC/AT-compatible 80386- or 80286-based single-board computers. An optional user-interface touchscreen suits the product for various applications, ranging from factory and machine control to point-of-sale terminals and medical equipment.

The display package's single-board computer includes as much as 16M bytes of dynamic RAM and 1M byte of EPROM; its processor's clock speed can run as fast as 20 MHz. The board also includes speaker and keyboard ports, two RS-232C ports, a parallel printer port, a real-time clock, a watchdog timer, and a math coprocessor. You can also add mass storage to the product via an onboard IDE (integrated device electronics) hard-disk interface and an industry-standard floppy-disk interface for 3½- or 5¼-in. drives.

The product features an amber EL display with 640 × 400-pixel resolution and a viewing angle that exceeds 160°. The display offers CGA and EGA compatibility and employs gray scale to simulate color images. The company plans to offer a VGA product in the next six months and may also offer the product using different display technology such as LCD.

You can run standard MS-DOS software on the system. The package can boot its disk-operating system from onboard RAM or ROM disks, as well as from an external drive. The company offers a ROM-based software tool that allows you to run target software developed on PCs without having MS-DOS present. Therefore, you don't have to buy MS-DOS licenses for each system used in embedded applications. The company can also supply software that allows you to use the touchscreen as if it were a mouse.

You can add features to the package via PC/AT-compatible expansion slots or with industry-standard iSBX-compatible cards. The com-

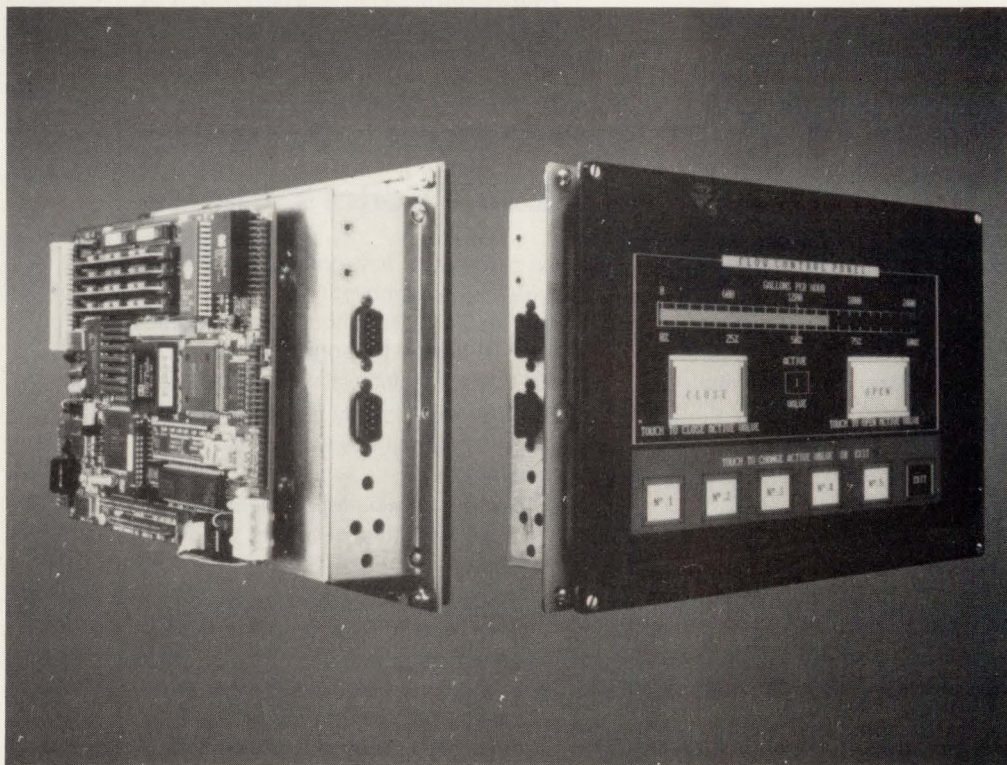
pany offers an expansion rack to hold either type of card; the slot increases only the depth of the unit's dimensions. The product features a NEMA-12 rating; therefore, it can operate in oily and wet environments. The system will operate over a 0 to 55°C temperature range and consumes only 37W of power.

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—Maury Wright

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AMP

Linear components for single-supply designs

The number of linear ICs tailored to operate from a single power-supply voltage has dramatically increased in the last few years. Using these devices requires a conservation-of-signal mentality and a conscious choice of what to call "ground."

Anne Watson Swager, *Regional Editor*

Designing linear circuits that operate from a single power-supply voltage is becoming an increasingly common system requirement. Applications that demand single-supply operation can feature strikingly different performance criteria. Possibly the most common application is a primarily digital system that can't afford the space, cost, or weight to add a negative supply to power a small percentage of analog components. These systems' linear circuits are limited by

voltage levels but not necessarily by power consumption.

Single supply doesn't necessarily mean five volts. Automotive and aircraft control circuits often require single-supply operation at 9 or 12V. In many cases, control circuits must deliver a significant amount of power to their loads. These circuits require high drive currents and must provide wide voltage swings. Battery-powered equipment offers the most constrained example of low-voltage operation. Not only do size and battery-voltage-level limits exist, but power is also at a premium. In fact, by far the most common characteristic of single-supply linear components—amplifiers, com-

parators, and data converters—is very low power consumption.

Compared with multiple-supply systems, single-supply systems have distinct advantages, or disadvantages, depending on your perspective. From a systems viewpoint, these systems require one power supply, consume less power—simply according to $P=VI$ —weigh less, and occupy less space. From a circuit designer's point of view, single-supply systems require that you adjust to new operating ranges and circuit techniques to accommodate those ranges. Designers—especially when working with op amps—must adhere to a new creed: conservation of signal. No longer do you have the $\pm 5V$ of head room typically available with op amps that run from $\pm 15V$ supplies.

Not only do you have to combat a familiar problem in mixed analog-digital systems—digital-system noise injecting itself into sensitive analog circuits—but you have less signal to combat the noise with. Single-supply op amps have lower output-power levels and slew rates compared with devices designed for $\pm 15V$ supplies. Depending on the level of your supply voltage, however, you may be able to use a $\pm 15V$ device (see **box**, "The single-supply vs standard op-amp debate"). Finally, when designing single-supply circuits, you have to adjust your way of thinking about what





ground really is, and design and lay out your circuit accordingly.

One of your first options is to avoid single-supply operation altogether by using a low-current charge pump or dc/dc converter to generate a negative voltage. Many low-cost and low-power devices are available for this purpose. However, these devices generate noise, which is the one major drawback of this approach. Depending on the requirements of your design, adding a converter may not be an option.

Fortunately, low single-supply voltages may not be as limiting as they seem. Although single-supply systems invariably reduce the available signal

Linear components such as op amps and data converters often have to work at a single-supply voltage—frequency 5V, the level at which digital systems operate. (Photo courtesy National Semiconductor)

range, the total dynamic range of some of the more recent single-supply op amps may not be such a liability when compared with that of older $\pm 15\text{V}$ op amps. A traditional op amp has a signal swing of $\pm 10\text{V}$ and an input offset around 2 mV, which results in a dynamic range of 10,000 to 1. Many op amps now have offset voltages as low as 100 μV . An amplifier with this offset and a 4V output swing has a range of 40,000 to 1. Of course, the dynamic range available from that same low-offset

The change in a single-supply op amp's behavior when a circuit violates the device's input or output range can be drastic.

op amp would be much greater when operating from $\pm 15V$ supplies.

Also, when using a 5V-powered amplifier instead of a $\pm 15V$ device, the common-mode range decreases from a total of 20 to 4V—a factor of 5—and the power-supply voltage goes down sixfold, from ± 15 to 5V. Thus, for the same power-supply rejection ratio and the same power-supply-voltage tolerances, the effect of power-supply variations on the signal levels may actually diminish. This point may be a subtle one, considering the extent to which digital supplies generate spurious signals that disrupt the operation of analog components and raise the level of the noise floor. Nevertheless, with careful design—especially adherence to device performance limits—a lower-voltage single-

supply system has the potential to perform just as well as a higher-voltage dual-supply system, despite reduced signal levels.

Consider op amps and data converters

Manufacturers of linear components have long recognized the trend to single-supply systems. Hundreds of linear components are now available, ranging from filters to switches to RS-232C drivers and receivers. Focusing on the basic linear categories of amplifiers and data converters provides a broad overview of single-supply components, definitions, and design techniques. Many initial and so-called "single-supply" parts had shortcomings, the best example of which is a single-positive-supply DAC that required a negative volt-

The single-supply vs standard op-amp debate

Using amplifiers in single-supply applications generates more questions than using other types of components. The most commonly asked question is whether—and if so how—you can use a $\pm 15V$ op amp in a single-supply situation.

The answer is yes, *if* that op amp has the input and output range—including head room—you need. Standard op amps don't know where ground is. Any op amp with the proper input range for your signal can work in single-supply applications as long as you bias the input so that your signal's range matches the device's input range. You can use any number of standard op amps if your single-supply voltage is 12 or 15V and your signal swings are commensurate with the input and output ranges of the device.

However, as you lower the supply voltage to 5V, the head room that most bipolar-supply op amps require reduces those ranges to the point where you're left with no useful signal swing. In a 5V single-supply circuit, the limited common-mode range and output swing of standard

op amps become liabilities.

Two op-amp manufacturers that don't have extensive single-supply offerings—Burr-Brown has one single-supply op amp and Comlinear has none—field many questions about using their op amps in single-supply situations. A Burr-Brown application note (Ref 1) describes several biasing schemes, and application engineers at Comlinear will explain how to use the company's current-feedback amplifiers in single-supply applications.

When using current-feedback op amps such as Comlinear's CLC401 (\$8.70), you have to be careful not to compromise the part's speed by limiting the voltage. For example, a total supply voltage less than 10V will slow the performance of the part. Exceeding the op amp's output voltage range will result in internal saturation, which in all cases results in very slow recovery time from overdrive. Each op-amp input may have different limits on how close it can come to the supply voltage. In essence, however, these types of limitations are no different from those you should

look out for when evaluating any amplifier.

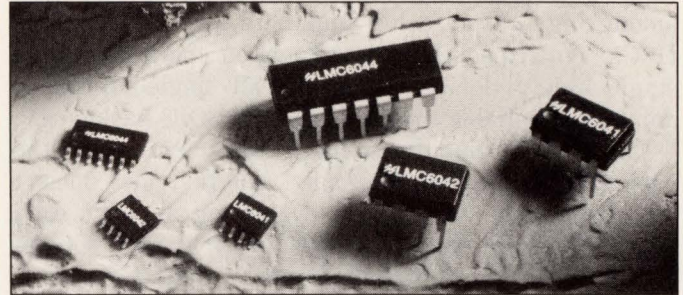
The underlying issue in the single-supply vs standard op-amp debate is how important buying a part specified for the way you plan to use it really is. Manufacturers of single-supply devices—including those that also produce standard op amps—maintain that if you're going to power a device with 5V, you ought to buy a part specified for 5V operation. The best 5V op amps are those specifically designed to work at that voltage, these companies say. Manufacturers warn against reading data sheets between the lines and say that assuming performance tested at $\pm 15V$ will be the same at 5V is a bad practice.

Fortunately, many manufacturers do test and specify single-supply components at 5V, but few do so at a single 12 or 15V. If a device's data sheet doesn't provide the information you need, ask the manufacturer. Don't be shy. Pin manufacturers down on the specs, and push them to tell you how the part operates under nonideal conditions.

age reference. Many early single-supply op amps had limited output ranges, which rendered them useless in certain output-drive situations.

Now, however, the number of amplifiers, comparators, and data converters tailored for single-supply operation that have useful input and output ranges is growing rapidly. **Table 1** lists manufacturers of basic linear components. Analog Devices and its newly acquired Precision Monolithics Division, Harris Semiconductor, Linear Technology, National Semiconductor, Maxim Integrated Products, Motorola, and Texas Instruments all have a wide range of product offerings. Each company has been actively designing and announcing new devices with single-supply operation as one salient feature.

You have a wide choice of amplifiers and A/D converters, especially of low-power op amps. A variety of precision op amps are available, featuring supply currents in the 10- to 100- μ A range (**Fig 1**). The speed of single-supply op amps extends from precision levels



Small size is crucial for portable instruments, and most single-supply op amps comply. The LMC604x series from National Semiconductor includes single, dual, and quad devices that are available in 8- and 14-pin SOICs and DIPs. Prices start at \$0.75 (100).

to Elantec's EL2243 (\$7.67) 90V/ μ sec decompensated op amp to Philips-Signetics' NE5209N (\$14.27) wide-band, variable-gain amplifier with a bandwidth of 85 MHz. (Unless otherwise noted, all prices in this article are for quantities of 100.) Fewer choices exist in the higher speed range, just as there are fewer choices

Table 1—Manufacturers of basic linear components designed for single-supply operation

Manufacturer	Op amps	Comparators	ADCs	DACs	Features/Comments
Advanced Linear Devices Inc	*	*			Rail-to-rail operation. CMOS.
Analog Devices Inc	*		*	*	Broad range of products including precision and micropower devices from the Precision Monolithics Div.
Apex Microtechnology Corp	*				High power.
Brooktree Corp			*		8-bit video ADCs.
Burr-Brown Corp	*				One precision, low-power, dual op amp.
Datel Inc			*		Video speed ADCs.
Elantec Inc	*				High speed.
Fujitsu Microelectronics Inc	*	*	*	*	Video speed converters.
GEC Plessey Semiconductor			*	*	Wide selection of low-cost (starting around \$3) and low-to-medium performance converters. Also RF products.
Harris Semiconductor	*	*	*	*	Broad range of products.
Hitachi America Ltd			*	*	Video speed, flash ADCs and 20 to 50-MHz DACs.
ILC Data Device Corp			*		One special-purpose device, a monolithic tracking resolver and LVDT converter.
Linear Technology Corp	*	*	*		Wide product line including precision and micropower devices.
Maxim Integrated Products	*	*	*	*	Wide product line.
Micro Linear Corp			*		Wide range of serial and microprocessor-compatible 8-bit ADCs.
Motorola Inc	*	*	*	*	Wide range of products available from both the MOS and bipolar product divisions.
Natel Engineering Co Inc			*		Special-purpose converters: hybrid 16- and 22-bit resolver-to-digital converters.
National Semiconductor	*	*	*	*	Wide product line.
Philips-Signetics	*				Low-voltage op amps, RF products.
SGS-Thomson Microelectronics Inc	*	*			Micropower emphasis.
Sipex Corp				*	Monolithic 12-, 14-, and 16-bit DACs that operate from 15V supplies.
Sony Component Products Co			*		Video speed ADCs.
Teledyne Components	*		*		Chopper-stabilized op amps, LCD-driver ADCs.
Texas Instruments	*	*	*		Wide range of products including low-power, precision, and low-noise devices. Micropower comparators.

Not only do you have to combat a familiar problem in mixed analog-digital systems—digital power-supply noise—but you have less signal with which to combat the noise.

among high-output-drive amplifiers and single-supply DACs. Small packaging is a common characteristic of single-supply devices. Virtually all single-supply op amps are available in small DIP and SOIC packages.

The wide availability of these components eases the design of single-supply circuits, but that fact doesn't let you off the hook when evaluating a part's data sheet. The front page of a data sheet may tout "single-supply operation," but manufacturers' definitions vary. Even if all manufacturers' definitions matched, you'd still have to look at the guaranteed specs on the data sheet. Obviously, the very least you can expect from any single-supply component is that it will operate within the manufacturer's stated power-supply limits.

In the case of data converters, however, you can take the operational definition at face value. Single-supply A/D converters cover a wide speed and precision range, from the signal-conditioning 8-bit AD670 (\$7.20) from Analog Devices to the video-speed ADCs available from several manufacturers in **Table 1**. Probably the most typical 5V ADC is the serial I/O, μ P-compatible type. Conversion rates for these ADCs range from 13 to 20 μ sec. In the case of the 12-bit LTC1290 (\$12.95) series from Linear Technology and the 10-bit ADC103x (\$8.90) series from National Semi-

conductor, these converters can include input multiplexers and S/H amplifiers. The input-signal range is a key specification for A/D converters, and the accompanying voltage reference largely determines it.

Examine voltage needs of supporting devices

Fewer DACs than ADCs work under single-supply constraints. The output swing of a DAC is an important specification. Unfortunately, many CMOS multiplying, current-output DACs, which by themselves do operate from a single positive supply voltage, require a negative voltage reference to generate a positive output. Voltage-output DACs need no positive supply. Another single-supply DAC liability to watch out for is that some devices aren't TTL compatible over their entire power-supply range. Also, the manufacturer may not specify the interface timing for the supply voltage you intend to use.

A limiting factor when exploiting the entire range of any 5V-powered data converter is the small supply of 4V references. More of these references are beginning to appear. Linear Technology's LTC1019 4.5V (\$3.90) reference is one example.

The definition of a single-supply op amp is more complex than the operational definition for data con-

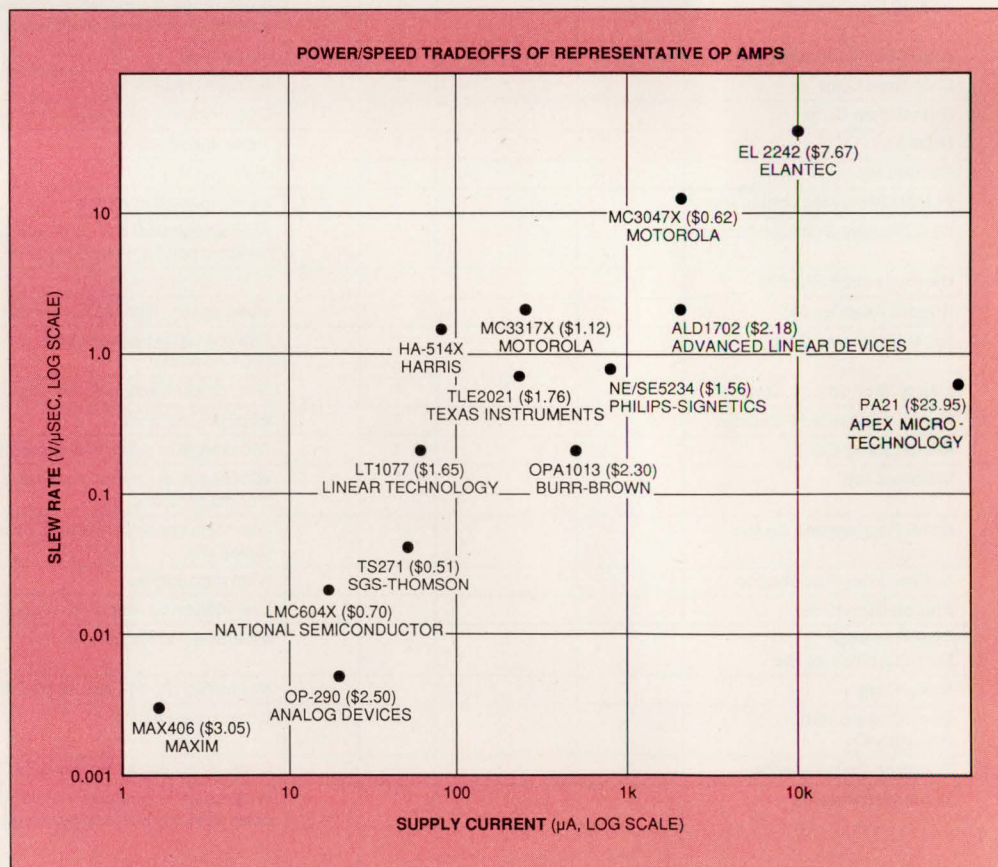
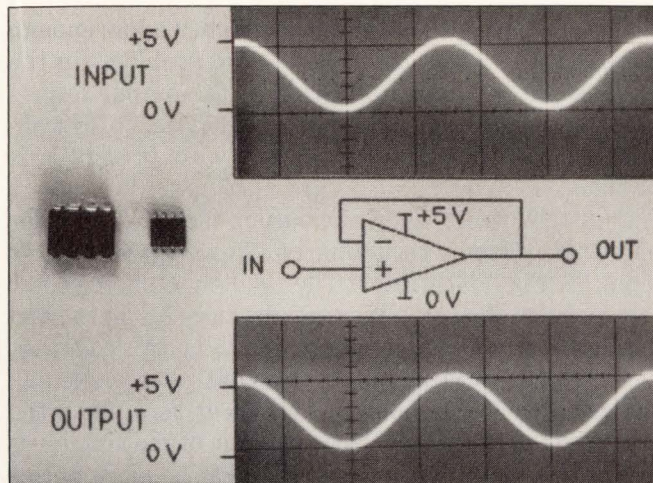


Fig 1—Although the general shape of this power-speed curve is no surprise, the curve places the operational power and speed ranges of representative single-supply op amps into perspective.



Several single-supply op amps have outputs that can swing to both power-supply rails, but few op amps' inputs can swing rail to rail. Advanced Linear Devices' CMOS op amps are one exception.

verters. The single most defining characteristic of a single-supply op amp is that its input can swing to the negative supply rail, which by definition is equal to ground in a single-supply system. Put another way, the op amp's common-mode input range must include ground. Comparators have similar restrictions on their inputs to suit single-supply operation.

This signal-swing characteristic doesn't necessarily apply to the output of a single-supply op amp. However, the outputs of many of the newer op amps can swing to ground, and more op-amp manufacturers include this capability in their single-supply parts. Comparing the output swings of various devices can be tricky. The outputs of some op amps need a pull-down resistor to help them along. Also, the output swing always depends on the load or the amount of sink current. A more precise definition of output swing, then, is the output swinging to ground while sinking current. Linear Technology and other manufacturers subscribe to this definition.

Keep in mind that swinging to ground is relative. The exact numbers that correspond with an amplifier's lowest input voltage varies. The highest power-output amplifier in **Table 1**, the PA21 (\$23.95) from Apex Microtechnology, can deliver 3A of peak current but has an input that can go only to within 300 mV of ground. Other device data sheets guarantee operation all the way down to ground or to within a few millivolts or a few hundred microvolts of ground. In a few cases, the guaranteed operation extends beyond the supply rails. The common-mode input range of Philips-Signetics' NE/SE5234 (\$1.56) quad, low-voltage op amp extends 250 mV beyond the supply rails. When driving a 600 Ω load, the NE/SE5234's output swings

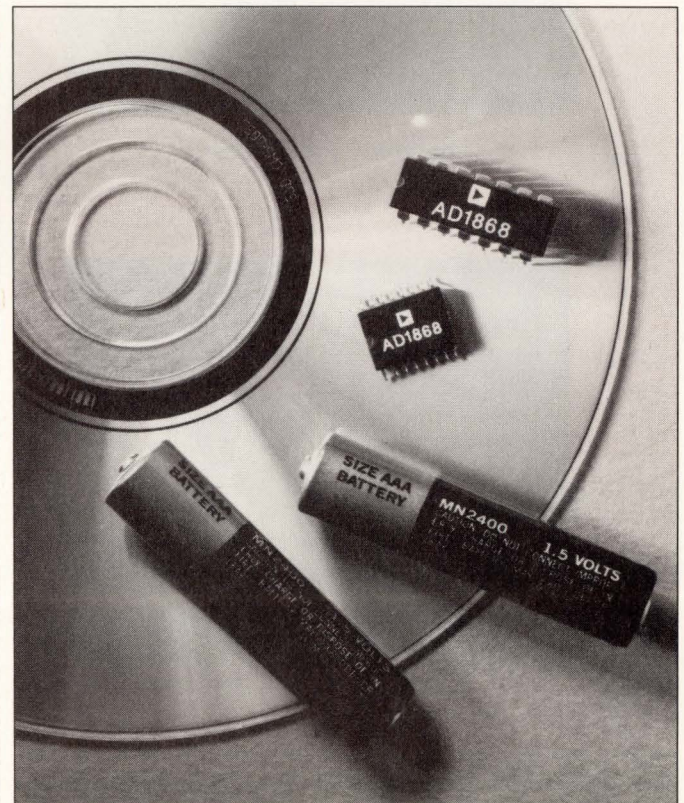
to within 250 mV of the rails. While sinking 100 μ A, the LT1077 (\$1.65) from Linear Technology is guaranteed to swing to within 130 mV of ground.

Rail-to-rail operation represents one more performance step for single-supply op amps. The output of a rail-to-rail op amp can swing from ground to the positive supply rail. The output swing is typically a limiting factor in single-supply designs, so rail-to-rail operation can be a real advantage. National Semiconductor has three families of rail-to-rail, single-supply op amps: the LMC/LPC660 quad (\$.90 to \$1.27), LMC/LPC662 dual (\$.80 to \$1.27), and the LMC6041/2/4 (\$0.70 to \$2.20) devices. Texas Instruments and Harris also have rail-to-rail output op amps.

The term "rail to rail" refers to the output of an op amp, but not necessarily—in fact, rarely—to the input. Two exceptions are Advanced Linear Devices' family of CMOS op amps and Philips's NE/SA5234. Both the inputs and outputs of these devices can swing from ground to the positive supply.

Failure protection prevents disaster

Once you've found an op amp that meets your basic performance requirements—input range, output swing, power, and speed—looking at what happens



Single-supply operation often goes hand in hand with battery-powered operation. Analog Devices' 18-bit DAC suits portable, audio applications.

Single-supply linear design

when your circuit violates a part's rated specifications, especially at the input, is essential. If your circuit violates guaranteed specs, the change in these op amps' behavior can be drastic. Unfortunately, a higher probability exists that your circuit will violate the input condition of a single-supply op amp than, for example, the specs of a device working from bipolar supplies. If your input-signal levels are near ground, any negative-going spikes riding on those signals can violate the input range.

Two potential problems that can occur when the input level exceeds an op amp's specs are phase reversal and, in dual and quad devices, crosstalk. In phase reversal, which Fig 2 illustrates, the output abruptly

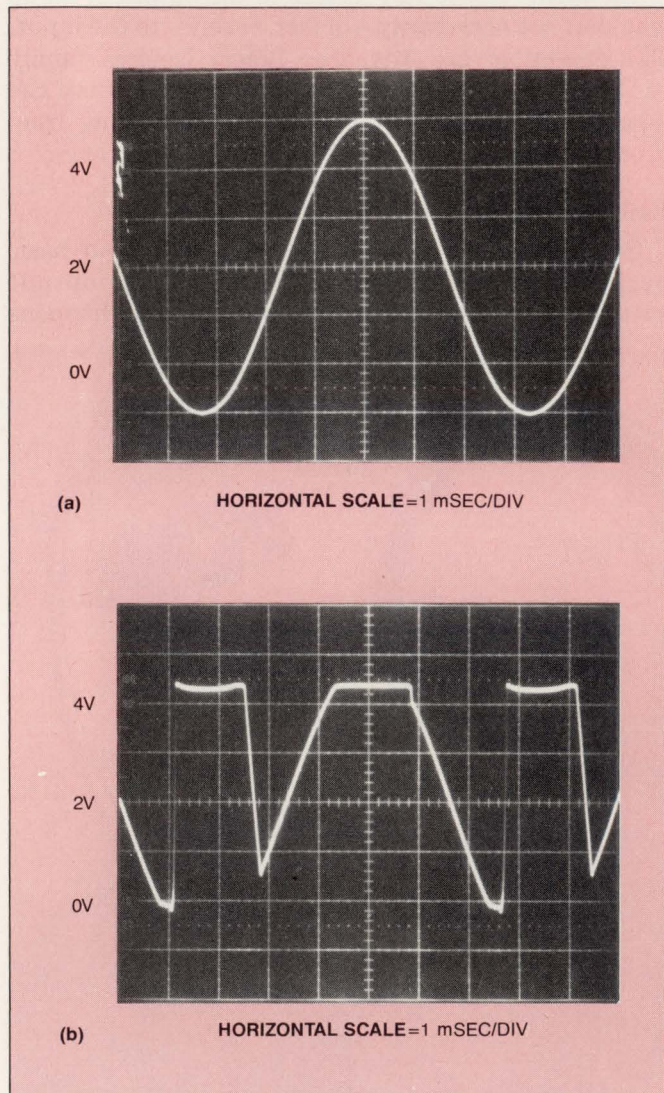


Fig 2—A single-supply circuit is likely to violate the input and output ranges of single-supply op amps, so investigate how the devices deal with such violations. The problem of phase reversal, demonstrated here when the input goes below ground, can trip up drive circuitry.

changes polarity when the input reaches a low enough point. This reversal can cause severe problems in the drive circuitry. The LT1077 clamps the output to prevent phase reversal. Texas Instruments' line of Excalibur op amps also includes circuitry to prevent this problem.

Crosstalk occurs when one output of a dual amplifier picks up problems occurring on the other amplifier's input, as Fig 3 illustrates. The two scope photos show two different dual amplifiers operating with one ac and one dc input, both of which violate each part's common-mode range. Both amplifiers prevent phase reversal; the outputs of each amplifier clamp at zero when the inputs go below ground. However, one of the amplifiers in Fig 3b's dual package outputs errant square pulses because the sine wave violates its companion amplifier's input.

All of Elantec's amplifiers, including the company's two high-speed, single-supply devices, prevent crosstalk because of their dielectrically isolated fabrication. Junction-isolated processes can't prevent the spread of carriers that disperse when an input stage saturates, however. The collectors of other transistors on the IC act as receivers of these carriers and can cause errors and abnormal device behavior. If you're using dual or quad devices, be extremely careful to characterize your input signals and add safety margin if necessary.

Crosstalk and phase reversal are problems you'll discover in testing—or worse yet, production. You can sometimes avoid these problems by checking the devices' data sheets. Reading every data sheet with the following check list in mind can help you determine if a part will fail gracefully. In many cases, manufacturers address these issues in the application information included in data sheets. If not, press the manufacturer for more information. Ultimately, your own breadboarding and analysis is the only fail-safe test.

- How has the IC designer protected the part against fault conditions?
- How fast does the device recover from overloads?
- Is the device monotonic; that is, do increasing inputs produce only decreasing outputs?
- What is the device's transient response?
- What happens when input signals are present before the power-supply voltages?
- What happens as the supply voltage comes up?

In addition to the answers to these questions, the minimum operating range of the part will indicate the part's range of predictable behavior. Unfortunately, you may not have to violate guaranteed specs to see anomalous behavior. A single-supply op amp may not maintain its performance specs through its entire rated

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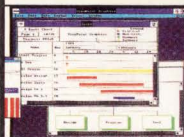
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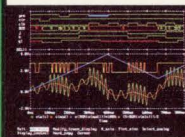


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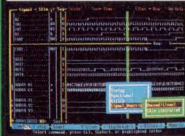
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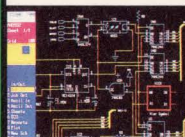


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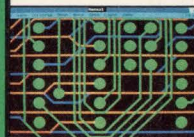


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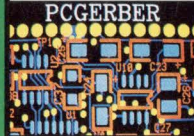
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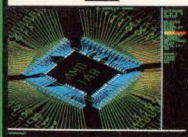


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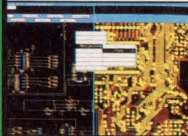
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Single-supply linear design

input and output range. For example, a component operating near its output-voltage-range limit may exhibit nonlinearities and show signs of distortion due to transistor voltage saturation. Allowing yourself some safety margin on the output swing will keep your signal safely within an amplifier's linear region.

Create a new concept of ground

Possibly the most important adjustment you must make when designing single-supply circuits is to your concept of ground. In single-supply systems, ground and the negative-supply rail are one and the same. Thus, ground can no longer serve as a convenient reference point—unless you design exclusively with unipolar signals—because input signals can't swing lower than ground. Also, signal ground and the power-supply return are one and the same. Ground now carries real current.

In some cases, you can use ac coupling to get around the need for input biasing, but this technique isn't an option for instrumentation equipment that measures absolute levels. Ultimately, you must consciously decide what voltage level to call "zero signal." This point will be your circuit's virtual, or pseudo, ground point.

Using resistive dividers or discrete voltage references are two ways to generate the new reference point for your circuit. The down side of bias schemes

is that the additional components consume more power. The precision of the new reference point is critical to your circuit's operation. Buffering the resistor divider or reference is usually necessary; the buffer must be able to run from your single supply's voltage. Linear Technology's LT1010 (\$2.50) power buffer can operate from a power supply as low as 4.5V. You can team this part with a few resistors and capacitors to generate a supply splitter that can source or sink 150 mA. Pseudo-ground references that both sink and source current help the circuit recover quickly from load changes.

A component that reduces the number of external parts necessary to generate a new ground is Texas Instruments' TLE2425 (\$0.69 (1000)) "virtual-ground" device. The device combines a micropower amplifier and reference to provide a stable 2.5V reference for 5V systems. It comes in a 3-terminal TO-226AA or 8-pin SOIC package and draws a maximum of 250 μ A. The device can typically source and sink 20 mA. The company has plans to introduce a number of these virtual-ground products for 9, 12, and 15V rails.

These biasing approaches were created under the assumption that you want to choose some midpoint operating range; for example, a 2.5V reference for a 5V-powered circuit. However, adding so much bias isn't always necessary. Biasing the input by a diode

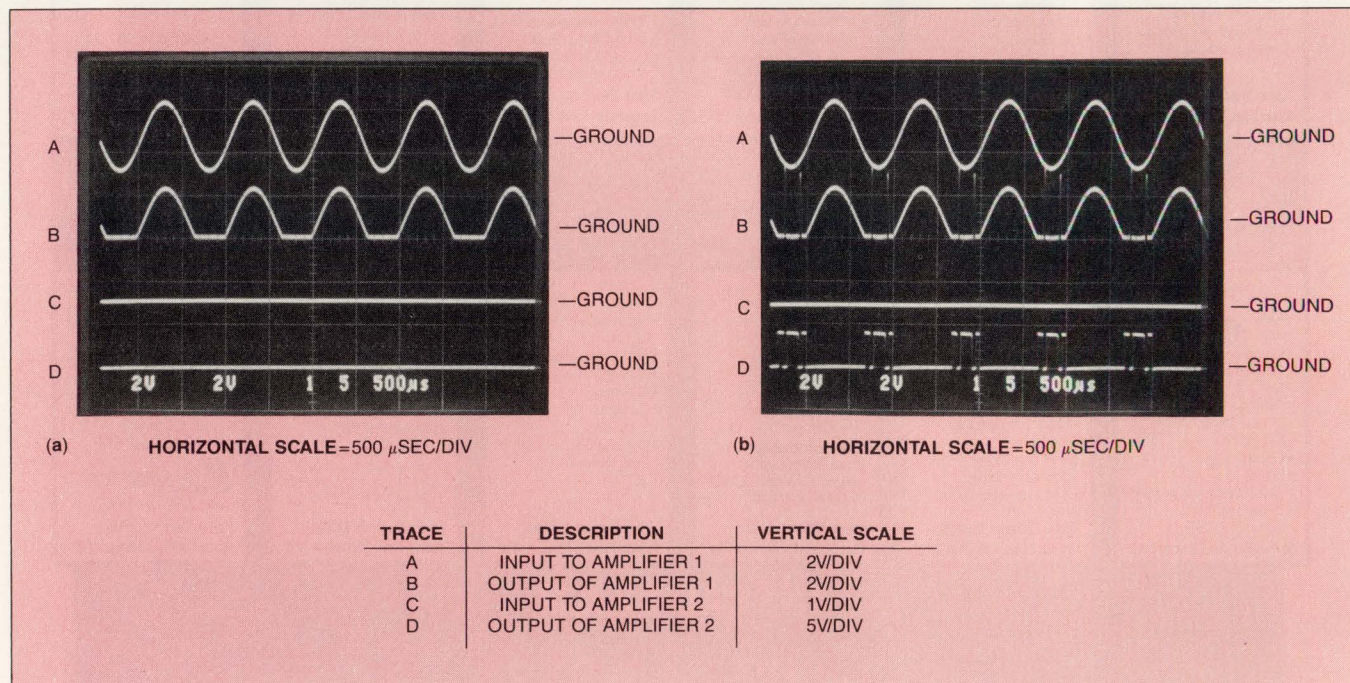
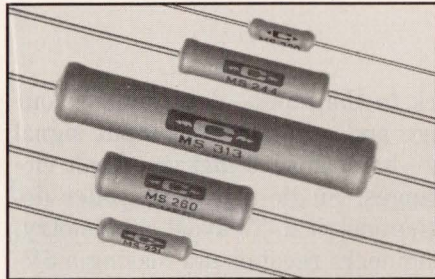


Fig 3—Violating the input range of one amplifier of a dual or quad op amp can cause problems for the other amplifiers. These photos show the response of each amplifier of two different dual op amps to a sine wave and a dc signal that violate the devices' common-mode input ranges. In a, both amplifier outputs clip at ground when either input is below ground. The output of the first amplifier in b also clips to ground when the sine wave goes below zero. However, the violation at this amplifier's input causes some strange signals to show up at the output of the second amplifier.

New

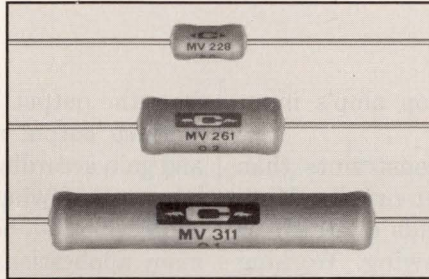
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For Type MS data, circle number 101

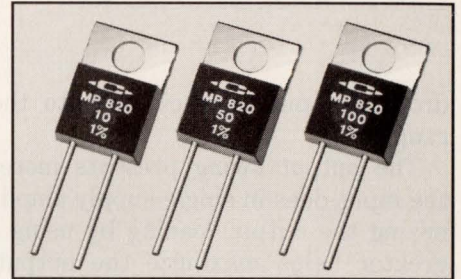
Type MV Low Resistance Power Film Resistors



- Resistance Range of 0.1 Ω to 50 Ω**
- **Non-Inductive Design** with power ratings from 1.5 Watts to 10 Watts
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 - Tolerance of 1%, 2%, 5% or 10%
 - Max. Operating Temperature of 275°C

For Type MV data, circle number 102

Type MP Kool-Tab® Power Film Resistors



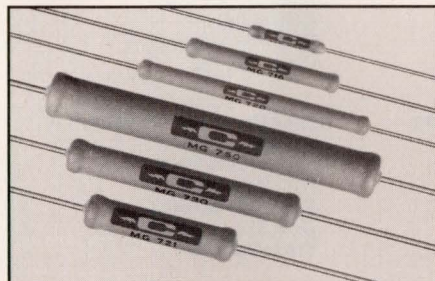
- 20 Watts in the TO-220 Package**
- **Non-Inductive Design**
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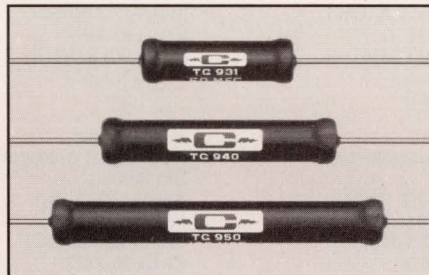
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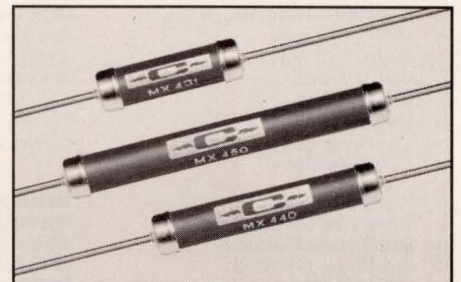
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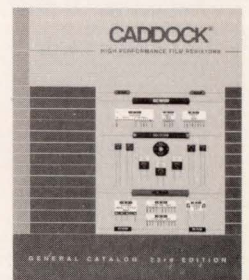
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Single-supply linear design

drop may put your circuit into the op amp's input range.

The output swing presents more constraints than the input does in single-supply amplifier circuits. Minimizing the output loading by using loads of 10 k Ω or greater helps maximize the output swing. Working

from the output back to the input—determining your working output range and adjusting the input signal and gain accordingly—helps ensure that you won't violate output-swing ranges. Single-supply amplifier designs will often be asymmetrical. To avoid asymmetry, many applications engineers recommend biasing a 5V-

Manufacturers of linear components

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

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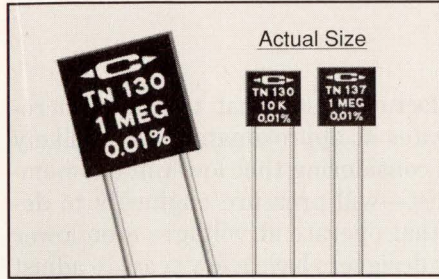
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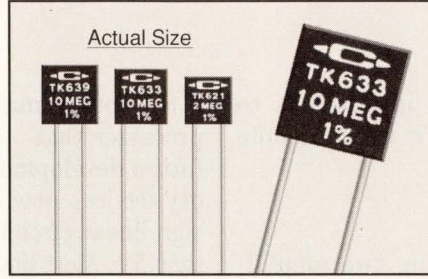
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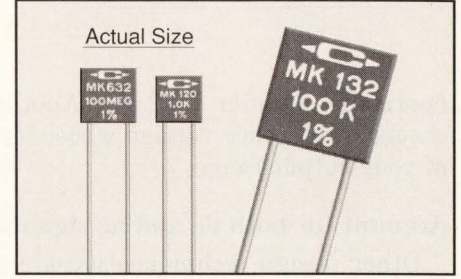
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Type MK Precision Power Radial-Lead Film Resistors

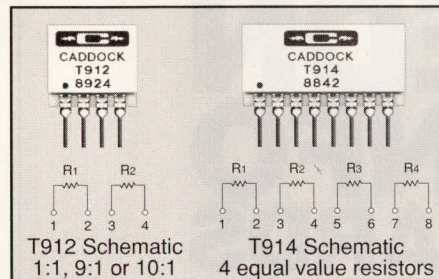


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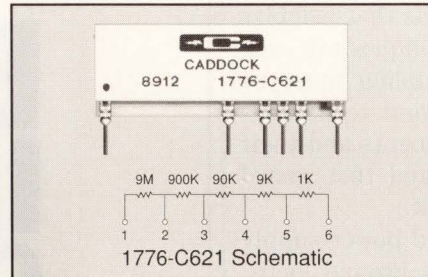
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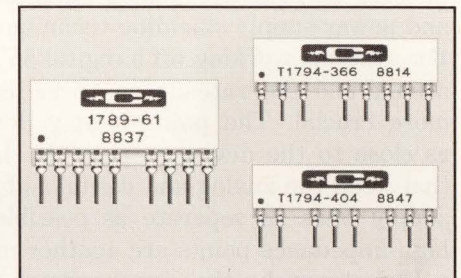
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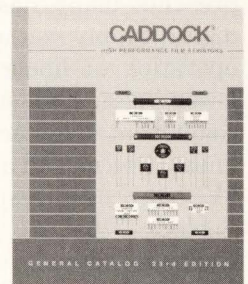
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Single-supply linear design

operated amplifier to 2.5V. Another approach is to choose a reference voltage whose level is in the middle of your output range.

Account for both dc and ac signals

Other design techniques include using two amplifiers: the first to perform a level shift and the second to perform the actual amplification. If you need special input and output characteristics, such as low offset or rail-to-rail output swing, you can choose two different amplifiers to accomplish the task. Using noninverting gain stages takes advantage of the fact that most single-supply op amps operate at the negative supply potential. Alternating complementary stages can widen the operating voltage range. Alternating stages means that you reference the first stage to the negative supply voltage, which inverts the signal for the next stage. Reference the next stage to the positive supply voltage, and so on. Terminating output loads to ground helps the amplifier obtain the greatest voltage swing.

Layout techniques are critical

The final, but most important, design suggestion applies to all sensitive analog circuits: Good grounding and power-supply shielding techniques are imperative. For systems working off a digital 5V bus that wobbles around and generates noise, these techniques are even more crucial. The power-supply decoupling must be as close to the device as possible. Layout techniques that keep the analog and digital components and their supply lines as separate as possible and that guard high-impedance points are another must.

Unfortunately, the signal current and power-supply return current can intermix and cause ground loops. For low-frequency designs, connecting all the grounds together at just one point reduces the chance of ground loops. However, as circuits increase in frequency to the audio range—anywhere between 100 and 1000 Hz—the inductances in these long ground connections become too dominant. For audio and higher frequencies, using a heavy ground plane is necessary.

The problem of analog and digital circuits sharing the same power source, and a low-voltage one at that, presents many design challenges. Because standard digital supply voltages have such an influence over the operation of linear circuits, you might expect even lower voltage constraints in the future. Some linear-component manufacturers express doubt that standard linear devices will operate at voltages much lower than 5V, but others—especially companies, such as Philips-Signetics, that are involved in the RF communications business—already offer single-supply parts that operate at 2V.

Still other manufacturers say that the first microprocessor that operates at approximately 3V—a likely future development considering that low-voltage memory devices now exist—will pressure engineers to design linear circuits that operate at voltages even lower than 5V. Most linear designers have a few years to adjust to single-supply constraints and circuit techniques without worrying too much about that eventuality.

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Reference

1. *The Handbook of Linear IC Applications*, "Single-supply operation of operational amplifiers," Burr-Brown Corp, 1987, pg 202.

Acknowledgment

Many thanks to Linear Technology and Elantec for providing scope photos.

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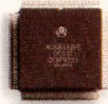
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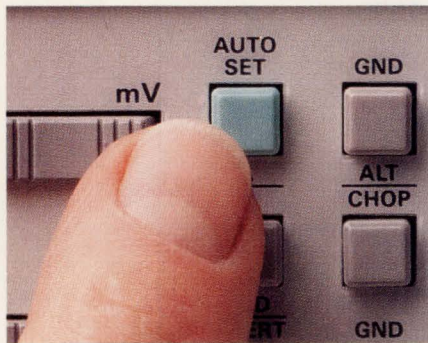
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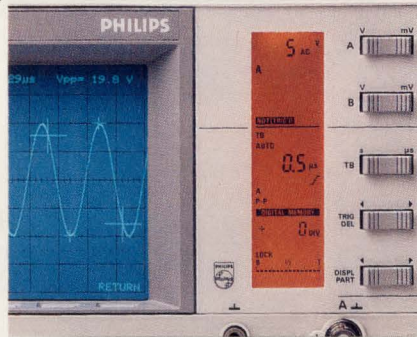
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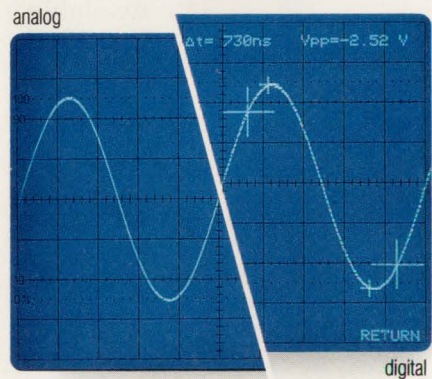
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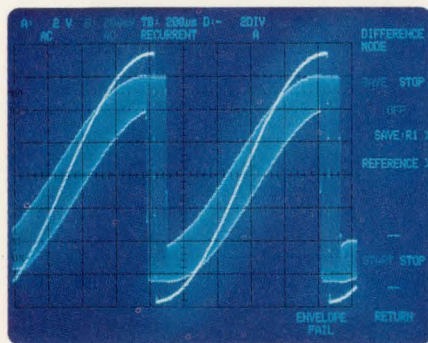
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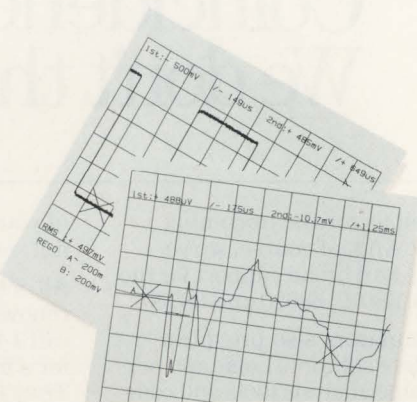
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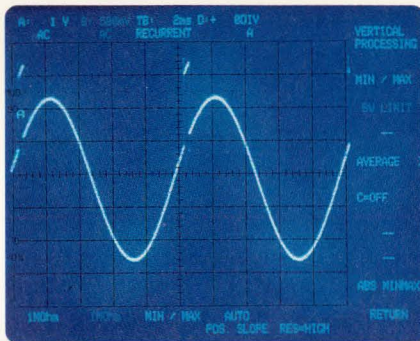
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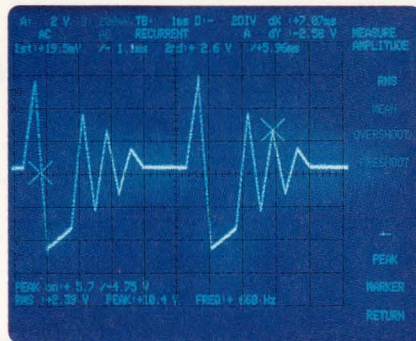


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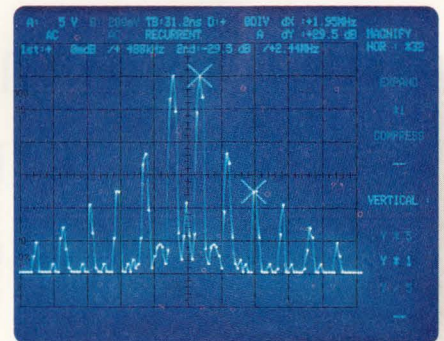
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Patience and reason solve digital-system debugging problems

When a bug strikes your digital system, try to suppress panic and approach the task systematically. Deductive digital debugging can help you find and eradicate any digital bug infestation.

Ronald M Jackson, *Fascinating Electronics*

When a bug turns up in a prototype, engineers are under considerable pressure to fix the problem quickly. I've seen engineers respond to this pressure with panic. The further behind schedule the project is, the deeper the panic. A panicked engineer is likely to wiggle components in their sockets, to apply freeze spray liberally, perhaps to swap a few ICs, and then, in desperation, to drag up an oscilloscope and probe about randomly. But if the problem is complicated, panic rarely leads to a quick resolution. An engineer in a state of panic may not realize how to solve his problem until days later—perhaps while he is in the shower just thinking about the problem. Complicated problems require less panic and more thought.

Richard Feynman, the Nobel prize-winning physicist, in his autobiography (**Ref 1**) recounts how, as a young boy, he repaired a radio by thinking:

"When we got there, I went over to the radio and turned it on. The thing began to roar and wobble—WUH BUH BUH BUH BUH—a tremendous amount of noise. Then it quieted down and played correctly.

So I started to think: 'How can that happen?' I started walking back and forth, thinking, and I realized that one way it could happen would be if the tubes were heating up in the wrong order—that is, the amplifier's all hot, the tubes are ready to go, and there's nothing feeding in, or there's some back circuit feeding in, or there's something wrong in the beginning part—the RF part—and therefore it's making a lot of noise, picking up something. And when the RF circuit's finally going, and the grid voltages adjust themselves, everything's all right. So the guy says, 'What are you doing? You come to fix the radio, but you're only walking back and forth!' I say, 'I'm thinking!'"

"Then I said to myself, 'All right, take the tubes out, and reverse the order completely in the set.' So I changed the tubes around, stepped to the front of the radio, turned the thing on, and it's as quiet as a lamb; it waits until it heats up, and then plays perfectly—no noise. When a person has been negative to you, and then you do something like that, they're usually a hundred percent the other way, kind of to compensate. He got me other jobs, and kept telling everybody what a tremendous genius I was, saying, 'He fixes radios by thinking!'"

I call this approach of bypassing the panic stage and thinking right from the start "deductive debugging." Like Dr. Feynman's customer, your manager may ask you why you aren't busy fixing the problem. At that point, you may be tempted to reach for the freeze spray. Before you do, consider the advantages of deductive debugging. Deductive debugging gives you an orderly plan of attack and consistently kills bugs. It

The most credible method of proving a theory is to capture the fault behavior as it occurs and to display the erroneous signals on a test instrument.

will inevitably lead to the real cause of the bug. The panic method won't work on complicated problems; deductive debugging will work on all problems. And you won't just seem to fix the problem, you will prove the cause of the bug. Deductive debugging will increase your reputation for mastery of both your product and its technology.

Steps in deductive debugging

Deductive debugging can be summarized as five basic steps (Fig 1). First, encourage and characterize the problem. Second, brainstorm possible causes. Third, propose a testable theory. Fourth, test the theory. Fifth, when the theory identifies an exact cause, implement and verify a fix.

For effective debugging, the bug should occur at a reasonable rate. A problem that occurs infrequently, every day or so, can really slow down your debugging efforts. What was the prototype doing before the bug showed up? Can you repeat that condition? Try increasing system activity, looping on challenging diagnostic tests, changing input conditions. You can use deductive debugging on a system that fails only once every few days (and, in fact, deductive debugging may be the only way to find an elusive, intermittent bug), but the process may take quite a while if you have to loop many times to test your theories.

To characterize the bug, collect observations about how the bug reveals itself, about the input/output conditions and prototype activity around the time the problem appears, and about possible outside influences on the prototype. These are your clues; be alert and thorough.

Brainstorm possible causes, spending a few minutes to create a list of all the causes you can think of. Then go back over the list and create one theory to test. If you have lots of clues, they may tend to rule out some possible causes and point to others. Your theory may combine several possible causes, in which case you will have to refine it further if it is proven true. The most important consideration is that the theory should be testable—the less ambiguously you can prove a theory true or false, the more useful the theory will be.

Test the theory. Perform an experiment to determine whether the system behaves as the theory predicts. The most credible method of proving a theory is to capture the fault behavior as it occurs and to display the erroneous signals on a test instrument.

In general, testing the theory by simply swapping parts is a bad idea. If you get a system running by

replacing a part whose timing or drive capabilities are marginal, you may put a marginal design into production. A better approach is to design out the sensitivity to marginal components. Unless you do so, you are likely to encounter problems when batches of parts that have varying characteristics appear in later production lots.

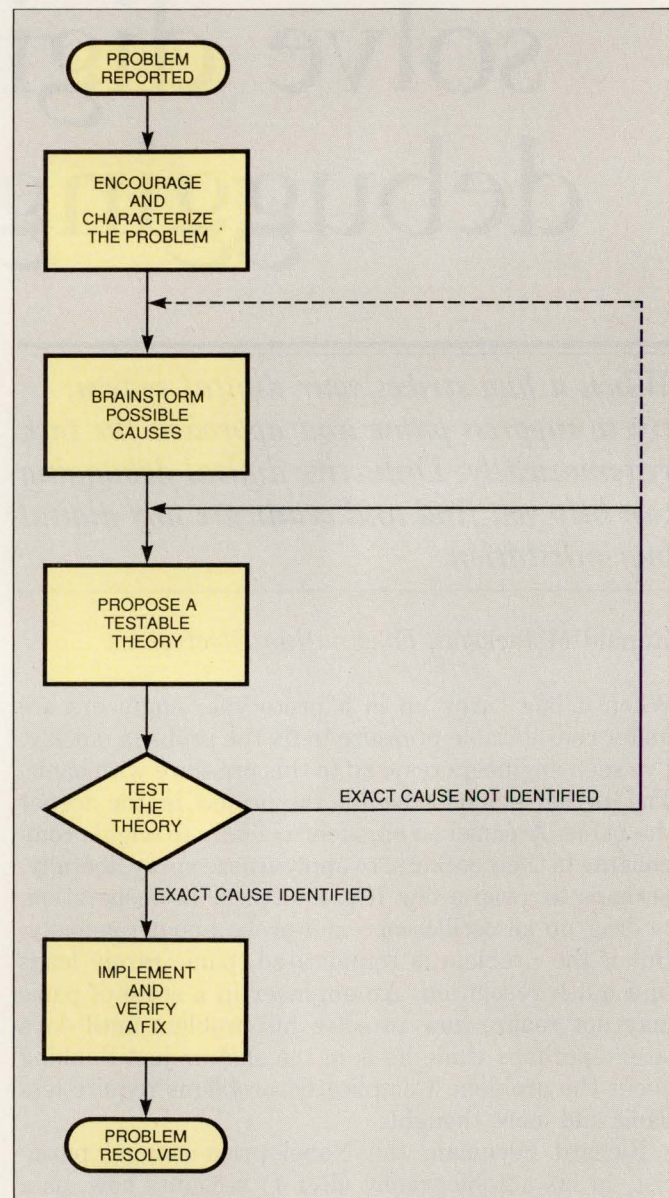


Fig 1—Deductive debugging is usually an iterative process. You try to explain what you observe, construct experiments to prove or disprove your hypothesis, and, unless experiments verify your theory, you try again. Only when experiments seem to prove you right, do you implement corrective measures.

For digital debugging, you should be able to sample the inputs and the outputs of suspect circuitry simultaneously. Because digital problems that recur may not always show up in exactly the same way, your test instrument will need to capture single-shot events. Quite often, problems in digital systems are truly one-in-a-million occurrences, so you need to focus on finding a way to trigger on the failure. Your instrument probably won't fortuitously sample system activity at the moment a failure occurs.

The ideal digital debugging tool is a logic analyzer with a fast sample rate, deep acquisition memory, and the ability to trigger on the kinds of logic and timing problems that you are solving. The logic analyzer used in the following example is a Tektronix Prism 3000 with a hardware-analysis module. This analyzer is well suited to digital debugging. In addition to high speed, deep memory, and flexible triggering, it has dual-threshold sampling (separate thresholds for logic 1 and logic 0). The analyzer's triggering is flexible, and setting up the trigger conditions is not difficult.

Let's follow the process of deductive digital debugging through a practical example. A digital system (Fig 2) samples many signals simultaneously. These signals have a randomly varying time relationship with the system clock; that is, they are asynchronous with the clock. Based on these inputs, one of two values will be selected, A or B. Depending on the selection, either A or B will become the new memory address. The memory will then yield new A and B addresses as well as other control signals. An address-readback cir-

cuit, operating under software control, samples the current address at relatively infrequent intervals.

The problem is that the address-readback software occasionally reports that the address makes momentary jumps to illegal values.

Characterize and encourage the problem

Because the address-readback software is unable to check the address at the system's full rate, many cycles of system activity are missed between software accesses. You can encourage the problem to appear by changing the software. Change the software so it programs the random-access memory to cause illegal addresses to command both the A and B values to access the same address—the current illegal address. With this change, *any* illegal address will cause the system to hang at one particular illegal address. Now you will not miss any illegal-address errors.

When fast asynchronous input signals are applied, the system fails, usually in less than a minute. When slower asynchronous signals are used, the system may run for periods of several minutes to hours before it fails. Also, certain patterns in the memory will make the system seem to be relatively immune to failures, whereas other patterns are likely to produce illegal addresses.

Your next step is to brainstorm possible causes: The memory could have soft bit errors in certain locations, which would explain the pattern sensitivity. Some of the components might be noise sensitive, so when the patterns being sent to memory are changing rapidly,

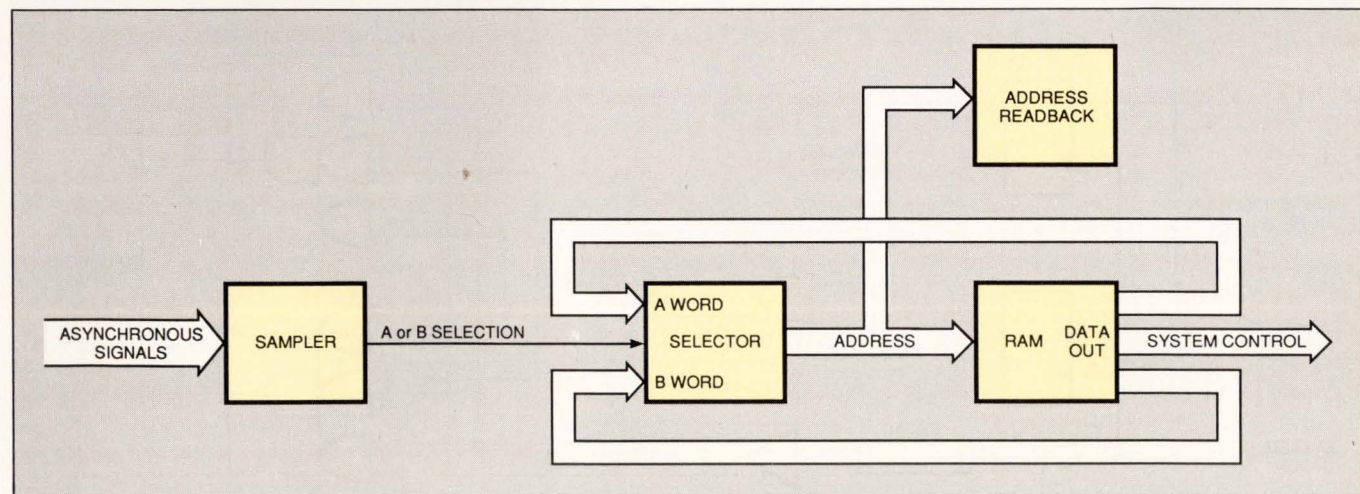


Fig 2—You can test the deductive approach on this random-access-memory-based state machine. Data appears asynchronously with the system clock. The sampler synchronizes the data and presents it to the word selector, which provides memory addresses. The data contained in the corresponding memory locations then forms part of new memory addresses.

If you get a system running by replacing a part whose timing or drive capabilities are marginal, you may put a marginal design into production.

noise could be corrupting the address. Or perhaps this noise is causing the data in the memory locations to change. Maybe there is a timing error in the sampler or the address multiplexer, so the address is being corrupted in the selection process, possibly because of inadequate timing margins or metastability in the input sampling.

You should soon note a pattern emerging here: You propose a theory and test it, which leads you to propose—and test—another theory, and so on. You begin by postulating the theory that, for some reason, the memory is putting out incorrect A and B addresses in response to correct address inputs. (This theory covers several possibilities, including a defective memory device and noise in the system. If this theory proves true, you will need to isolate the cause further.)

To test this theory, you connect a logic analyzer to the memory inputs and outputs. You set the analyzer to trigger if the memory receives an illegal address. In this example, you find that the address going to the memory is illegal even before the memory responds with an illegal address. This failure throws suspicion on the sample-and-selection circuit (Fig 3).

This circuit presents a vast array of possible failure mechanisms. The system clock is a narrow pulse that clocks the sampling flip-flops and is delayed to form strobes that enable the OR-AND gates to pick up a new address. The choice of the A or B address depends on the state of the selection signals at the time of the address and latch strobes. Imagine the potential prob-

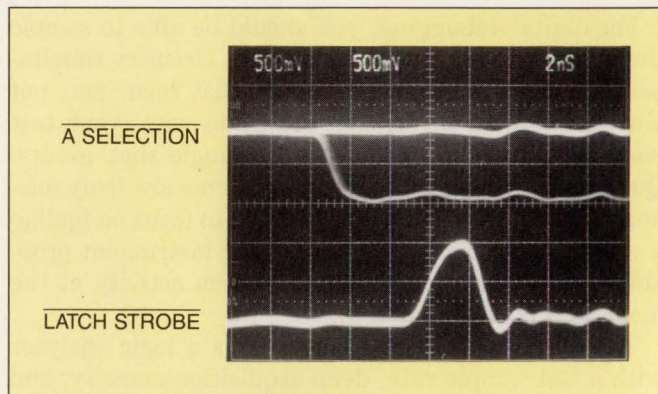


Fig 4—A little fuzziness on the edge of the A and B selection signals, as seen in this oscilloscope photo, is a clue that ultimately leads to the implication of metastability as the cause of the intermittent failures.

lems of timing, pulse width, and noise in this circuit! The circuit could be the cause of the illegal-address problem.

Suppose that timing is marginal in the A and B selection, the strobes, or the A and B address-feedback paths around the address-multiplexer/latches (OR-AND gates).

To see whether this theory is valid, you can use an oscilloscope to measure the timing margin on the address selectors/latches. You observe adequate timing margin on all signals! However, you do see some faint edge fuzziness in the timing of the A and B selection signals (Fig 4). This fuzziness may be the result of

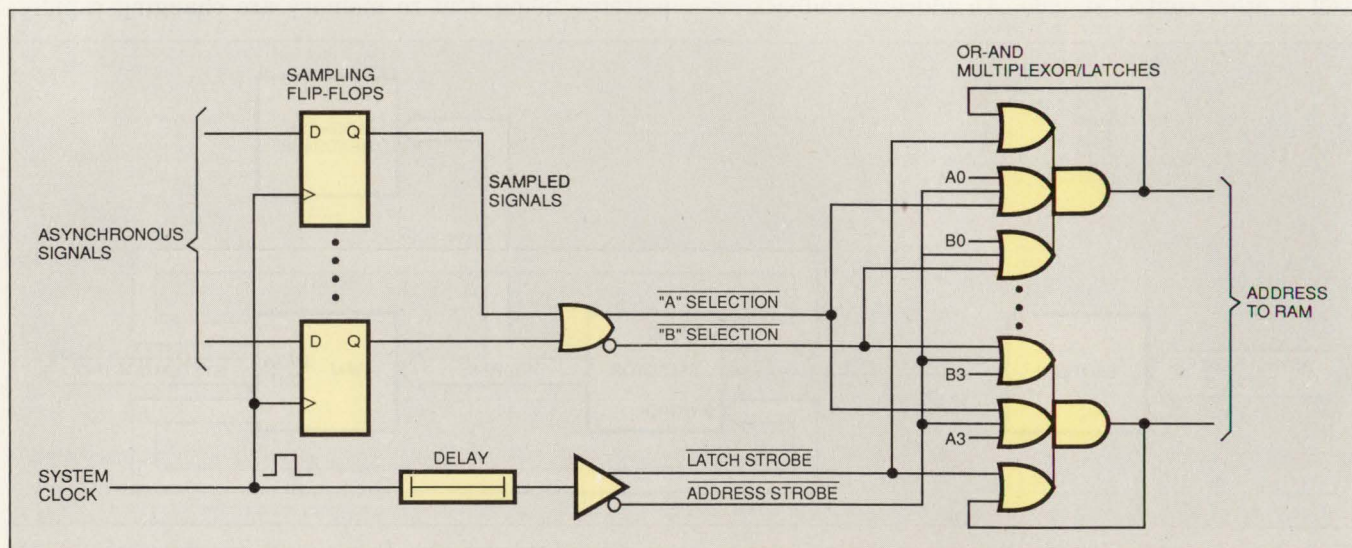
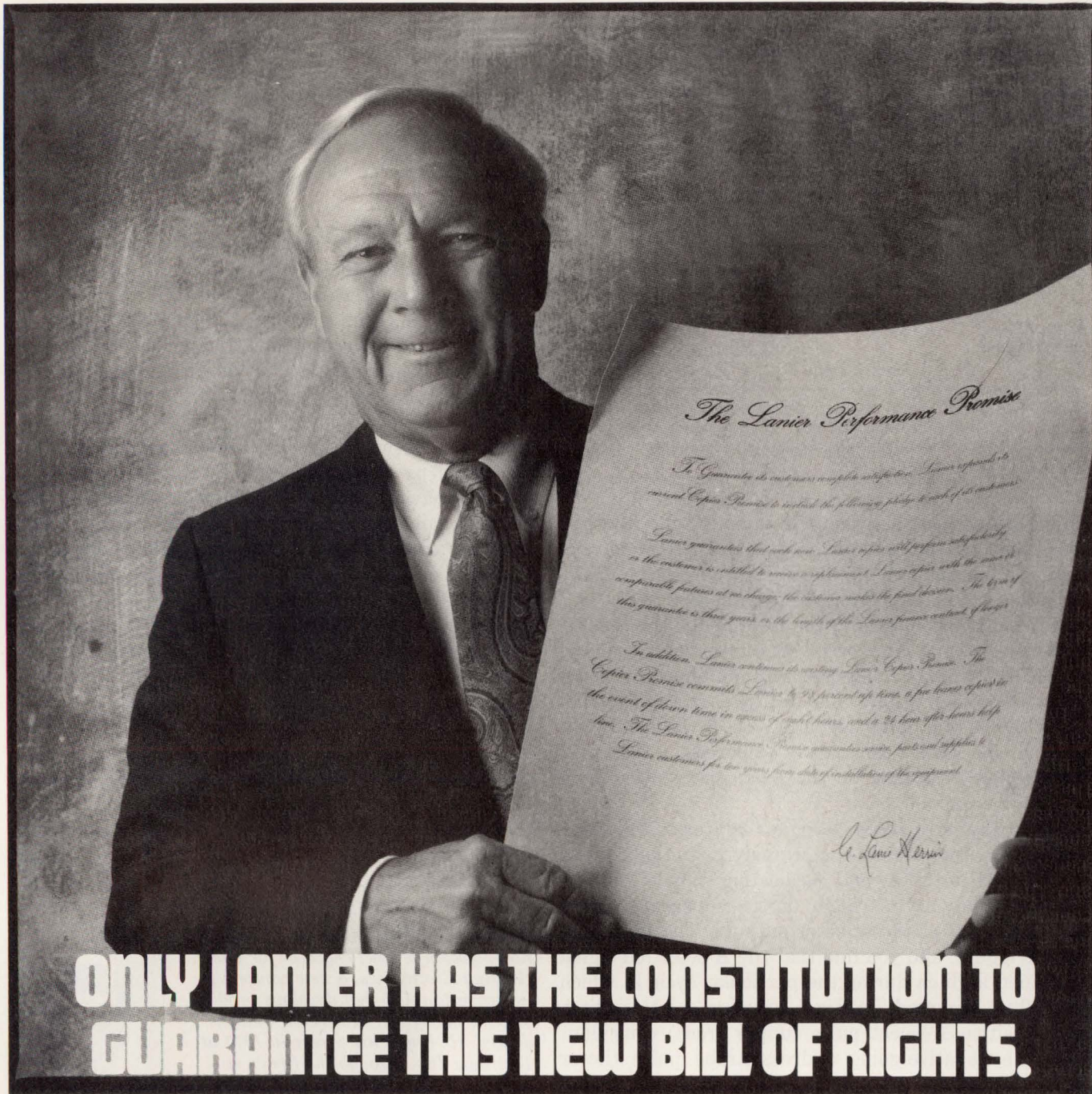


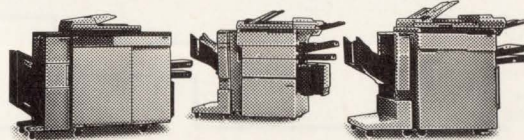
Fig 3—At the heart of the state machine are the sampling and selection circuits. Most of the time, they work as desired—but not always. Your job: Find the cause of and the remedy for the intermittent failures.



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A pattern emerges. You propose a theory and test it, which leads you to propose—and test—another theory, and so on.

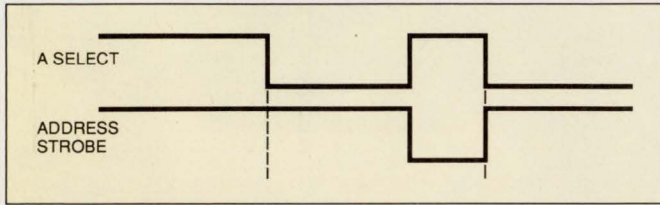


Fig 5—The glitch, which you can see as a positive A-select pulse in the upper trace, appears only once in approximately a million address strobes. Nevertheless, because of its triggering facilities, the logic analyzer captures it.

timing differences between the sampling flip-flops, or there may be another cause—perhaps metastable behavior in the sampling flip-flops. But there still appears to be about 5 nsec of timing margin here.

Now, consider how fully you have tested the theory. The problem may only occur once in many millions of cycles. An analog oscilloscope will not show one trace among a million others, and a digital-storage oscilloscope (DSO) will only show a few cycles (probably not the one where a failure actually occurred). A DSO may not happen to sample on the particular wave where the error occurred.

You really need to use a logic analyzer to fully test the theory. You connect a logic analyzer to the address strobe, and to the A- and B-selection signals. You set the logic analyzer to trigger on the appearance of an illegal address at the selector outputs. The logic analyzer triggers, and you find that the A-selection signal contained a glitch during the particular cycle in which the failure occurred. In Fig 5, you can see this glitch as a positive A-select pulse (upper trace) coincident with the negative-going address-strobe pulse (lower trace). This A-select pulse appears only once in approximately a million address strobes, but, because of its triggering facilities, the logic analyzer captures it.

Suppose that metastability is occurring in one or more of the sampling flip-flops, producing an indeterminate logic level. This indeterminate level will corrupt

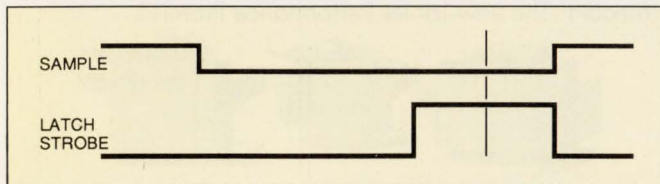


Fig 6—The top trace reveals that the amplitude of the negative-going pulse is less than that of the latch-strobe pulse in the lower trace. Although most logic analyzers display only two data states, the Prism's hardware-analysis module captures the intermediate level caused by metastability and displays that level as distinct from others.

the A- and B-selection signals and cause some OR-AND gates to choose the A-address value while others choose the B-address value.

To test this theory, you set the logic analyzer to its dual-threshold acquisition mode and probe the sampled signals. When the logic analyzer triggers, one of the sampled signals does not swing all the way from logic high to logic low. Instead it dips from logic high into the region between thresholds for about 10 nsec, and then returns to a logic high—a classic metastable-circuit behavior. Fig 6 shows this metastable behavior. If you examine the top trace closely, you will note that the amplitude of the negative-going pulse is less than that of the positive latch-strobe pulse in the lower trace. Although most logic analyzers display only two data states, the Prism logic analyzer's hardware-analysis module captures the intermediate level that indicates metastability and displays it as distinct from the normal 1 and 0 logic levels.

The last steps are to implement a fix and to verify that it works. Add a flip-flop between the OR gate and the OR-AND multiplexer/latches, and adjust the clock delay timing. Retest the system. Now you find that the system no longer fails under any of the previously tested conditions.

EDN

Author's biography

Ron Jackson is chief engineer for Fascinating Electronics, a new company in Beaverton, OR that develops products for hobbyists, education, and industry. He began his career in 1977 at Tektronix Inc, through the firm's student-internship program. In 1981 he graduated from Harvey Mudd College (Claremont, CA) with a BS in Engineering. While at Tektronix, Ron worked on many logic-analyzer products, including the DAS 9100, 1240, and Prism 3000. He holds five US patents and has other applications pending. His spare-time activities include flying his own airplane.



Reference

1. Feynman, Richard P, "Surely You're Joking, Mr. Feynman!" *Adventures of a Curious Character*, W W Norton and Company, 1985, pg 20.

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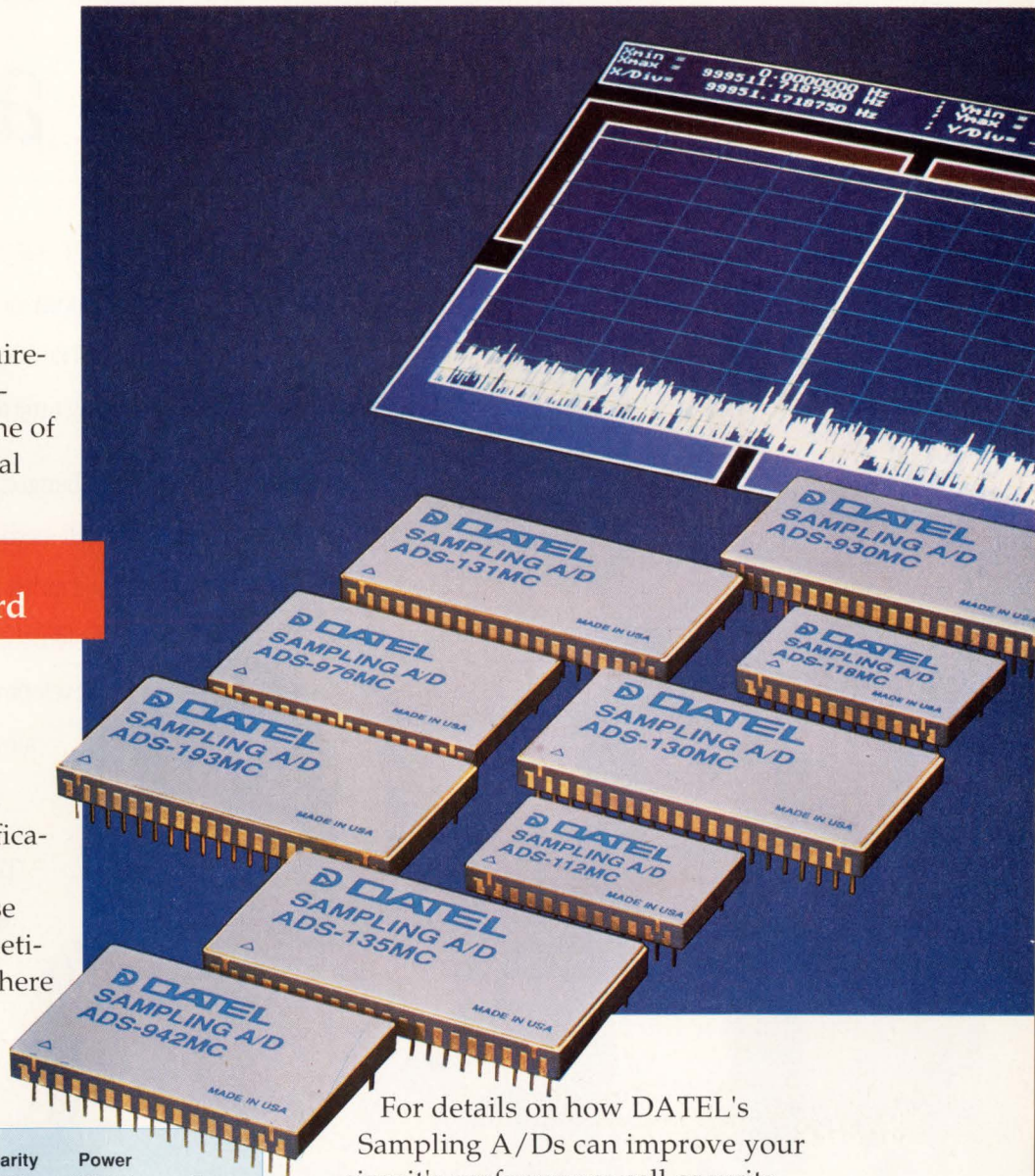
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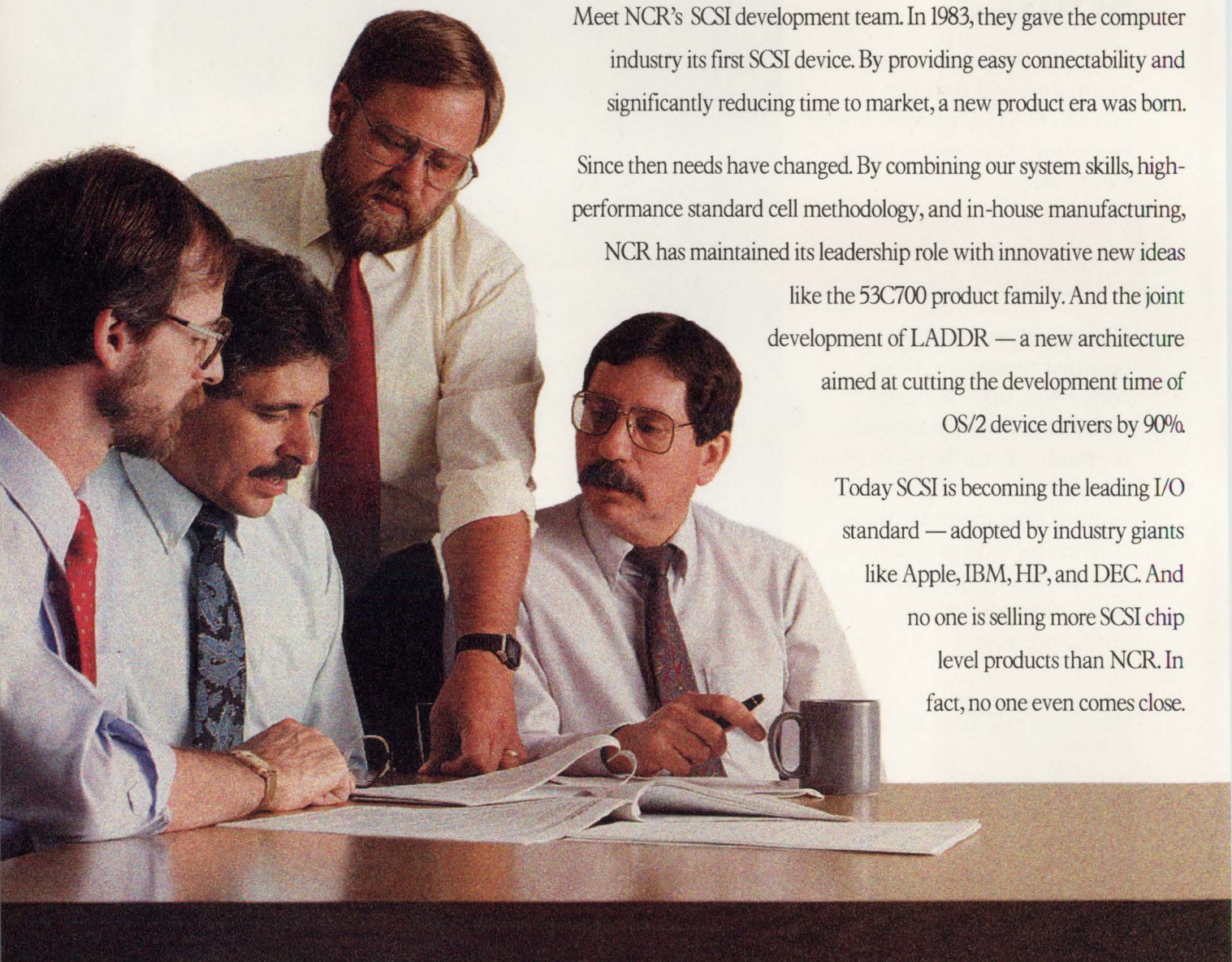
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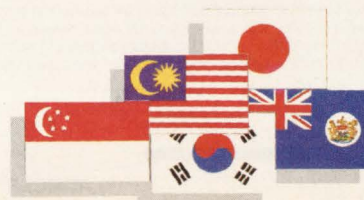
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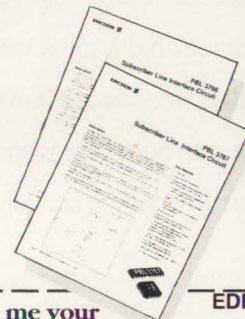
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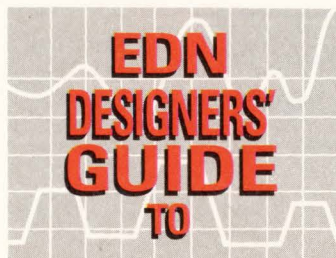
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part 3

Classical tests are inadequate for modern high-speed converters

Part 1 of this 3-part series covered the architecture and operation of subranging ADCs. Part 2 covered the devices' parameters and specifications. Part 3 concludes the series with a discussion of testing high-speed subranging ADCs. Classical dc tests such as the cross-plot and dc-histogram tests can reveal ADCs' differential and integral nonlinearities. However, you'll need different test methods to measure the dynamic parameters of a high-speed converter.

Ray K Ushani, *Datel Inc*

No single test can completely characterize a high-speed A/D converter's performance under dynamic conditions. You'll have to perform a variety of tests such as fast Fourier transforms (FFTs) for both single-tone and multitone frequencies, sine-wave curve fitting, and noise-to-power-ratio testing to characterize the dynamic behavior of an A/D converter.

A sine-wave input is best for measuring a converter's dynamic performance. Mathematically defining a sine wave is easy because it has a single component at the fundamental frequency in its amplitude spectrum. Also, sine waves are easier to generate than other types of waves; commercially available ultralow-distortion oscillators have a total harmonic distortion of less than -95 dB.

The sine wave's performance must exceed that of the A/D converter so that inaccuracies in the ADC's output cannot be attributed to the input signal. Once

you have a spectrally pure sine wave, you can begin the dynamic testing by using a computer to capture the digital output of the A/D converter. Once the computer digitizes and stores the test sine wave, you can begin the analysis.

The FFT is a computational tool that lets you use a computer for signal analysis. Operationally, it computes the discrete Fourier transform (DFT) of a series of data samples. You can use the FFT to characterize an A/D converter in the frequency domain in much the same way you use a spectrum analyzer to determine the linearity of an analog circuit. The significant differences in the derivation of the two spectra are due to the time-sampled nature of the converter. The FFT of a steady signal $x(t)$ is

$$x(f) = \int_{-\infty}^{\infty} x(t)e^{-j\omega t} dt,$$

where ω equals $2\pi f$, f is frequency, and t is time. This expression includes the amplitude and phase of every frequency in $x(t)$.

Unfortunately, you can't use the FFT in this form for an A/D converter because the converter only digitizes $x(t)$ at N finite points that are spaced by Δt in time. With an A/D converter, you have to use the DFT, which is defined by the expression

$$x_D(N\Delta f) = \sum_{R=0}^{N-1} x_R(t)e^{-j2\pi N\Delta f R\Delta t},$$

where N is the total number of points in the record, Δt is the observation time of $x(t)$ divided by N , and Δf is $(1/2)Nt$.

The best source for testing the dynamic performance of ADCs is a sine-wave input.

Notice that $x(f)$ has infinite spectral resolution, but $x_D(n \Delta f)$ has a discrete frequency resolution of Δf because there is a finite number of points in the data record. $x_D(n \Delta f)$ accurately describes the spectrum of $x(t)$ at frequencies less than or equal to a maximum frequency, f_{MAX} , which is $1/(2\Delta t)$. The finite record length requires that you address three FFT problem areas: aliasing, leakage, and the picket-fence effect. Each problem affects the spectrum-analysis results.

Aliasing occurs when the sampling rate is too slow to result in a correct reading and causes a high-frequency signal to appear as a low-frequency signal. In this case, several different signals could be the original source of the sampled signal. The appearance of the false signal is explained by the Nyquist theorem, which states that the sampling rate must be at least twice the frequency of the signal in order to reconstruct the sampled signal. **Fig 1** illustrates the point.

Note that the function the dotted line in **Fig 1** indicates appears to be changing at a slower rate than the signal the solid line represents. The frequency of change the dotted line implies is called an alias of the frequency the solid line implies. Thus, if you don't sample signals often enough, you could wind up with false information. To avoid aliasing effects, preceding the A/D converter with a continuous-time filter that removes all frequencies above the Nyquist frequency is usually necessary.

Leakage is inherent in the Fourier analysis of any finite data record. The record has been formed by analyzing the actual signal for a period of T seconds and

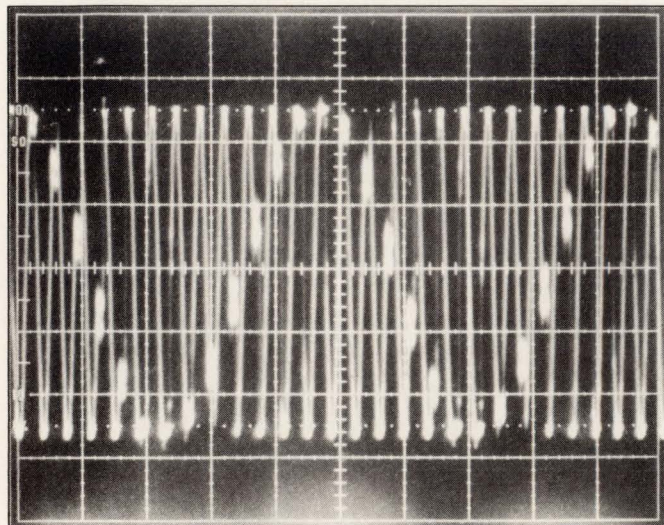


Fig 1—Aliasing problems arise when you sample at a rate that is lower than the Nyquist rate. The aliased waveform, which is superimposed on the original signal, has a frequency that is approximately $1/11$ th that of the original.

neglecting everything that happened before or after this period. This monitoring is equivalent to multiplying the signal by a rectangular data window. Multiplication in the time domain is analogous to convolution of the corresponding functions in the frequency domain. The Fourier transform of a rectangular window is a sinc function. Convoluting the spectrum of the data ($x(n \Delta t)$) with this function smears the spectrum of $x(t)$ that the FFT calculates because the spectral amplitudes of $x(f)$ will leak through the side lobes of the sinc function.

Therefore, in the frequency domain, the actual transform results from the FFT's convolution of two transforms: the window-function transform, which is usually rectangular; and the desired waveform. For example, if you truncate a cosine waveform to include an integral number of cycles, you'll end up convoluting a sinc function with a double-impulse function in the frequency domain. If the number of cycles in the FFT-truncated time sequence is an integer, however, no leakage will occur because the DFT periodically extends the sequence.

To ensure that no leakage occurs, choose the analog input frequency (f_1) using the expression $f_1 = (n/N)f_s$. In this expression, f_s is the sampling frequency, N is the number of samples (a power of 2 to simplify the mathematical operation), and n is a prime number chosen such that the input frequency is as close as possible to the desired value, but smaller. Using a prime number for n guarantees that each data point in the record is unique.

You can reduce leakage by multiplying the data in the record by a windowing function that weights the points in the center of the record heavily while smoothly suppressing the points near the ends. The windowing functions commonly used for sine waves are the 4-term Blackman-Harris, Hanning, Hamming, and Rectangular. Each of these windows offers various amplitude-resolution versus frequency-resolution tradeoffs. Windows are not suitable for testing ADCs that have resolutions of 14 or more bits. For such units, use coherent testing while making sure that you phase-lock the signal and clock generators.

Harmonics cause problems

If the data record has frequencies that are integral multiples of the original record length T , the FFT will yield the correct amplitudes at the correct frequencies and zero at the other frequencies. Ideally, the sampling frequency should be equal to the derived number of data points times the fundamental frequency component. The picket-fence effect occurs if the analyzed

waveform includes a frequency that is not one of the harmonic frequencies.

A frequency between the Nth and the Nth + 1 harmonics (where N + 1 is much less than the number of FFT points divided by 2) primarily affects the magnitudes of the Nth and Nth + 1 harmonics. Such a frequency secondarily affects the magnitude of all other harmonics and can cause leakage, which in turn may cause aliasing. A signal between the third and fourth harmonics, for example, would show up in both the third and fourth harmonic spectral windows but at an amplitude less than 1. In the worst case—exactly halfway between the computed harmonics—the amplitude of the signal decreases to 0.637 in both spectral windows.

Although the picket-fence effect is not a problem in single-tone testing, in multitone testing it becomes an issue. To illustrate the picket-fence effect, consider this task. You must add three sinusoidal signals: The first one has a 120-kHz fundamental frequency and a peak amplitude of unity; the second has a 150-kHz frequency and a peak amplitude of 0.5; and the third has a frequency of 300 kHz and a peak amplitude of 0.5. Let the sampling frequency be 3.84 MHz (32×120 kHz). By looking at the amplitude spectrum in Fig 2, you can see that resolving the three frequencies is not possible because the frequency sample interval is 120 kHz. Aliasing does indeed occur.

The aliasing occurs because the 150- and 300-kHz components do not have an integral number of cycles in the record length T. Leakage occurs, which in turn causes pseudo-aliasing. If you change the number of points from 32 to 64 and leave the sampling frequency

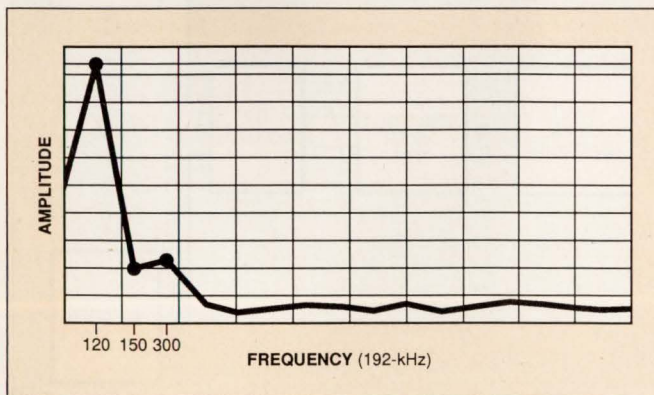


Fig 2—The picket-fence effect becomes an issue in multitone testing, as this example illustrates. The amplitude spectrum shows the result of trying to add sinusoidal signals of 120, 150, and 300 kHz and then trying to resolve the individual components. Resolving the 150- and 300-kHz signals at a sampling frequency of 3.84 MHz is impossible because neither component has an integral number of cycles in the observation time T.

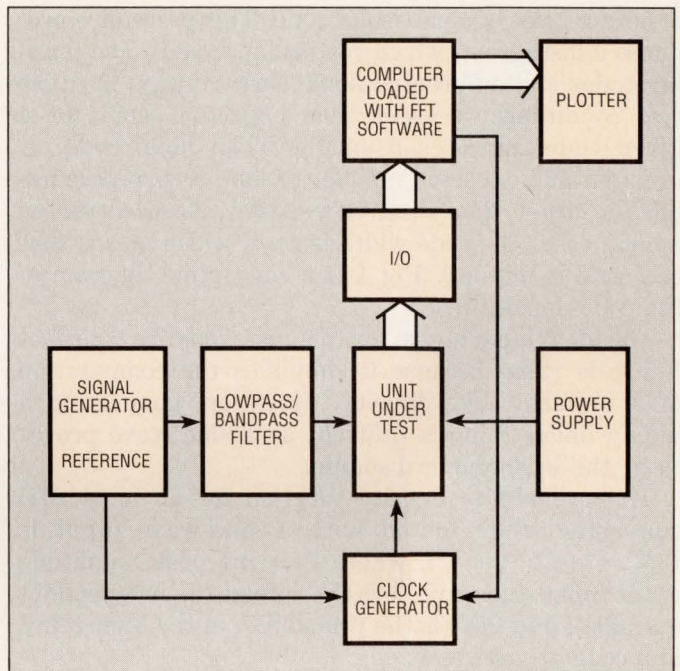


Fig 3—You can use this basic test setup to perform all dynamic tests for A/D converters.

at 3.84 MHz, you can resolve the 300-kHz component in the amplitude spectrum. The reason is that the sample interval is now 60 kHz—the 300-kHz component is an integral multiple of the sample interval. Resolving the 150-kHz component at this record length is still not possible. To resolve this component, you must increase the number of points to 128 while leaving the sampling frequency at 3.84 MHz. The sample interval is now 30 kHz, so all three frequency components appear in the spectrum because they're all integral multiples of the sampling frequency.

A variety of FFT programs are available for personal computers. Some have options to overcome aliasing, leakage, the picket-fence effect, and other problems. Equipped with the proper software, you can make the simple test setup in Fig 3, which you can use to evaluate a converter's dynamic performance in a matter of seconds. Errors such as harmonic distortion, signal-to-noise ratio, intermodulation distortion, differential nonlinearity, missing codes, noise, and aperture uncertainty will show up as an elevated noise floor.

In the code-density test, the ADC digitizes an input with a known probability density function a significant number of times at sampling times that are asynchronous to the input signal. Each possible output code is the address of a memory location. Each time the code occurs, the content of the code's memory location increments. Thus, each memory location records the number

Aliasing occurs when you test an ADC at too slow a sampling rate.

of occurrences of a particular code. This procedure produces a histogram, which you can analyze to find missing codes and differential nonlinearity during dynamic test conditions. A lower than expected count for a given code indicates a smaller than ideal code. A greater than expected number of code occurrences implies a larger than ideal code width. No occurrences indicate that the code width is zero, which means that the code is missing. Fig 4 is a conceptual diagram of the code-density test.

The ideal input signal for this test would be a perfect full-scale ramp because it simplifies the computation of a uniform code density. However, generating a highly linear ramp is difficult, so a sine wave proves to be the best practical source.

The probability density function for an ideal A/D converter when tested with a sine-wave input is $P(V) = 1/(\pi\sqrt{A^2 - V^2})$, where A is the peak amplitude of the input sine wave, V is the voltage (an independent variable), and P(V) is the probability of the occurrence of a code at voltage V.

The probability density function of a voltage sample in the range V_A to V_B is

$$P(V_A, V_B) = \int_{V_B}^{V_A} P(V) dV = \frac{1}{\pi} \left\{ \sin^{-1} \left[\frac{V_B}{A} \right] - \sin^{-1} \left[\frac{V_A}{A} \right] \right\}.$$

If $V_B - V_A = \text{LSB}$ size in this equation, then the resulting equation yields the probability of the occurrence of an arbitrary code I (P(I)) in an ideal A/D converter:

$$P(I) = \frac{1}{\pi} \left\{ \sin^{-1} \left[\frac{(I-2^{n-1}) V_F}{2 A} \right] - \sin^{-1} \left[\frac{(I-1-2^{n-1}) V_F}{2 A} \right] \right\},$$

where V_F is the full-scale range of the A/D converter and n is the bit width of the ADC.

In an actual converter, a code width that is wider than ideal will have more occurrences in the converter's histogram, and a bit width smaller than ideal will have fewer occurrences. Therefore, a large code will produce a P(I) that's larger than ideal for optimal ADC operation, and a narrow code will produce a P(I) that's smaller. Given this fact, you can calculate the differential nonlinearity of a code I as

$$\text{Differential linearity of code I} = \frac{P(I) \text{ actual ADC}}{P(I) \text{ ideal ADC}} - 1 \text{ LSB}$$

$$P(I) \text{ actual ADC} = \frac{H(I)}{N_T}$$

where H(I) is the number of code-I occurrences and N_T is the total number of samples. The minimum number of samples required depends on two factors: how

precisely you must know the differential nonlinearity and the desired level of confidence or probability that the calculation is correct. The minimum number of samples required to achieve β -bit precision and C% confidence for an n-bit converter is $N_T = (Z\alpha)^2 \pi 2^{(n-1)} / \beta^2$. In this expression, $Z\alpha$ is the number of standard deviations found in a tabulated listing of the standard normal distribution for any chosen α where $\alpha = (100 - C)/200$.

The code-density test is a powerful tool. It provides a means of testing for localized differential nonlinearity and also provides a global description of the converter. The test does have some shortcomings when the converter under test has hysteresis. The number of code-I occurrences depends on the direction of the ADC's input. A code could be wider when the input is slewing in a positive direction and narrower when the input is slewing negatively. However, the total number of occurrences of a code may be ideal and indicate a perfect code after data analysis. This perfect-code indication is incorrect.

Pinning down aperture uncertainty

Getting an exact measurement of aperture uncertainty is impossible—parameters such as test-setup timing jitter, noise on the input signal, and the A/D converter's noise are not distinguishable from aperture uncertainty. The data-sheet specification is simply a good-faith estimation. In the histogram test, if the sam-

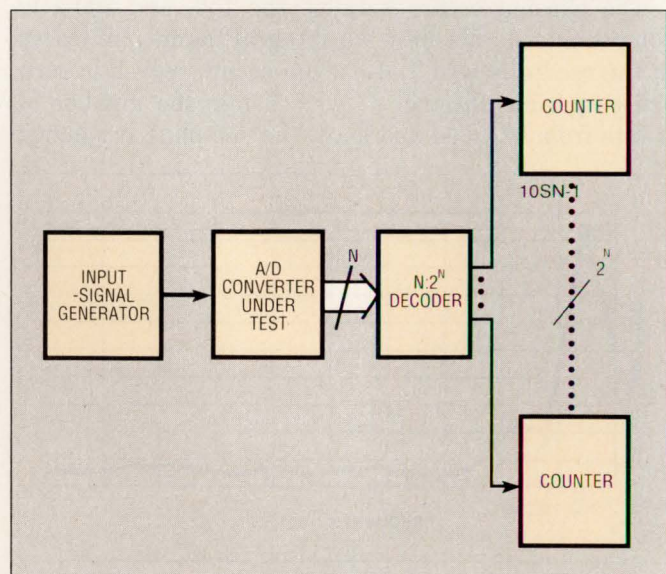


Fig 4—To establish code density, this circuit uses an input with a known probability-density function. The converter under test digitizes this input a significant number of times at sampling rates that are asynchronous with the input signal. Each possible converter output code is the address of a memory location; each time the code occurs, the appropriate memory location increments.

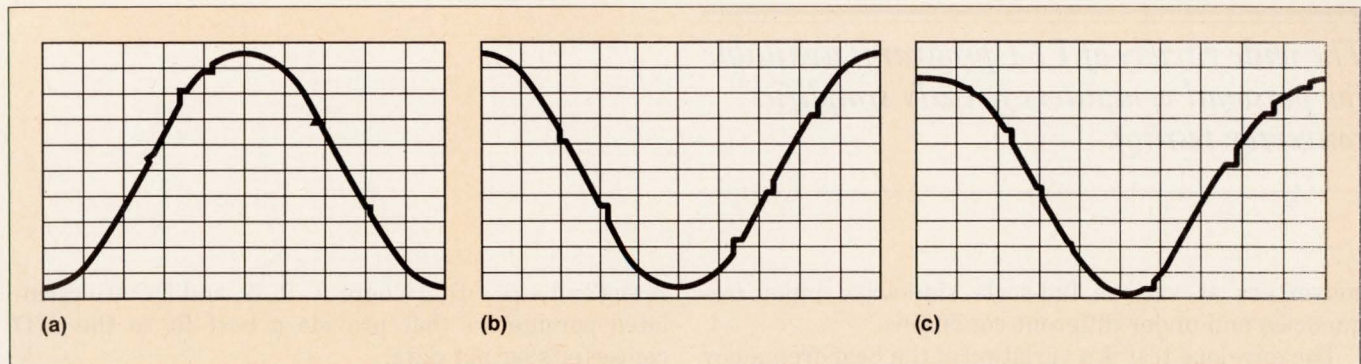


Fig 5—Errors in the beat-frequency test show up as deviations from a smooth sine wave. These curves illustrate the reconstructed outputs for converters at sampling rates of 0.5 MHz (a), 1 MHz (b), and 5 MHz (c). In all cases, missing codes show up as a widening of the individual codes appearing on the sine waves.

ple command and the signal being sampled are synchronized, an ideal converter would output the same digital code each and every time. An ideal converter behaves this way because it does not exhibit any noise or aperture jitter. Hence, the converter would sample the same analog input whenever it receives a convert command. The result is no spread on the ideal converter's histogram plot.

In an actual A/D converter, any noise or timing jitter will cause the sample point to vary. By taking sufficient samples and producing the histogram plot, you can estimate the aperture uncertainty and noise. Noise is a constant; the aperture uncertainty is directly proportional to the input frequency, or slew rate. Therefore, test the ADC once at a low input frequency (100 Hz) to estimate the noise, and once at a higher frequency (1 MHz) to find the aperture uncertainty.

The standard deviation of the histogram provides an rms estimate of the amount of spread in LSBs. With the rms estimate, you can calculate aperture uncertainty for an n-bit converter by using the equation

$$T_A = \sqrt{\left(\frac{SDH}{2\pi f_H 2^n}\right)^2 - \left(\frac{SDL}{2\pi f_L 2^n}\right)^2},$$

where T_A is the aperture uncertainty time, SDH is the standard deviation of the histogram with a high-frequency sine-wave input, SDL is the standard deviation of the histogram with a low-frequency sine-wave input, and f_H and f_L are the high and low input frequencies.

This variation of the histogram test is called the locked histogram test. You can use a circuit similar to the one in Fig 3 to perform this test. The timebase generator that provides the input for the converter should have significantly less jitter than the aperture uncertainty of the device under test.

The aperture uncertainty, as well as other noise sources, corrupts the noise floor in the magnitude spectrum of an A/D converter. The other noise sources include quantization noise, integral and differential nonlinearities, thermal noise, and timing jitter. As a result, measuring the effect of an individual noise source from the digitized data of the same A/D con-

verter is difficult. However, you can measure the aperture jitter if it is the dominating factor.

This measurement utilizes a new digital-spectrum-analysis theory for nonuniform sampling. The theory treats the aperture uncertainty as a nonuniform sampling system with random sampling offsets. Based on this theory, an analysis of the average spectral magnitude shows that you can approximate the noise floor caused by the aperture jitter from the expression:

$$SNR_A = -20(\log 2\pi + \log (f_i/f_s) + \log 100f_s T_A) + 10\log (N/2ENBW).$$

SNR_A is the signal-to-noise ratio obtained by spectral averaging, f_i is the input sine-wave frequency, f_s is the sampling frequency, T_A is the aperture uncertainty time, ENBW is the equivalent noise bandwidth of the window function used in the DFT calculation, and N is the number of FFT data points.

Calculating beat frequencies

In Fig 3's test setup, the A/D converter will ideally output the same digital code when the frequency of the full-scale input sine wave is equal to the sampling frequency of the converter. In this case, the output of the A/D converter could be any code between the negative and positive full-scale voltages, depending on the phase of the input with respect to the sample command. If you change the frequency of the input sine wave slightly while leaving the sampling frequency unchanged such that $f_s = f_i - \Delta f$ (where Δf = offset, or beat, frequency), the converter's reconstructed output will be a sine wave whose frequency is Δf .

You must choose Δf such that the ADC's output will ideally change by 1 LSB at the slew rate's maximum point over one period of the input sine wave.

The beat-frequency test is a qualitative test that provides a quick visual demonstration of an A/D converter's gross dynamic errors. In this test, errors show up as deviations from a smooth sine wave. Missing codes, for example, would appear as local discontinuities in the sine wave. The large codes would appear as a widening of the individual codes appearing on the sine wave. Fig 5 shows the test results of three A/D

The wide variety of FFT programs available for personal computers greatly simplifies converter testing.

converters at various full-scale sine-wave input frequencies and under different conditions.

The envelope test is a variation of the beat-frequency test in which you select the beat frequency Δf such that the ADC output would be at the extreme ends of its range on successive cycles of the input sine wave (Fig 6a). Like the beat-frequency test, the envelope test is a qualitative test but is much more demanding on an ADC because it places a worst-case slew condition on the unit's input. This condition represents the most stringent test of a converter's settling time. You can ensure that samples are taken on alternate half cycles of the input signal by introducing a slight offset between the input frequency and half the sampling frequency. Fig 6b shows the results of the envelope test on four A/D converters.

The sine-wave curve-fit test averages the integral nonlinearity, differential nonlinearity, noise, aperture uncertainty, and quantization noise of an ADC to give a global description of the ADC's transfer function. This test provides the effective bits of the converter. In this test, you apply a sine wave of specified frequency that is within 0.5 dB of full scale to the input of the A/D converter. A software analysis of the converter's output signal using least-square minimization techniques will generate an ideal sine wave of the form

$A \cdot \sin(2\pi ft + \phi) + DC$, where A , f , ϕ , and DC are calculated parameters that provide a best fit to the A/D converter's output data.

Any difference between the output signal and the best-fit sine wave constitutes error. The rms error between the actual data and the best-fit sine wave is given by the expression

$$\text{rms error} = \sum_{m=1}^N [D_m - A \cdot \sin(2\pi f_{T(m)} + \theta) - DC]^2,$$

where N is the data record length, D_m is the data at point m , and A , f_m , θ , and DC are the parameters of the best fit sine wave as calculated for the smallest rms error. You can get these numbers by taking the partial derivative of the rms error with respect to each of the four parameters. Then, iteratively solve the resulting equations to obtain values for the parameters.

Once you've calculated the rms error, you can express the effective number of bits as

$$\text{effective bits} = n - \log_2 (E/Q/\sqrt{12}),$$

where n is the number of resolution bits of the A/D converter, E is the calculated rms error, Q is LSB weight (code size), and $Q/\sqrt{12}$ is the theoretical rms quantization error for an n -bit ideal A/D converter.

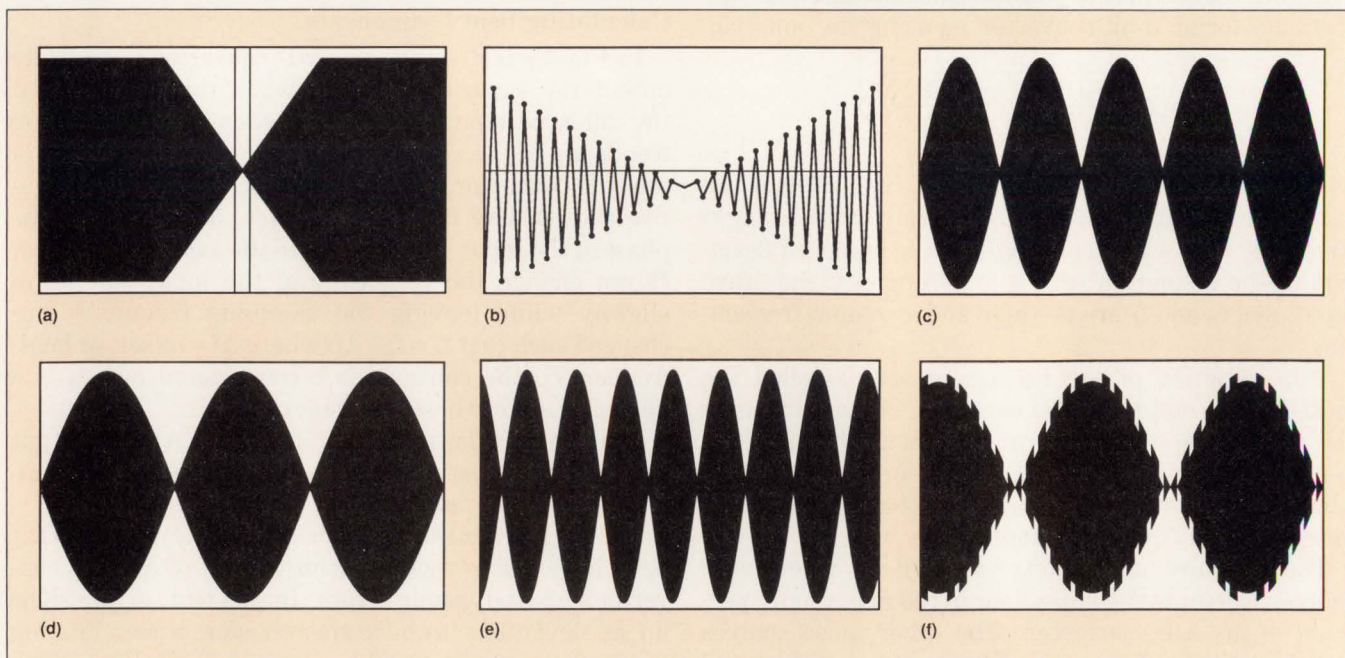


Fig 6—The envelope test is more demanding than the beat-frequency test because it places a worst-case slew condition on the converter's input. The reconstructed converter output in **a** is for a 500-kHz clock rate. An enlarged view of the area within the cross hairs is shown in **b**. The remaining waveforms are envelope-test results for input sine-wave frequencies of 499 kHz (**c**), 998 kHz (**d**), and 4.995 MHz (**e**). The curve in **f** illustrates gross linearity problems for a converter with a 998-kHz input sine wave and a 1-MHz clock rate.

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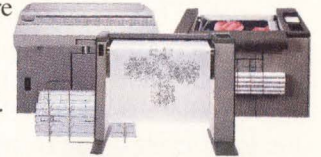
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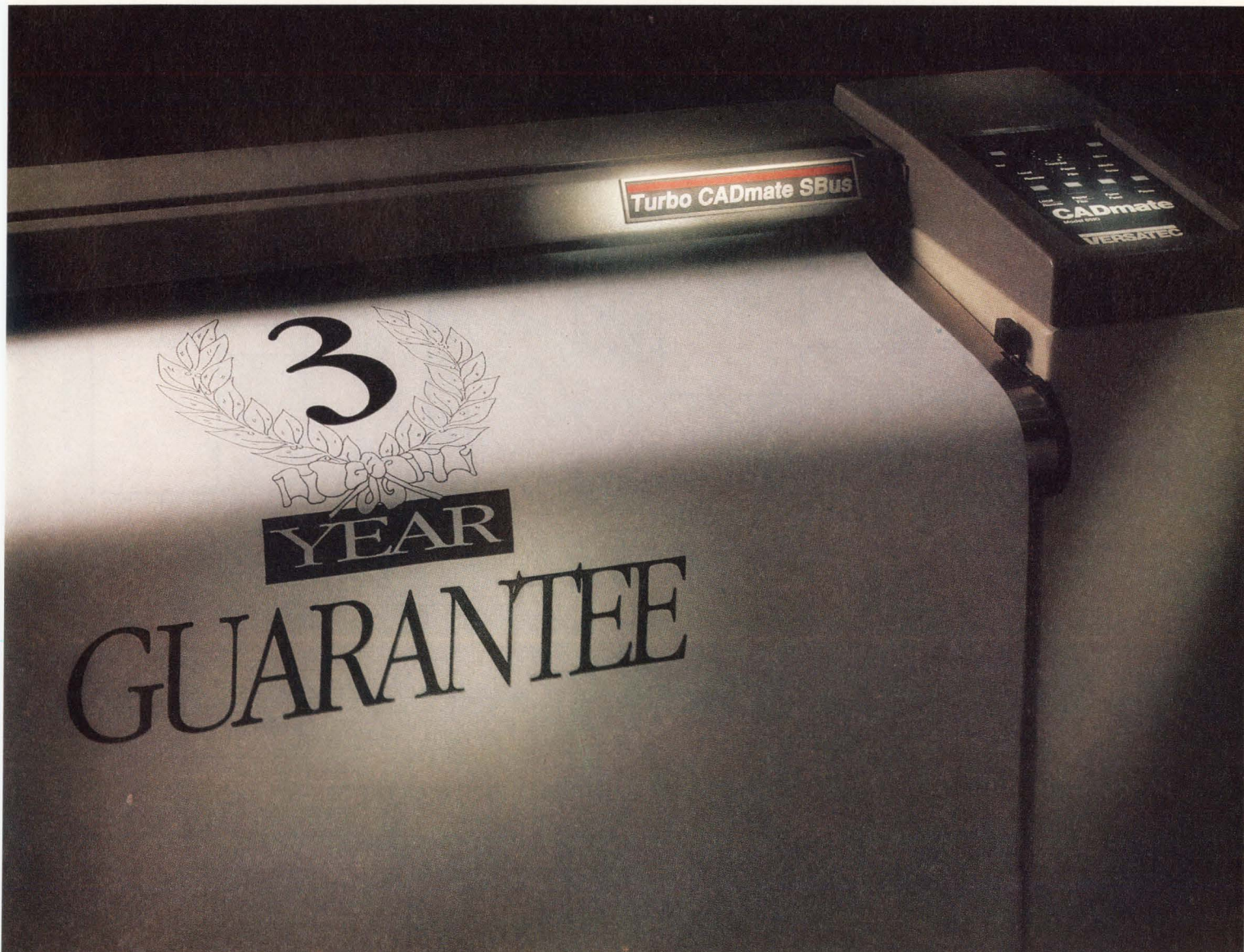
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Parameters such as test-setup timing jitter, noise on the input signal, and the A/D converter's noise are indistinguishable from the aperture uncertainty.

To avoid potential pitfalls during the sine-wave curve-fit test, you must take care to consider two points. First, you must make sure that the input frequency is not harmonically related to the sample frequency—a subharmonic, for example. If you ignore this point, the number of occurrences of a certain code would increase, and some other codes might never occur. This false code information occurs because the same codes are sampled at exactly the same voltages for each cycle—you're not exercising the full range of the A/D converter. Also, if the sample and input frequencies are harmonically related, the resulting higher signal-to-noise ratio will produce a higher effective-bit value. This higher value occurs because certain harmonics will alias back onto the fundamental.

The second point concerns sampling. You must employ a sufficiently large number of data points (4096 points at least) to ensure that ADC errors do not affect the calculated frequency of the best-fit sine wave. If the number of data points is too small, the wrong codes at critical points in the data record could alter the frequency of the calculated best-fit sine wave. This

alteration would cause a false effective-bit measurement.

The effective bits calculated by the sine-wave curve-fit test should match the value calculated by the FFT signal-to-noise ratio (SNR), which is

$$\text{effective bits} = (\text{SNR} - 1.76 \text{ dB})/6.02.$$

You can use the setup of **Fig 7** to test an ADC's transient response. In the circuit, the output of a high-speed analog multiplexer switches between two reference voltage levels. Set one of the reference levels to be slightly less positive than the converter's positive full-scale level; set the other slightly less negative than the converter's negative full-scale level. The clean, fast-settling square wave this technique develops serves as the input for the converter under test.

This test circuit introduces a delay between the converter's start-convert command and the falling or rising edge of the input square wave. If this delay is less than the transient response time of the A/D converter, any slight change in the delay will cause a change in

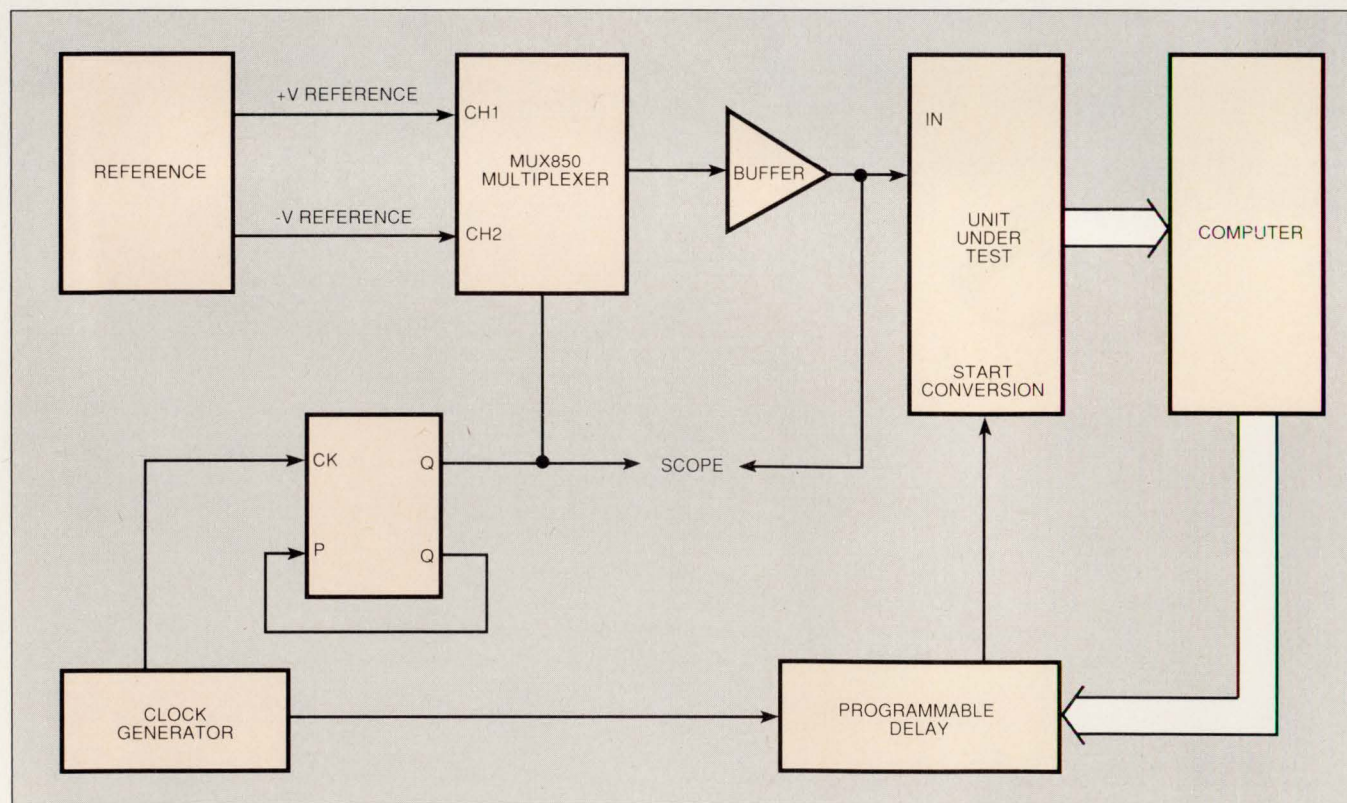


Fig 7—This test setup introduces a delay between the converter's start-convert command and the input. You can use this delay to determine the converter's transient response.

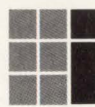


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The beat-frequency test provides a simple demonstration of an A/D converter's gross dynamic errors.

the converter's digital data output. You can determine the converter's transient response time by increasing the delay until the converter's output no longer changes value. This response time is the sum of the conversion time and the delay time; in other words, the time between the transition of the input and the triggering time of the A/D converter. The input transition should occur as soon as the conversion time is complete. You must be sure that the delay time does not exceed the device's specified conversion time.

You can also measure the transient response time by introducing a slight offset between the sampling frequency and the input square wave. Then, count the number of samples the converter's reconstructed output requires to settle to its final value after a full-scale input change. The transient response time = $M(1/f_1 - 1/f_s)$, where M is the number of samples the ADC needs to settle following an input change, f_1 is the input frequency, and f_s is the sampling frequency.

The accuracy of the measurement depends on the sampling time difference:

$$T_s = (1/f_1 - 1/f_s),$$

where T_s is the difference in time from one data point to the next data point. For high-speed fine measurements, T_s has to be small but not zero.

By making two changes, you can use the setup of Fig 7 to test an ADC's overvoltage recovery time.

First, adjust one of the reference voltages in the test setup until it equals the maximum allowable overrange value in that direction. Second, set the other reference for a valid input level near the full-scale point in the opposite direction. The delay time is now the transition time of the input signal from the setting point to the valid-input point.

Evaluating the noise-to-power ratio

The noise-to-power-ratio (NPR) test was developed in 1955 for frequency-division-multiplex communications equipment. At the time, industry studies showed that when as few as 64 operators were simultaneously using the equipment, the random signal approximated random noise. Today, a universally accepted practice for simulating a large number of telephone users is to add noise to the baseband signal.

Fig 8 illustrates an NPR test setup. To make the measurement, first add white noise that has a spectrum ranging from low frequencies to frequencies as high as the Nyquist rate to the input of the A/D converter. Then, adjust the power of the input noise so that the converter is fully loaded (-1 dB below the maximum NPR). A deglitched D/A converter converts the A/D converter's output into an analog signal. The D/A converter's output passes through a bandpass filter. Using the test setup's receiver, you can measure the rms noise power of the test signal within the filter notch. Go through this process twice—once with the notch

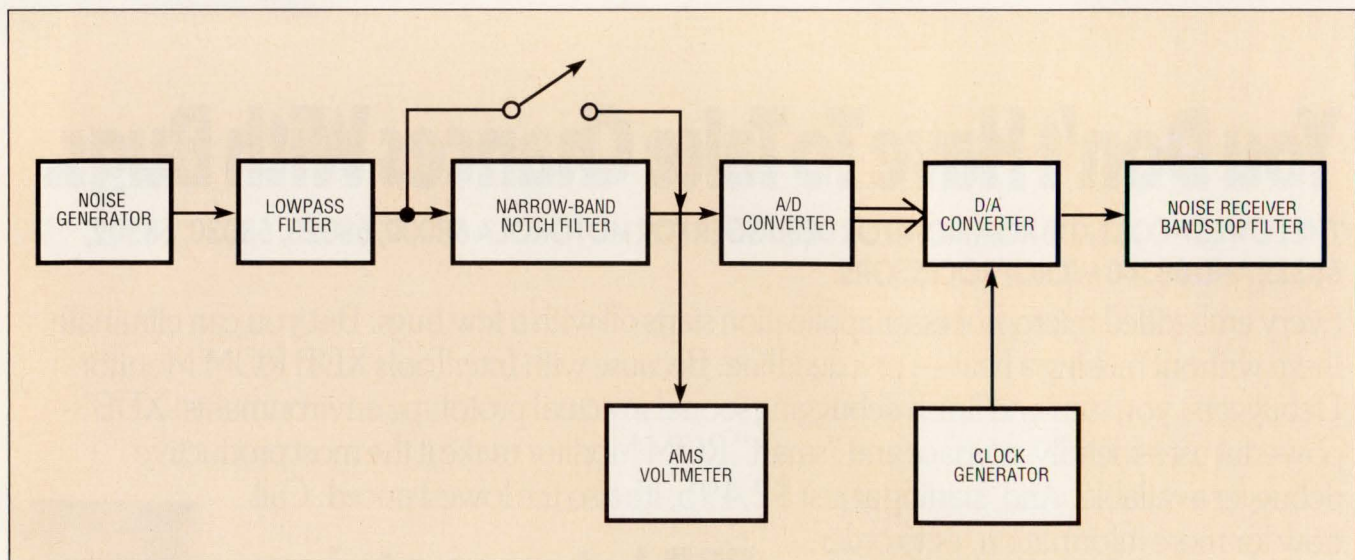


Fig 8—The noise-to-power-ratio test requires you to add white noise to the converter's input. The power level of the input noise is adjusted until the converter is fully loaded. A deglitched D/A converter takes the output of the ADC and converts it back to an analog signal. The D/A-converter output then passes through a narrow bandpass filter. The receiver measures the filter output to determine the rms noise power of the signal within the notch filter.

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The envelope test is demanding because it puts a worst-case slew condition on the converter input.

filter switched out (which is equivalent to a listener hearing the noise 500 or more subscribers produce) and then with the notch filter included. Expressed in decibels,

$$\text{NPR} = 10 \log (\text{rms noise-power reading with filter out}) \div \log (\text{rms noise-power reading with filter in}).$$

Fig 9a illustrates a common method for measuring the differential gain of an A/D converter using the standardized test signal in Fig 9b. You apply this signal, which is called the 20-IRE modulated ramp (1V = 140 IRE units), to the input of the A/D converter. A high-accuracy D/A converter and a lowpass filter reconstruct the output of the A/D converter. You obtain the differential gain error by analyzing a display of the filter output on a vector scope (Fig 9c). To perform the analysis, measure the peak-to-peak curvature of the center of the waveform (the dotted line in Fig 9c). You can evaluate an ADC's fidelity by comparing the ideal differential gain to the differential gain you measure. The differential gain error is the differ-

ence between the ideal differential gain and the actual differential gain.

You can measure differential phase in the same manner as differential gain by taking the center line distance of the signal and finding its maximum peak-to-peak deviation. The difference between the actual differential phase of the device and its theoretical differential phase is the differential phase error. **EDN**

Author's biography

Ray Ushani is the manager of the Advanced Development Group at Datal Inc (Mansfield, MA). He has been with the company for six years and has been instrumental in the development of several A/D converters, multiplexers, and S/H circuits. Ray has an MSEE from Northeastern University (Boston, MA) and is a PhD candidate at Tufts University (Medford, MA). Not one to stray far from his vocation, Ray's hobbies include RF and microwave design.

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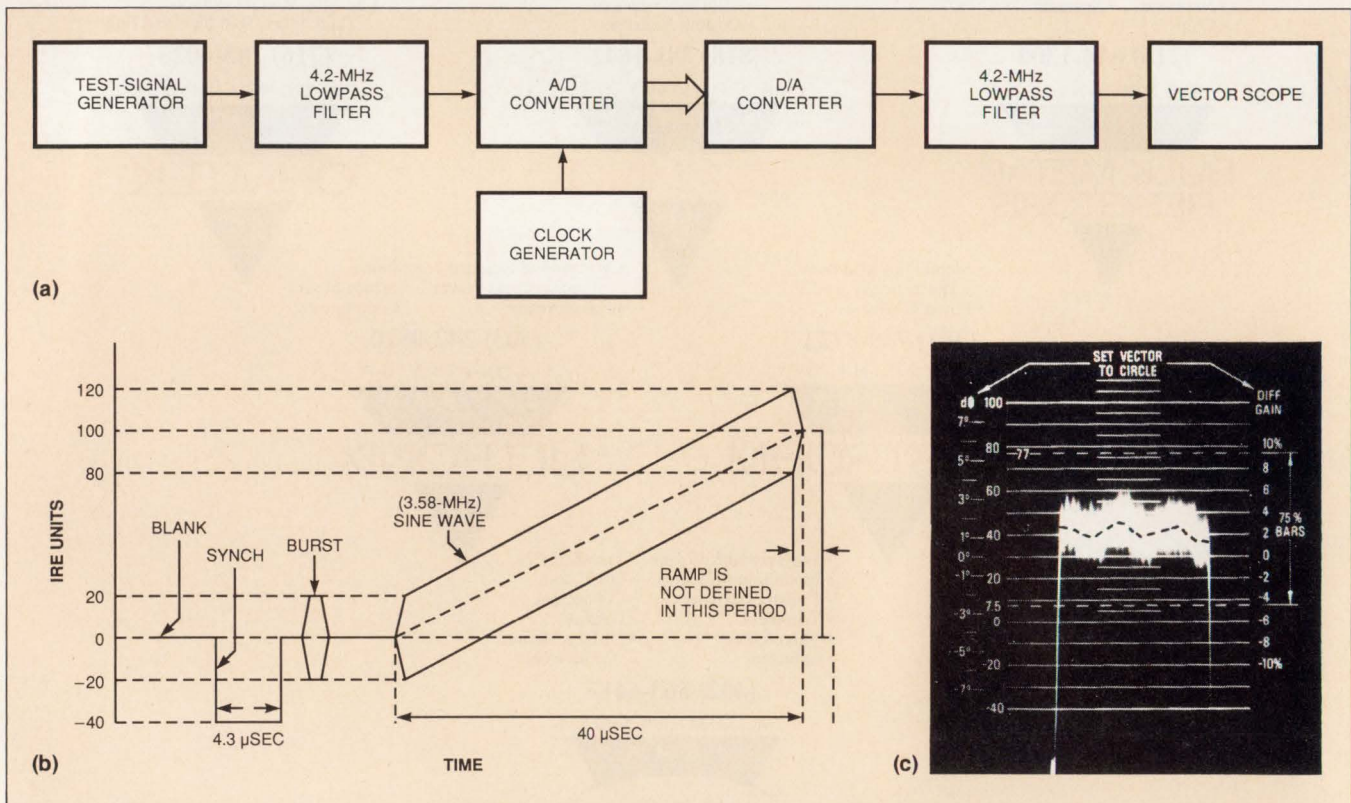


Fig 9—For differential-gain testing, you can use the setup in a and the standardized test signal in b as the converter input. The waveform in b is called the 20-IRE modulated ramp (1V = 140 IRE units). You can determine the differential gain by measuring the peak-to-peak curvature—the dotted line in c—of the output waveform.

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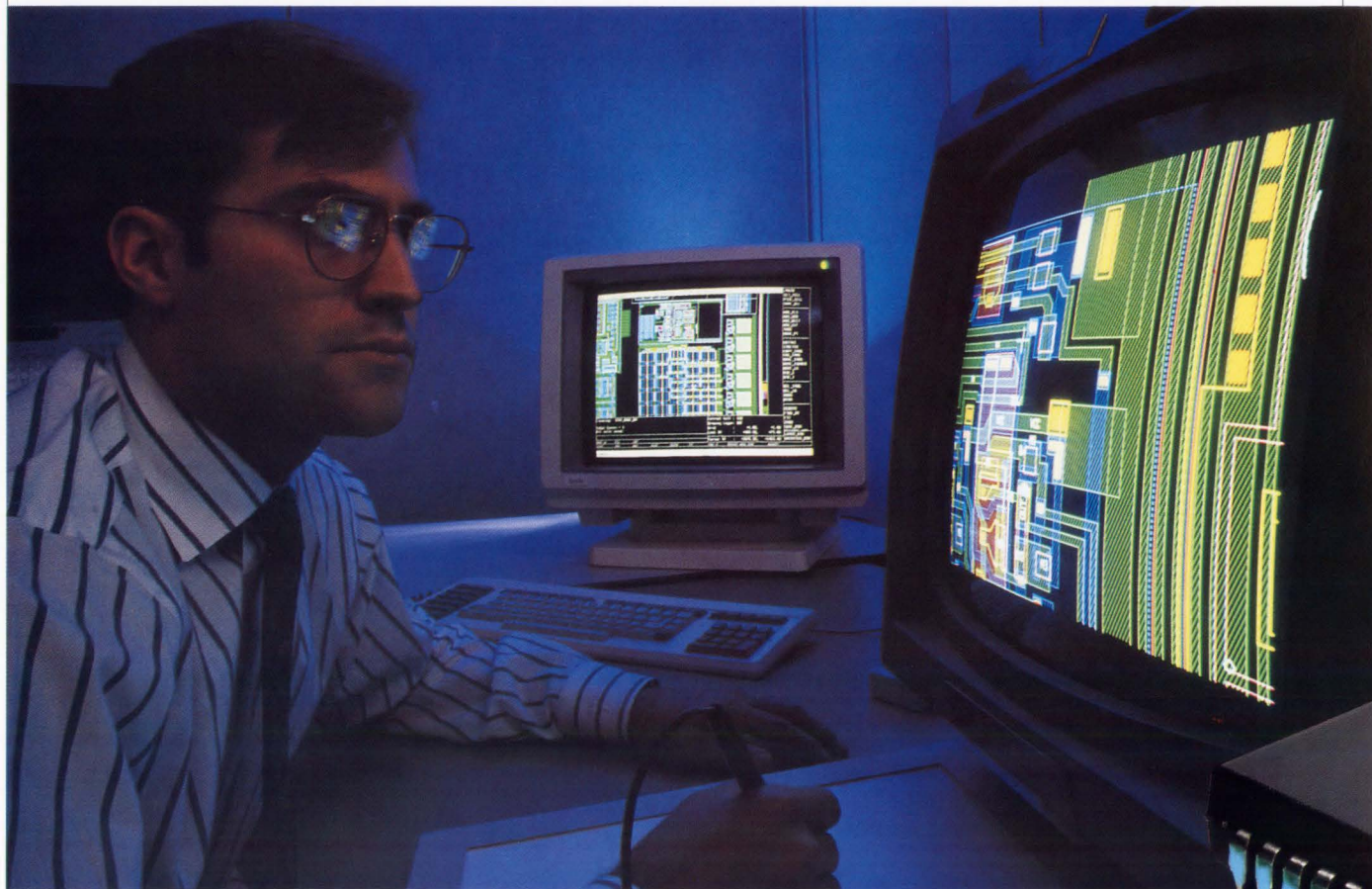
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Telecommunications and Networks Group
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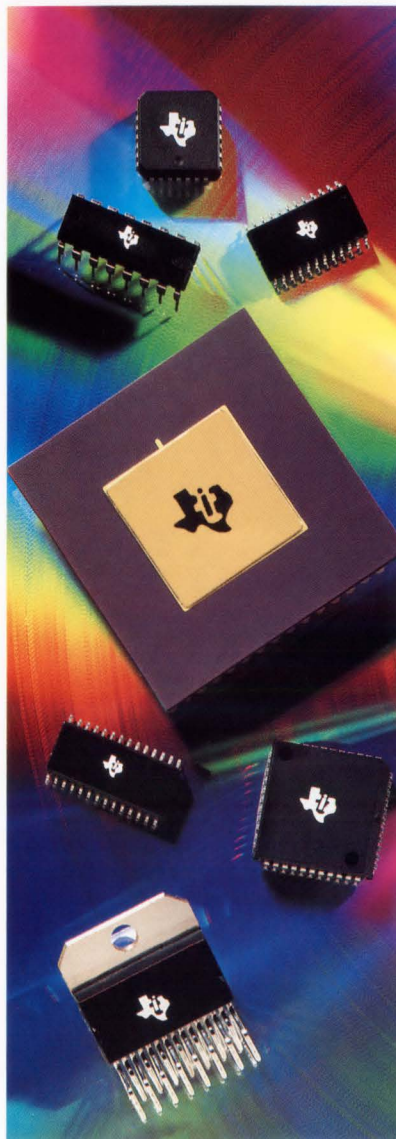
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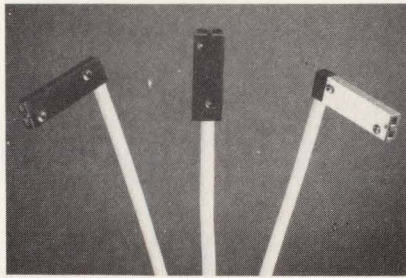
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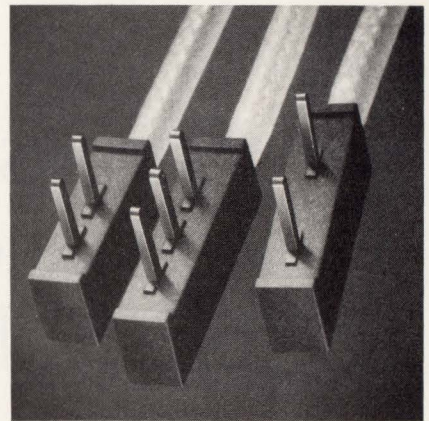
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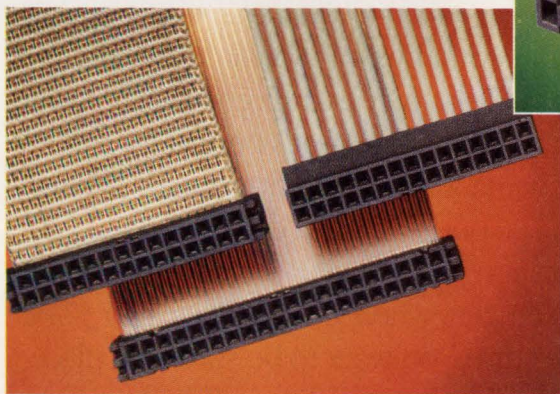
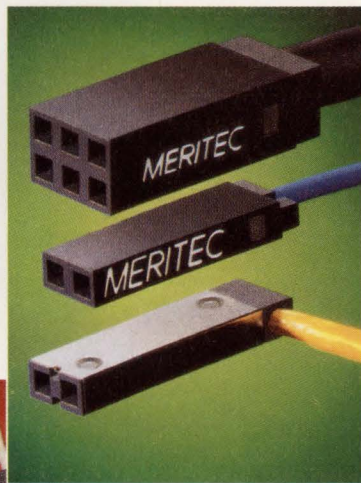
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CIRCLE NO. 127

DESIGN IDEAS

EDITED BY CHARLES H SMALL

Synchronous system measures $\mu\Omega$ s

Moshe Gerstenhaber and Mark Murphy
Analog Devices, Wilmington, MA

The circuit in **Fig 1** uses a synchronous-detection scheme to measure low-level resistances. Other low-resistance-measuring circuits sometimes inject unacceptably large currents into the system under test. This circuit synchronously demodulates the voltage drop across the system under test and can hence use extremely low currents while measuring resistance.

The 10V-pk, 1-kHz carrier generator injects a 1-mA reference current into unknown resistor, R_{TEST} . Instrument amplifier IC_1 and precision op amp IC_{2A} amplify the voltage across R_{TEST} by a gain of 100,000. Synchronous detector IC_3 demodulates this voltage, then op

amp IC_{2B} acts as a lowpass filter on the demodulated voltage. The lowpass filtering will attenuate all uncorrelated disturbances, such as noise, drift, or offsets, while passing a dc voltage proportional to the unknown resistance.

The relationship between the output voltage and the unknown resistance is

$$V_{OUT} = 10 \times (2V/\pi) \times R_{TEST} \times 10^5/10 \text{ k}\Omega, \text{ or} \\ R = 0.0157 \times V_{OUT},$$

which is 15.7 m Ω /V at the circuit's output.

(EDN BBS /DL_SIG #963)

EDN

To Vote For This Design, Circle No. 746

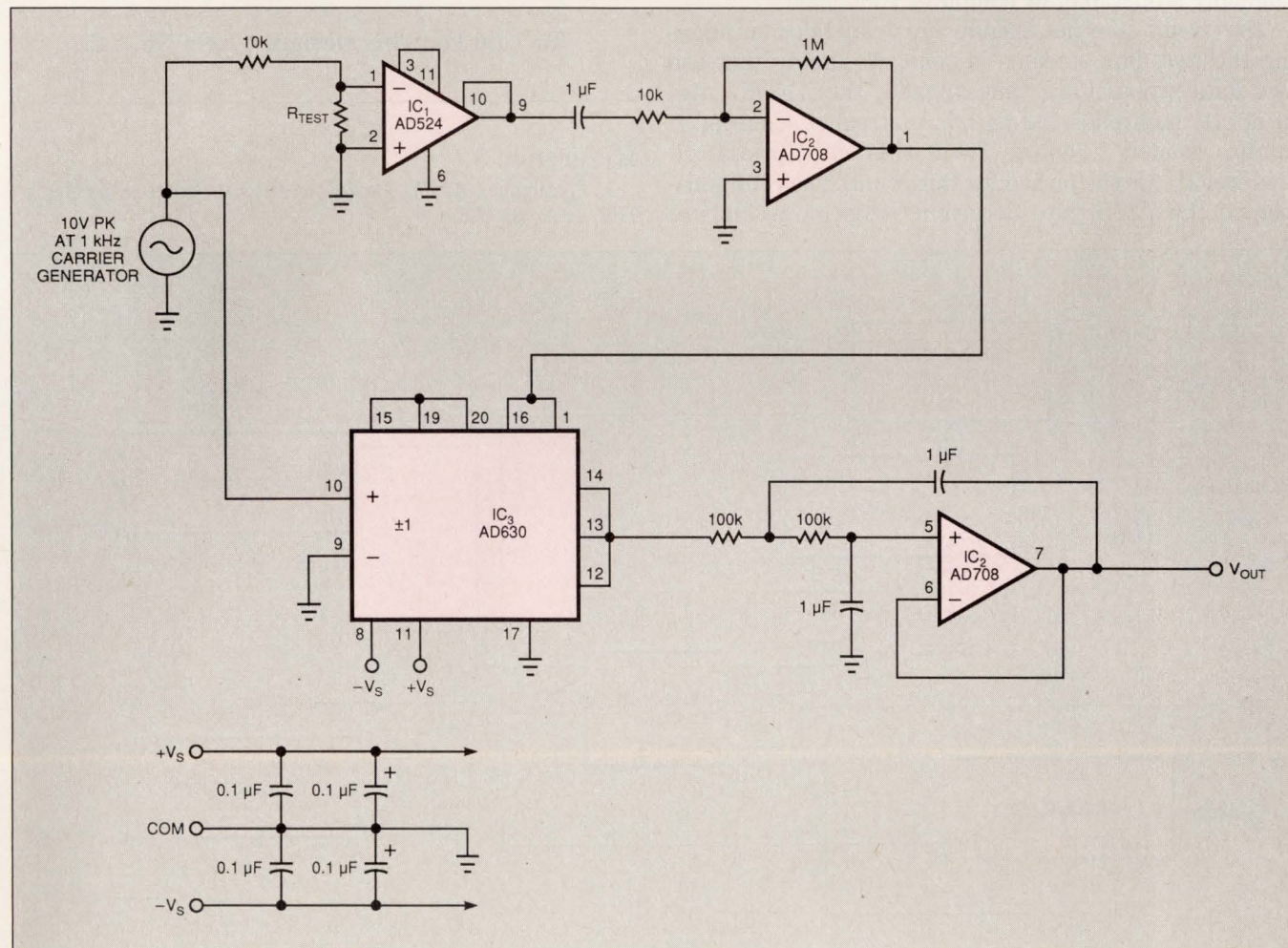


Fig 1—A synchronous demodulator helps this circuit measure low-level resistances while rejecting uncorrelated disturbances, such as noise, drift, and offsets.

Digital correlator defeats noise

John D Charlton
Lancaster, CA

Laboratory tests of the digital correlator in **Fig 1** demonstrate that it can quickly detect signals having very low signal-to-noise ratios much better than RC or sum-and-dump correlators can. The correlator compares two digital-data streams in real time, developing a positive output if the two data streams are similar to a certain predetermined degree. You can think of the correlator as performing a running, or "boxcar," average of the number of bits that agree in the two digital-data streams. Applications include radar, sonar, radio astronomy, and noisy phase-locked loops. You can modify the circuit to make its thresholds permanently set, manually adjustable, or computer controlled.

The circuit does not include any delay lines for aligning the two data streams in time. Assuming that the two data streams are time aligned, the XNOR gate, in effect, multiplies the two data streams. Counter A counts positive results from this multiplication. Counter B sets the period for this count. The configuration of the AND gate determines the lower limit of

data-stream agreement. If the count presented to the AND gate exceeds this limit, the AND gate will clock a 1 into the flip-flop; otherwise the AND gate will clock a 0 into the flip-flop.

The shift register collects the flip-flop's 1s and 0s, and the m-of-n detector continuously decides, based on the number of 1s in the shift register, whether the two signals are correlated.

The output port allows you to calculate the signal-to-noise ratio. The signal is the average count in Counter A when the signal is present minus the average count when the signal is absent. The noise is the rms deviation from average. You can also use the circuit to measure the unit impulse response of a linear system (**Ref 1**). (EDN BBS /DL-SIG #964) **EDN**

To Vote For This Design, Circle No. 747

Reference

1. Peatman, J B, *The Design of Digital Systems*, McGraw-Hill, 1972, pg 376.

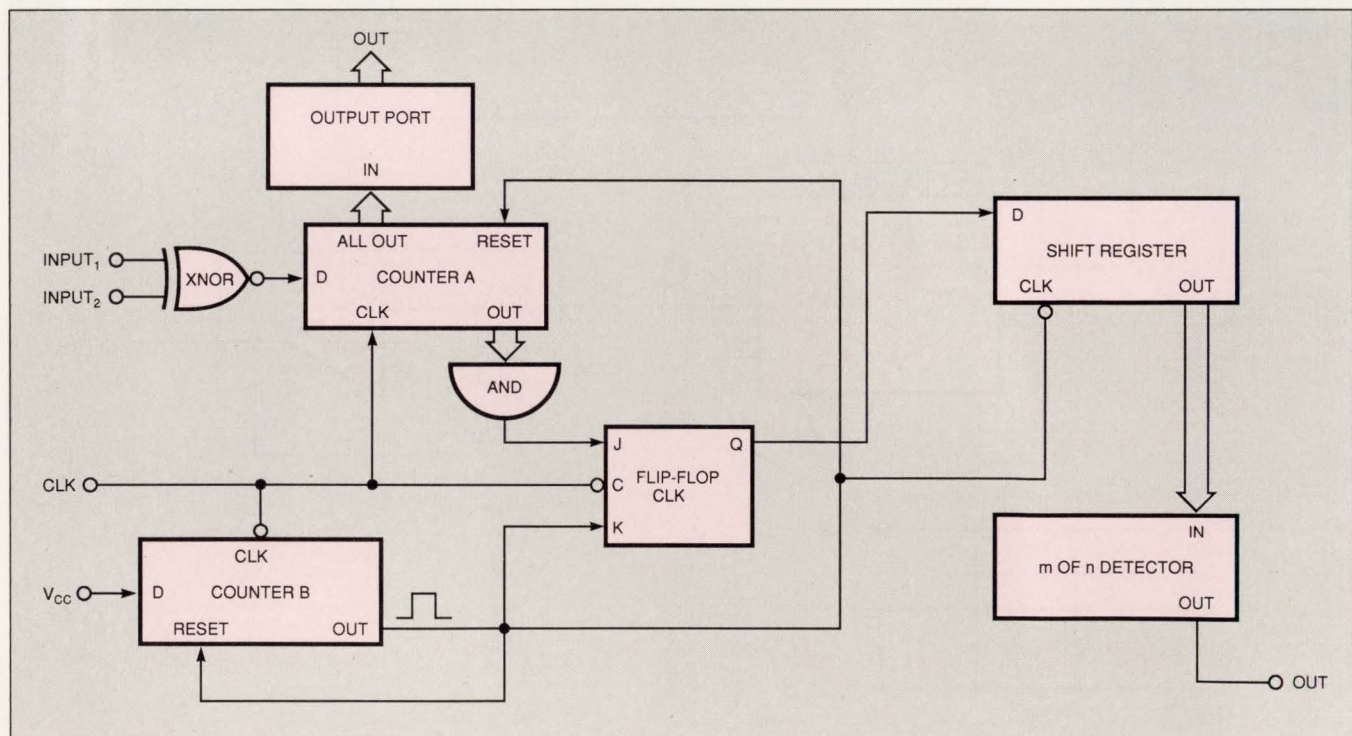
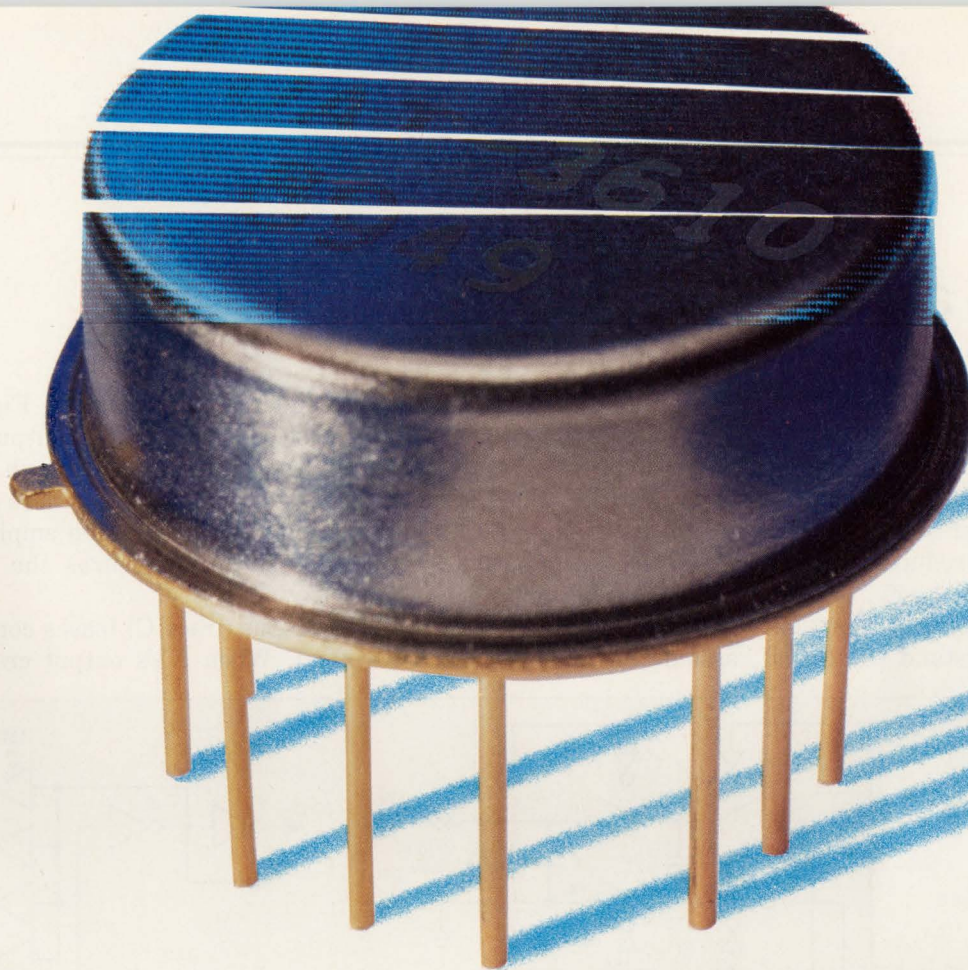


Fig 1—This digital correlator can extract a signal from noise or determine the degree of correlation between two signals better than customary analog circuits can.



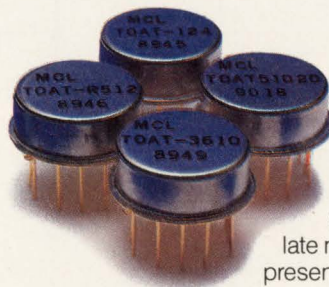
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2.0	0.2	4.0	0.3	10.0	0.3	20.0	0.4
2.5	0.32	5.0	0.5	13.0	0.6	25.0	0.7
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CIRCLE NO. 100

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VFC accepts bipolar inputs

Jim Williams
Linear Technology, Milpitas, CA

The voltage-to-frequency converter (VFC) in Fig 1 accepts bipolar-ac inputs. For -10 to $+10$ V inputs, the converter produces a proportional 0 to 10-kHz output. Linearity is 0.04%, and temperature coefficient (TC) measures about 50 ppm/ $^{\circ}$ C.

To understand the circuit, assume its input sees a

bipolar square wave (trace A, Fig 2). During the input's positive phase, IC₁'s output (trace B) swings negative, driving current through C₁ via the full-wave diode bridge. IC₁'s current causes C₁'s voltage to ramp up linearly. Instrumentation amplifier IC₂ operates at a gain of 10 and measures the differential voltage across C₁.

IC₂'s output (trace C) biases comparator IC₃'s negative input. When IC₂'s output crosses zero, IC₃ fires

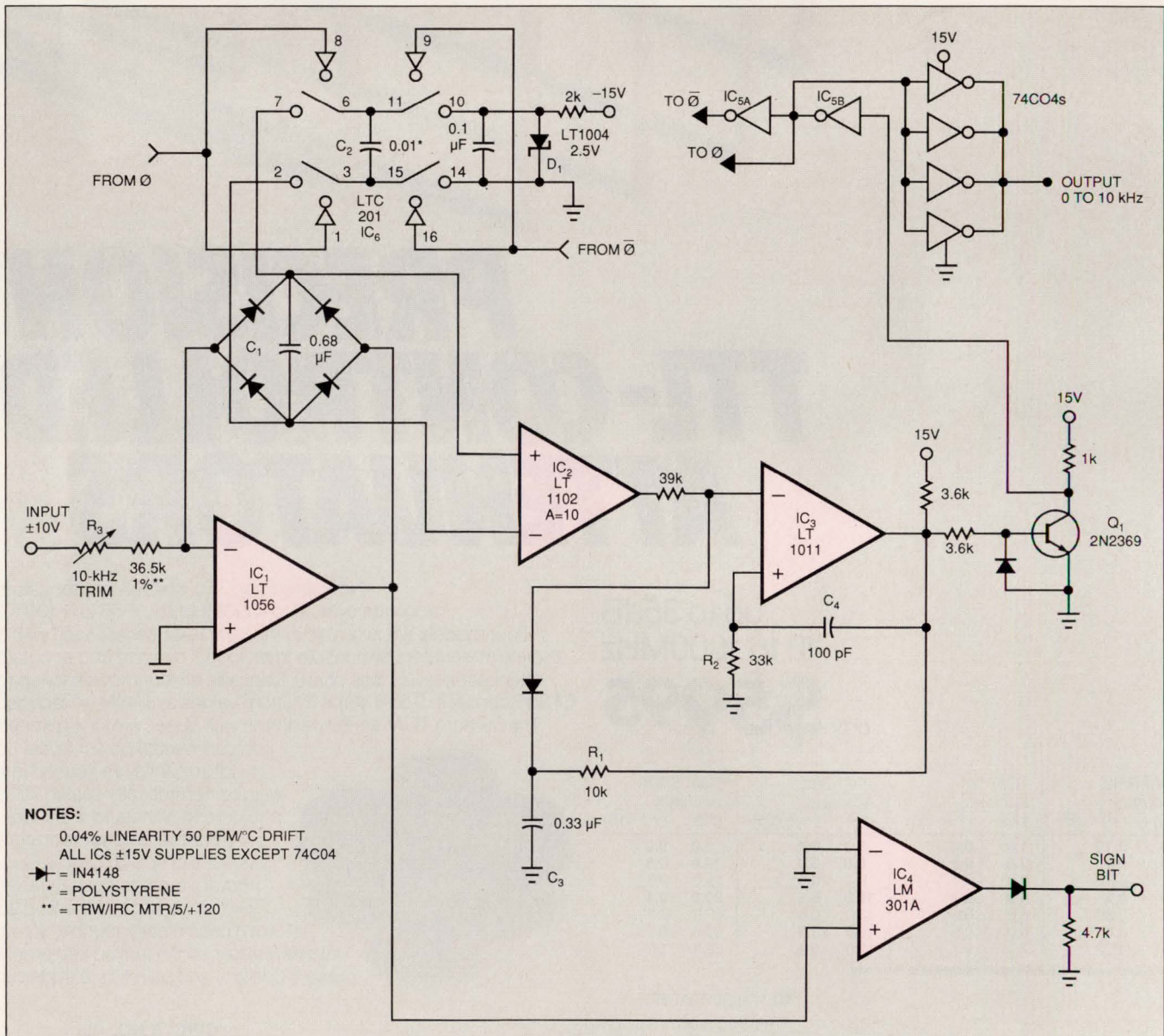


Fig 1—This voltage-to-frequency converter accepts bipolar inputs.

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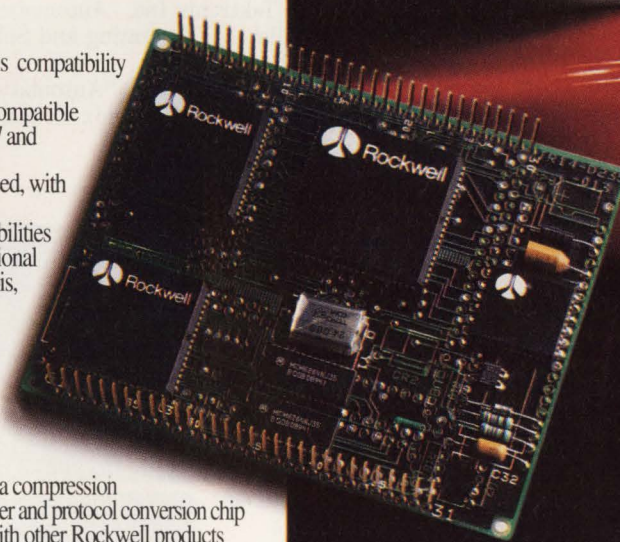
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DESIGN IDEAS

(trace D). AC positive feedback to IC₃'s positive input (trace E) hangs up IC₃'s output for about 20 μ sec. The Q₁ level shifter drives ground-referred inverters IC_{5A} and IC_{5B} to deliver biphasic drive (traces G and H) to the LT1004 switch, IC₆.

IC₆, configured as a charge pump, places C₂ across C₁ each time the inverters switch, resetting C₁ to a lower voltage. The LT1004 reference, D₁, along with C₂'s value, determines how much charge the charge pump removes from C₁ each time the charge pump cycles. Thus, each time IC₂'s output tries to cross zero, the charge pump switches C₂ across C₁, resetting C₁ to a small negative voltage and forcing IC₁ to begin recharging C₁.

The frequency of this oscillatory behavior is directly proportional to the input-derived current into IC₁. During the time C₁ is ramping towards zero, the switch, IC₆, places C₂ across the reference diode, D₁, preparing C₂ for the next discharge cycle.

The action is the same for negative input excursions (Fig 2), except IC₁'s output phasing is reversed. IC₂, looking differentially across IC₁'s diode bridge, sees the same signal as it does for positive inputs; therefore, the circuit's action is identical.

IC₄, detecting IC₁'s output polarity, provides a sign-bit output (trace F, Fig 2).

In Fig 3, an amplitude-expanded version of IC₁'s and IC₂'s outputs shows more detail. Trace A is the input, while traces B and C are IC₁'s and IC₂'s outputs, respectively. Complementary bias points and ramping action are clearly visible in IC₁'s output, whereas IC₂ responds identically for both input phases. The two conducting bridge diodes establish IC₁'s output bias points. When the input switches polarity, integrator IC₁ responds immediately, and the loop oscillation frequency settles to its final value within 1 to 2 cycles.

Start-up or overdrive conditions can cause this loop

to latch. Because of this possibility, the circuit employs a start-up mechanism adapted from oscilloscope-trigger circuitry. If C₁ charges past the point where C₂ can reset it, loop closure ceases, and IC₂'s output saturates positive, causing IC₃ to go negative. IC₃'s prolonged negative state, detected by the R₁/C₃ filter, pulls IC₃'s negative input towards -15V. When IC₃'s negative input crosses zero, its output changes state and charges R₁/C₃ positively. IC₃'s input rises above zero, causing output reversal, and free-running oscillation commences.

As in normal mode, the 33-k Ω /100-pF R₂/C₄ filter aids transitions. IC₁ and the inverters transmit IC₃'s oscillations to the charge pump. C₂ pumps charge out of C₁, driving the voltage across it towards zero. C₂ comes out of positive saturation and heads negative, eliminating positive bias at IC₃'s input. IC₃'s free-running oscillation stops, and normal loop action resumes.

To calibrate this circuit, apply either a -10 or a +10V input and set the 10-k Ω trimmer, R₃, for exactly 10-kHz output. The low offsets of IC₁ and IC₂ permit operation down to a few hertz with no zero trim required. (EDN BBS /DL_SIG #961) **EDN**

To Vote For This Design, Circle No. 748

References

1. Tektronix Inc, "Automatic Stability Circuit," Type 547 Oscilloscope Operating and Service Manual, Tektronix Inc, 1964.
2. Tektronix Inc, "Automatic Trigger," Oscilloscope Trigger Circuits, Tektronix Concept Series, Tektronix Inc, 1969, pp 39-49.

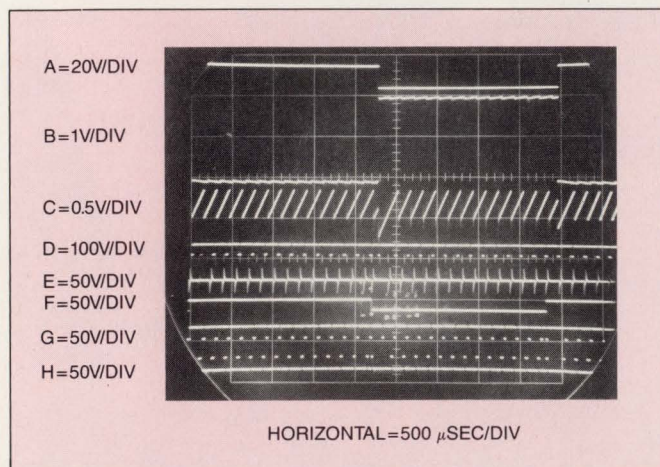


Fig 2—This scope photo illustrates the V/F converter's operation.

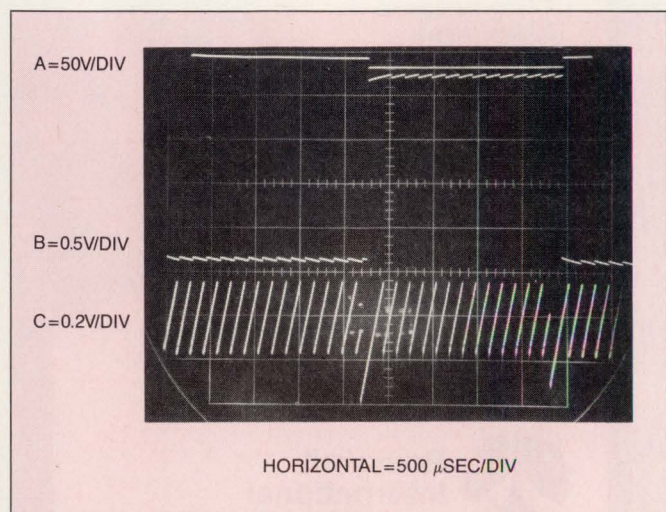


Fig 3—This scope photo shows IC₁ and IC₂'s outputs in greater detail.

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DESIGN IDEAS

PAL makes μ P see double

Krish Narasimhan and James G O'Connor
*Broad Band Technologies,
 Research Triangle Park, NC*

The 22V10 PAL, IC₁, in **Fig 1** fools a 16-bit, single-chip, National HPC series μ P, in this case a

16400PLCC μ P, IC₂, into thinking that the normal complement of two ROM devices are present when, in fact, the circuit has only one ROM device. In addition, the PAL enables RAM bank switching.

A peculiarity of the HPC μ Ps is at the heart of this scheme. Even in 16-bit mode, the HPC μ Ps fetch only

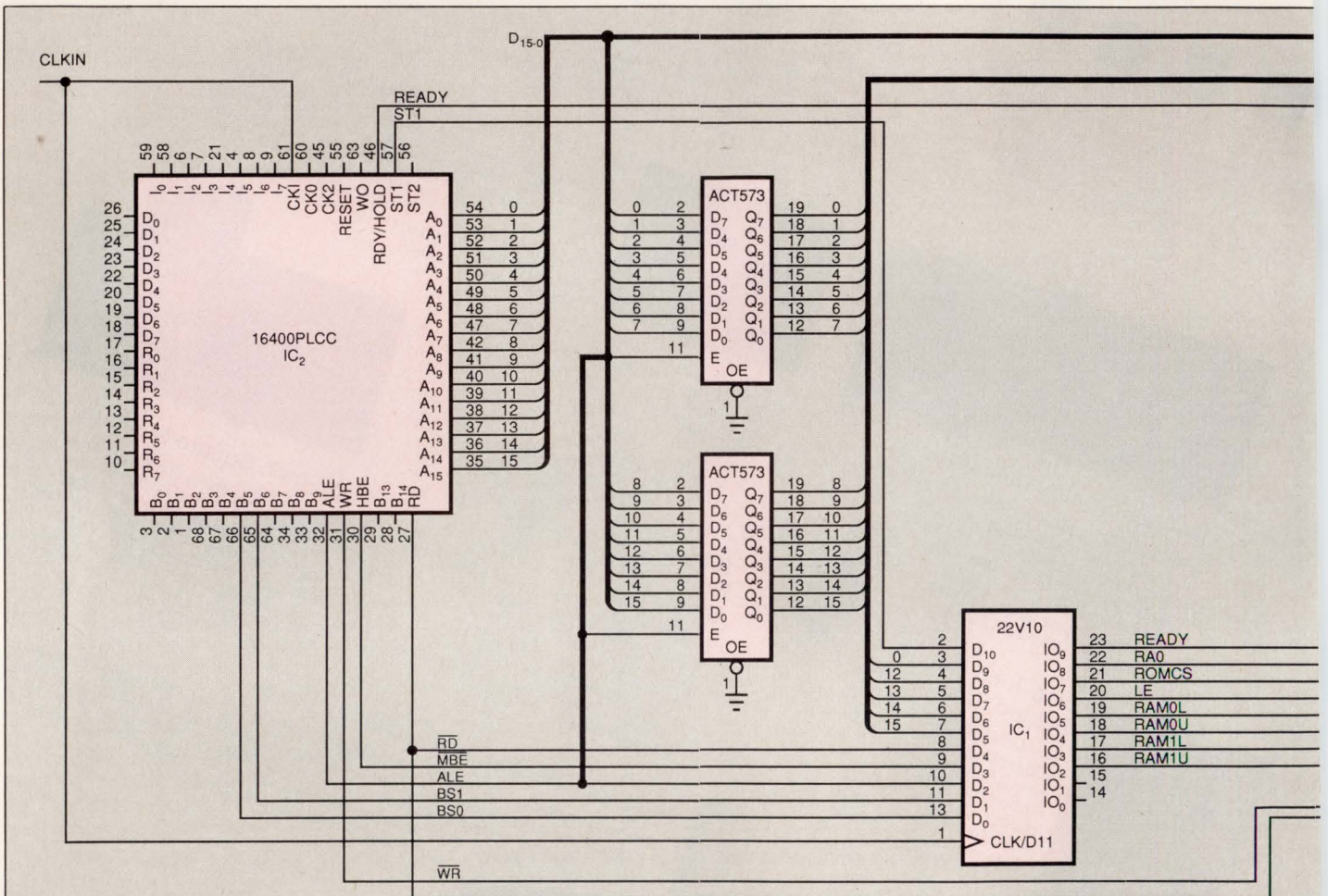
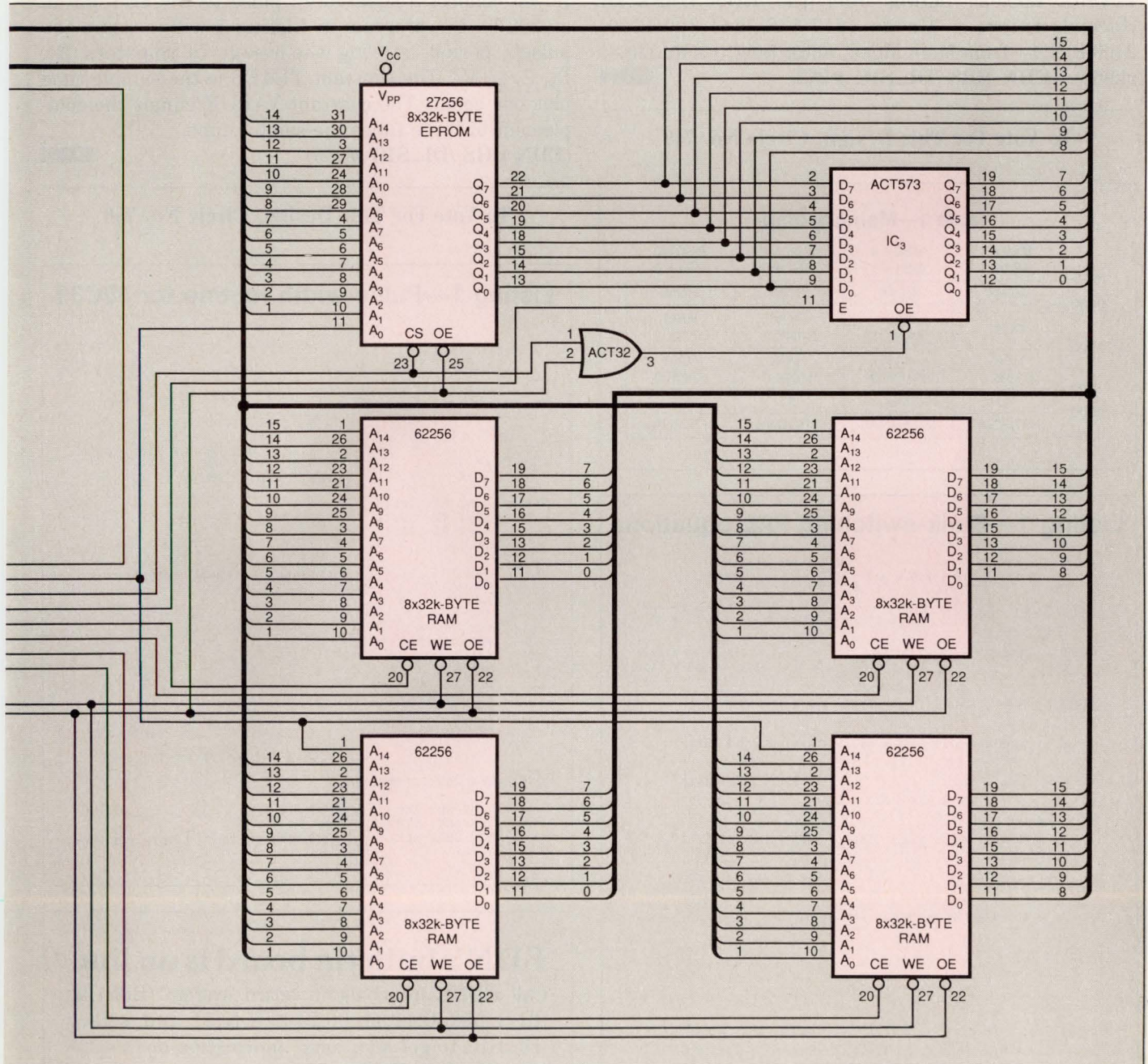


Fig 1—The 22V10 PAL in this circuit fools the μ P into thinking two ROM devices are present by requesting a wait state, during which it fetches two bytes from a single ROM device.

DESIGN IDEAS

bytes during instruction-fetch cycles; data fetches are, however, 16-bit-word fetches. If your ROMed program were to contain only instructions, then you could easily use just a single 8-bit-wide ROM device to hold the program. This scheme hits a snag, however, if the ROMed program contains 16-bit data words.

In operation, the 22V10 solves this problem by decoding the μ P's status lines to determine if the μ P is fetching either a 16-bit data word or an 8-bit byte. If the PAL detects a word fetch, it causes the μ P's RDY/HOLD line to trigger a wait state. During the wait state, the PAL latches the even byte into latch IC₃.



DESIGN IDEAS

Then the PAL toggles the ROM's A_0 line to access the odd byte. When the μP resumes execution after the wait state, it encounters both the low and high bytes of the complete data word on its data bus.

The PAL also decodes the μP 's bank-switching pins, B_5 (BS0) and B_6 (BS1), to select either RAM or ROM banks according to **Table 1**. **Listing 1** shows the Boolean equations for the PAL. You can obtain the 22V10's Boolean listing from the EDN BBS's DI Special Interest Group (617-558-4241,300/1200/2400,8,N,1—from Main Menu, enter (s)ig, <di_sig>, rk962). (EDN BBS /DI_SIG #962) **EDN**

To Vote For This Design, Circle No. 749

	BS0=1 BS1=1	BS0=0 BS1=1	BS0=1 BS1=0	BS0=0 BS1=0
FFFF	ROM	ROM	ROM	ROM
F000	ROM	RAM BANK 1	RAM BANK 2	RAM BANK 3
8000	RAM BANK 0	RAM BANK 0	RAM BANK 0	RAM BANK 0
1000	I/O	I/O	I/O	I/O
0200	INTERNAL	INTERNAL	INTERNAL	INTERNAL
0000	INTERNAL	INTERNAL	INTERNAL	INTERNAL

Listing 1—Bank-switching PAL equations

```

!ROMCS = A15 & BS0 & BS1 & !ALE
          # A15 & A14 & A13 & A12 & !ALE;

!RAM0L = !A0 & !ALE & (!A15 & (A14 # A13 # A12)
          # A15 & !BS0 & BS1 & (!A14 # !A13 # !A12));

!RAM0U = !HBE & !ALE & (!A15 & (A14 # A13 # A12)
          # A15 & !BS0 & BS1 & (!A14 # !A13 # !A12));

!RAM1L = !A0 & !BS1 & !ALE & A15 & (!A14 # !A13 # !A12);

!RAM1U = !HBE & !BS1 & !ALE & A15 & (!A14 # !A13 # !A12);

RA0 = A0 & (A15 & BS0 & BS1 & !ALE
          # A15 & A14 & A13 & A12 & !ALE)
      # !LE
      # !BS0 & !BS1 & A15 & (!A14 # !A13 # !A12) & !ALE;

!Q0 := (A15 & BS0 & BS1 & !ALE
        # A15 & A14 & A13 & A12 & !ALE)
      & !RD & !ST1 & !HBE & !A0;

!LE := !Q0;

!Q1 := !LE;

!READY = ((A15 & BS0 & BS1 & !ALE
           # A15 & A14 & A13 & A12 & !ALE)
          & !RD & !ST1 & !HBE & !A0)
        & Q1;
    
```

80C39- μP routine measures pulse width

Xu Jiankang
Haida Co, Qingdao, Shandong, China

If you connect a squared-up pulse to the INT pin of an 80C39, the program in **Listing 1** will measure the pulse's period, storing the result in registers R_1 , R_2 , . . . , R_7 . The constant TIMES is the sample time plus one count. The constant VALUE equals the complement of three times the sample time. (EDN BBS /DI_SIG #965) **EDN**

To Vote For This Design, Circle No. 750

Listing 1—Pulse-width routine for 80C39

```

MAIN PROGRAM
-----
MOV R0, TIMES           ;HOW MANY TIME TO SAMPLE
MOV R1, VALUE          ;INITIALIZE COUNTER
MOV R2, ZERO           ;INITIALIZE COUNTER
MOV R3, ZERO           ;INITIALIZE COUNTER
-----
ENI                     ;IF THE COUNTER NOT BIG ENOUGH
IDLE                    ;ENABLE EXTERNAL INTERRUPT
                        ;WAIT FOR EXTERNAL INTERRUPT

BEGIN: DJNZ R1, BEGIN   ;COUNTING
       DJNZ R2, BEGIN
       DJNZ R3, BEGIN
-----
NEXT: DISI              ;DISABLE EXTERNAL INTERRUPT
      MOV A, R1
      CPL A
      INC A
      MOV R1, A
      MOV A, R2
      CPL A
      INC A
      MOV R2, A
      MOV A, R3
      CPL A
      INC A
      MOV R3, A
      -----
      ; PROCESS THE VALUE AS YOU LIKE

INTERRUPT SERVICE ROUTINE
-----
DJNZ R0, END
MOV R0, STOCK_BOTTOM
MOV @R0, NEXT          ;SECOND INLET FOR MAIN PROGRAM
END: RETR
    
```

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DESIGN IDEAS

FEEDBACK AND AMPLIFICATION

Reader worries that idea is unsafe

I am writing to express my concern about V Lakshminarayanan's Design Idea, "Hall sensor detects ground faults," (EDN, October 11, 1990, pg 235, DI #892). The circuit, which also appeared in the December 27, 1990, issue of *Electronic Design*, does indeed detect earth-line leakage current. It does not, however, protect against shock hazard, as the text states, and should not be used as an alternative to UL-recognized ground-fault-protection circuitry.

First, to protect against shocks, the circuit must detect fault currents that return to earth via pathways other than the power system's neutral conductor. The Design Idea cannot detect such ground-fault currents. Second, if the circuit were to trip an input breaker after detecting, for example, a power line shorted to the equipment's case, that equipment would be left in an unsafe condition. The circuit opens the equipment's neutral connection, potentially leaving the case still energized by the shorted power line.

Thomas H Hoover, PE
Fairmont Railway Motors
415 N Main St
Fairmont, MN 56031

Author regrets double submission

I made an error in the above-referenced circuit's schematic. The circuit breaker should open the power lines and not the neutral conductor.

I sincerely regret the inconvenience I caused [by sending this idea to two magazines]. The mixup occurred due to a records-keeping error. In the future I will ensure that such mixups do not occur. I hope to contribute many more Design Ideas exclusively to EDN in the future.

V Lakshminarayanan
Centre for Development of Telematics
SNEHA Complex—71/1 Miller Rd
Bangalore, 560-052, India

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Also, Design Ideas should not use patented circuits or special ICs that require licensing.

Charles H Small and Anne Watson Swager

Author rebuts reader

I have just read the comments by Heiner Schlichting about my Design Idea ("Peak detector holds signal indefinitely," EDN, May 24, 1990, pg 173) in the March 1, 1991, edition of EDN. Mr Schlichting supposes that adding a R/2R ladder will improve the performance of my peak detector. But he has missed the point of my circuit. The circuit is an analog peak detector, *not* an A/D converter. The R/2R ladder would supposedly improve the linearity and monotonicity of my Design Idea. However, neither of these specifications is important for my Design Idea's function: tracing a slowly changing analog signal to within 10 mV and providing an analog output. Adding an R/2R ladder would not degrade my Design Idea's performance but it wouldn't improve the performance either; adding an R/2R ladder would therefore be expensive overkill.

Steve Hageman
Calex
3355 Vincent Rd
Pleasant Hill, CA 94523
(415) 932-3911

Editor notices mistake

Unfortunately, two errors crept into the artwork for Jim Williams' Design Idea "Amplifier scheme lowers drift and noise," (EDN, March 1, 1991, pg 135). IC₁ should be an LTC1028 and IC₂ should be an LTC1097. If you build the circuit using the LT1037s as incorrectly shown, your circuit's noise will be much higher than that for the correct design, and the circuit will likely oscillate.

Anne Watson Swager
Design Ideas Editor



DESIGN NOTES

Switching Regulator Generates Both Positive and Negative Supply with a Single Inductor – Design Note 47

Brian Huffman

Many systems require $\pm 12V$ from a 5V input. Analog or RS-232 driver power supplies are obvious candidates. This requirement is usually solved by using a switcher with a multiple-secondary transformer or multiple switchers. These solutions can be complicated, requiring either transformer design or two inductors. An alternative approach, shown in Figure 1, uses a single inductor and charge pump to obtain the dual outputs. This solution is particularly noteworthy because it uses off-the-shelf components.

Figure 1 uses an LT1172 to generate both the positive and negative supply. The LT1172 is configured as a step-up converter to obtain the positive output. To generate the negative output a charge pump is used. The pump capacitor, C2, is charged up by the inductor when D2 is forward biased and discharges into C4 when the LT1172's power switch pulls the positive side of C2 to ground. The output capacitor provides current to the load during the charging cycle.

Figure 2 shows the regulator's operating waveforms. Since the LT1172 has a ground referred power switch, the inductor has the input voltage applied across it when the switch is on. Trace A is the V_{SW} pin voltage and trace B is its current. The inductor current, trace C, rises slowly as the magnetic field builds up. During this interval, energy is being stored in the inductor and no power is transferred to the +12V output. When the switch is turned off, energy is no longer transferred to the inductor, which causes the magnetic field to collapse. The collapsing magnetic field induces a change in voltage across the inductor causing the V_{SW} pin to rise until output diode D1 forward biases.

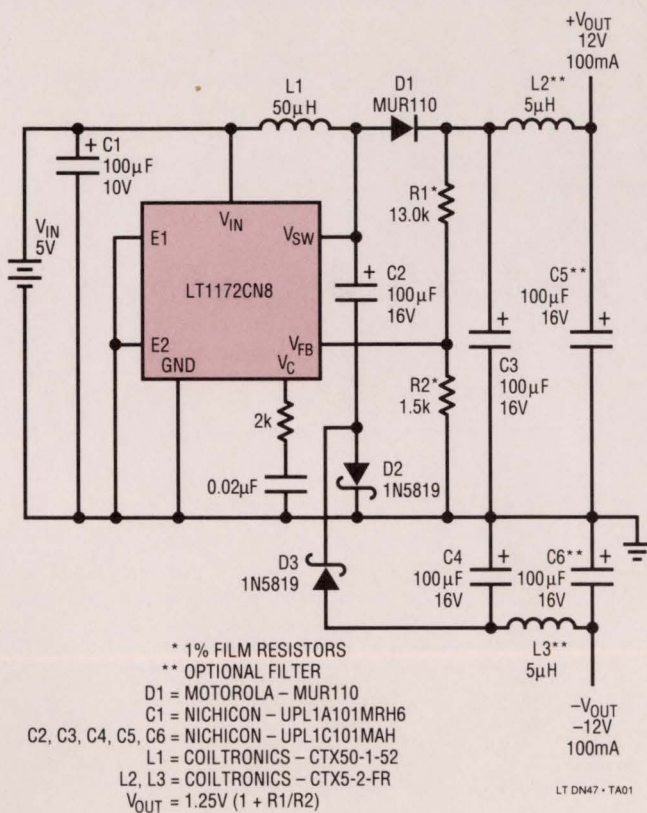


Figure 1. Inductor and Switch Capacitor Techniques Provide Bipolar Output

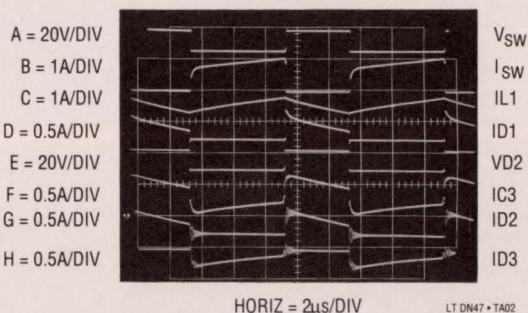


Figure 2. Switching Waveforms for $\pm 12V$ Output Converter

Trace D is the diode's current waveform. The diode provides a current path for the energy stored in the inductor to be transferred between the load and the output capacitor. When the diode is reverse biased, the output capacitor provides the load current. The LT1172's error amplifier compares the feedback pin voltage, from the $13k\Omega$ – $1.5k\Omega$ divider, to its internal 1.24V reference and controls duty cycle. The output voltage can be varied by changing the R1–R2 divider ratio (see Equation 1). An RC network at the V_C pin provides loop compensation.

A charge pump is used to invert the +12V output to a -12V output. When the LT1172's power switch turns off, the voltage on C2's positive side rises until D1 is forward biased. The inductor charges C2 when the voltage on C2's negative side rises enough to forward bias D2. Trace F shows C2's current waveform, trace E is D2's voltage waveform and trace G is its current. The voltage across C2 will be equal to a diode drop above + V_{OUT} minus a Schottky diode drop. When the LT1172's power transistor turns on, the positive side of C2 is pulled to ground. During this period diode D3 is forward biased (trace H is its current waveform), and C4 is charged by C2. An optional LC filter is added to each output to attenuated output voltage ripple. Efficiency for this circuit generally exceeds 70%.

Diode junction losses (D2 and D3) preclude ideal results, but performance is quite good. This circuit will convert + V_{OUT} to - V_{OUT} with losses as shown in Figure 3. Negative output load current should not exceed the positive output load by more than a factor of 5, otherwise the imbalance will cause the -12V transient response to suffer.

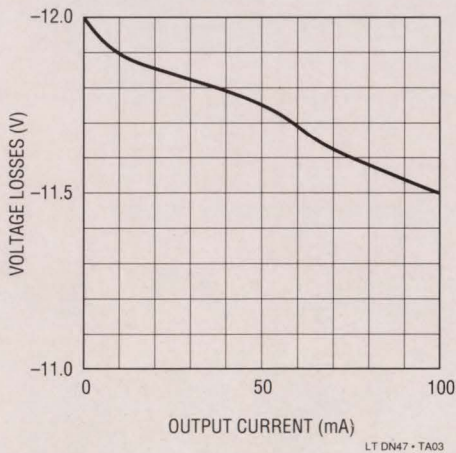


Figure 3. Losses for Charge Pump Converter

Figure 4 can be used for a LCD display contrast control. It is similar to the previous circuit except that all the load current is drawn from the negative output. This requires C3 to be small so negative output load fluctuations are quickly reflected to the positive output. Resistor R3 adjusts output voltage between -12V to -21V.

The LT1172 provides an elegant solution to power shutdown problems by integrating a shutdown feature; eliminating the need to place a power MOSFET in series with the input voltage. When the voltage of the V_C pin is pulled below 150mV, the IC shuts down pulling only 150 μ A. This is implemented by turning on Q1, reducing the circuit's quiescent current from 6mA to 150 μ A.

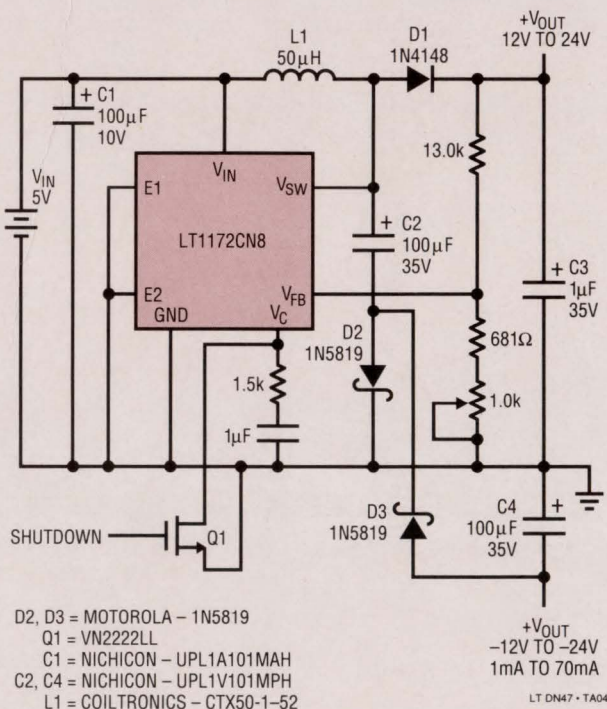
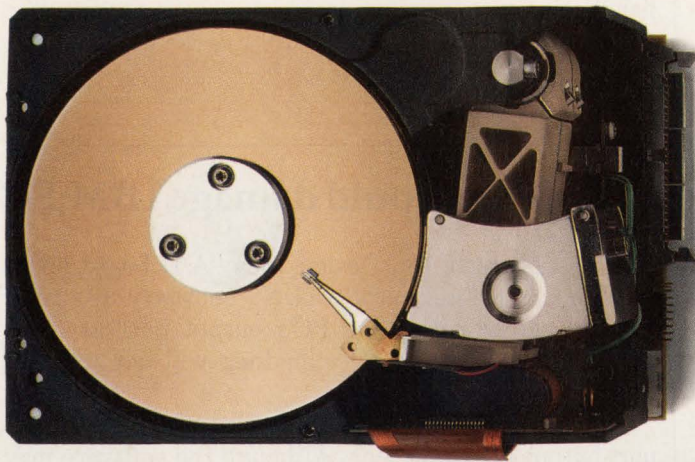


Figure 4. LCD Display Contrast Control Power Supply

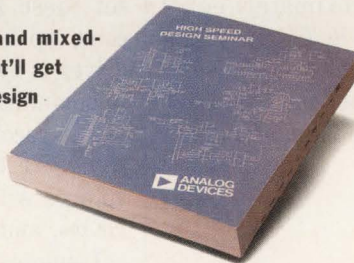
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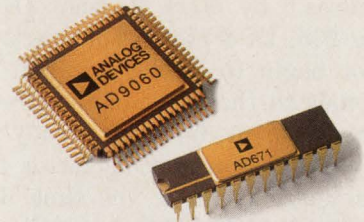


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Pulse stretcher stretches truth

The operation of the circuit in "Single gate stretches pulses," by Mark Krasnov (EDN, October 11, 1990, pg 238, DI #748) is not exactly as described. C_1 does not begin to discharge when a negative-going pulse comes to the input of the circuit (cathode of D_1). At this moment, C_1 must already be discharged, and this condition is a limiting factor for the input-signal parameters (that is, the time during which the input signal is high). If C_1 is not discharged, there will be a negative-going peak at the output of the 7407.

Charging of C_1 begins with the positive-going pulse at the input. Charging ends and discharging begins when the voltage at the anode of D_1 reaches the switch threshold of the 7407's input. C_1 charges through R_2 and the output of the 7407 and discharges through R_2 , R_1 , and D_2 . The stretched pulse is approximately equal to the input pulse's duration plus the R_2/C_1 time constant. Also, the circuit can violate the 7407's safe-operating requirements. The 7407's output should not be tied to a voltage higher than 5V. In this circuit, its voltage can exceed 6V.

Evgeni Bobilov

SII, MPS

Slavjanska Str 10

7000 Russe, Bulgaria

Oversized cap forces integration

Richard Majestic's Design Idea, "Audio compressor splits the band" (EDN, January 21, 1991, pg 160), is a variation of his circuit in the PMI/SSM Audio Handbook, Volume 1. In that version, he used PMI parts throughout, with SSM2134s in place of the NE5534s. By studying both versions, you can see slight component adjustments. However, one change is undoubtedly a typo: the final op-amp stage at the output has a 33- μ F capacitor across its feedback resistor, making it an integrator. This capacitor should probably be 33 pF, not 33 μ F.

John Lyles

E I du Pont de Nemours and Co

Wilmington, DE

(302) 478-6272

Author offers corrected schematic

In addition to the error that Mr Lyles spotted, the published schematic has other errors. I will mail a correct schematic to anyone who writes me.

My Design Idea is similar to one published in the

PMI-SSM Audio Handbook. That's because I wrote and designed all but one of the application notes in the handbook.

Richard A Majestic

2117 Bay Front Terrace

Annapolis, MD 21401

A/D board could damage IBM PC

The A/D board in the Design Idea "A/D board hooks to IBM PC printer port" (EDN, February 18, 1991, pg 184) cleverly uses the PC's output port as a dc-power source. But the Design Idea will not work as implemented.

The first problem comes from connecting six printer-port output lines together. Although the software may set these lines high during power-up, the lines may come up in an arbitrary state. The PC's printer-port driver is typically a 74LS244 that may self-destruct in this condition.

The second problem is the voltage of the line labeled "5V." At the load currents in this Design Idea, the voltage will be about 3.5V. That level cannot drive the LEDs, and it does not meet the Max171's specs.

I suggest diode-ORing the printer port lines with low-drop Schottky diodes and applying the resulting 3V dc to a 5V dc/dc converter.

Carl Spearow

Sundstrand Corp

4747 Harrison Ave

Rockford, IL 61125

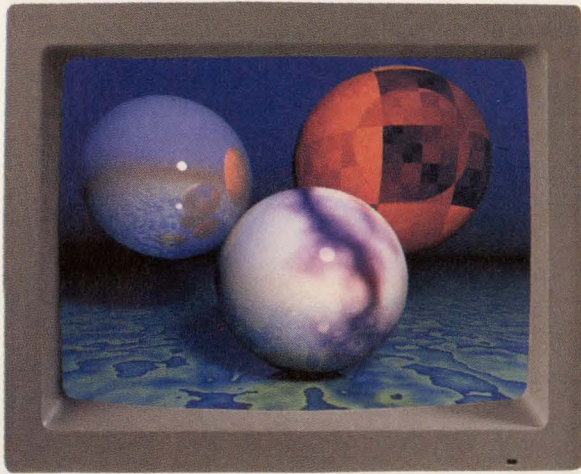
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"Board does work" says author

Mr Spearow's suggestions are good suggestions, but he is not correct in saying that the Design Idea as shown will not work. As Mr Spearow perceives, the 74LS374 can come up in an arbitrary state on power-up. (Note: the 74LSA244 is not the driver that powers the I/O board; the 74LSA244 feeds data back to the PC.) But the latch-up would persist for only a short time because the PC's normal power-on self-test clears the register. Further, the 27 Ω series resistors offer some protection. We have used this scheme through hundreds of bootup cycles on at least six different PCs.

As to the second problem, Mr Spearow is correct; the derived supply voltage will be about 3.5V, whereas we labeled it 5V. The 3.5V value is outside the Max171's data-sheet spec and would be a problem if we were running the device at its maximum conversion rate.

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Marball. Original image courtesy of University of California, Davis.



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After analyzing semiconductor suppliers, many of the leading oscilloscope and spectrum analyzer manufacturers chose Analog Devices for their mixed-signal components. One reason is our ability to deliver high performance at high levels of integration—for example, our AD640, which replaces a chain of discrete log-amps for higher accuracy.



With our motion control ICs, several major aircraft companies are staying right on course. High reliability and accuracy are hallmarks of our 2S80, AD598 and the rest of our nearly 400 defense-qualified products.

Today, Analog Devices offers a better line of high-performance mixed-signal components than anyone else. And no one has a better record for reliability, or more experience in analog, DSP and mixed-signal ICs. If you want mixed-signal components that'll help you design better products, the best thing to do is to call us at 1-800-262-5643.

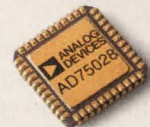
Continuous Edge Graphics is a trademark of Edsun Laboratories.



ADSP-2111—Better integration on the best architecture in the industry. Adds an 8/16-bit host port to the two serial ports, timer, hardware companding and memory already on the ADSP-2101. And like all our DSPs, it's got fast, flexible arithmetic, wide dynamic range and a single cycle fetch of two operands (on- or off-chip). Plus it's code-compatible with the rest of our DSP family, so what's written today will be useful tomorrow.



ADV7141—Our new Continuous Edge Graphics™ RAM-DAC gives users of standard low-end color monitors better graphics on their PCs. Graphics that are virtually the same as those produced on expensive engineering and scientific workstations. It does this by eliminating jagged edges, providing photo-realistic colors and shading, and displaying text comparable to a 300-dpi laser printer.



AD75028—This custom ASIC passes the test for a top automatic test equipment manufacturer. Serving the function of 21 separate 12- and 8-bit D/A converters and providing on-chip static RAM, it also has seven channels of level setting (other monolithics only have four), and can automatically remove gain and offset errors.



The idea of taking power from the PC is really not central to the Design Idea; the main idea is starting and clocking two serial ADCs and then inputting the two resulting streams of serial data through what is usually considered an output port. Our software is a larger part of the idea than the hardware.

Mr Spearow's circuit is an appealing idea, but I fear that it might have problems of its own before the printer port is initialized—consider the case of one of the outputs being forced to carry the whole load, the load being considerably higher because of the switcher.

Bob Underwood

*Maxim Integrated Products Inc
120 San Gabriel Dr
Sunnyvale, CA 94086
(408) 737-7600*

Trapped flux forms capacitor

If you design surface-mounted components into circuits that are sensitive to small shifts in capacitance, beware! Flux trapped beneath components forms a relatively good dielectric and thus adds a parallel capacitor across your otherwise precision part. The symptom of this problem is components that test within specs when removed from a pc board yet exhibit 1 to 2% too much capacitance in-circuit. The solution is a thorough cleaning. Soak the boards in solvent and then run them through a dishwasher.

*Richard Lamoureaux
13220 Haneworth Ave
Hawthorne, CA 90250
(213) 643-7221*

Author corrects schematic error

I made errors in the schematic and equations I submitted with my Design Idea, "Buffers stabilize oscillator," (EDN, February 4, 1991, pg 105, DI #933). Connect resistor R_2 to the outputs of buffers A and B rather than to their inputs. Also, note an obvious typo in the first equation's denominator: The equals sign appearing between R_1 and R_2 should be a plus sign. Lastly, because $R_1' = R_1'' = 2R_1$, the second equation should read: $R_1 = (R_1'R_1'')/(R_1' + R_1'')$.

For these formulas to work, the op amp's gain/bandwidth product should be very large compared to f_0 . Note that this circuit's maximum f_0 is 70 Hz.

Maxwell Strange

*NASA
Goddard Space Flight Center
Greenbelt, MD 20771*

Design Entry Blank

\$100 Cash Award for all entries selected by editors. An additional \$100 Cash Award for the winning design of each issue, determined by vote of readers. Additional \$1500 Cash Award for annual Grand Prize Design, selected among biweekly winners by vote of editors.

To: Design Ideas Editor, EDN Magazine
Cahners Publishing Co
275 Washington St., Newton, MA 02158

I hereby submit my Design Ideas entry.

Name _____

Title _____ Phone _____

Company _____

Division (if any) _____

Street _____

City _____ State _____

Country _____ Zip _____

Design Title _____

Home Address _____

Social Security Number _____

(Must accompany all Design Ideas submitted by US authors)

Entry blank must accompany all entries. Design entered must be submitted exclusively to EDN, must not be patented, and must have no patent pending. Design must be original with author(s), must not have been previously published (limited-distribution house organs excepted), and must have been constructed and tested. Please submit software listings and all other computer-readable documentation on a 5¼-in. IBM PC disk.

Exclusive publishing rights remain with Cahners Publishing Co unless entry is returned to author or editor gives written permission for publication elsewhere.

In submitting my entry, I agree to abide by the rules of the Design Ideas Program.

Signed _____

Date _____

ISSUE WINNER

The winning Design Idea for the February 18, 1991 issue is entitled "A/D board hooks to IBM PC printer port, submitted by Bob Underwood of Maxim Integrated Products (Sunnyvale, CA) and Mark Underwood (Cupertino, CA).

Your vote determines this issue's winner. All designs published win \$100 cash. All issue winners receive an additional \$100 and become eligible for the annual \$1500 Grand Prize. **Vote now**, by circling the appropriate number on the reader inquiry card.

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More gadgets for less money, and make it work better—that's the only way to survive in consumer electronics, the most competitive market there is. That's why three of the top five Japanese electronics firms rely on us to meet their mixed-signal needs in applications ranging from CD players to video cameras.

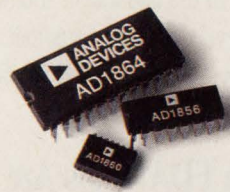
We're far from your local component boutique. Over half of our \$540 million in revenues comes from international sales. And with manufacturing and stocking facilities on just about every continent, getting products to you quickly is a snap. Plus multiple manufacturing facilities allow us to take advantage of the right talent and processes for the job at hand.



With billions of dollars in annual sales at stake, the video game market is anything but child's play. One leader in this market found that with our DSP they could create more realistic and interactive games. As a result, they're driving away with a bigger share of the market.

Today, Analog Devices offers more cost-effective solutions to your high-performance mixed-signal needs than anyone else. Solutions that are surprisingly affordable, whether they're available off the shelf or developed for a specific application. To find out more about how we can help you develop products more efficiently, or for a free copy of our recent Mixed-Signal Technology white paper, call us at 1-800-262-5643.

Analog Devices, Inc., One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106. Headquarters: (617) 329-4700. Offices and applications support available worldwide.



SOUNDPORT DACs—We've made these DACs cost-efficient by making them complete with output amplifier, reference and digital logic interface. Perfect for high-fidelity digital audio and multi-media applications, these mixed-signal ICs achieve SNRs as high as 108 dB and THDs as low as 0.0025%.



AD712—If you're working in professional audio and compact disc applications, you'll like the sound of this—an IC that combines two high-performance op amps in one compact package. You get low offset voltage and low input bias currents coupled with superb transient response, ambience, clarity and dynamic range.



ADSP-2105—High performance DSP at an incredibly low price. So low, in fact, you can now consider DSP in a host of new applications. And since it's pin-compatible with the ADSP-2101, and code-compatible with all of our other DSP processors, upgrading is easy and inexpensive.



This EDA Industry Forum is a "must attend" event for the movers and shakers of the industry. Learn what will drive EDA into the 90's. The results of two comprehensive research studies will examine which tools readers plan to use and a look at how standards development impacts tool use and selection. **Joe Costello, EDAC Executive Chairman will set the stage for:**

• **Which EDA Tools Are Used?**

John Russell, Editor of EDN News Edition will present the results from EDN's annual survey of EDA tool use among its readers. He'll compare this year's results with last year, and examine the demographics of surveyed tool users by title and industry.

• **Which Standards Are Most Essential?**

Mitch Weaver, EDAC Standards Committee Chairman, will look at what users say about standards, and reveal how standards help determine which tools engineers will select and which they avoid.

EDA IN THE 90's: Find Out What Users Say About Tools, Standards and More

EDAC/EDN NEWS EDITION INDUSTRY FORUM

• **How Should Tool Standardization Proceed?**

Mitch Weaver will present the next essential steps towards adoption of the most important standards.

• **Who Should Attend?**

EDA Engineering Professionals

You'll have the chance to find out:

- Your colleagues assessments of tools and plans
- Board and ASIC densities being tackled
- What's the preferred platform
- Top concerns of users

Design Automation Vendors

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EDAC (Electronic Design Automation Companies)
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EDAC
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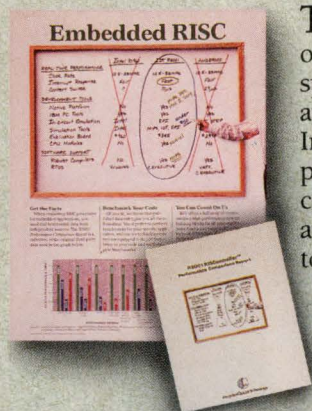
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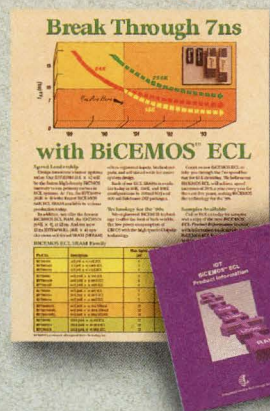
Count On IDT

The R3001 RISController™: The Embedded Processing Solution



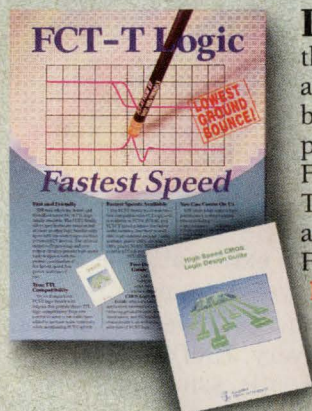
The R3001 is the first derivative of the R3000 processor designed specifically for embedded control applications. Compared to the Intel 960 and AMD 29K processors, the R3001 is the most cost-effective solution for these applications—we have the data to prove it! Call and ask for **KIT CODE 0091A** to get an **R3001 Performance Comparison Report**.

BiCEMOS™ ECL SRAMs: Technology for the '90s



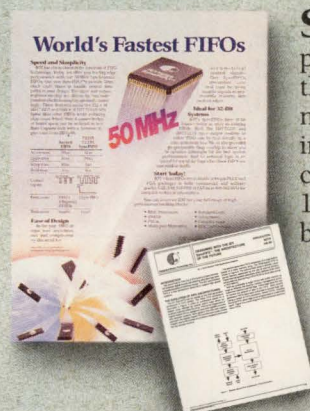
Design the fastest systems with IDT's BiCEMOS ECL family. At 7ns, the IDT10494 is the fastest BiCEMOS 64K ECL SRAM in production. 256K and synchronous self-timed SRAMs are also available in 10K/100K/101K configurations. Call and ask for **KIT CODE 0091B** to get a copy of the **BiCEMOS ECL Product Information** booklet.

FCT-T Logic: Fastest Speed/ Lowest Ground Bounce



IDT's FCT-T Logic Family is the fastest logic family available and has the lowest ground bounce—up to 40% less than previous FCT devices! The FCT-T family provides direct TTL logic compatibility and is available in FCT, FCT-AT, and FCT-CT speeds. Call today for **KIT CODE 0091C** and get a copy of the **High-Speed CMOS Logic Design Guide**.

The SyncFIFO™ Family: Double Your FIFO Performance



SyncFIFOs offer leading-edge performance that is 50% faster than other FIFOs. The synchronous architecture is easy to implement and reduces chip count 9-to-1. SyncFIFOs have 18-bit buses and are ideal for 32-bit systems. Ask for **KIT CODE 0091D** to get **AN-60: Designing with the IDT SyncFIFO™**.

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IDT offers a complete line of board-level subsystem products, including cache memory, shared-port memory, writable control store, RISC CPU, high integration modules, and custom designs for specific applications. Call today for **KIT CODE 0091E** and receive technical data and a **free IDT puzzle!**

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IDT's cache tag SRAMs have the features you want to design in: single-pin block reset, totem-pole match output, 4K and 8K depths, industry standard pinouts, and an on-board comparator to simplify design. Call and ask for **KIT CODE 0091F** to get **free samples** of the IDT6178 cache tag.

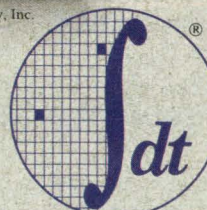
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Contact us today to receive data sheets and other design information on IDT's products.

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3236 Scott Boulevard, P.O. Box 58015, Santa Clara, CA 95052-8015
EDN May 9, 1991

CIRCLE NO. 135



When cost-effective performance counts

Integrated Device Technology, Inc.

NEW PRODUCTS

INTEGRATED CIRCUITS

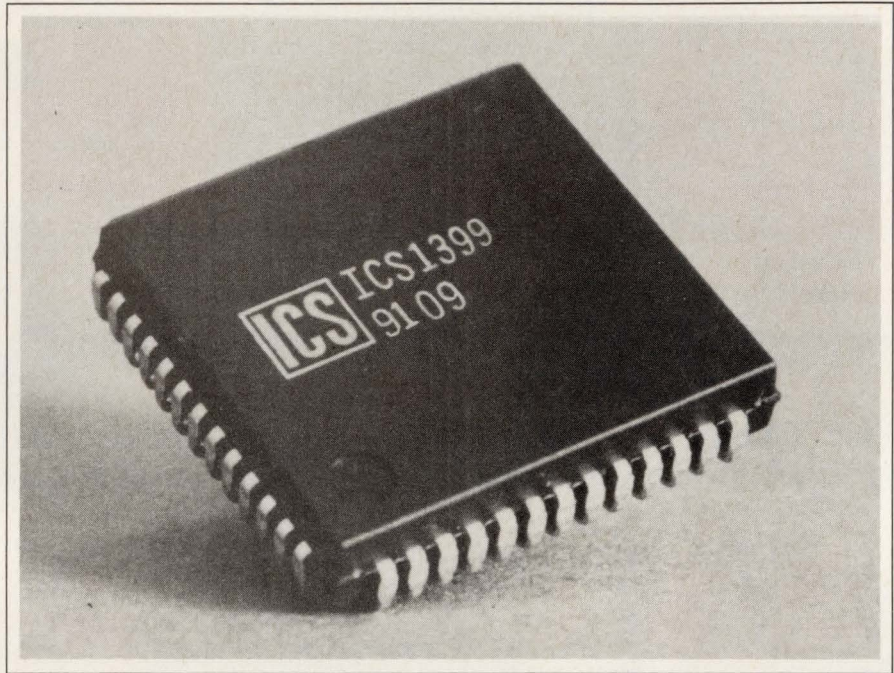
Multimedia Sound Processor

- Meets Microsoft's multimedia sound specification
- Uses waveform-table look-up-based synthesis

The ICS1399 digital sound generator provides music, speech, and sound effects. The chip synthesizes the waveforms via table look-ups. High-quality sound is a result of direct output of PCM data sample rates to 48 kHz, 25 voices each with a 4-pole digital filter, and 12-bit resolution. Small quantities are available from stock. \$15 (1000).

Integrated Circuit Systems Inc., Box 968, Valley Forge, PA 19482. Phone (800) 220-3366; in PA, (215) 666-1900. FAX (215) 666-1099.

Circle No. 351



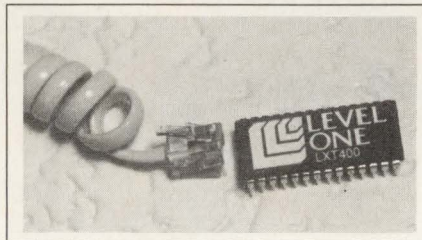
16-Bit CPU And Dual MMU

- Operates at 16 MHz
- Dual MMU manages 16M-byte address space

The 16C04 is a 16-MHz version of the Z16C00 family of μ Ps. The processor offers eight addressing modes and 414 total instructions using hardwired logic. Data types and addressing modes include sixteen 16-bit general-purpose registers; seven data types, which range from bits to 32-bit-long-word, and word and byte strings. The dual memory-management unit (DMMU) contains a dynamic-segment relocation feature that allows user addresses to be independent of physical memory. Segments are protected by modes of permitted use. Twenty-two I/O instructions from the central processor control the DMMU. Z16C04 in a 68-pin plastic leaded chip carrier, \$18.23; Z080210 DMMU, \$33 (1000).

Zilog Corp., 210 Hacienda Ave, Campbell, CA 95008. Phone (408) 370-8000. FAX (408) 370-8056.

Circle No. 352



Integrated DDS Transceiver

- Operates at any of 14 preset data rates
- Compatible with #19 to #26 AWG twisted-pair cable

The LXT400 integrated-line interface circuit for digital data services operates to five DDS1 primary rates, five DDS2 secondary rates, and four Pacific Bell rates ranging from 2.4k to 72k bps. At the same time, the transceiver provides transmit pulse shaping, receive signal detection, and timing recovery. The IC's transmit section comprises a level programmable, 50% alternate-mark inversion encoder; a programmable switched-capacitor notch filter; and a continuous reconstruction filter. The receive section

requires an external 4.096-MHz clock or crystal to perform line equalization, data decisions, and timing recovery. LXT400JE in a 28-pin ceramic DIP, \$30 (1000).

Level One Communications Inc., 105 Lake Forest Way, Folsom, CA 95630. Phone (916) 985-3670.

Circle No. 353

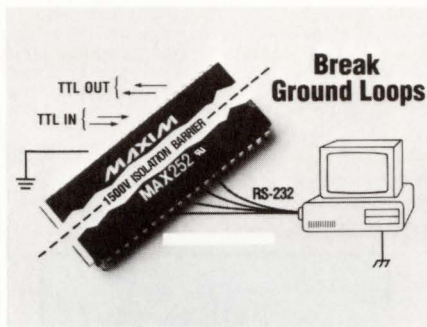
Voltage Multiplier/Regulator

- Pin-switchable output voltage from $3V \pm 5\%$ to $5V \pm 4\%$
- Maximum 11- μ A operating-current consumption

The S-8430AF CMOS IC includes an oscillator circuit, a switching regulator, a series regulator, and a Schottky diode. External signals change the output voltage between 3 and 5V, and they start and stop the IC's internal oscillator for standby or operating modes. The chip operates as either a series regulator, when the input voltage exceeds the specified output voltage or as a step-up switching regu-

More Analog Solutions For Tough Design Problems

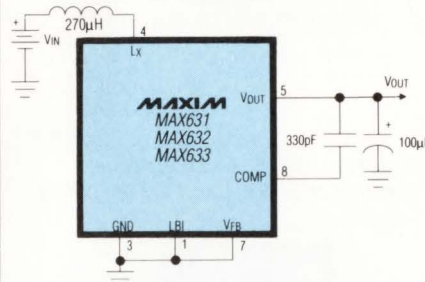
Isolated RS-232 in One Package!



The **MAX252** provides a complete isolated interface in one +5V-powered standard 40 pin DIP package by delivering voltage isolation up to UL levels (1500V for 1 sec.).

(CIRCLE 1)

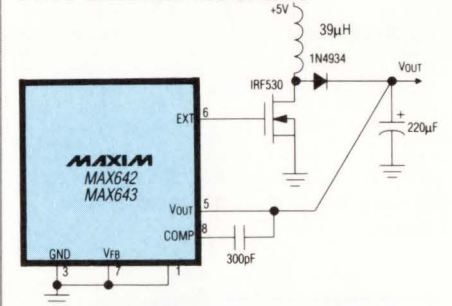
Step-Up Switching Regulators Require Only 3 External Components



The **MAX631/632/633** +5V, +12V, and +15V fixed-/adjustable-output DC-DC converters are ideal for minimum-component, high-efficiency DC-DC converters. They have 80% typ efficiency, a charge pump for negative output, and operate from as little as 135µA.

(CIRCLE 2)

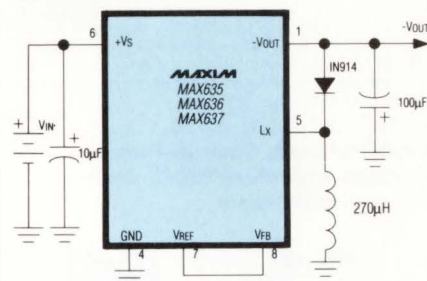
10W Step-Up Switching Regulators Drive External MOSFETS



The **MAX641/642/643** are designed for simple, high-efficiency DC-DC circuits in the 5mW to 10W range. These devices have fixed +5V, +12V, +15V and adjustable output voltages, 80% typ efficiency, 135µA typ operating current, and require only 5 external components.

(CIRCLE 3)

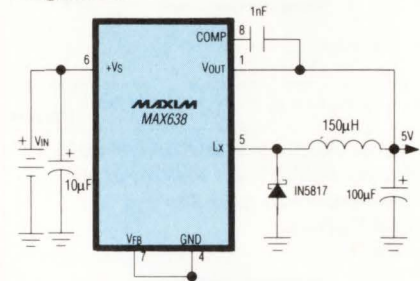
80µA Inverting Switching Regulators for Battery Powered Systems



The **MAX635/636/637** are designed for low-power, high-efficiency DC-DC conversion in the 5mW to 500mW range. The circuits include preset -5V, -12V, -15V and adjustable outputs, 85% typ efficiency, and require only 4 external components.

(CIRCLE 4)

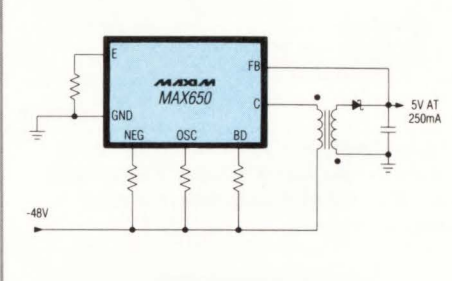
85% Efficiency, +5V/Adjustable-Output, Step-Down Switching Regulator



The **MAX638** is ideal for efficient, low-power DC-DC regulation. The converter operates from 135µA, requires only 5 external components, and has a low-battery detector.

(CIRCLE 5)

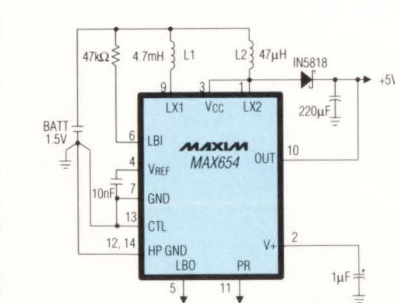
-48V to +5V Output Switching DC-DC Converter



The **MAX650** contains all control functions and a 140V, 250mA PNP transistor, reducing external components. The converter has a selectable soft-start function, a Shutdown pin for output on-off control, and peak-current limiting on the PNP output.

(CIRCLE 6)

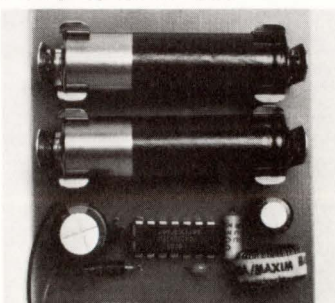
+5V Step-Up DC-DC Converter Operates from +1.15V!



The **MAX654** provides +5V at 60mA from a single-cell battery. This device minimizes component count and includes a low power mode (80µA quiescent current), low-battery indication, and a power-ready function.

(CIRCLE 7)

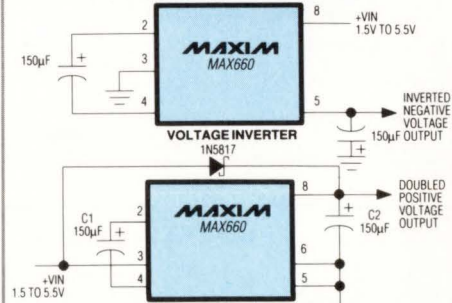
Evaluation Kit for Simple +3V to +5V Step-Up Converter



The **MAX655** Evaluation Kit includes everything needed to build and test a circuit that converts 2AA cells to +5V. The kit includes an evaluation board with low-noise layout, a MAX655, and all components necessary for prototyping with the MAX655.

(CIRCLE 8)

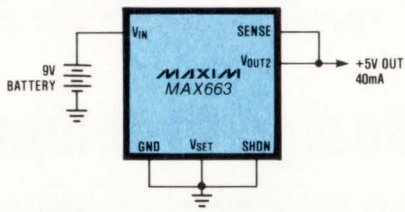
100mA-Output, Monolithic Voltage Converter Upgrades ICL7660



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

(CIRCLE 9)

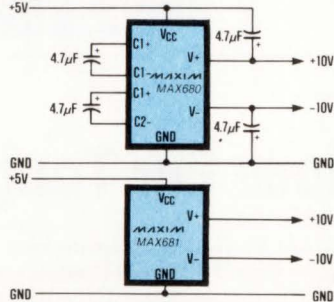
Dual-Mode™, +5V/Adjustable, Micropower Voltage Regulators



The MAX663/664/666, ideal for battery-powered systems, have 12µA max quiescent current, 40mA output current, +2V to +16V operating range, and a low-battery detector (MAX666). Maxim's parts, plug-in upgrades of the ICL7663/4, improve performance and eliminate external resistors in 5V applications.

(CIRCLE 10)

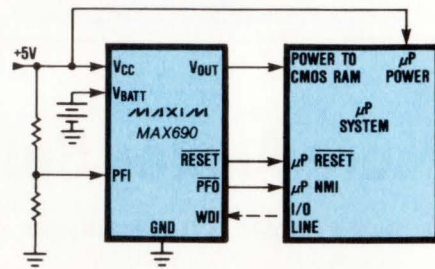
85% Efficiency, +5V to ±10V Voltage Converters



The MAX680/681 dual charge-pump voltage converters generate ±10V from a 5V source. Well-suited for portable applications, they have 85% power-conversion efficiency, +2V to +6V voltage range, and 500µA supply current. The MAX681 requires no capacitors, while the MAX680 needs only 4.

(CIRCLE 11)

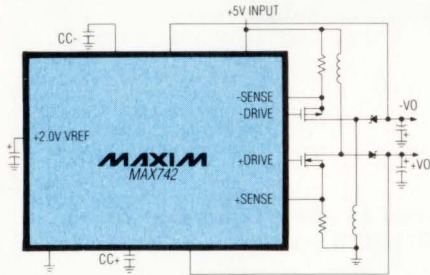
µP Supervisory Circuit Combines 5 Functions in 1 IC



The MAX690-5 reduce component count for power-supply monitoring and battery-control functions in µP systems. The MAX690 family includes µP reset and backup-battery switchover, watchdog timer, CMOS-RAM write protection, and power-failure warning.

(CIRCLE 12)

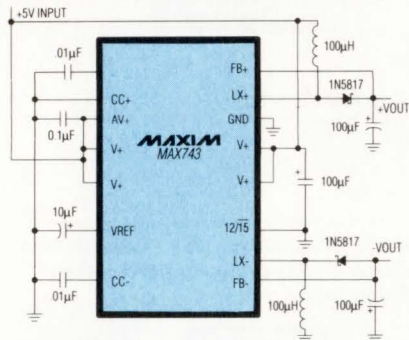
+5V to ±12V or ±15V, Dual-Output Converter—Powers up to 60W Loads!



The MAX742 relies on simple, two-terminal inductors rather than transformers to regulate both outputs independently to within ±4% over temperature, line, and load. Current-mode control provides tight regulation and operation free of subharmonic noise.

(CIRCLE 13)

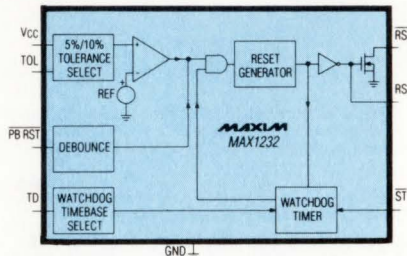
Dual-Output, Current-Mode Regulator (+5V to ±12V or ±15V)



The MAX743 uses minimum components to generate a regulated ±12V or ±15V 100mA output from +5V. A complete, current-mode DC-DC converter can be built for < 1/3 the cost of pre-packaged modules.

(CIRCLE 14)

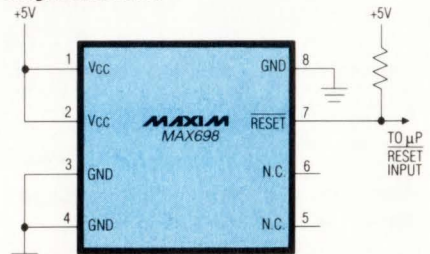
Microprocessor Supervisory Circuit—Upgrades DS1232 with 1/10th the Power!



The MAX1232 provides a simple, compact solution for power-supply and software monitoring in µP systems. The combination of a low 50µA supply current with 8-pin miniDIP and surface-mount packages makes the MAX1232 ideal for portable applications. All parts are pre-trimmed to monitor +5V systems and need no external components.

(CIRCLE 15)

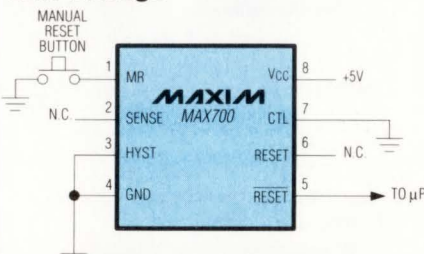
Low-Cost, Power-On Reset and Watchdog Controllers Eliminate All External Components and Adjustments



The MAX698/699 monitor the +5V supply in µP and digital systems. They supply a RESET pulse of at least 140ms on power-up, power-down, and during brown-out conditions. The MAX699 also includes a watchdog input to monitor µP activity.

(CIRCLE 16)

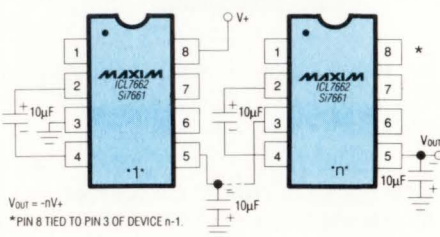
Power-Supply Monitor—Provides 200ms RESET on Power-Up, Power-Down, and During Low-Voltage



The MAX700/701/702 supervisory circuits monitor power supplies in µP and digital systems. The devices provide excellent circuit reliability at a low cost by eliminating external components and adjustments in +5V applications.

(CIRCLE 17)

High-Voltage, Charge-Pump Voltage Inverters Work with Inputs up to +20V



Maxim's ICL7662/Si7661 convert a +4.5V to +20V supply to a -4.5V to -20V output. For increased output voltage, the devices can be cascaded as shown above. Maxim's parts are pin compatible with the ICL7660.

(CIRCLE 18)

*** DATA SHEETS ***

- | | | |
|---------------------|----------------------|-----------------------------|
| MAX252 (Circle 1) | MAX655 (Circle 8) | MAX1232 (Circle 15) |
| MAX631-3 (Circle 2) | MAX660 (Circle 9) | MAX698-9 (Circle 16) |
| MAX641-3 (Circle 3) | MAX663-6 (Circle 10) | MAX700-2 (Circle 17) |
| MAX635-7 (Circle 4) | MAX680-1 (Circle 11) | ICL7662/ Si7661 (Circle 18) |
| MAX638 (Circle 5) | MAX690-5 (Circle 12) | |
| MAX650 (Circle 6) | MAX742 (Circle 13) | |
| MAX654 (Circle 7) | MAX743 (Circle 14) | |

*** FREE SAMPLES ***

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

HSPICE

TRANSMISSION LINES

As technology advances, ICs are running faster and printed circuit boards are becoming more densely populated and complex. Signal integrity is at question. Packaging must be considered to get an accurate assessment of the design feasibility. The combination of Meta-Software's HSPICE optimizing circuit simulator and its advanced modeling capabilities provide consistent, accurate and reliable results.

Meta-Software's transmission line model is fully functional for transient, DC, AC, optimization and Monte Carlo analysis. HSPICE transmission lines exhibit resistive loss, time delays and reflections. A compact model allows thousands of transmission lines in a single circuit simulation.

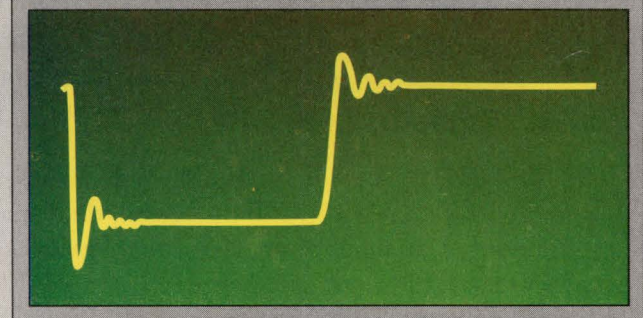
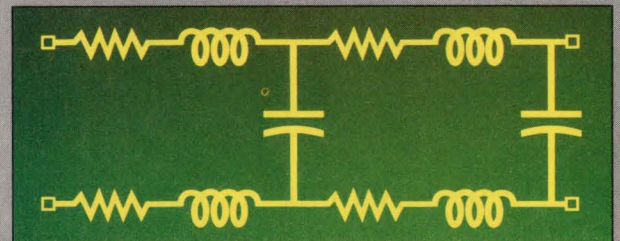
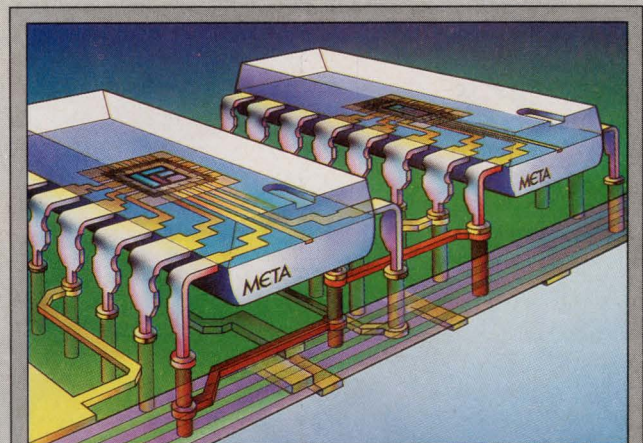
The HSPICE transmission line model includes:

- 1, 2 and 3 conductor coupled micro-strip/stripline for PCB use
- coaxial cable
- twin-lead

Models are calculated using advanced look-up table techniques for board/hybrid and LSI applications. Accuracy is maintained over frequency or time by dynamically synthesizing equivalent circuits as a function of transient timestep or maximum frequency.

Key applications include high frequency backplane design, silicon and GaAs substrate transmission line effects, IC packaging and printed circuit board signal analysis.

Contact Meta-Software today for more information on HSPICE—The Circuit Design Advantage!



Transmission line analysis with HSPICE: Measure physical sizes of conductors (top). Simulate using output buffer and transmission line models (middle). View results (bottom).



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lator when the input voltage is below the output voltage. \$1.55 (1000). Delivery, stock to 14 weeks ARO.

Seiko Instruments USA Inc, Semiconductor Products Group, 1150 Ringwood Ct, San Jose, CA 95131. Phone (408) 433-3208. FAX (408) 433-3214. **Circle No. 354**

Communications And Data-Monitoring Chip Set

- Includes microcomputer and EEPROM
- Operates at low voltages

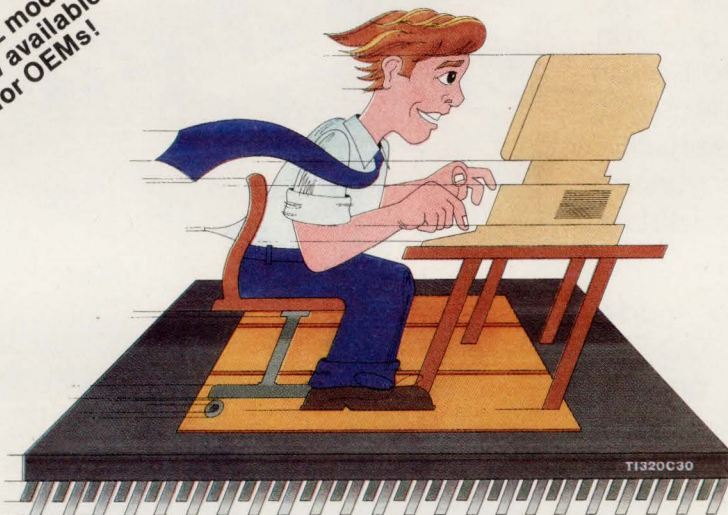
The SMC6235 4-bit microcomputer has high-frequency and low-speed clocks. Other features include a 4k x 12-bit ROM, a 576k x 4-bit RAM, a

sound generator, an LCD driver, an analog comparator, and a watchdog timer. Three voltage levels allow the device to operate between 0.9 and 3.5V. The SPM28C51C 512-bit serial EEPROM operates in read mode at 1 to 5.5V. SMC6235, in a 100-pin quad flatpack, \$8.75; SPM28C51C, \$1.95 (1000).

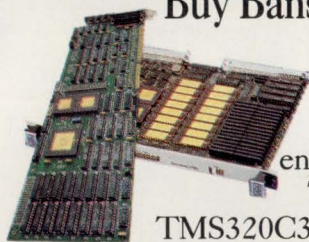
SMOS Systems, 2460 N First St, San Jose, CA 95131. Phone (408) 922-0200. FAX (408) 922-0238.

Circle No. 355

VME model now available for OEMs!



For Screaming 'C30 Speed from your AT, Buy Banshee® and hang on!



The Banshee System from ASPI can turn your AT or compatible into a full-blown C processing engine.

The Banshee Board, based on TI's TMS320C30 processor, delivers 33 MFLOPS speed that qualifies your AT for high-speed calculations and 'C30 DSP development.

The basic system includes the SPOX real-time operating system; a C Compiler; a C Source Debugger; and ASHELL, ASPI's DOS shell that links the whole system together.

Options include a memory expansion board that can add up to 64 Mbytes of DRAM to the system and a 16-bit, dual-channel 200 kHz A-D/D-A data acquisition system.

For detailed specifications and prices, contact Atlanta Signal Processors, Inc., 770 Spring St., Atlanta, GA 30308. Telephone 404/892-7265. Fax 404/892-2512.



WORLD LEADERS IN DSP DESIGN TOOLS
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4M-Bit Static RAM

- Packaged in a multichip module
- Access times of 70 nsec

The Puma 2S4000 4M-bit CMOS static-RAM module is available in a 1.120-in.², 66-pin package. You can configure the module with battery backup. The package is hermetically sealed for military and industrial use. Although processed to MIL-STD-883C level B rev C, the devices are noncompliant. The devices are available in 70-nsec versions; 45- and 55-nsec devices are expected in the third quarter of 1991. \$850 (100). Delivery, six to eight weeks ARO.

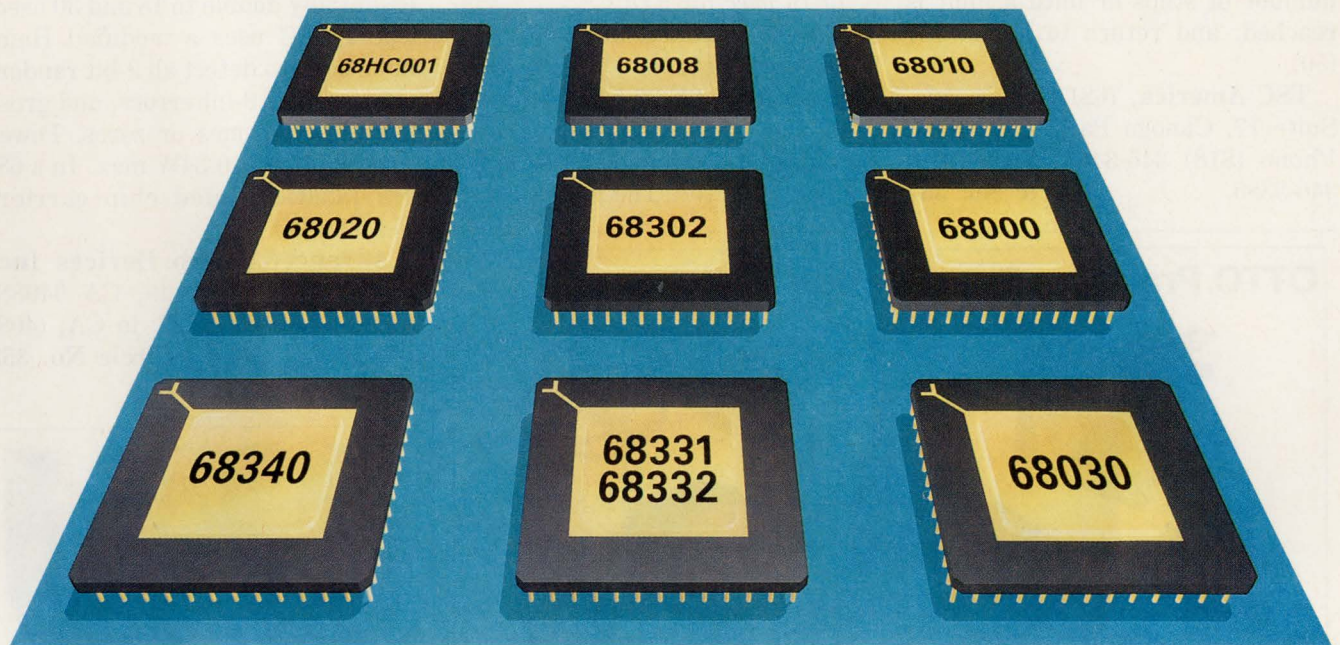
Mosaic Semiconductor Inc, 7420 Carroll Rd, San Diego, CA 92121. Phone (619) 271-4565. FAX (619) 271-6058. **Circle No. 356**

Intelligent Motor Controller

- Interfaces to ISA and STD buses
- Offers step rates to 240,000 steps/sec

The PCL-240AK intelligent motor controller relieves the CPU of motor-control responsibility. It contains an encoder interface, separately programmable acceleration and deceleration, 16,777,215 steps/single motion, two end-limit inputs, two decelerating stop-limit inputs, and one home-position-limit input. A position register is always accessible. The chip also features a number of commands such as accelerate

Designing with Motorola's



Microprocessors?

Then you need HMI's development systems, we support the entire 68000 family. As Motorola enhances and increases integration of its microprocessors, you can count on HMI to be there with

high-quality development products to support your projects. HMI believes in supporting the entire family of products for the Motorola family. Ease of use and familiarity are common in all the emulators.

Features of HMI's development systems includes:

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

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

Motorola Devices Supported Include:

68000	68030	68340
68008	6809	68HC001
68010	68302	68HC11 including
68020	68332/331	F1 and D3

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Huntsville Microsystems, Inc.

3322 South Memorial Parkway
Huntsville, AL 35801
Tel.: (205) 881-6005
FAX: (205) 882-6701

to speed, then decelerate to stop, constant speed for either a given number of steps or until a limit is reached, and return to home. \$67 (50).

TSC America, 7621 Canoga Ave, Suite 17, Canoga Park, CA 91304. Phone (818) 346-3467. FAX (818) 346-3385. **Circle No. 357**

32-Bit EDAC IC

- *Worst-case propagation delays of 14 nsec for EDC*
- *Can be cascaded for 64-bit memory systems*

The Am29C660E 32-bit error detection and correction (EDAC) features worst-case single-bit error detection of 9 nsec. The IC can detect

and correct errors in 14 nsec. When cascaded in 64-bit mode, the delays essentially double to 18 and 30 nsec. The EDAC uses a modified Hamming code to detect all 2-bit random errors, some 3-bit errors, and gross errors of all ones or zeros. Power consumption is 0.34W max. In a 68-pin plastic leaded chip carrier, \$74.90 (100).

Advanced Micro Devices Inc, Box 3453, Sunnyvale, CA 94088. Phone (800) 222-9323; in CA, (408) 749-5703. **Circle No. 358**

OTTO Precision Snap-Action Switches



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Because we add value to your switch solution

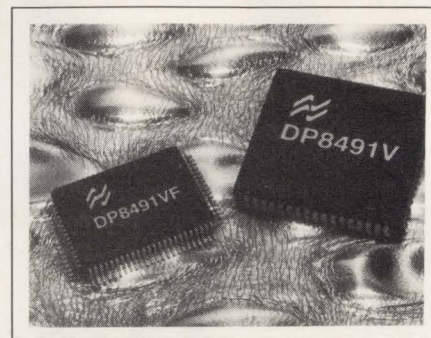
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Hard-Disk-Drive Read-Electronics Chip

- *Capable of 33M-bps data rates*
- *Operates from single 5V supply*

The DP8491 integrated read-channel chip incorporates a pulse/servo detector, a data synchronizer, a frequency synthesizer, and write pre-compensation circuits for hard-disk drives. Data rates can run as high as 33M bps. The IC supports zoned data recording by dividing the disk into zones with matched data rates. As a result, the chip allows outer portions of the disk to include information at the same density as inner portions. The IC also includes selective power-reduction options such as partitioned power-down control modes and a power control pin for pulse detector/servo circuits. The chip is available in plastic quad flatpacks or plastic leaded chip carriers. \$35 (100)

National Semiconductor Corp, Box 58090, Santa Clara, CA 95052. (408) 721-5000. **Circle No. 359**

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NEW PRODUCTS

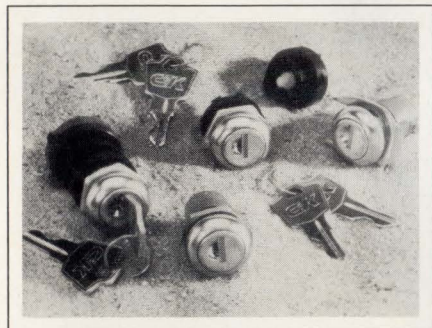
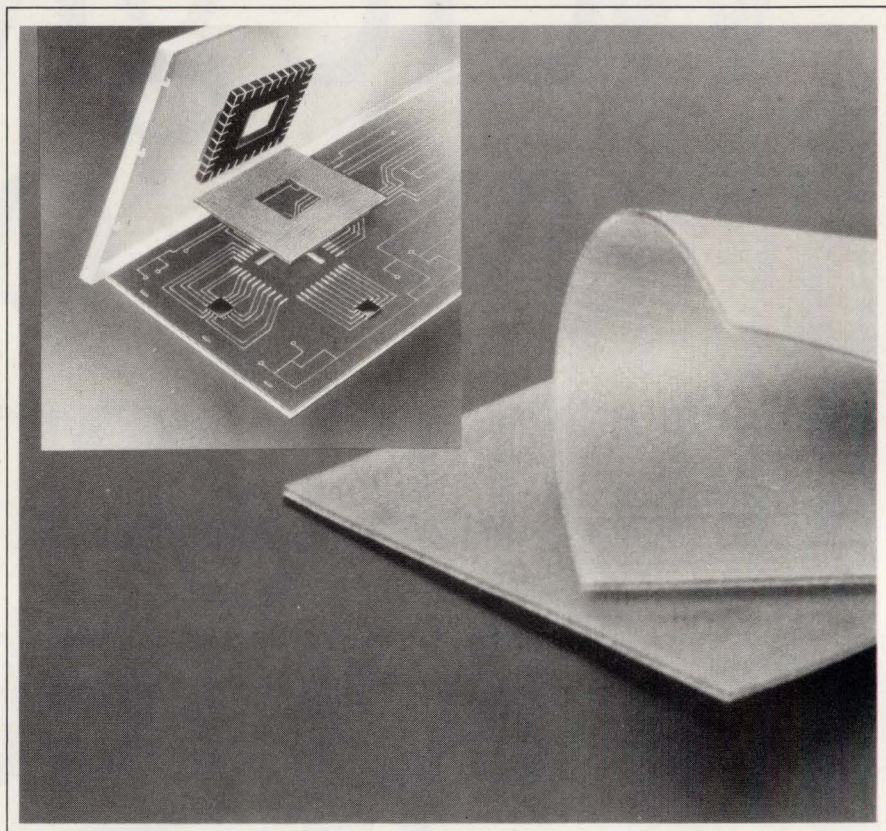
COMPONENTS & POWER SUPPLIES

Connector Material

- Achieves high density
- Can carry 5A/mm²

GD connector material features an array of conducting fibers mounted in a thin silicone elastomer binder-sheet material. The design achieves densities as high as 36 conductors/mm² by aligning the 0.04-mm-diameter metal fibers in an X-Y grid array with 0.2-mm center-to-center spacings. The gold-over-nickel fiber protrudes several microns from both the top and bottom of the sheet, giving the material its anisotropic or Z-axis conducting properties. The material can carry 5 A/mm². Contact resistance is 50 mΩ max with a 0.6-mm² contact area. The material is available in sheet form in sizes ranging to 50×250 mm. \$0.80/cm² (1000/cm²).

Shin-Etsu Polymer America,
34135 7th St, Union City, CA
94587. Phone (415) 475-9000. FAX
(415) 475-0613. **Circle No. 367**



Keylock Switches

- Available with gold or silver contacts
- Come in 4-pole versions

All the units in the A, H, and Y Series of keylock switches feature a sliding key-entry shutter that reduces lock contamination problems. The switches are available with either gold or silver contacts for logic-level and high-level (12A at 125V ac or 6A at 250V ac) switching applications, respectively. The devices are available in 1-, 2-, 3-, and 4-pole versions, and all carry UL

and CSA approvals. Terminal choices include solder-lug, printed-circuit, quick-connect, and wire leads. The switch-lock facing has a stainless-steel or high-gloss, nickel-over-brass finish. \$4.59 to \$8.30 (1000).

C&K Components Inc, 15 Riverdale Ave, Newton, MA 02158. Phone (617) 964-6400. FAX (617) 332-2379. **Circle No. 368**

External Power Supplies

- Deliver 55W
- Feature universal input

PUP55 Series external power supplies include 10 models that develop 55W from 1, 2, or 3 outputs. The supplies feature a universal 85 to 264V ac input and include overvoltage, overcurrent, and input-surge protection as standard. Line regulation equals ±0.5%, and output ripple and efficiency measure 1% max and 65% min, respectively. The se-



ries complies with UL, CSA, VDE, and IEC requirements. An EMI filter limits conducted emissions to VDE level A and FCC class B. The units are housed in a polycarbonate case, which carries a 94V-0 UL rating. An IEC320 input connector and a 5-pin DIN output connector come with the units. \$40 (OEM qty).

International Power Sources Inc, 200 Butterfield Dr, Ashland, MA 01721. Phone (508) 881-7434. FAX (508) 879-8669.

Circle No. 369

Position Sensor

- Has 18-mm diameter
- Operates to 70°C

Measuring only 18 mm in diameter, the 945 Series ultrasonic position sensor is designed for applications that require background suppression. It operates at 215 kHz to improve noise immunity. The sensor offers a choice of two factory preset switch points that you can change by using an external potentiometer. Maximum sensing distance equals either 200m or 500 mm. Features include a current-sensing output and an inhibit/synchronization input that you can use for multiplexing and synchronizing the sensors. You can configure two units to operate in a through-scan ultrasonic arrangement. The sensors are temperature compensated to operate within $\pm 0.5\%$ of the setpoint over a range of 0 to 50°C. Total operation range spans 0 to 70°C. \$189.

Micro Switch, 11 W Spring St, Freeport, IL 61032. Phone (815) 235-6600. **Circle No. 370**

RTD Input Modules

- Work with three standard temperature detectors
- 6-pole filter has 95 dB of normal-mode rejection

SCM5B34 linearized RTD (resistance temperature detector) input modules work with three standard RTDs—100Ω platinum, 120Ω nickel, and 10Ω copper. Each module has a single input channel which is filtered, isolated, amplified, linearized, and converted to a 0 to 5V analog output. The units feature a 6-pole filter that provides 95 dB of normal-mode rejection. Output selection time equals 2.5 μsec, and output noise at 100 kHz is 200 μV rms. Two internal matched current sources provide excitation current for the RTD. Other key module features include 1500V isolation, IEEE-472 transient protection, 240V ac continuous-input protec-

tion, and 160-dB CMRR. Accuracy and drift equal $\pm 0.05\%$ and $\pm 1\text{-}\mu\text{V}/^\circ\text{C}$, respectively. The modules require a 5V source and operate over a -25 to +85°C range. \$105 (100).

Burr-Brown Corp, Box 11400, Tucson, AZ 85734. Phone (800) 548-6132. **Circle No. 371**

Passive Backplane Chassis

- Features an EISA backplane
- Includes a power supply

The PX1101 19-in. rack-mountable chassis features a 13-slot EISA (extended-industry-standard architecture) 32-bit passive backplane. The chassis includes a 200W power-

VME BREAKTHROUGH

Announcing VMIC's New VME to VME Links Breakthrough

VMIC's new VME-to-VME Links:

- VMIVME 5610L - High Speed Direct Memory Access Link with 32-Bit VME-to-VME Data Transfers at 13 Mbytes/s
- VMIVME 5530L - Fiber Optic Repeater Link for Remote VMEbus System Linkage
- VMIVME 5550 - Multidrop Reflective Memory with Interrupts and broadcast capability.

VMIC's line of VME-to-VME links gives you a wide variety of options which support the interconnection of all mainframes and minicomputers designed with a VMEbus based front end. These links may be used with Sun Workstations, Concurrent, Encore 91 Series, Silicon Graphics, Motorola Delta Series, Alliant, DEC, Harris and more.

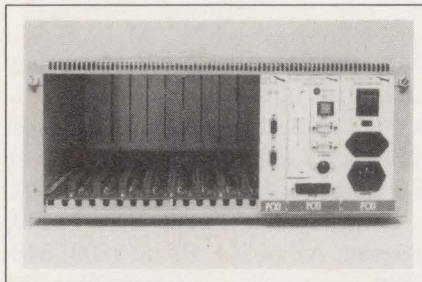
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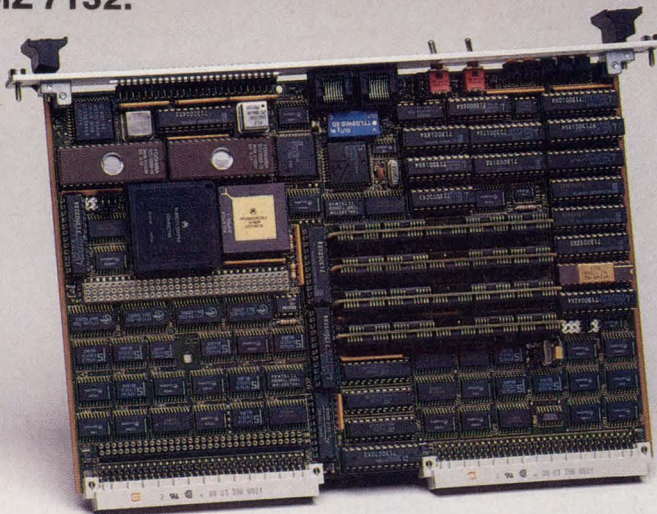
VMIC products are internationally represented by distributors throughout the world. Call or FAX VMIC for complete information.

supply module and two built-in 72-cfm positive-pressure cooling fans. The backplane features 8-layer construction and has all bus signals terminated. Large power-plane design coupled with three ground planes helps minimize noise problems and maximizes power distribution. The backplane design includes six EISA



Super Cache

Bring your entire application aboard Mizar's MZ 7132.



If your application requires not only superior 68030 performance, but plenty of on-board memory, Mizar's MZ 7132 is the answer. An economical, yet powerful, VMEbus single board computer, the MZ 7132 provides 16 Mbytes of dual-ported memory as well as a 16 Kbyte cache. Now, you can implement your memory-intensive applications more efficiently by avoiding the performance degradation of off-board memory. And, if you need more than 16 Mbytes, treat the on-board memory as a large cache and use the MZ 7132's optional VSB interface to access an additional memory pool.

The fully-featured MZ 7132 includes a 68EC030 or 68030 CPU with on-board SCSI, serial I/O, and optional Ethernet. OS-9™ and VxWorks™ support is also available. For more information on the MZ 7132 and other Mizar products, call today: 1-800-635-0200.

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CIRCLE NO. 47

bus master slots and one specific address slot for EISA cards with discrete enable control. \$2095.

Rapid Systems Inc, 433 N 34th St, Seattle, WA 98103. Phone (206) 547-8311. FAX (206) 548-0322.

Circle No. 372

Data Retiming Module

- Meets SONET standards
- Operates at 155.52M bps

The Tru-200C clock-recovery and data-retiming module extracts the clock signal from a received data stream and retimes the data. The unit meets SONET (synchronous optical network) standards for telecommunications-transmission equipment operating at a 155.52M-bps data rate. The hermetically sealed 28-pin DIP contains a single micro-wave complementary bipolar IC and a SAW filter. The ECL-compatible device operates over a range of -40 to +85°C at a supply voltage of 4.75 to 5.5V. The nominal bit-error rate is 10⁻⁹, and phase noise is reduced from as much as 70% at the input to less than 10% at the output. Coupled with the ODL 200 receiver, the module can re-time data with less than 1-dB optical power allowance. \$135 (1000).

AT&T Microelectronics, Dept 52AL300240, 555 Union Blvd, Allentown, PA 18103. Phone (800) 372-2447. FAX (215) 778-4106.

Circle No. 373

Box-Style Capacitors

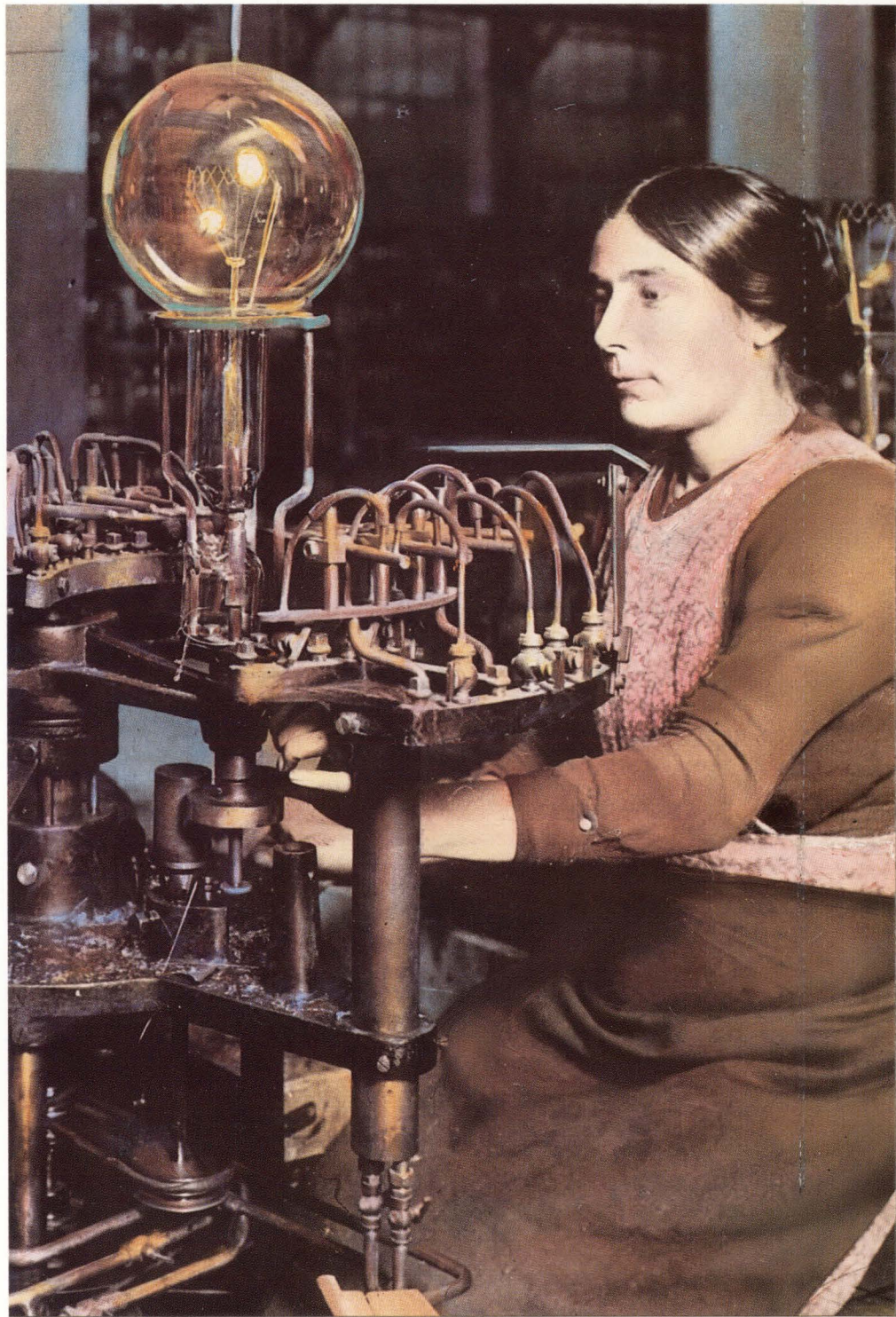
- UL, CSA, and VDE rated
- Offer capacitance of 0.047 μF

Type-Mey box-style capacitors are designed for interference-suppression service. The units are UL, CSA, and VDE rated and operate over a -40 to +85°C range. Capacitance values range from 0.001 to 0.047 μF, and tolerance values of ±5, ±10, and ±20% are available. Operating voltage equals 250V ac, and dissipation factor and

Text continued on pg 211



How A Spirit
Grew To Span
The Globe...
The People
Who Powered
A Century Of
Leadership.



Philips Components



PHILIPS

A Look Back At A Company Built On Looking Ahead.

A Family Business Evolves Into A Global Community United By A Sense Of Teamwork And Pride.



Outside Philips Eindhoven headquarters plant, circa 1917.

There is strength in numbers, the adage goes. The first century of Philips suggests there's much to be gained from diversity as well.

Incandescent lamps were the single focus of the company Gerard Philips inspired in 1891. Today, you'll find the Philips name not only on lighting products but also television sets, electric shavers, stereo systems and thousands of

other products that improve life. Supporting all these products are the people of Philips.

Tens of thousands of men and women staffing hundreds of factories, offices and laboratories in 160 countries across six continents. All reflecting vast differences...in languages, creeds, cultures and backgrounds. Performing hundreds of different jobs. Yet in spite of those differences, they're celebrating 100 years of coming together as a team.

It's Philips people behind the lab equipment at the renowned Center for Manufacturing Technology (CFT) in Eindhoven, The Netherlands, and at Philips Laboratories in Briarcliff Manor, New York—where scientists and engineers continue basic and applied research on new materials, products and technologies.

It's people who have made Philips the world's leading producer of lighting products, consumer products, professional products and components.

It's Philips people who helped fuel the continued drive toward miniaturization with advances in products and packaging. In the late 1960s, Philips invented the SOT23—the industry's first surface mount package for discrete semiconductors. Recent advances include the SOT223, the first discrete surface mount package capable of dissipating up to 1 watt on standard printed circuit boards at ambient temperature of 60°C.

In recent years, Philips introduced a series of ceramic capacitors with exceptionally small dimensions, while the development of flat-profile ferrite cores helped make increasingly smaller switched mode power supplies a reality in hundreds of professional, industrial and consumer systems.

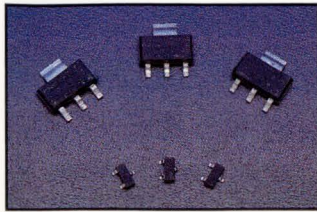
Today, the Discrete Products Division is known for the thousands of components going into a broad spectrum of products.

Behind them all are thousands of quality Philips people who through their work, dedication and contributions have kept their communities and their company moving ahead for 100 years.

On front: A young Dutch worker finishes a carbon-filament lamp at the turn of the century.

Our century-long spirit of innovation continues. Use the attached reply card to learn more about our products.

**2 New N-Channel JFETs
In SOT23, SOT223 SMD®
Packages.**



Now Philips puts industry-standard JFETs into space-saving surface mount packages.

PMBFJ108, 109 and 110 are packaged in SOT23 encapsulations.

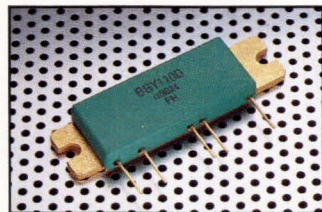
PZFJ108, 109 and 110 are housed in the unique SOT223 package.

Both new series are silicon symmetrical n-channel junction FETs ideal for use in analog switches, choppers and commutators and audio amplifiers.

Both provide high-speed multiplex switching in data transmission systems. They feature interchangeable drain and source connections, and RDS (on) of less than 8 ohms at zero gate voltage.

Mounted on a conventional printed circuit board, the Philips-invented SOT223 dissipates up to 1 watt (up to 2 watts on ceramic substrates). Standard T092 packaged versions of the J108, 109 and 110 are also available: they're plug-in replacements for existing industry types. Delivery for the new SMD versions is 8 weeks ARO.

**New High-Efficiency 900 MHz
RF Amplifier Modules.**



Samples are now available for Philips new four-stage BGY110 series RF amplifier modules.

Hand-held cellular phones and specialized mobile radio systems are among applications for the 900 MHz modules with typical efficiencies of 43%.

Available in five versions, the amplifier modules offer 6V and 7.2V operation. Their high efficiency reduces power consumption, allowing the use of smaller, lighter batteries.

Models BGY110A (over U.S. frequencies from 824 to 849 MHz) and BGY110B (UK frequencies from 872 to 905 MHz) are 6 volt supply types providing 1.2W output power into 50Ω loads.

Conventional 7.2 volt models BGY110D (U.S. band), BGY110E (UK band) and BGY110F (Nordic band) all produce 1.7 watt output into a 50Ω load.

The new amplifier modules, when specified at 0dBm (equal to 1mW drive power) eliminate the need for an amplifier between the VCO and module.

**5 Reed Switch Series
Earn UL Recognition.**



Philips glass-encapsulated single-pole industrial dry reed switches are now qualified for use in UL listed products.

Series RI-23, RI-25, RI-27, RI-29 and RI-46 switches are extremely small—the largest measures just 21.5mm long by 2.8mm in diameter. Perfect for AC or DC use, they are designed open until activated by coil or magnet.

Maximum switched power for the new devices ranges from 10 to 40W. Maximum switched voltage is 140, or 250 VAC/200VDC.

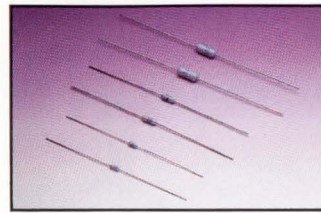
Switches contain a ferromagnetic contact blade hermetically sealed in a glass envelope of inert gas. They offer low resistance when contacts are closed; greater than 10¹² ohms when opened.

High contact forces and special ruthenium-over-diffused-gold contact layers provide a typical low contact resistance of 60 to 100 milliohm.

Applications include reed relays, proximity switches and level detectors in instrumentation, security systems, appliances and automotive equipment.

Volume delivery is 8-12 weeks.

**Ultra Precision Metal Film
Resistors Available Now.**



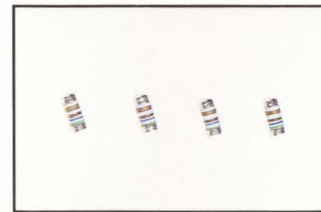
Philips is taking aim at test and instrumentation and measurement equipment with its UPR 5000Z series of ultra precision metal film resistors.

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

Available in three body sizes ranging from 1/20W to 1/3W, the resistors feature tolerances as low as ±.01% and temperature coefficients starting as low as ±2ppm/°C. Other series characteristics: excellent temperature and time stability, low voltage, low noise, and high initial accuracy and tracking.

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

**Thin Film Technology, SMD®
Combined in MELF Resistor.**

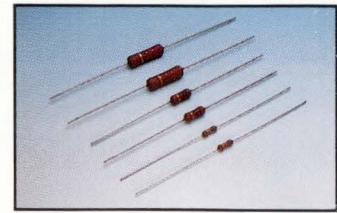


Philips 9B1406 MELF precision resistor benefits from technology used in manufacturing leaded metal film resistors—even though it comes in a surface mount package.

This thin film SMD® resistor is formed by depositing metal film on a high alumina core which is then capped and spiralled to value. The 9B1406's end caps are coated with nickel-copper-nickel and pure tin. The result: excellent soldering characteristics are maintained after long storage.

The MELF resistor offers TCs down to ±15 PPM/°C and tolerances to .1%. Availability is .22 ohm to 10 megohm in the 5% 50 PPM version. In bulk or tape and reel.

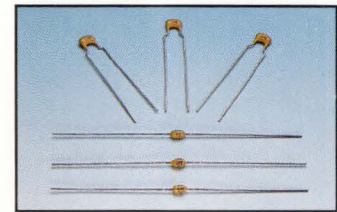
**1, 2 and 3W Power
Metal Film Resistors.**



Now replace expensive wire-wound resistors with Philips commercial 1, 2 and 3-watt metal film resistors. The series of miniature resistors feature 5% tolerances and temperature coefficients of 250 ppm.

Small size is a major benefit: advanced metal film technology produces 1W resistors measuring just .295 inches CL-CL. The result is a high wattage resistor with low hot spot parameters and metal film stability. The PR series is available on RN296D Class 1, tape and reel for automatic insertion, 5000 piece reels.

**Coated Ceramic Capacitors
In Radial Or Axial Designs.**

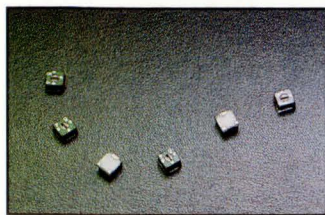


Between Philips MonoKap® radial and MonoAxial® axial product lines, there's a conformally coated ceramic multilayer capacitor to fit every circuit need.

Capacitance values start at 10pF with voltage ratings of 50, 100 and 200 VDC. Z5U, X7R and COG (NPO) dielectrics are available.

MonoKap lead styles range from .100 inches (2.5mm) to .400 inches (10mm) depending on component size and configuration. Packaging: bulk or EIA tape and reel and ammo pack for automatic insertion.

First O-Ring Sealed Surface Mount 3mm Single-Turn Trimmer.



Saving space is the key phrase in describing Mecpocal's new 3mm single-turn trimmer.

With their O-ring seals, ST-3 series surface mount trimmers can withstand vapor phase reflow cycles of up to 215 °C for three minutes; dip and reflow temperatures to 260 °C for 10 seconds.

The trimmers are sealed against immersion — passing the flourinert™ leak test @ 85 °C — and other boardwashing processes. Precious metal alloy contacts assure exceptional resistance stability in low current applications.

Operation temperature range is -55 ° to +125 °C.

Among other features, the trimmers offer a resistance range of 100 ohms to 1 megohm; power rating is 0.1W @ 70 °C. Rotational life is 100 cycles with a maximum shaft torque of 50gcm.

And they're designed to resist shock: thermal shock from -65 ° to +125 °; shock of 100G and vibration of 20G @ 10 to 2,000 Hz. The trimmers tolerate high temperature exposure up to +125 °C for 250 hours. Available on tape and reel.

Mecpocal is a joint venture of Philips Components and Copal Electronics USA.

Smaller Photomultipliers Allow More Compact, Lighter Camera Heads.



Philips brings new technology to photomultiplier tubes (PMTs) for medical imaging, scientific and industrial applications.

New foil structure dynodes developed by Philips allow PMTs to be shorter, so gamma camera heads incorporating the tubes can be lighter and more compact.

Philips PMTs feature fast response times and high resolution. They're available in a variety of shapes and sizes, including 3/4-inch to 10-inch diameters and hexagonal, round and square configurations.

Covering the spectral range of 200 nm to 1000 nm, these PMTs are available with up to twelve multiplier stages.

Sales Offices and Manufacturer Representatives

AL	Huntsville, Over & Over, Inc.	(205) 837-7105
AZ	Tempe, Philips Components	(602) 820-2225
CA	Anaheim, Philips Components	(714) 441-0385
CA	Folsom, Webster Associates	(916) 989-0843
CA	Mission Hills, Philips Components	(818) 891-6299
CA	San Diego, Philips Components	(619) 453-0332
CA	Sunnyvale, Philips Components	(408) 991-2110
CO	Englewood, Philips Components	(303) 779-9696
FL	Altamonte Springs, Philips Components	(407) 339-5073
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GA	Norcross, Over & Over, Inc.	(404) 449-6205
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Philips Components



PHILIPS

insulation resistance figures are 1% max and $15 \times 10^9 \Omega$, respectively. Capacitor leads are tin plated with 60Sn/40Pb to improve solderability. The units come in a plastic case, carrying a 94V-0 UL rating. From \$0.13 (1000).

Tecate Industries Inc., Box 711509, Santee, CA 92072. Phone (619) 448-4811. **Circle No. 374**

Tilt Switch

- Breaks the vertical to horizontal barrier
- Has a $\pm 3^\circ$ repeatability

The TS7Q low-contact-resistance tilt switch maintains either open or closed contacts over an operating angle ranging from vertical to below horizontal. The NO or NC contact status depends on whether the leads are pointing up or down. When mounted vertically with leads down, for example, the switch con-

tacts will not open until the unit is tilted from the vertical to as much as 135° in any direction. Switch contact resistance equals 0.25Ω at 1 mA, and switch repeatability measures $\pm 3^\circ$. The switch is housed in a package that measures 0.4 in. in diameter by 0.35 in. high. The mercury-wetted contacts are housed in a welded steel case and are hermetically sealed. The minimum life expectancy equals 250,000 operations. \$1 (OEM qty).

Fifth Dimension Inc., 801 New York Ave, Trenton, NJ 08638. Phone (609) 393-8350. FAX (609) 599-9508. **Circle No. 375**

Current Monitor

- Provides high, go, and low outputs
- Has a 0.1 to 10V range

When combined with precision resistors, Model 546 Voltensor acts

as a shunt to ensure that current levels stay within preset limits. The unit provides high, go, and low outputs; should the current level fall dangerously low or a power supply fail, you can use the low output to trigger an alarm or energize a backup power supply. If a short causes a dramatic rise in current, the sensor's high output can disconnect the load and protect the supply. The unit shunts voltages of ± 0.1 to $\pm 10V$ with an overall accuracy of 0.1%. The Model MK379 pc-board mounting kit allows you to plug the sensor in a standard 15-pin connector. Potentiometers on the mounting kit allow you to adjust the set points. \$120. Delivery, stock to six weeks ARO.

Calex Mfg Co Inc., 3355 Vincent Rd, Pleasant Hill, CA 94523. Phone (800) 542-3355; in CA, (415) 932-3911. FAX (415) 932-6017.

Circle No. 376

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CCLM0035 THRU CCLM5750 (SMD).

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NEW PRODUCTS

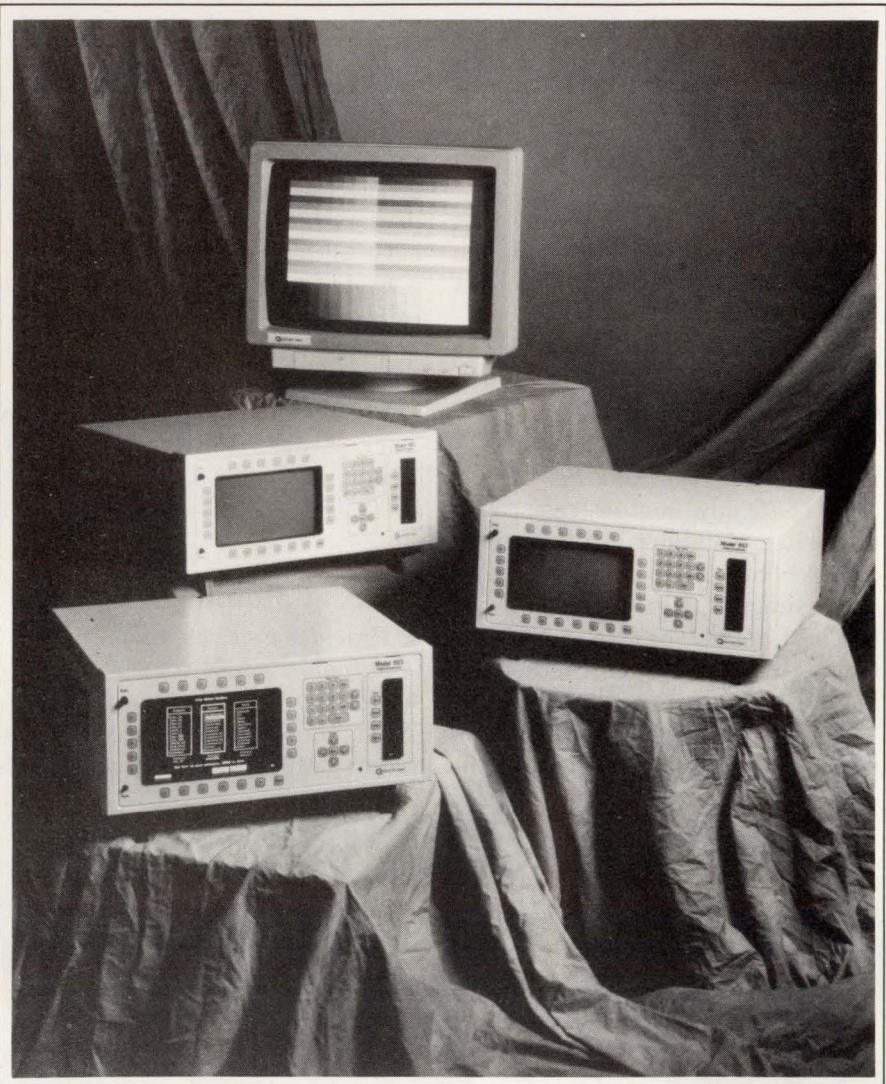
TEST & MEASUREMENT INSTRUMENTS

Generators For Testing Video Displays

- Handle dot clocks to 250 MHz
- Store formats, images and tests on 1.44M-byte floppy disk

The 900 series of video signal generators comprises three models. The 901 unit works with dot-clock frequencies from 1.4 to 87 MHz; the 902 unit works with frequencies from 2 to 135 MHz; and the 903 version works with frequencies from 2 to 250 MHz. All units include a CRT. At start-up, the screen displays windows of formats, images, and tests. Approximately 35 test images let you make size, linearity, focus, and color adjustments. All units include a 3.5-in., 1.44M-byte, MS-DOS-compatible, floppy-disk drive for storage of formats, images, and tests. The units incorporate IBM PC bus expansion slots and have a printer port. The vendor furnishes a plug-in QWERTY keyboard as a standard feature; the front panels have a numeric keypad and function keys. 901 unit, \$4950; 902 unit, \$8500; 903 version, \$11,500. Delivery, six to eight weeks ARO.

Quantum Data, 2111 Big Timber Rd, Elgin, IL 60123. Phone (708) 888-0450. **Circle No. 377**



High-Level Debugging Tools For Logic Analyzer

- Support C, C++, and Pascal
- Work with CISC- and RISC-based embedded systems

With the LA-Connect tool set you can use Microtec Research's C, C++, and Pascal cross-compilers and x-ray in-circuit, source-level debugger with Tektronix's DAS 9200 logic-analysis system. Besides the compilers and debugger, the package includes Tektronix LA-Link software and Microtec's in-circuit debug monitor. The monitor lets you debug with only an RS-232C link between a host workstation and your target system. The logic ana-

lyzer adds hardware breakpoints and real-time trace capability to the monitor facilities. The LA-Link package extracts symbolic information from the object code and converts it to a form readable by the analyzer. MS-DOS tool set, from \$2000.

Tektronix Inc, Box 4600, MS 92-688, Beaverton, OR 97075. Phone (503) 629-1969. **Circle No. 378**

Digital I/O Boards

- Have 24 and 64 channels
 - Communicate with host via RS-232C or RS-485 to 38.4k bps
- The H1750 board provides 24 digital

input/output channels; the H1770 provides 64. The boards communicate with their host computer via an RS-232C or RS-485 link at speeds from 300 to 38.4k bps. You configure each channel using software; the board retains the configuration information in EEPROM. All inputs have pull-up resistors. Outputs are open-collector transistors capable of withstanding 10V and sinking 15 mA. The 24-channel board measures 4x5 in.; the 64-channel model measures 5x10 in. Both operate from a single 5V power supply. For rated performance, the ambient temperature should be 0 to 70°C; but, with de-

rating, the boards operate from -25 to +85°C. H1750, \$275; H1770, \$350.

DGH Corp, Box 5638, Manchester, NH 03108. Phone (603) 622-0452. FAX (603) 622-0487.

Circle No. 379

Power-Line Disturbance Analyzer

- Connecting to wall outlet supplies power and signal
- Prints fault diagnosis and remedy on strip chart

The 100G Powervisa plugs into single-phase, 50- or 60-Hz, 90 to 290V ac power lines anywhere in the world. In addition to drawing operating power from the line, the 8×11×2.5-in. unit monitors the line for disturbances. It also measures ambient temperature and humidity. When disturbances exceed

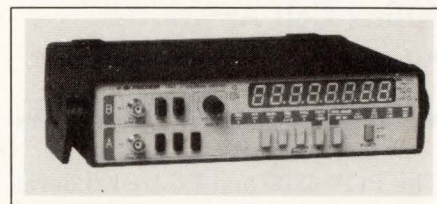
a preset threshold, the instrument captures the waveform and prints it out on an integral strip-chart recorder. Using artificial intelligence, the unit recognizes patterns, prints out the most likely cause of a disturbance, and recommends remedies. You can set the messages to appear in any of six languages. The instrument accepts a current probe and has an RS-232C port. \$3295.

Basic Measuring Instruments, 335 Lakeside Dr, Foster City, CA 94404. Phone (415) 570-5355. FAX (415) 574-2176. Circle No. 380

175-MHz Counter/Timer

- Has two channels
- Measures low frequencies with high accuracy

The 1823 universal counter has frequency, period, period-average, ratio, time-interval, and totalize func-

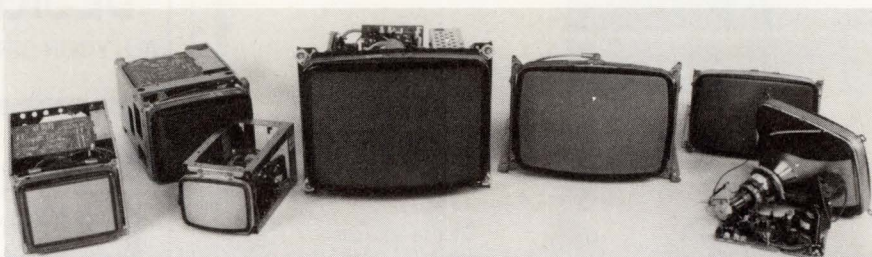


tions. It has two inputs and handles signals from 5 Hz to 175 MHz. The timebase is stable to 10 ppm from 0 to 50°C. The period mode, which makes high-accuracy measurements at low frequencies, handles durations from 0.5 μsec to 0.2 sec. The resolution in the period mode is from 100 psec to 100 nsec. The time-interval function provides similar specs for intervals that start with an input to channel A and end with an input to channel B. The 8-digit LED display is 0.56 in. high. \$395.

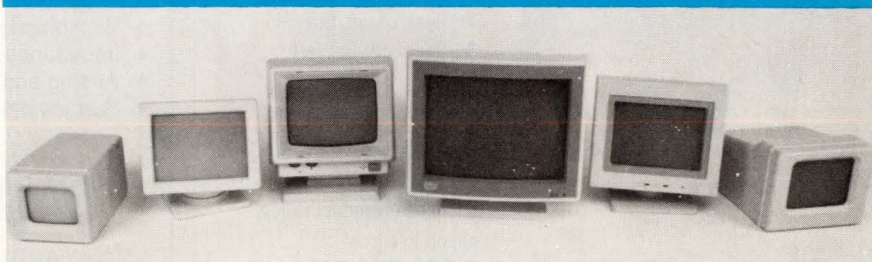
B&K Precision, 6740 W Cortland St, Chicago, IL 60635. Phone (312) 889-1448. Circle No. 381

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Development Aids For Xilinx Cell Arrays

- Connect Xilinx devices to your system
- Connect emulators and verifiers to your circuits

The PCA 6800 and PCA 8400 development boards work with Xilinx 2000 and 3000 series logic-cell arrays in 68- and 84-pin packages, respectively. The boards are general-purpose breadboarding tools that let you try out the Xilinx parts in your system and hook up emulators and analog and digital verifiers. The units do away with constructing test fixtures and let you prove out your design before pc-board layout. Included are a 3-output power supply; a socket for the Xilinx part; prototyping areas with solderless, push-in connections; jumper wires; an extraction tool for the plastic leaded chip carrier; magnetically latched drawers; a set of 10-Hz to

1-MHz RC oscillators mounted on headers; and a variety of accessories. \$1200.

Electronics Corp, PCA Development, 555 Commerce Dr, Amherst, NY 14228. Phone (716) 691-3913. FAX (716) 691-3940.

Circle No. 382

30W Dual-Range Benchtop Power Supplies

- Provide constant voltage and current
- Have separate digital V and I displays

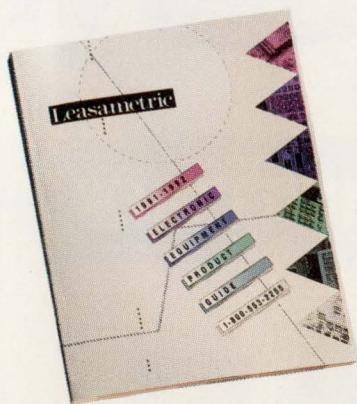
The HP E3610A provides 0 to 8V at 3A, or 0 to 15V at 2A. The HP E3611A provides 0 to 20V at 1.5A, or 0 to 35V at 0.85A. Both are linear supplies that offer ripple and noise below 200 μ V rms. They offer constant-voltage/constant-current operation with automatic crossover between modes; LEDs indicate



whether the units are producing constant voltage or constant current. The power supplies provide separate digital displays for voltage and current and a "CC-set" button that lets you adjust the constant-current level without shorting the output. \$300.

Hewlett-Packard Co, 19310 Pruneridge Ave, Cupertino, CA 95014. Phone (800) 538-8787; (800) 752-0900. Circle No. 383

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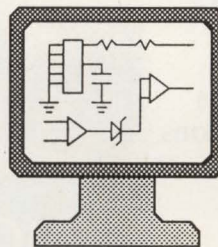
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CIRCLE NO. 51

VXIbus Arbitrary-Waveform Generators

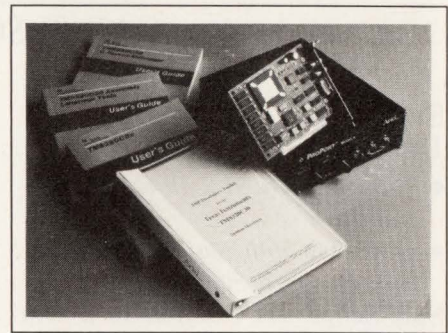
- C- and B-size units resolve 13 and 12 bits, respectively
- Convert 42.9M samples/sec

The HP E1445A is a C-size VXIbus arbitrary-waveform generator; the HP E1340A is its B-size counterpart. E1445A Option 005 waveform-generation software works with both units. The generators convert digital data to waveforms at a maximum rate of 42.9M samples/sec. They respond to commands in the SCPI (standard commands for programmable instruments) syntax. The C-size unit resolves 13 bits, stores 256k samples, and includes a frequency-agile timebase whose clock speed you can change on the fly. The B-size unit resolves 12 bits, stores 16k samples, and switches on command between programmed clock speeds. You can divide the units' memory into wave-

form segments and switch among the segments at full speed. B-size unit, \$2500; C-size unit, \$8000; software, \$400. Delivery, six to eight weeks ARO.

Hewlett-Packard Co, 19310 Pruneridge Ave, Cupertino, CA 95014. Phone (800) 752-0900.

Circle No. 384



Development System For TMS320C30 DSP μ P

- Has C debugger, library of applications, and assembler
- Can have 14- or 16/20-bit analog I/O hardware

The C30 developers' tool kit is an IBM PC-based system that provides an assembler/linker, a C source-level debugger, and a library of application programs for spectral analysis, image generation, and audio recording. Also included is application-development hard-

ware, including 16k words of zero-wait-state static RAM. System with a 14-bit, single-channel analog I/O board, \$1295; version with a 2-channel board that has 16-bit inputs and 20-bit outputs, \$2590.

Ariel Corp, 433 River Rd, Highland Park, NJ 08904. Phone (908) 249-2900. FAX (908) 249-2123. TLX 4997279.

Circle No. 385

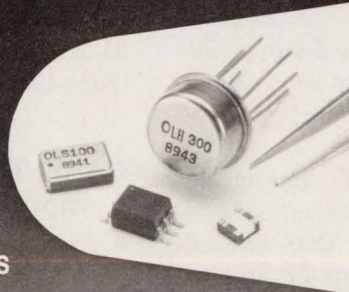
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CIRCLE NO. 52

Surge Protection for AC Power Lines



Starts at \$80⁰⁰

A large percentage of equipment malfunctions are due to the failure of sensitive semiconductor devices when exposed to transient overvoltages.

MCG Electronics Inc. has a series of low profile AC power line protectors designed specifically for the needs of the OEM user. They are available in 120VAC in 7.5A, 15A and 25A and 240VAC, 25A.

Models 407, 415, 416, 417 offer compact, cost-effective protection designed to be incorporated into original equipment. The units employ a sophisticated blend of high speed clipping and filtering to reduce IEEE 587 Cat. B impulses (6000V/3000A) to less than 350V peak between line and neutral.



12 Burt Drive, Deer Park, NY 11729 1-800-851-1508
Phone: (516)586-5125 Fax: (516)586-5120

CIRCLE NO. 53

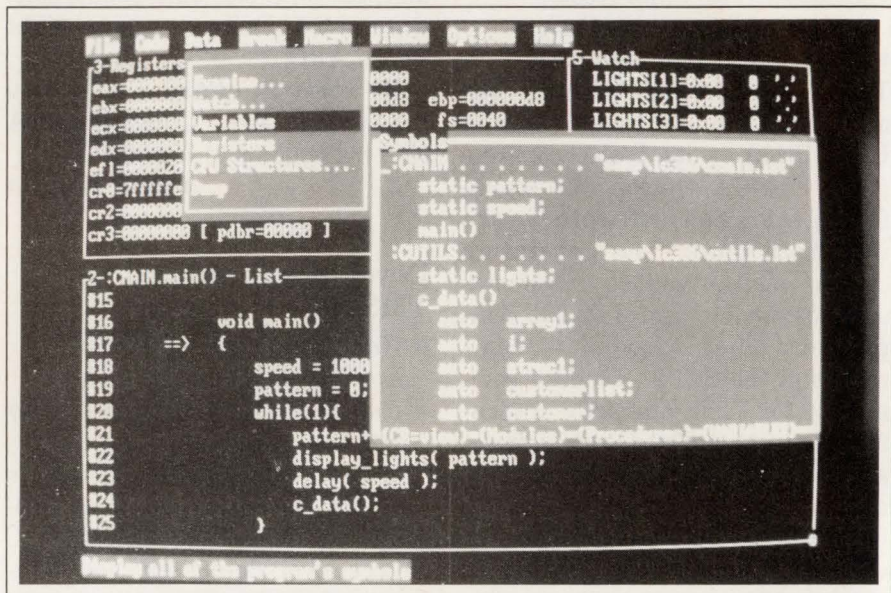
NEW PRODUCTS

CAE & SOFTWARE DEVELOPMENT TOOLS

Source-Level Cross-Debugger

- Comes bundled with a software monitor
- Supports both real and protected modes on all 80X86 μ Ps

Soft-Scope III/CSimon is a windowed, source-level, IBM PC/AT-hosted cross-debugger for the development of embedded systems based on Intel's 8086, 80186, 80286, 80386, and 80486 μ Ps. The debugger comes bundled with the vendor's CSimon software monitor and a complete set of monitor source code. The debugger can work with both real- and protected-mode target systems; it can handle code compiled by most popular compilers, (Intel, Metaware, and Microsoft) and it works with both Phar-Lap (Cambridge, MA) and Intel linkers. If you're debugging protected-mode systems, the program gives you ac-



cess to the extended register set and can display the descriptor tables (GDT, IDT, and LDT); it also provides source-level reporting of protection traps such as General

Protection and Stack Fault. \$1500.

Concurrent Sciences Inc, Box 9666, Moscow, ID 83843. Phone (208) 882-0445. FAX (208) 882-9774.

Circle No. 390

Development Software For CMOS PEEL Arrays

- Performs logic transformation and reduction
- Provides multilevel logic simulator

PLACE (PEEL Architectural Compiler and Editor) can accept Boolean logic equations and standard schematic symbols as input. The program then performs both logic transformation and logic reduction in order to get the maximum amount of logic into a PEEL (programmable, electrically erasable logic) device. In addition, PLACE provides a multilevel logic simulator that analyzes and simulates both internal and external signals by means of a waveform display. When the analysis is complete, you can direct the programming data to the vendor's programmer, or download it to another popular programmer. To run the program, you need an IBM PC or

compatible that has 640k bytes of RAM, an EGA or VGA graphics display, and a mouse. \$695.

Gould AMI, 2300 Buckskin Rd, Pocatello, ID 83201. Phone (208) 233-4690. Circle No. 391

EDIF Interface-To-Mentor Simulator

- Lets you simulate designs with more than 200,000 gates
- Can simulate isolated design sections

Version 6.0 of Susie runs on both 80386- and 80486-based systems, and comes with a DOS extender that lets you simulate designs with more than 200,000 gates and cells. A software accelerator allows you to simulate isolated design sections, thereby improving the simulation speed for large designs by 10 to 100 times. During each clock cycle, the program verifies every IC pin for timing violations and bus conflicts;

it displays errors on the screen and generates an error report. The program comes with an EDIF interface that lets you import Mentor-generated schematics for simulation; it also works with several VHDL modeling tools. Susie 6.0 with EDIF interface, \$9995.

Aldec Co Inc, 3525 Old Conejo Rd, Suite 111, Newbury Park, CA 91320. Phone (805) 499-6867. FAX (805) 498-7945. Circle No. 392

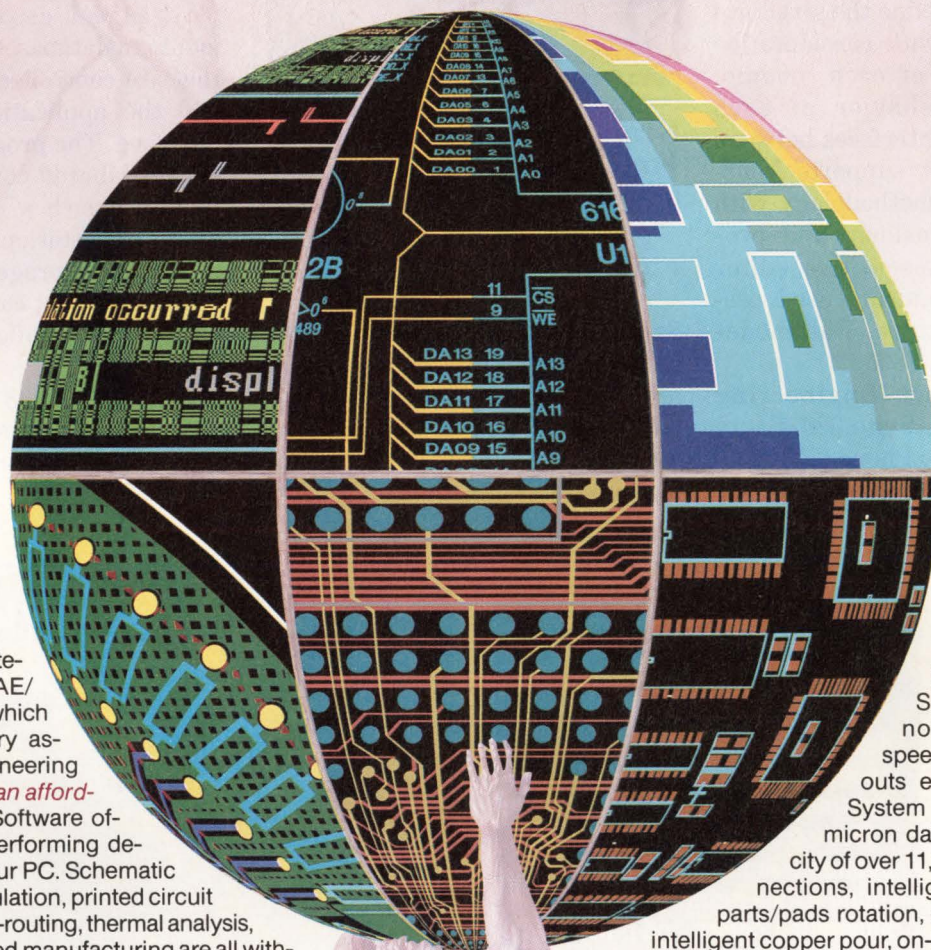
CASE Tools For Macintosh Computers

- Provide database-design facilities
- Provide structured-design capabilities

Datamodeler and Quickchart are the latest releases in the vendor's Powertools suite of CASE tools for the Macintosh computer. Datamodeler consists of an entity-relationship-attribute editor and

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PADS-PCB sets the standard for affordable high performance PCB design. A one mil database, 30 layers, automatic design rules checking, SMD ability, excellent interactive routing, and a set of ECO routines which ensure fast accurate changes, are just some of the features which have made **PADS-PCB** the #1 selling PC based PCB design system.

PADS-2000, the star that outshines any other PC-Based PCB design system, can handle even the most complex designs, including double sided SMD's, mixed technology boards, high speed designs, and layouts exceeding 2000 IC's. System features include a 1 micron database, design capacity of over 11,000 parts/32,000 connections, intelligent T-Routing, 0.1° parts/pads rotation, curved trace routing, intelligent copper pour, on-line and batch design rules checking, digital, analog and high speed/critical circuit auto-routers are included in **PADS-2000**.

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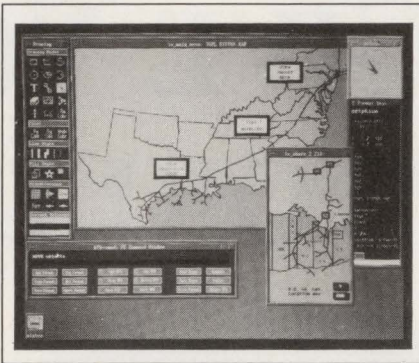
CAD
Software, Inc.

(800) 255-7814, Inside MA, (508) 486-8929
119 Russell Street, Littleton, MA 01460

dictionary, and helps you define software data requirements during the analysis phase. You can use Datamodeler in conjunction with other modules of Powertools to create the information-structure diagram portion of Shlaer/Mellor object-oriented analysis. Quickchart helps you define the structure of the software with consideration for the content of each module, the external behavior of each module, and the interfaces between them. Quickchart supports Yourdon/Constantine methodology with Page-Jones extensions, and provides a language-sensitive editor for the most commonly used programming languages. Datamodeler or Quickchart, \$995.

Iconix Software Engineering Inc., 2800 28th St, Suite 320, Santa Monica, CA 90405. Phone (213) 458-0092. FAX (213) 396-3454.

Circle No. 393



Graphics Display Builder For Unix

- Lets you develop and customize graphical displays
- Handles data from multiple applications and databases

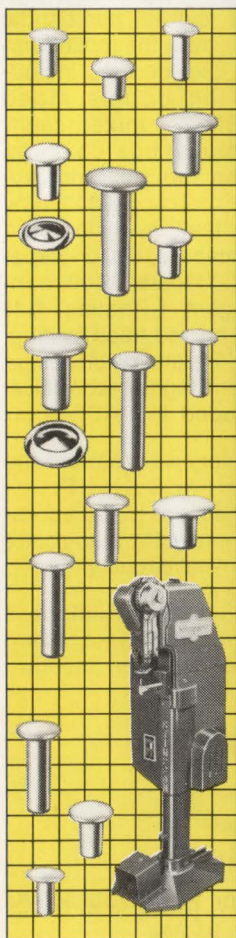
Sammi is a graphical user environment (GUE) that lets you develop and customize graphical displays without complex coding. You can interactively present, organize, manipulate, and interpret information from multiple applications and data-

bases. The system has three components: the runtime environment, which resides in the host system and handles the display, data-communications, and end-user commands; the format editor, which allows users to import, design, and draw graphical elements for display, as well as connect these elements to databases and applications that are controlled by the network; and the application programming interface. The program is optimized for distributed-computing applications in which a network of Unix-based workstations share the processing and storage capabilities of a centralized host computer. Depending on host configuration, \$12,500 to \$25,000.

Kinesix, 10333 Richmond Ave, Suite 1100, Houston, TX 77042. Phone (713) 953-8300. FAX (713) 784-4159.

Circle No. 394

Text continued on pg 222



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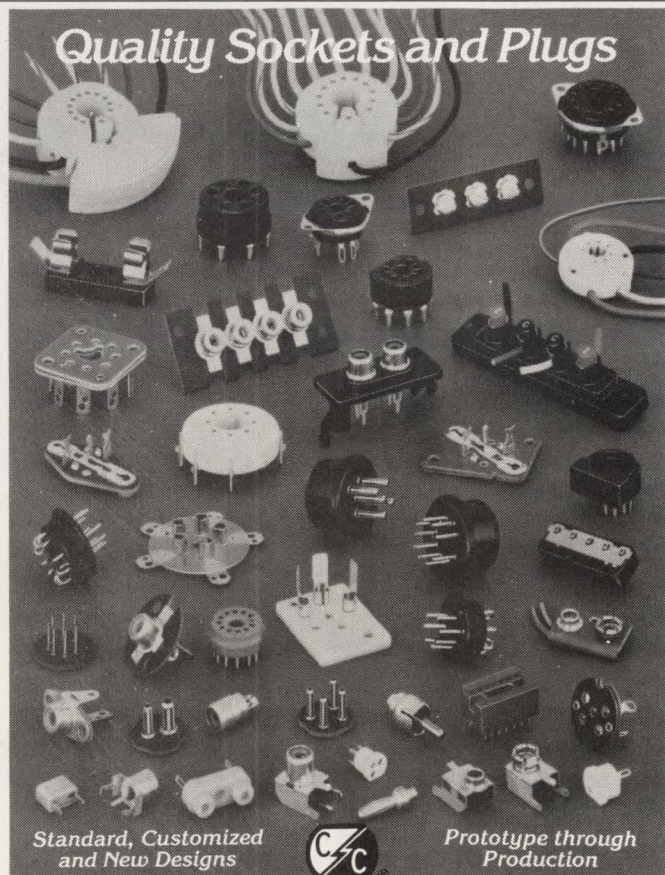
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CIRCLE NO. 54



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CIRCLE NO. 55

EDN May 9, 1991

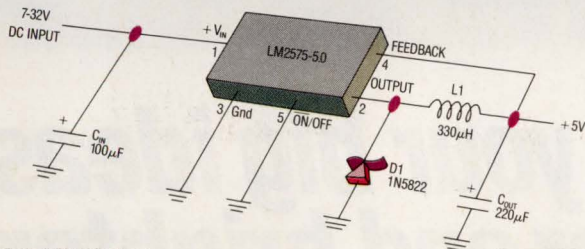
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THE LM2575/LM2577 FAMILY OF SWITCHING REGULATORS. EASY TO USE, AND JUST AS EASY TO PAY FOR.

No matter how you're doing it now, our Simple Switchers will change the way you use regulators.

No more losing valuable design time to tedious inductor selection. No more parting with precious board space to accommodate as many as 10 extra components. And no more expensive DC-to-DC converters.

Instead, we offer our monolithic LM2575 step-down (buck) and LM2577 step-up (boost) regulator families, in 5V, 12V, 15V and adjustable versions. They're a lot easier to use than a traditional switching regulator, and cost about one-fifth as much as a DC-



Typical 5V application.

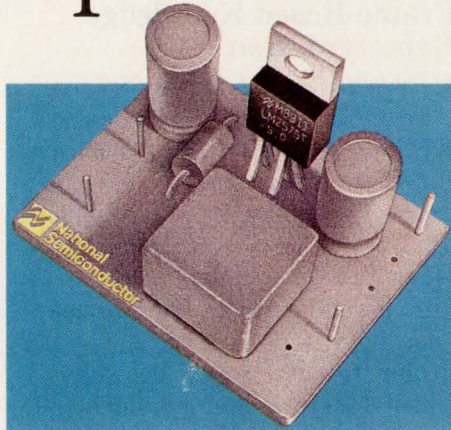
to-DC converter.

Now you can save design time, board space *and* money.

MINIMUM DESIGN EFFORT.

Designing a reliable, efficient, power supply used to be complex and tedious. No more. Our LM2575 Simple Switcher requires only four external components—

Simple Switcher is a trademark of National Semiconductor Corporation. ©1990 National Semiconductor Corporation.



National's LM2575 Simple Switcher requires just four external components.

an inductor, a diode, and two capacitors—and selecting them is a breeze.

Take the inductor: We provide a nomograph right in the datasheet, along with tables associating inductor codes with their corresponding values and manufacturers. You simply look up the inductor value required by your application. Then you can purchase the inductor (as well as the capacitors and the diode) right off the shelf. And you put them to work with a simple, three-step design process.

MAXIMUM SYSTEM PERFORMANCE.

There's nothing commonplace about the Simple Switcher's performance. For example, the LM2575T-5.0 features a 5V output capable of driving a 1A load with impressive line and load characteristics. Operating at 82% efficiency (compared to 40-50% for a linear regulator), it will help your system consume less power.

And you won't have to sacrifice the quality and reliability you've come to expect from a National three-terminal regulator: current limit, thermal shutdown and a guaranteed system output voltage tolerance ($\pm 3\%$). If you're looking for MIL-STD-883B Rev. C-compliant devices, we offer the LM1575 and LM1577, scheduled for qualification later this year.

ONE SIMPLE PHONE CALL.

This is a power solution that won't try your patience or test

PART	APPLICATIONS	SWITCH CURRENT	PACKAGES
LM2575-5.0	STEP-DOWN	1A	K,T
LM2575-12	STEP-DOWN	1A	K,T
LM2575-15	STEP-DOWN	1A	K,T
LM2575-ADJ	STEP-DOWN	1A	K,T
LM2577-12	STEP-UP FLYBACK, FORWARD CONVERTER	3A	K,T
LM2577-15	STEP-UP FLYBACK, FORWARD CONVERTER	3A	K,T
LM2577-ADJ	STEP-UP FLYBACK, FORWARD CONVERTER	3A	K,T

The Simple Switcher family. K=TO-3 T=TO-220

your budget. If you'd like to know more, give us a call. We'll even send you a complete Simple Switcher design aid kit, with an optional PC-DOS-compatible design diskette. In the U.S., call **1-800-624-9613, Ext. 25**. In Canada, call **1-800-548-4529, Ext. 25**. Or write us at **National Semiconductor, P.O. Box 7643, Mount Prospect, Illinois, 60056-7643**.

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Synthesis Tools For ASIC System Design

- Provides new desktop design viewer
- Includes facilities for FPGA synthesis

Version 2.0 of the vendor's suite of synthesis tools for ASIC-based designs features a new graphical user interface and design viewer/analyzer; the Test Compiler that automates design-for-test and provides automatic test-pattern generation; and the ECL Compiler for the synthesis of ECL-based designs. The design viewer/analyzer's pull-down menus make software easier to learn and use; prior to synthesis and optimization, you can view schematics, rearrange design hierarchy, and set design constraints. Test Compiler and ECL Compiler minimize power consumption and optimize designs for speed, area, and fault coverage. Design viewer/

analyzer, \$5000; Test Compiler, \$25,000; ECL Compiler, \$35,000.

Synopsys Inc., 1098 Alta Ave, Mountain View, CA 94043. Phone (415) 962-5000. FAX (415) 965-8637.

Circle No. 395

Frame-Based Knowledge Representation

- Provides path-following for traversal of complex relationships
- Supports hypothetical reasoning and subproblem solving

Phase 1 of the Initiative for Managing Knowledge Assets (IMKA) provides the core functionality of a high-performance, frame-based knowledge representation. In particular, this phase provides slots in which to store information about the represented objects; inheritance, which allows you to pass characteristics from one frame to another; contexts, which let you

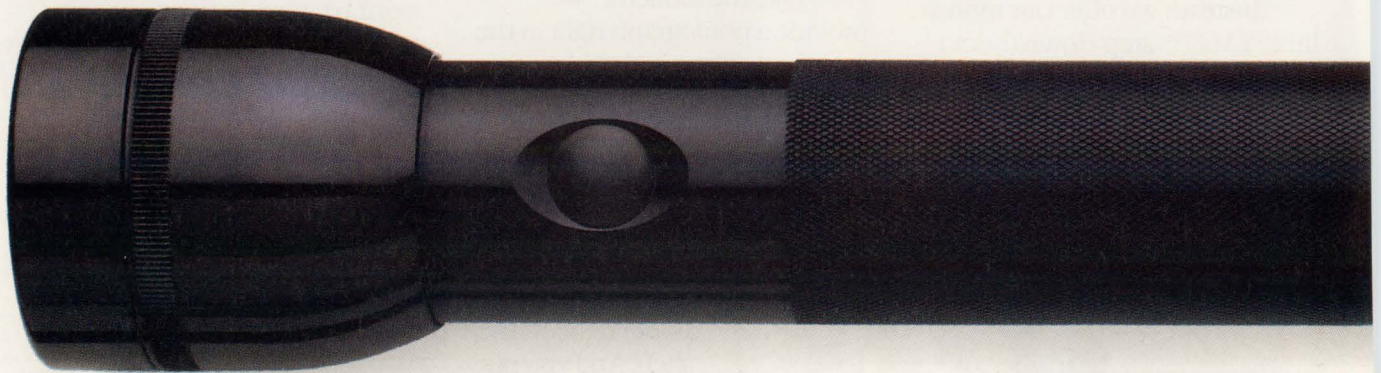
perform hypothetical "what-if" reasoning and subproblem solving; and path-following facilities for the efficient traversal of compound relationships. In addition, phase 1 provides object-oriented programming facilities, declarations and optimizations, dynamic knowledge representation, browsing, and error-handling facilities. Depending on the host-computer configuration and your license requirement, \$5000 to \$25,000.

Carnegie Group Inc., 5 PPG Pl, Pittsburgh, PA 15222. Phone (412) 642-6900. FAX (412) 642-6906. TLX 497-0240.

Circle No. 396

LAN Archival Software

- Works with DAT, cassette, and QIC tape subsystems
 - Supports Novell's Netware 386
- Tapeware 3.0 is a tape-backup software package for local area net-



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Today's emphasis on smaller, lighter, more powerful portable devices requires a bright idea in battery technology. It's here.

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works; it now supports Novell's Netware 386 version 3.1, and provides a quick-file-access (QFA) feature not present in earlier versions of Tapeware. You can operate the software from the file server console without any intervention from a workstation; backup is invisible and there is no workstation down time. The package provides loadable network drivers that work with IPX, NetBIOS, TCP/IP, and ADSP simultaneously across the network, so that one system can back up any other computer on the network. The package protects sensitive data by causing the computer on which the data is resident to encrypt the data before transmitting it across the network. The software can work with 8-mm helical scan tape, 4-mm DAT, cassette, and quarter-inch cartridge (QIC) tape subsystems, as well as most SCSI devices. Software (including host

adapter), depending on host computer, \$325 to \$995; Tapeware hardware/software subsystems, depending on type of tape drive, \$895 to \$5995.

Tapeware, 2750 N Clovis Ave, Fresno, CA 93727. Phone (209) 292-8888. FAX (209) 292-8908.

Circle No. 397

Data Object Manager For C And C++

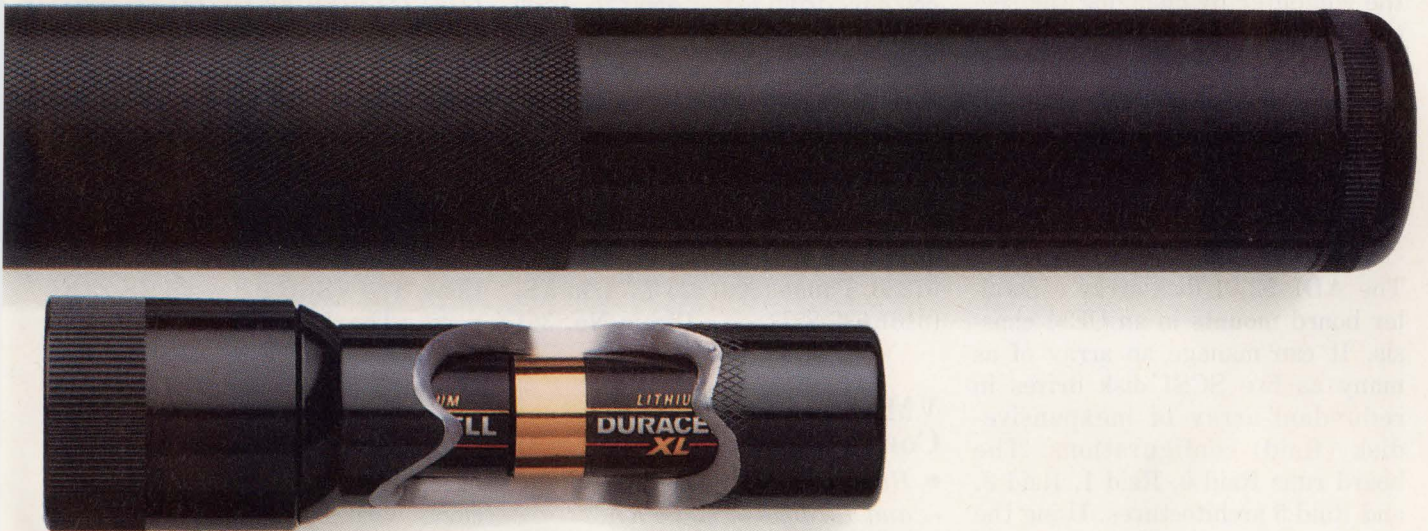
- Provides means of automating the management of program data
- Retrieves objects from library, connecting them to applications

Organized C is a set of tools for the management of internal data (data object libraries) that allows the rapid generation of fast, memory-resident databases. The tools run on IBM 80286-based PCs and compatibles, making use of Phar-Lap's (Cambridge, MA) 286/DOS Exten-

der which makes all physical memory available to the program. Two versions of the tool set are available. The C version is based on simple generic commands that cause all data-related pointers to disappear from your code. The C++ version is based on fully encapsulated classes that are uniform and simple to use. Most classes are available in source code; you can modify existing classes or create new ones. The program implements data persistency in a new way: You don't have to write special I/O functions for every class, because the system automatically creates these functions. Depending on host-computer configuration and compiler, from \$295 to \$2095 per seat.

Code Farms Inc, 7412 Jock Trail, Richmond, ON, K0A 2Z0, Canada. Phone (613) 838-4829. FAX (613) 838-3316.

Circle No. 398



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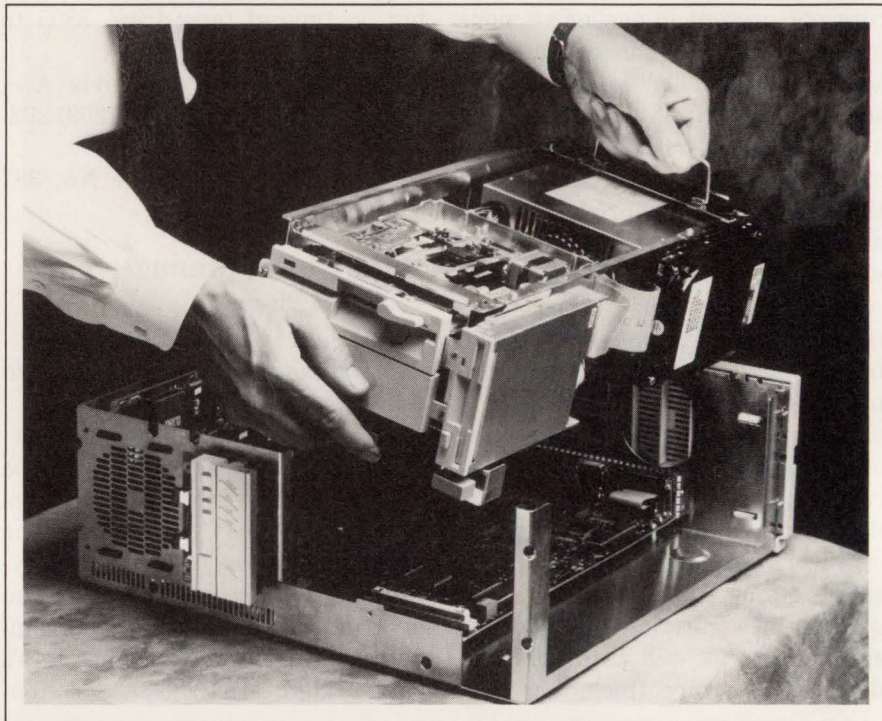
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NEW PRODUCTS

COMPUTERS & PERIPHERALS

EISA Bus Computers

- Have 25-MHz 80386, 33-MHz 80386, or 25-MHz 80486 μ P
 - A removable unit holds a 200W supply and four disk-drive bays
- The 386/25E, 386/33E, and 486/25E EISA bus computers have a 25-MHz 80386, a 33-MHz 80386, and a 25-MHz 80486 μ P, respectively. The systems use a modular architecture that includes a removable unit. This unit holds a 200W power supply and four disk-drive bays that have two 5 $\frac{1}{4}$ -in. and two 3 $\frac{1}{2}$ -in. drives. In addition, the design splits the mother board into two sections. One section contains the BIOS ROM, VGA circuit, EISA bus control logic; six EISA expansion slots; two serial ports; a parallel port; and a mouse port. The μ P resides on a removable section along with the coprocessor, the cache memory, and as much as 16M bytes of RAM. This configuration allows you to upgrade the computer by changing the section. The system's flash ROM lets



you upgrade the BIOS, using a floppy disk. 386/25E, from \$3995; 386/33E, from \$4995; 486/25E, from \$5995.

Amkly Systems Inc, 60 Technology Dr, Irvine, CA 92718. Phone (714) 727-0788. FAX (714) 727-9521.

Circle No. 360

Disk-Array Controller

- Can manage as many as five SCSI disk drives
- Mounts in OEM system and SCSI port connects to a host

The ADP-92-01 disk-array controller board mounts in an OEM chassis. It can manage an array of as many as five SCSI disk drives in redundant-array of inexpensive-disk (Raid) configurations. The board runs Raid 0, Raid 1, Raid 3, and Raid 5 architectures. Using the company's 53C916 fast SCSI-2 chip, the board can transfer data at 10M bytes/sec in Raid 3 and at 5M bytes/sec in Raid 5 configurations. A dedicated SCSI-2 port communicates with a host computer at 10M bytes/sec. A 32-bit μ P controls the SCSI-2 chip and the company's 53C920 data chip. Features of the board include request-queue management, simul-

taneous request servicing, end-to-end error detection, and built-in self diagnostics. \$2500.

NCR Corp, Peripheral Products Div, 3718 N Rock Rd, Wichita, KS 67226. Phone (800) 325-7274; in KS, (316) 636-8511. **Circle No. 361**

VMEbus Single-Board Computers

- Have 16.7-MHz 68HC000 μ Ps and 1M byte of static RAM
- Offer six or four serial ports and 20 parallel ports

The VSBC-2 and VSBC-3 single-board computers (SBCs) are designed for the VMEbus. They have a 16.67-MHz 68HC000 μ P, as much as 1M byte of zero-wait-state static RAM, and as much as 1M byte of zero-wait-state ROM. Other features include a watchdog timer and

a real-time clock. The SBCs can operate as masters on the VMEbus and have a 7-level interrupt handler, a single-level bus arbiter, and complete system-controller functions. The VSBC-2 has six RS-232C ports. The VSBC-3 has four RS-232C ports and a 68230 interface/timer IC that provides 20 parallel TTL I/O lines and a 24-bit timer. Both boards use CMOS logic and dissipate less than 3W. The boards come with Pepbug software and drivers for OS-9, VRTX, VxWorks, and PDOS operating systems. VSBC-2, \$750; VSBC-3, \$750 (OEM qty). Delivery, four to six weeks ARO.

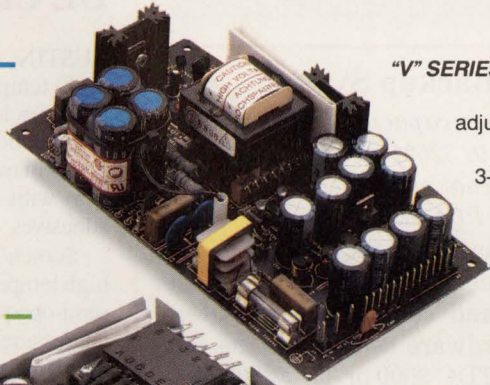
Pep Modular Computers Inc, 600 N Bell Ave, Carnegie, PA 15106. Phone (800) 228-1737; in PA, (412) 279-6661. FAX (412) 279-6860.

Circle No. 362

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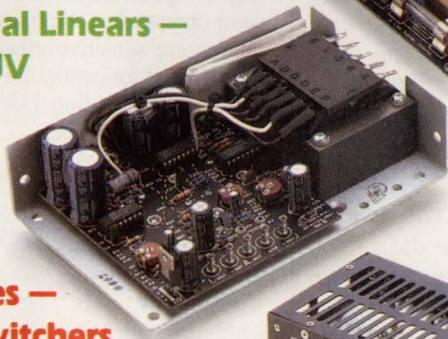
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 - High peak current disk drive outputs and closely regulated 3-terminal outputs • Pass vibration and shock per MIL-STD 810D
 - Full load burn-in; 2-year warranty

International Linears — UL/CSA/TUV approved.



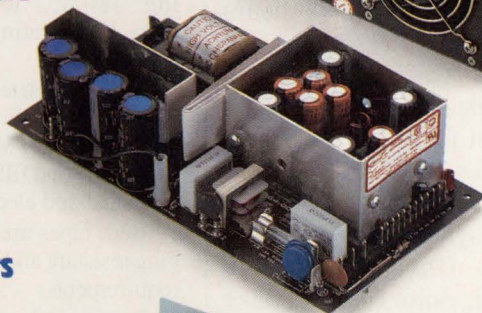
- INTERNATIONAL LINEARS:**
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 - Hermetically sealed power transistors • MTBF 200,000+ hours per Mil Hndbk 217D • 2-hour burn-in with cycling; 3-year warranty

"PAC" Series — enclosed switchers with Power, Approvals and Cooling.



- "PAC" SERIES:** • 17 models, 4 power levels, 85 to 185 watts • Up to 5 outputs • AC input: 90-132/180-264 VAC, 47-63 Hz • Fully protected: factory-set current limit, built-in OVP and reverse voltage protection
- Powerfail signal at 150- and 185-watt levels • High peak current disk drive outputs and closely regulated 3-terminal outputs
 - Pass vibration and shock per MIL-STD 810D
 - Full load burn-in; 2-year warranty

SDS/SDM switchers meet FCC/VDE Level B and have agency safety approvals.



- SDS/SDM MODELS:** • 20 single- and 29 multiple-output models, 5 power levels, 45 to 200 watts • AC input: 90-132 VAC/180-264 VAC, 47-63 Hz • Fully protected: adjustable current limit, built-in OVP and reverse voltage protection
- Powerfail signal and logic inhibit on 140- and 200-watt levels • High peak current disk drive outputs and closely regulated 3-terminal outputs • Pass vibration and shock per MIL-STD 810D • Full load burn-in; 2-year warranty

Medical switchers and linears — designed to meet UL 544/IEC 601/CSA 22.2 No. 125.

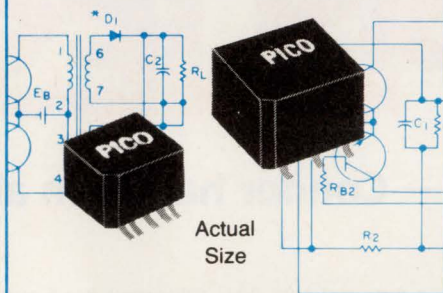


- MEDICAL SWITCHERS:** • 16 models, 5 power levels, 30 to 110 watts
- Up to 5 outputs • AC input: 90-132 VAC/180-264 VAC, 47-63 Hz
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- MEDICAL LINEARS:** 38 models, 3 power levels, 5 to 92 watts • AC input: 110/120/220/240 VAC, 47-63 Hz • OVP on all 5V outputs • Meets EMI per FCC/VDE B • Hermetically sealed power transistors and IC's
- MTBF 200,000+ hours per Mil Handbook 217D • 8-hour burn-in with cycling; 3-year warranty

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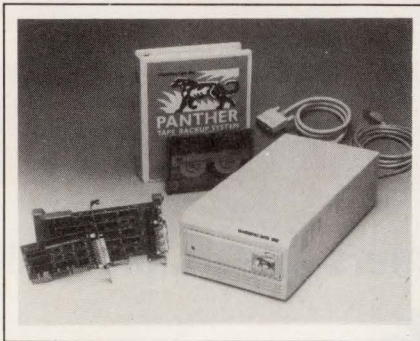
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CIRCLE NO. 57

COMPUTERS & PERIPHERALS



Tape Backup System

- Storage capacity ranges from 60M to 525M bytes
- External or internal units run on IBM PCs and PS/2s

The Panther tape backup system provides storage for IBM PCs, PS/2s and compatible computers. The hardware uses either the company's TDC 3600 or TDC 3800 quarter-inch cartridge tape drives. The backup system uses either internal or external units having capacities of 60M to 525M bytes. The system can back up and restore data from 5M to 12M bytes/minute. The top-end model can back up 525M bytes of data in less than 45 minutes. The software runs on DOS, OS/2, Unix, Xenix, Prologue, Pick, Novell, and LAN Manager operating systems. The system uses the company's DC 6000 or equivalent tape media. It features an MTBF of 80,000 hours and error rates of less than 1 in 10^{15} . External systems come in a cabinet that measures $3.5 \times 6.5 \times 14$ in. The cabinet for internal systems measures $1.75 \times 5.75 \times 8.5$ in. 525M-byte external system, \$2695; 60M-byte internal system, \$995.

Tandberg Data Inc., 2649 Townsgate Rd, Suite 600, Westlake Village, CA 91361. Phone (805) 495-8384. FAX (805) 495-4186.

Circle No. 363

Embedded Controller

- Runs commercial IBM PC-compatible software
 - Contains 20-MHz 80386SX μP
- The EPC-6 embedded-controller

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New proprietary film matched with acrylic and silicone adhesives for UL Class $155^{\circ}\text{C}/180^{\circ}\text{C}$

AUSTIN, Tex. — Two newly developed high temperature electrical insulating tapes are lower priced than current tape constructions now on the market. The secret is in matching new tough proprietary film with appropriate high temperature adhesives.

Scotch™ Electrical Tape 72 is thin, high temperature resistant, light tan, and semi-opaque. It is combined with an acrylic pressure-sensitive adhesive, and is UL Recognized for continuous use at temperatures not exceeding 155°C , for class F operating components.

Scotch™ Electrical Tape 73 is thin, high temperature resistant, light brown, and semi-transparent. It is combined with a silicone pressure-sensitive adhesive, and is UL Recognized for continuous use at temperatures not exceeding 180°C , for class H operating components.



Flexibility, conformability and flagging resistance are also key features. UL Component Recognition.



Typical high temperature electrical insulating applications are in motors, coils, transformers, TV yoke/deflection magnets, wrap and fill capacitors, and similar electrical and electronic products.

Both tapes are flame retardant, flagging resistant and meet NASA outgassing requirements.

Permanently printable using conventional tape printing equipment. Standard widths from $1/16''$ to 4'. Custom slitting available.

For more information, contact a 3M Electrical Specialties Division representative or authorized distributor or call 1-800-233-3636.

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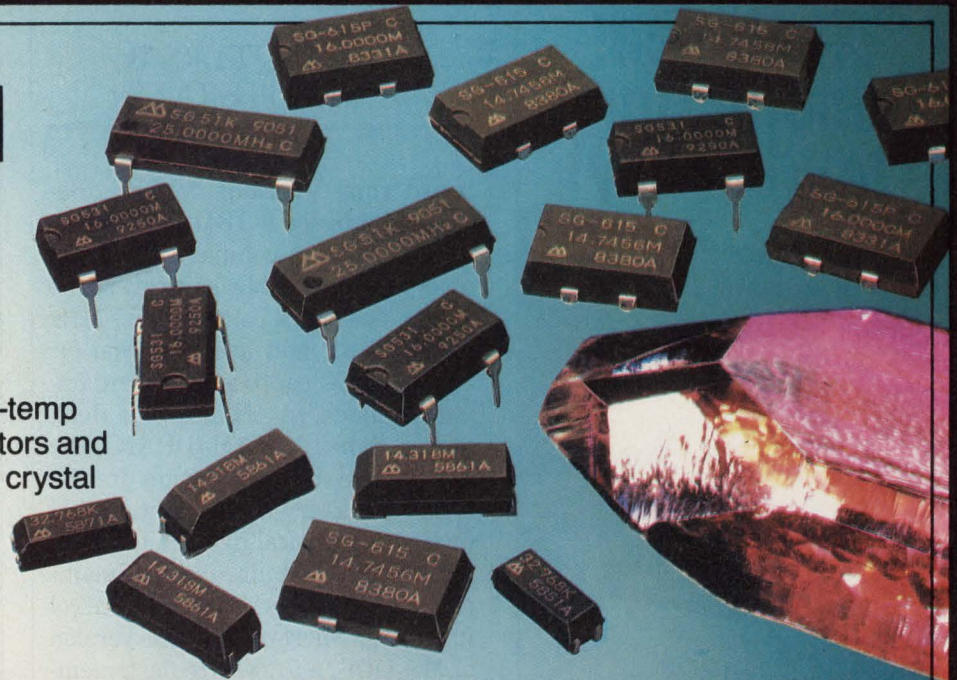
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technologies into
the 90's with...

the most cost effective hi-temp
SMD crystals and oscillators and
low cost plastic thru-hole crystal
oscillators.



EPSON SURFACE MOUNT CRYSTALS AND OSCILLATORS



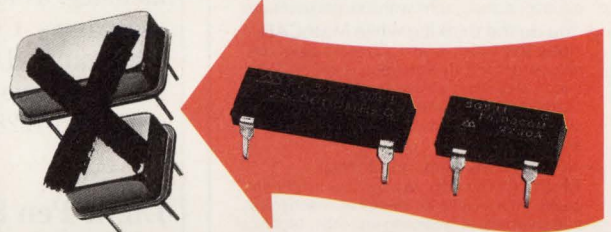
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Rise/Fall Time: 5 nsec (TYP)
Tristate: Available
Compatible Technology: CMOS and TTL
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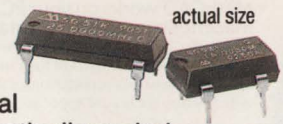
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MODEL SG-51/SG-531 OSCILLATOR

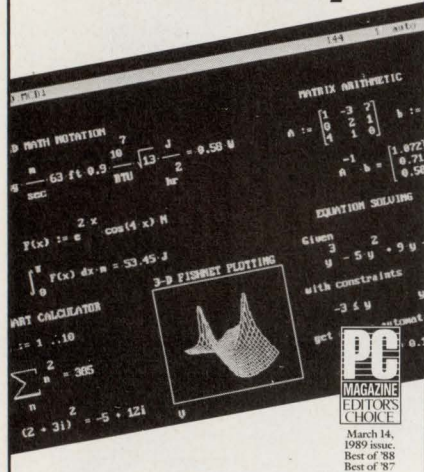
Frequency: 1.5 to 66.7 MHz
Symmetry: 45/55 (TYP)
Rise/Fall Time: 5 nsec (TYP)
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Compatible Technology: CMOS and TTL

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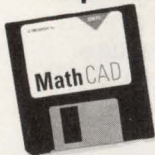
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#13 EDN 5/9/91

CIRCLE NO. 59

COMPUTERS & PERIPHERALS

board runs VMEbus systems. Because the board is IBM PC compatible, it can run commercially available PC-compatible software. The single-slot board contains a 20-MHz 80386SX μ P and has an option for an 80387SX coprocessor. Containing as much as 4M bytes of dual-ported dynamic RAM (DRAM), the board also has an option for 8k bytes of battery-backed static RAM for storing critical data. A 16k-byte instruction and data cache maintains high speed for the control functions. Microsoft's ROM version of MS-DOS, a 512k-byte flash memory for storing programs comes with the board. An EXM expansion slot accepts the company's expansion cards. \$1995; EPControl software package for developing programs on a PC and downloading program to board's DRAM or flash memory, \$1450.

Radisys Corp., 19545 NW Von Neumann Dr, Beaverton, OR 97006. Phone (503) 690-1229. FAX (503) 690-1228. **Circle No. 364**

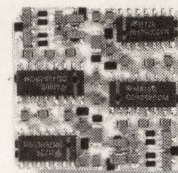
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- *Emulates a Sunmouse for SunSPARC workstations*
- *Includes a light pen, Sbus board, and software*

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Text continued on pg 233

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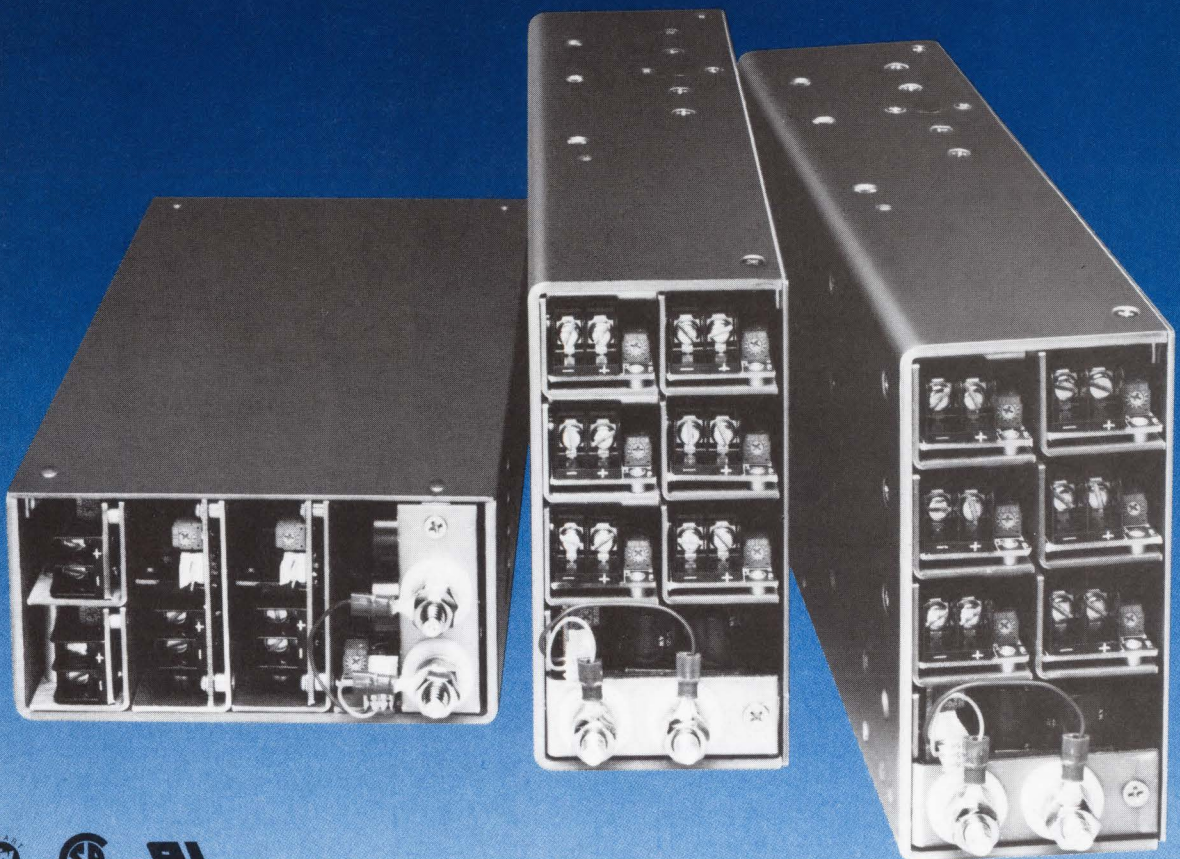
CIRCLE NO. 60




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- FINTEGRA – Distributed Thermal Management with Cooling Fins Integral to Each Module



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- Current mode control
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Deltron inc.
POWER PRODUCTS

SPECIFICATIONS

INPUT

90-132 VAC or 180-264 VAC, 47-440 Hz. Strappable.

INPUT SURGE

Less than 68 Amps peak from cold start. For 1000W and 1500W units less than 136 Amps peak.

HOLDUP TIME

20 milliseconds from loss of nominal AC power.

OUTPUTS

See model selection table.

ADJUSTABILITY

±5% trim adjustment. All 5VDC outputs are adjustable up to 5.2VDC @ full output.

OUTPUT POLARITY

All outputs are floating from chassis and each other and can be referenced to each other or ground as required.

LINE REGULATION

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

LOAD REGULATION

±0.2% or ±10mV for load changes from 50% to 0% or 100% of max. rated values.

MINIMUM LOAD

Main output requires a 10% minimum load for full output from auxiliaries.

REMOTE SENSING

On all outputs except those less than 100 watts and less than 20 Amps.

RIPPLE & NOISE

1% or 100mV pk-pk, 20 MHz bandwidth.

OPERATING TEMPERATURE

0-70°C. Derate 2.5%/°C above 50°C.

COOLING

A min. of 10 LFS cooling air directed over the units for full rating. Two test locations on chassis rated for max. temperature of 90°C. 1000 and 1500 watt units have built-in fan.

TEMPERATURE COEFFICIENT

±0.02%/°C.

EFFICIENCY

80% typical.

SAFETY

Units meet UL 1950, CSA 22.2 No. 220, CSA bulletin 1402C, EN 60 950, DIN VDE 0805/05.90. Certifications in process.

DIELECTRIC WITHSTAND

3750 VRMS input to ground.
3750 VRMS input to output.
700 VDC output to ground.

SPACING

8 mm primary to secondary.
4 mm to grounded circuits.

LEAKAGE CURRENT

0.75 mA at 115 VAC 60Hz. input.
1.5 mA for 1000 watt and 1500 watt models.

EMISSIONS

Units meet FCC 20780 Part 15 Class A and VDE 0871/6.78 Class A for conducted emissions. Compliance with Class B limits by use of additional external filter. 1000 watt and 1500 watt models require optional filter for Class A.

DYNAMIC RESPONSE

Peak transient less than ±2% or ±200mV for step load change from 75% to 50% or 100% max. ratings.

RECOVERY TIME

Recovery within 1%.
Main output – 200 microseconds.
Auxiliary outputs – 500 microseconds.

AC UNDERVOLTAGE

Protects against damage for undervoltage operation.

OVERVOLTAGE PROTECTION

Standard on main output.

REVERSE VOLTAGE PROTECTION

All outputs are protected up to load ratings.

OVERLOAD & SHORT CIRCUIT

Outputs protected by duty cycle current foldback circuit with automatic recovery. Auxiliaries have additional backup fuse protection.

THERMAL SHUTDOWN

Circuit cuts off supply in case of local over temperature. Units reset automatically when temperature returns to normal.

SOFT START

Units have soft start feature to protect critical components.

FAN OUTPUT

Nominal 12 VDC @ 12 watts maximum.

INHIBIT

TTL compatible system inhibit provided.

SHOCK

MIL-STD 810-D Method 516.3, Procedure III.

VIBRATION

MIL-STD 810-D Method 514.3, Category 1, Procedure I.

MECHANICAL

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

POWER FAIL MONITOR

Optional circuit provides isolated TTL and VME compatible power fail signal providing 4 milliseconds warning before main output drops by 5% after an input failure. Available on units with a high current 5 volt output.

AUTO RANGER

Optional circuit provides automatic operation at specified input ranges without strapping. Not available on single output units.

PILOT BIAS

Optional circuit provides SELV output of 5 volts at 1 Amp independent of the main power converter. Output isolation compliant to safety specifications referenced above. Not available on single output units.

EMI FILTER

For Class A on 1000 and 1500 watt units.

COVER

Optional flat cover recommended when customer supplied fan cooling is directed through the length of the unit.

FAN COVER

Optional cover with brushless DC fan which provides the required air flow for full rating of VM power supplies.

POWER FACTOR CORRECTION

Refer to Bulletin FM-101 for FM Series units with 0.99 power factor and harmonic currents compliant to IEC 555-2.

DESCRIPTION

VM Series switchers comprise a line of open frame power supplies with output combinations that are required for a large variety of bus systems such as VME, VXI, and FUTUREBUS. Units in this fully modular family offer power density up to 10 watts per cubic inch. The small size and high power available permits more system hardware to be packaged in a given enclosure. The extended function without additional cabinet overhead will give your product a competitive edge in the marketplace.

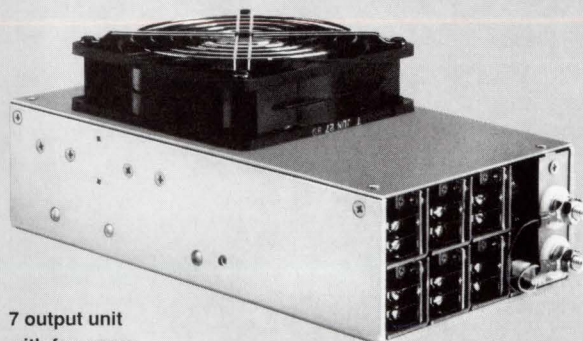
VM Series feature outstanding quality, insuring full compliance to specifications, reliable field operation and long service life. This exceptional quality is a result of three major efforts.

- Meticulous innovative engineering design.
- Total modular mechanical design.
- Excellent thermal management.

VM Series are available in power ratings from 400 to 1500 watts and with 1 to 7 outputs in a single package.

FEATURES

- TUV, UL, CSA.
- 10 watts per cubic inch.
- 120 kilohertz MOSFET design.
- Current mode control.
- All outputs:
 - Adjustable.*
 - Floating.*
 - Overload and short circuit proof.*
- System inhibit.
- Load proportional DC fan output.
- Options include:
 - Auto ranger for continuous input operation.*
 - Power fail monitor.*
 - Pilot bias.*
 - EMI filter for 1000 and 1500 watt units.*
 - Cover.*
 - Fan cover – 1000 and 1500 watt units have fan built in.*



7 output unit
with fan cover

SINGLE OUTPUT MODELS

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

MULTIPLE OUTPUT MODELS

Model VM1A-YY

Total Power: 400 Watts
Case: 1
Ratings: 5VDC @ 50A
5VDC @ 10A
12VDC @ 12A
12VDC @ 6A

Model VM2A-YY

Total Power: 400 Watts
Case: 1
Ratings: 5VDC @ 50A
12VDC @ 6A
12VDC @ 6A
24VDC @ 6A

Model VM1B-YY

Total Power: 500 Watts
Case: 1
Ratings: 5VDC @ 80A
5VDC @ 10A
12VDC @ 12A
12VDC @ 12A

Model VM2B-YY

Total Power: 500 Watts
Case: 1
Ratings: 5VDC @ 80A
12VDC @ 12A
12VDC @ 6A
24VDC @ 6A

Model VM3B-YY

Total Power: 500 Watts
Case: 1
Ratings: 5VDC @ 80A
12VDC @ 12A
24VDC @ 6A
5VDC @ 10A
12VDC @ 6A

Model VM1D-YY

Total Power: 750 Watts
Case: 2
Ratings: 5VDC @ 120A
12VDC @ 12A
24VDC @ 6A
5VDC @ 10A
12VDC @ 6A

Model VX1B-YY

Total Power: 500 Watts
Case: 1
Ratings: 5VDC @ 30A
2VDC @ 10A
5VDC @ 10A
12VDC @ 6A
12VDC @ 6A
24VDC @ 3A
24VDC @ 3A

Model VX1D-YY

Total Power: 750 Watts
Case: 2
Ratings: 5VDC @ 60A
2VDC @ 12A
5VDC @ 12A
12VDC @ 8A
12VDC @ 8A
24VDC @ 4A
24VDC @ 4A

Model VX1E-YY

Total Power: 1000 Watts
Case: 3
Ratings: 5VDC @ 80A
2VDC @ 20A
5VDC @ 20A
12VDC @ 10A
12VDC @ 10A
24VDC @ 5A
24VDC @ 5A

Model VX1F-YY

Total Power: 1500 Watts
Case: 4
Ratings: 5VDC @ 120A
2VDC @ 30A
5VDC @ 30A
12VDC @ 15A
12VDC @ 15A
24VDC @ 8A
24VDC @ 8A

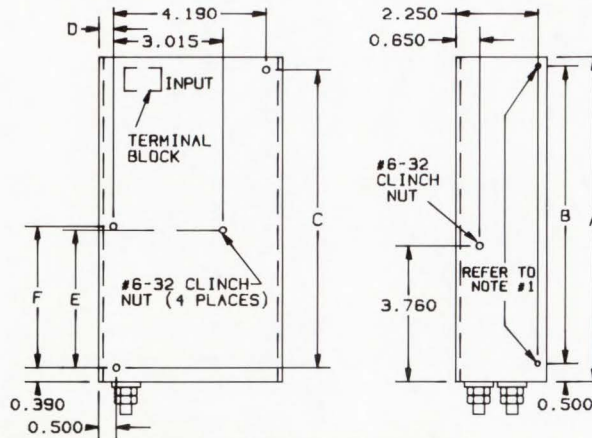
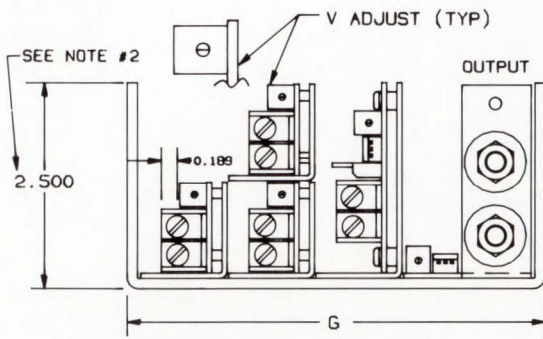
OPTIONS

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

Notes:

1. All 5VDC outputs adjustable to 5.2VDC. Others trim adjustable $\pm 5\%$.
2. On models VX1E-YY and VX1F-YY the max. total power for the sum of outputs #1 to #3 must not exceed 500 watts and 750 watts respectively.
3. Models VX1E-YY and VX1F-YY include built-in fan.
4. Models VX1E and VX1F require EMI Filter option to meet FCC and VDE Class A for conducted emissions.

DIMENSIONS

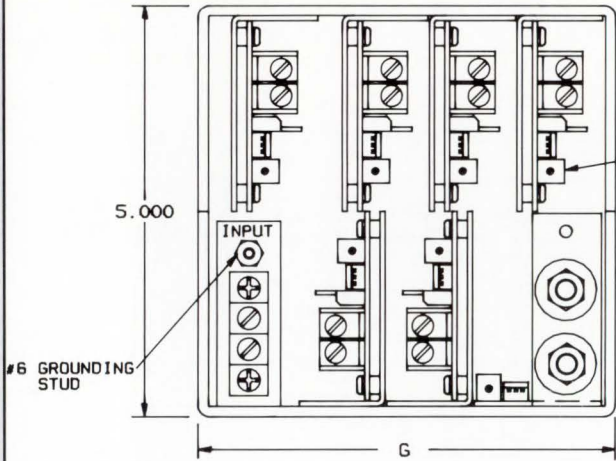


CASE 1 & 2

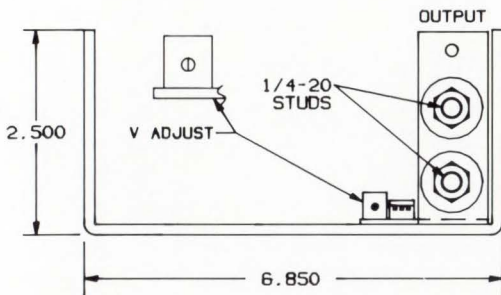
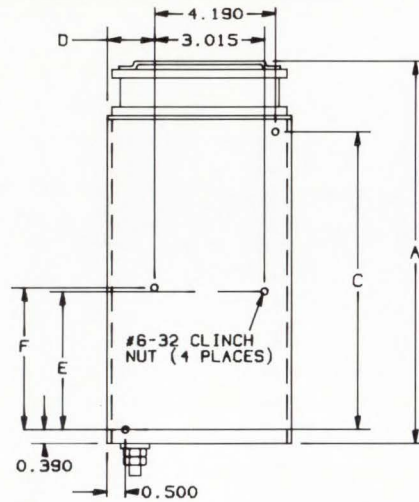
NOTES:

- (1) WITH COVER (#6-32), W/O COVER (.150 DIA.)
- (2) W/FAN COVER UNIT HEIGHT (4.100)
- (3) TERMINAL BLOCKS (#6-32)
- (4) STUDS (1/4-20)

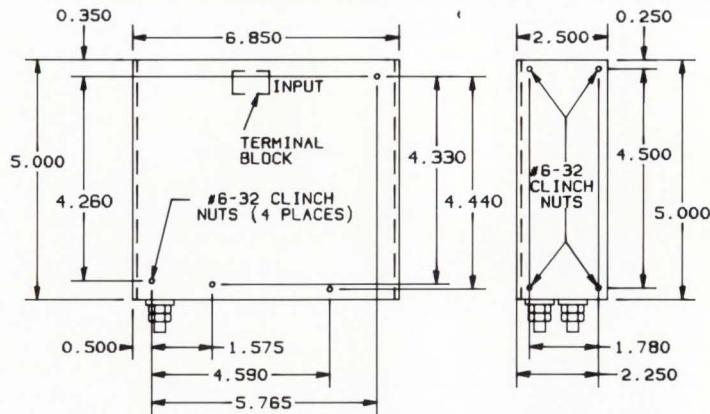
	CASE 1	CASE 2	CASE 3	CASE 4
	400/500 W	600/750 W	1000W	1500W
A	9.000	9.630	10.400	11.000
B	8.250	8.880	-----	-----
C	8.260	8.890	8.260	8.890
D	.410	.425	.410	.425
E	3.820	4.450	3.820	4.450
F	3.930	4.560	3.930	4.560
G	5.050	5.200	5.050	5.200



CASE 3 & 4



CASE 5

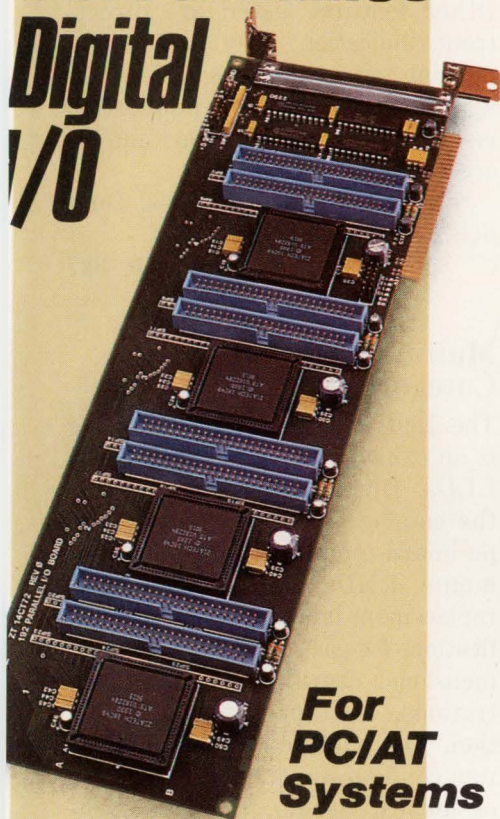


290 WISSAHICKON AVENUE, P.O. BOX 1369, NORTH WALES, PA 19454
PHONE: 215/699-9261 • FAX: 215/699-2310

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CIRCLE NO. 61

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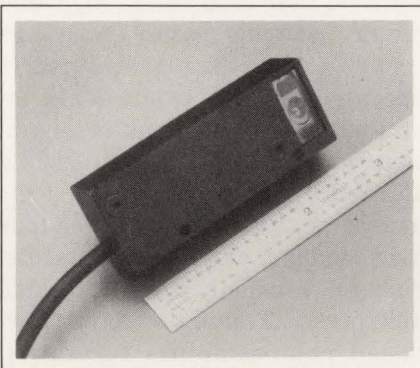
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COMPUTERS & PERIPHERALS

but also the effect on object distance. Position accuracy is ± 1 pixel, and jitter is less than 1 pixel. \$698.

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Circle No. 365



Fixed Bar-Code Scanner

- *Installs in terminals where operator supplies motion*
- *Orientations for apertures allow two scanning modes*

The Scanteam 6600 is a bar-code scanner for instruments and terminals where the operator or a mechanical device supplies the motion. The fixed scanner has an aluminum housing with two mounting holes and measures 2.68 x 0.98 x 0.61 in. You can opt for either visible red, 660-nm or infrared, 880-nm LEDs; rectangular or diamond aperture; and TTL or open-collector digital output. You can also choose between two aperture orientations. The two orientations allow the bar code to move past the scanner in either a step-ladder or picket-fence fashion. Scan speeds range from 3 to 30 in./sec. The focal plane of the scanner is 0.39 in. from the housing, and the depth of the field is 0.18 in. for a bar code having a 7-mil bar width. \$197.

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1000 VDC Output

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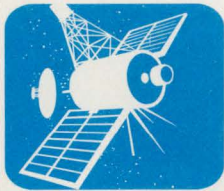
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CIRCLE NO. 57

The New STD Bus....

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in
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depths,



and out
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Micro/Sys	818-244-4600
Mizar Digital Systems	800-635-0200
Octagon Systems Corp.	303-430-1500
Pro-Log Corporation	800-538-9570
Robotrol Corporation	408-683-2000
Teknor Microsystems	514-437-5682
Versalogic	800-824-3163
WinSystems	817-274-7553
XYZ Electronics	800-852-6822
Ziatech Corporation	805-541-0488

CIRCLE NO. 62

LITERATURE

Catalog Of T&M Products And Peripherals

This 1991 catalog highlights more than 3000 products. It provides three ranges of categories: electronic test and measurement instruments, professional broadcast equipment, and computer peripherals. The 388-pg hard-bound publication lists new products such as digital signal analyzers, communications signal analyzers, high-end digital sampling scopes, midrange scopes, and a handheld battery-operated scopes. Other T&M instruments include pulse-signal source generators and Centurion, a 100-MHz plug-in module for logic analyzers. Also listed are VXIbus card modular plug-in products. Peripheral products covered include Tekxpress, a family of X-Window-based color-graphics terminals; Phaser II color printers; high-resolution display monitors; stereoscopic 3-D display systems; and a plug-in board for a Macintosh II computer.

Tektronix Inc, Box 500, Beaverton, OR 97077. **Circle No. 386**

safety, such as the yellow plastic meter case for improved visibility. Other features listed are direct-trend indication, easy nulling and peaking, and quick checks for voltage and current. The publication also provides specifications and an accessory list.

Simpson Electric Co, 853 Dundee Ave, Elgin, IL 60120.

Circle No. 387

Multitude Of LEDs Categorized

The 1991 Packaged LEDs Catalog is an exhaustive guide to packaged LEDs. Divided into four sections, the catalog covers discrete LEDs; pc-board-mounted LEDs; panel-mount LEDs; and incandescent replacement lamps. Technical specifications for each product include dimensional drawings, photos, illustrations, and application information. The publication provides custom configurations from a selection of lenses, bezels, LED configurations, bases, and terminations. Also included are an alphanumeric index and an incandescent-lamp cross reference.

Data Display Products, Box 91072, Los Angeles, CA 90009.

Circle No. 388

Software Development Tools Cataloged

This catalog describes development issues and offers product solutions. For example, it lists Source Control/Configuration Management and offers its Polytron Version control system, Polymake, and professional editor as solutions. Other areas addressed in this 48-pg edition are prototyping, object-code optimization, graphical user interfaces, and AD/cycles. The publication also provides applications, as well as articles and contests.

Sage Software Inc, 1700 NW 167th Pl, Beaverton, OR 97006.

Circle No. 389





Analog Multimeters
260[®]-8Xi and 260[®]-8XPⁱ

Professionals have long recognized that a Simpson 260 analog meter has many things that other 260s (VMA meters) do not have. It is used as well as measuring fluctuating forces and torques. The new 260-8Xi Series continues this tradition.

It has more drive torque than you can come to expect from its predecessor. The yellow meter case for enhanced visibility and new safety features is the trademark of the 260-8Xi. The meter is packaged in a durable ABS plastic case providing high-impact resistance and increased shock protection in the toughest environments.

FEATURES

- Instant trend information for quick results. "Yes/No" display
- Auto 800 ohms
- 100, 1244 auto
- Audible continuity check
- Minimized noise for greater resolution and greater accuracy of reading.
- Adjustable overrange circuit protection (260-8XP only)
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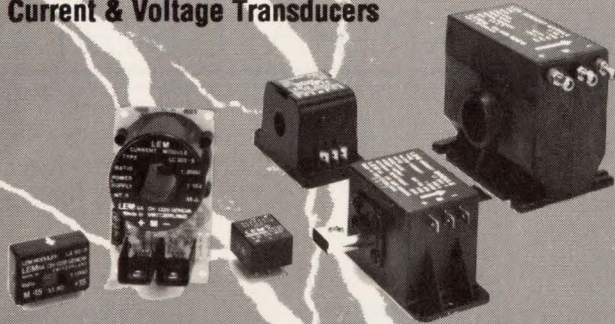


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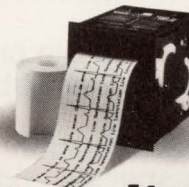


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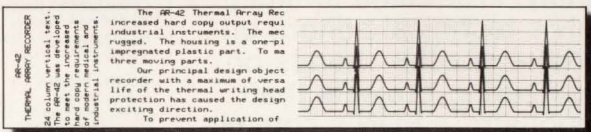


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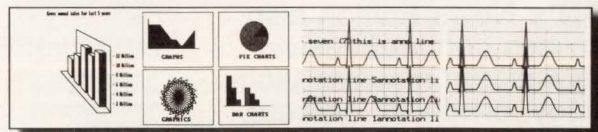


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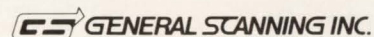
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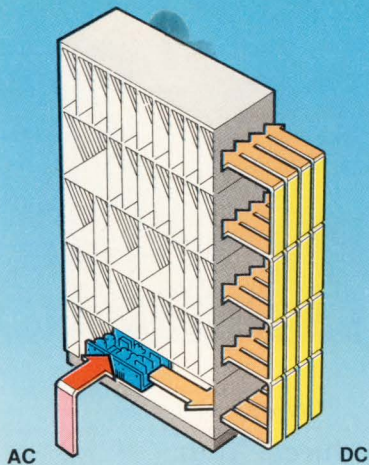
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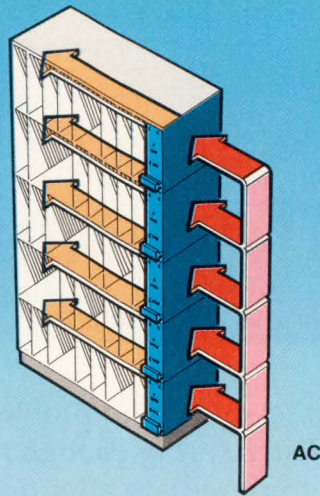
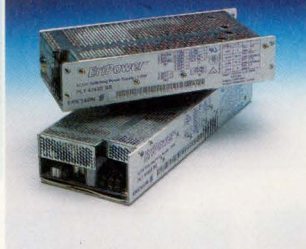
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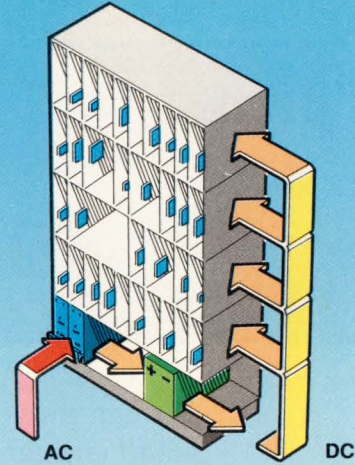
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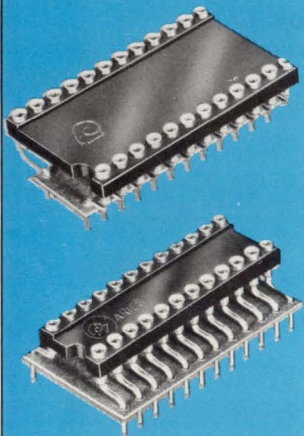
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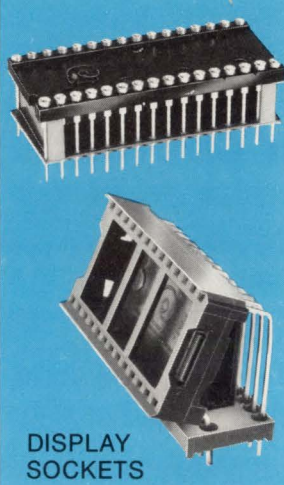
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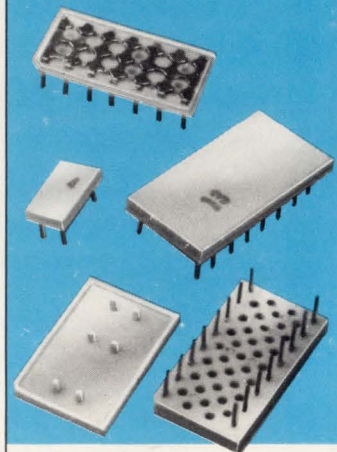
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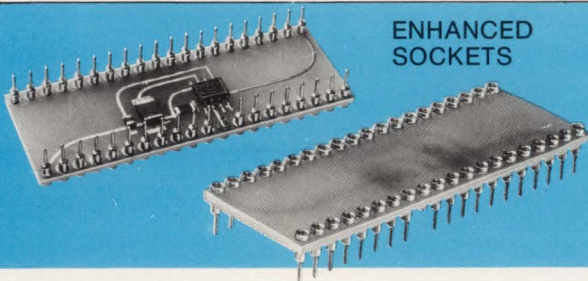
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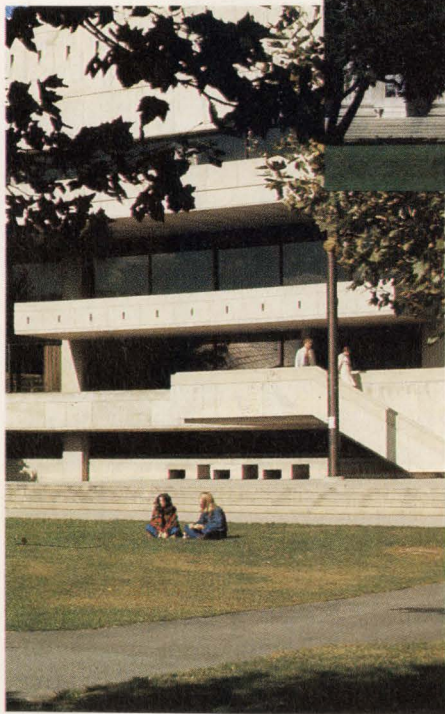


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Engineering schools try new approaches to old problems

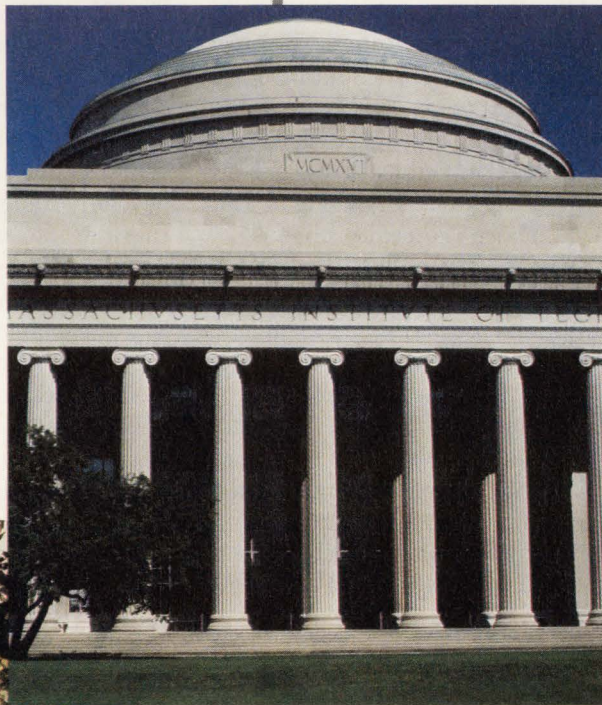
Coalitions, better recruiting, and volunteer programs show real promise.



Jay Fraser, Associate Editor

The current state of undergraduate engineering education in the US has been described as in flux, in a slow decline, in a rapid decline, and in a crisis. Educators have different opinions, but they agree that there are some serious problems with engineering education today, and if those problems aren't solved soon the situation will only grow worse.

"We're in a crisis," says Mac Van Valkenburg, former Dean of Engineering at the University of Illinois and now a regular columnist for *Engineering Education* magazine. "Enrollments continue to decline and the quality of the students who come out [of the programs] continues to decline."



Statistics from the US Department of Education support what Van Valkenburg says about enrollments. According to the department's figures, released in 1989, the number of students earning BS degrees in engineering peaked in 1984 and has

been declining since then. The National Science Foundation (NSF) has published studies with similar findings. The NSF's statistics have been disputed by the IEEE, the American Association of Engineering Societies (AAES), and other groups. However, it has projected that if current trends continue, by the year 2010 there will be a shortage of 70,000 engineers in this country.

The quality of today's students compared to those in the past is more difficult to quantify. Van Valkenburg was a professor of electrical engineering for more than 30 years before he became a dean. Over the years he noticed a distinct difference in the students. "Students just don't have the same drive and enthusiasm as they used

to," he says. "You can see it when you give the same test that you gave 10 years ago. The students just don't do as well. A lot of students take the business program today because it's easier."

Of course, college students have been accused for centuries of not working hard enough at their studies. In late 20th-century America, it's easy to blame distractions like MTV and video games for students' short attention spans and laziness. But the problems aren't all caused by students. The course of study at our engineering schools needs to be examined, too.

Francis Kennedy, Jr is the chairman of the engineering sciences department at Dartmouth College (Hanover, NH). Although he doesn't agree that engineering education is in a crisis, he acknowledges that there are real problems.

"Engineers aren't as adaptable in the job market and perhaps not as able to communicate with others outside their [peer group] as they ought to be," Kennedy says. "There is a general lack of breadth and depth in new areas of engineering education contributing to this problem." People are trying to figure out ways to address this, but they're running into a roadblock—

it is increasingly difficult to put everything that needs to be done within the 4-year limitation.

In the past, the answer was to take nonscience courses out of the curriculum. Now educators realize they've probably done their students a disservice, Kennedy says. They can't cut the science and engineering courses, so they're beginning to wonder just what they can do.

It isn't surprising that college students have a different view of the problems involved in engineering education. Garrett Love is a senior majoring in civil engineering at MIT (Cambridge, MA). One of the biggest stumbling blocks he sees is a lack of practical instruction.

"The courses are too theoretical. There's not enough hands-on experience," he says. "If you're only dealing with a bunch of equations, you'll just forget them right after the test. Not much is applicable to the real world." He says that many students worry that when they graduate they won't have the training to do anything practical.

Craig Lozofsky is a junior studying astronautics at MIT. He believes the quality of the instruction isn't always very high. "A lot of the professors aren't really interested in teaching. They don't take input from the students. They keep teaching only because they have to. They'd rather be doing their research," he says. "Some of the subjects are just plain boring and often the professor doesn't help much."

In addition to complaints about courses that are too theoretical, boring, or badly taught, students charge that there are so many required courses for some engineering disciplines that they're prevented from taking electives. The sheer amount of course work necessary to earn an engineering degree these days causes some students to give up.

Matthew Martinez entered MIT last September to study nuclear engineering, but by November he had switched to political science. "I took a look at the list of requirements and realized that I wasn't going to have time to live. I couldn't have finished in five years, much less four," he says. "I look around here and all I see is constant grinding. I don't want to spend eight hours a day studying. That's not what I consider a college experience."

Technical illiterates

Unmotivated students, indifferent professors, and excessive amounts of course work may all be affecting the current state of engineering education. However, many people charge that another serious problem occurs before students even arrive at college—the poor preparation provided by secondary and elementary schools, especially in math and science. Engineering instructors have repeatedly accused American high schools of turning out technical illiterates.



Mac Van Valkenburg

"Students just don't have the same drive and enthusiasm they used to."



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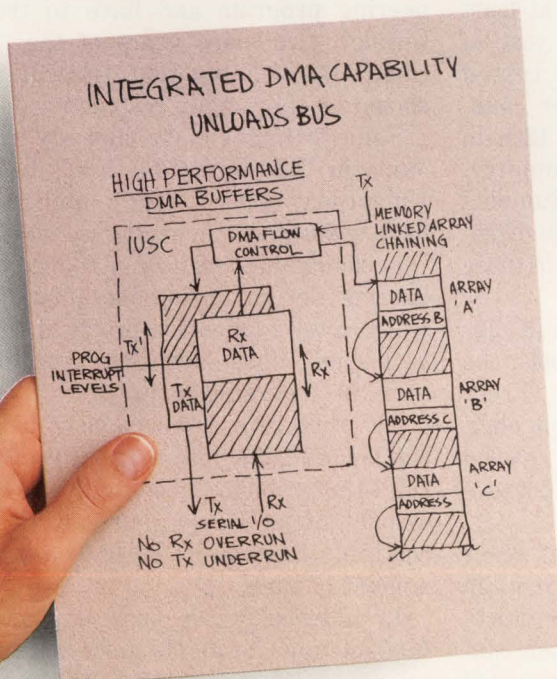
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"The problem of mediocrity in public education has become intolerable," says Richard Ellis, director of manpower studies for the Engineering Manpower Commission of the AAES. "I don't think that anyone doubts that secondary and elementary education in the United States is not satisfactory." He points to cross-national test scores where students from Korea score substantially better on the standard tests than Americans as an example.

Not only do Korean students score better on the tests than Americans, but students from many other countries do, too. In its most recent survey, conducted in the early 1980s, the International Association for the Evaluation of Educational Achievement singled out high-school seniors whom it considered serious mathematics students. The students were in courses of study that required at least two years of algebra and one year of geometry. When they were tested against students from 15 other countries, the Americans finished 12th in functions/calculus, 12th in geometry, and 14th in advanced algebra. Students from Hong Kong finished first and students from Japan second in each of these subject areas.

Whether you believe the fault lies with the colleges, the high schools, the students themselves, or all three, there's no shortage of problems in engineering education today. This has led people in and out of academia to propose a variety of solutions.

If many of the problems that beset engineering colleges have their roots in elementary and high schools, then something has to be done to strengthen education on those levels. More required math and science courses and better teacher training are often suggested, but these are not much use unless students are convinced that math and science are relevant to their lives.

For students who may be considering a career in engineering, meeting and talking with a working engineer about his or her job can be very beneficial. A number of volunteer programs have sprung up to give students an opportunity to meet with professionals.

The AAES is preparing a program that will place a volunteer in every elementary school in the US. "That's how seriously we take this problem," Ellis says.

Other professional associations, such as the Junior Engineering Technical Society and the National Society of Professional Engineers, also have volunteer programs that bring engineers to the classroom.

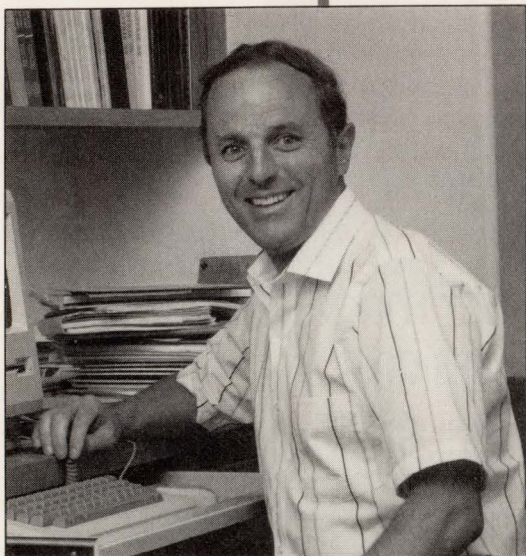
When students arrive at engineering schools, too often they find themselves quickly locked into a rigid schedule of required courses that are mostly abstract and theoretical. The drudgery of slogging through them is near the top of their list of complaints.

Van Valkenburg notes that college freshmen have come straight from three or four years of math, physics, and general sciences. Then, they enter the engineering program and have to trudge through two more years of the same thing. He believes that the curricula should be thoroughly restructured.

Some colleges have already taken steps in that direction. MIT, Cornell University (Ithaca, NY), and others have redesigned their courses of study. One change has been to introduce engineering design during freshman year, which gives students a practical course with some hands-on work to counterbalance the theoretical courses.

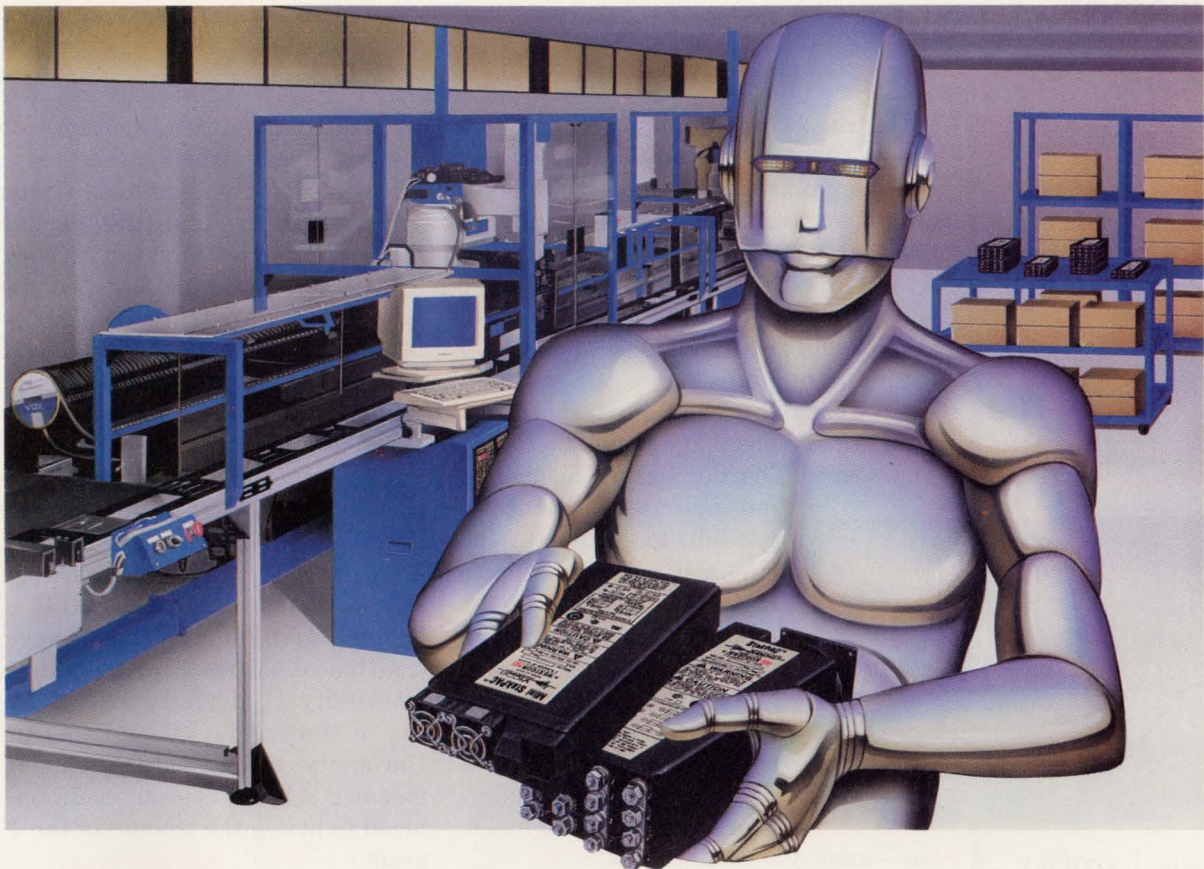
Restructuring curricula may help to sustain students' interest, but it doesn't solve the problem of how to fit the large amount of necessary course work that confronts students today into a limited amount of time.

In addition to the basic engineering fundamentals, students must fit current science and technology into the curriculum. Nationally this has meant most engineering students spend more than four years in school. "We can't extend the time any longer and still call it a 4-year program," Kennedy says.



Francis Kennedy, Jr.

"There is a general lack of breadth and depth in new areas of engineering education."



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SP2-1803	5 @ 120	12 @ 66			
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SP2-1805	15 @ 53	15 @ 53			
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SP3-1802	5 @ 150	12 @ 33	12 @ 16		
SP3-1803	5 @ 180	15 @ 13	15 @ 13		
SP3-1804	5 @ 150	15 @ 26	15 @ 13		
Quad Output					
SP4-1801	5 @ 150	12 @ 16	12 @ 16	5 @ 30	
SP4-1802	5 @ 150	15 @ 13	15 @ 13	5 @ 30	
SP4-1803	5 @ 150	12 @ 16	12 @ 16	24 @ 8	
SP4-1804	5 @ 150	15 @ 13	15 @ 13	24 @ 8	
Five Output					
SP5-1801	5 @ 120	12 @ 16	12 @ 16	5 @ 30	24 @ 8
SP5-1802	5 @ 120	15 @ 13	15 @ 13	5 @ 30	24 @ 8
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Dual Output					
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ST2-1402	5 @ 60	5 @ 60			
ST2-1403	5 @ 60	12 @ 33			
ST2-1404	12 @ 33	12 @ 33			
ST2-1405	15 @ 26	15 @ 26			
Triple Output					
ST3-1401	5 @ 60	12 @ 16	12 @ 16		
ST3-1402	5 @ 60	15 @ 13	15 @ 13		
ST3-1501	5 @ 90	12 @ 8	12 @ 8		
Quad Output					
ST4-1401	5 @ 30	12 @ 16	12 @ 16	5 @ 30	
ST4-1402	5 @ 30	15 @ 13	15 @ 13	5 @ 30	
ST4-1403	5 @ 30	12 @ 16	12 @ 16	24 @ 8	
ST4-1501	5 @ 30	15 @ 13	15 @ 13	24 @ 8	
ST4-1502	5 @ 60	12 @ 16	12 @ 8	5 @ 15	
ST4-1503	5 @ 60	15 @ 13	15 @ 7	5 @ 15	
ST4-1504	5 @ 60	12 @ 16	12 @ 8	24 @ 4	
ST4-1505	5 @ 60	15 @ 13	15 @ 7	24 @ 4	
Five Output					
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Dartmouth's solution was to institute a 5-year course of study that leads to a bachelor of arts in engineering sciences after four years and a professionally accredited bachelor of engineering after five. Other schools are considering adopting similar programs. One variation would award students an MS after five years of study.

US Census Bureau figures show a decline in the college-age population in recent years. The decreasing number of engineering students is partially a result of this decline. If schools want to maintain or increase the number of incoming engineering students, they're going to have to try harder to recruit students from those groups that have been traditionally under-

represented in engineer-

ing—women and minorities. During the last two decades schools have significantly increased their efforts to attract women and minorities. National organizations that encourage and assist these students in their college careers are springing up around the country. For example, the Minority Engineering Program is now represented at 89 American colleges and universities. It provides counseling, tutoring, moral support, and even emergency funds for minority students.

These efforts are paying off. The percentage of minority students enrolling in engineering majors has increased steadily since 1986, although these students still make up only 6.5% of all engineering graduates, according to AAES figures. The number of women engineering graduates, on the other hand, has declined slightly in recent years. Women currently constitute approximately 13% of the total.

Until very recently the attack on the problems of engineering education had been piecemeal. Colleges and universities took different approaches without coordinating, or even communicating about what they were doing, with other institutions.

Recognizing this lack of collaboration, the NSF made two \$15 million grants

last fall to fund two coalitions of engineering schools. The Synthesis Coalition includes Hampton Institute (Hampton, VA), Tuskegee Institute (Tuskegee, AL), Southern University (New Orleans, LA), California State Polytechnic University (San Luis Obispo), University of California—Berkeley, Stanford University (Stanford, CA), Iowa State University (Ames), and Cornell University (Ithaca, NY). The ECSEL (Engineering Coalition of Schools for Excellence in Education and Leadership) is made up of City College of New York (New York, NY), Howard University (Washington, DC), MIT (Cambridge, MA), Morgan State University (Baltimore, MD), Pennsylvania State University (University Park), University of Maryland (College Park) and the University of Washington (Seattle). The member schools in each coalition combined to match the amount of the NSF's grant.

Each coalition has the broad goals of improving the quality of engineering education and increasing the interest of students in an engineering career. The schools individually and in various combinations seek to do this through a variety of programs. Some bring non-traditional disciplines such as the humanities and economics into engineering curricula. Others are designed to forge links with high-tech companies or draw on the expertise of business leaders. It's too early to see many concrete results yet, but the Synthesis Coalition alone already has more than 60 collaborative programs underway.

It's impossible to predict how effective these efforts by engineering schools are going to be, although some of the new approaches have already shown encouraging results. No one can deny that engineering education in this country is facing some serious problems, but no one can deny that serious thought and serious money is going into solving them.

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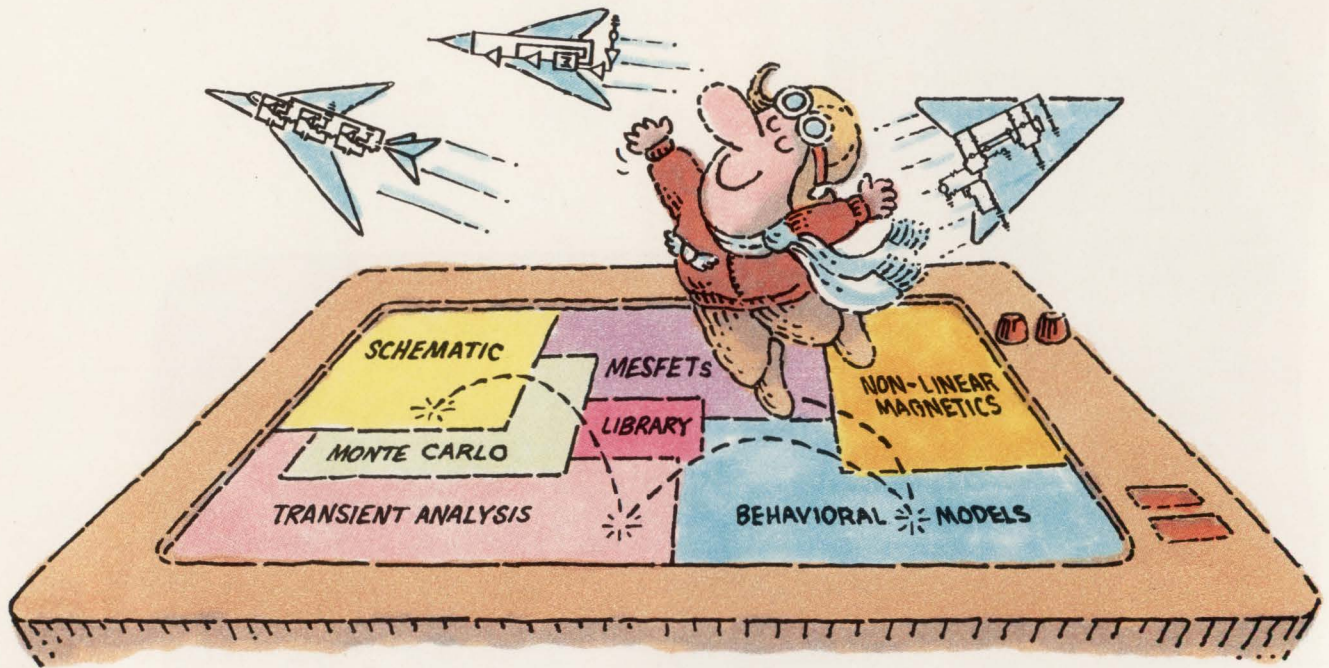
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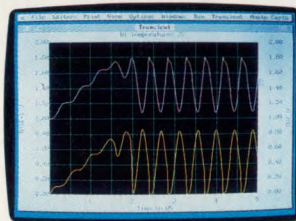
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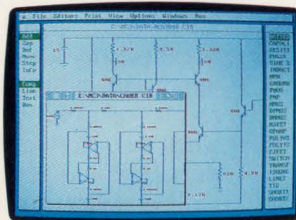
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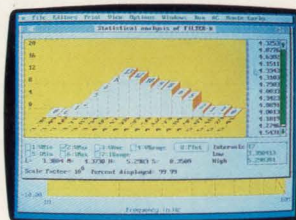
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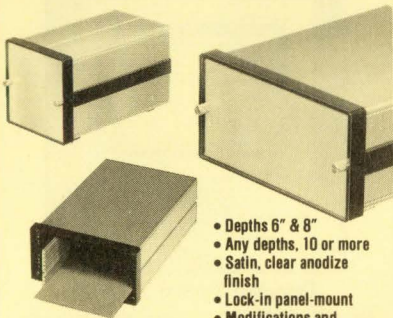
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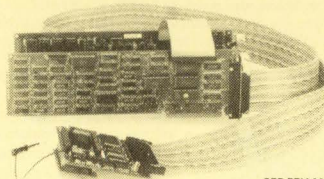
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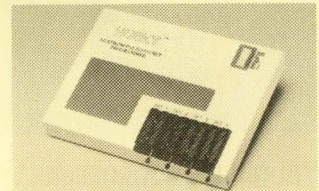
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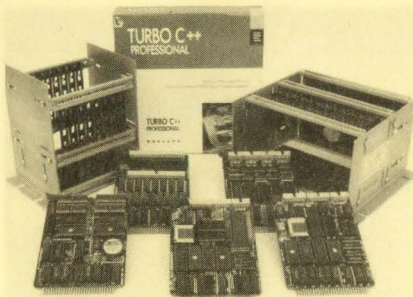


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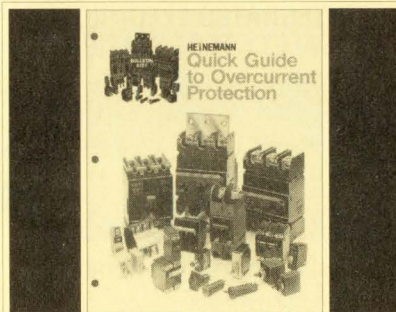
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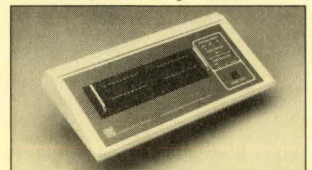
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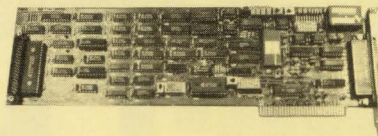
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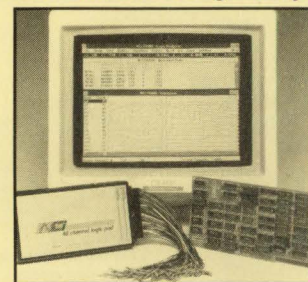
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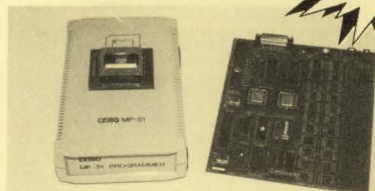
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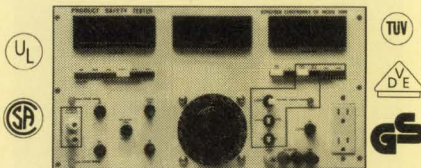
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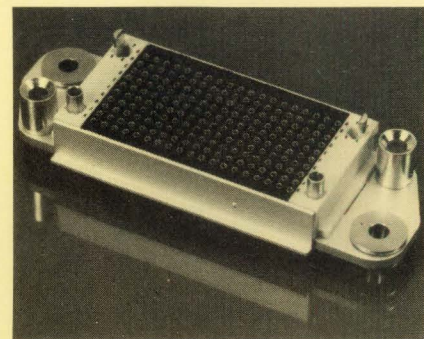
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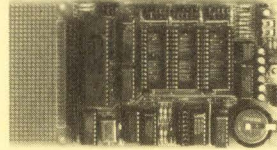
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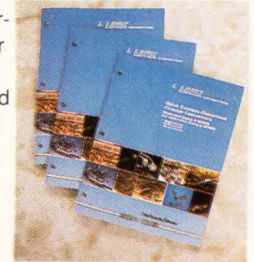
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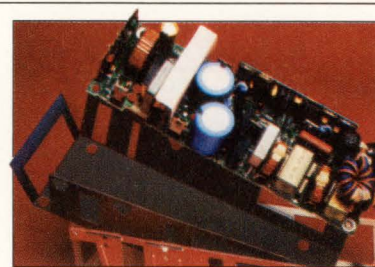


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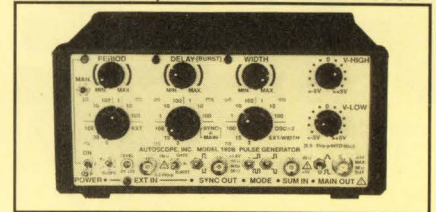


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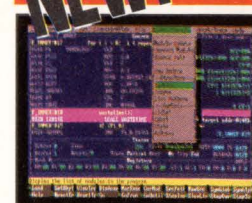
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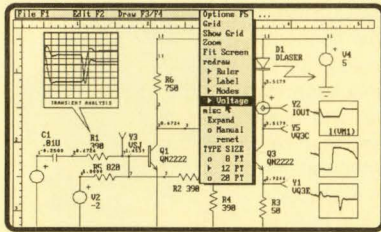
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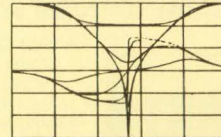
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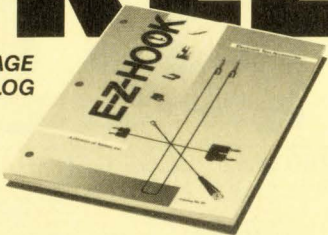
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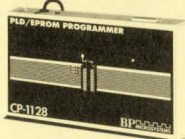
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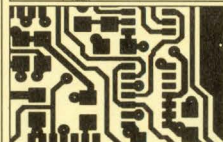
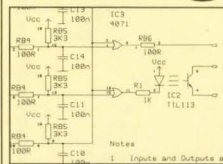
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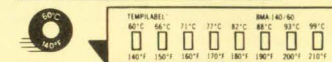
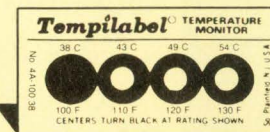
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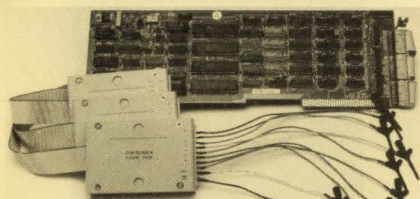
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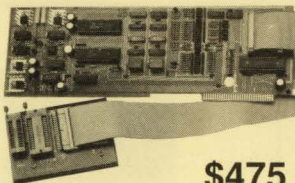
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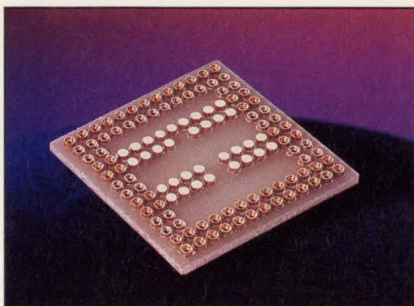
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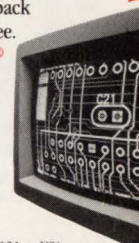
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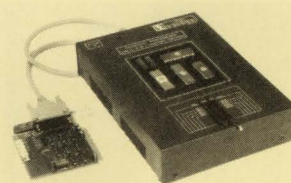
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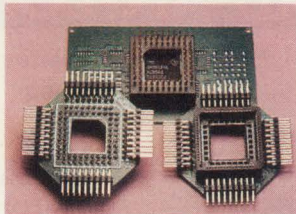


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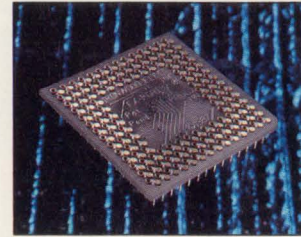
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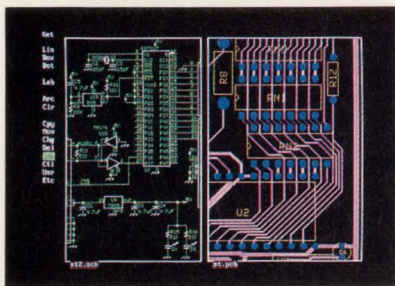
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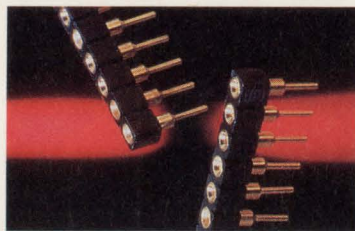
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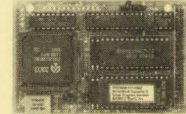
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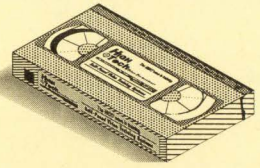
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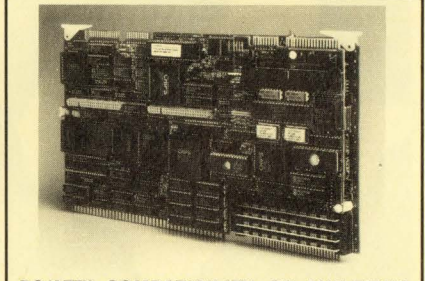
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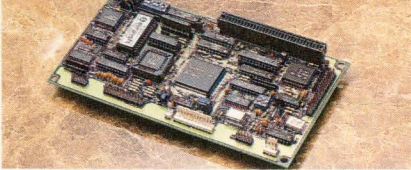
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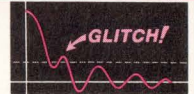


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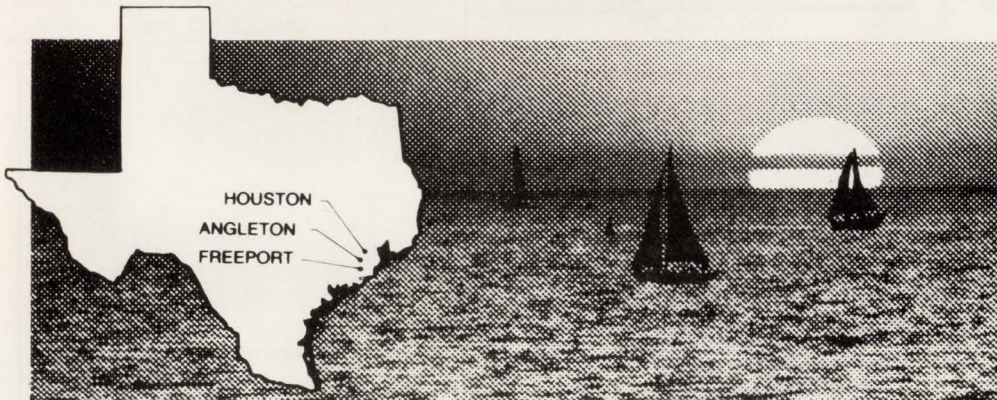
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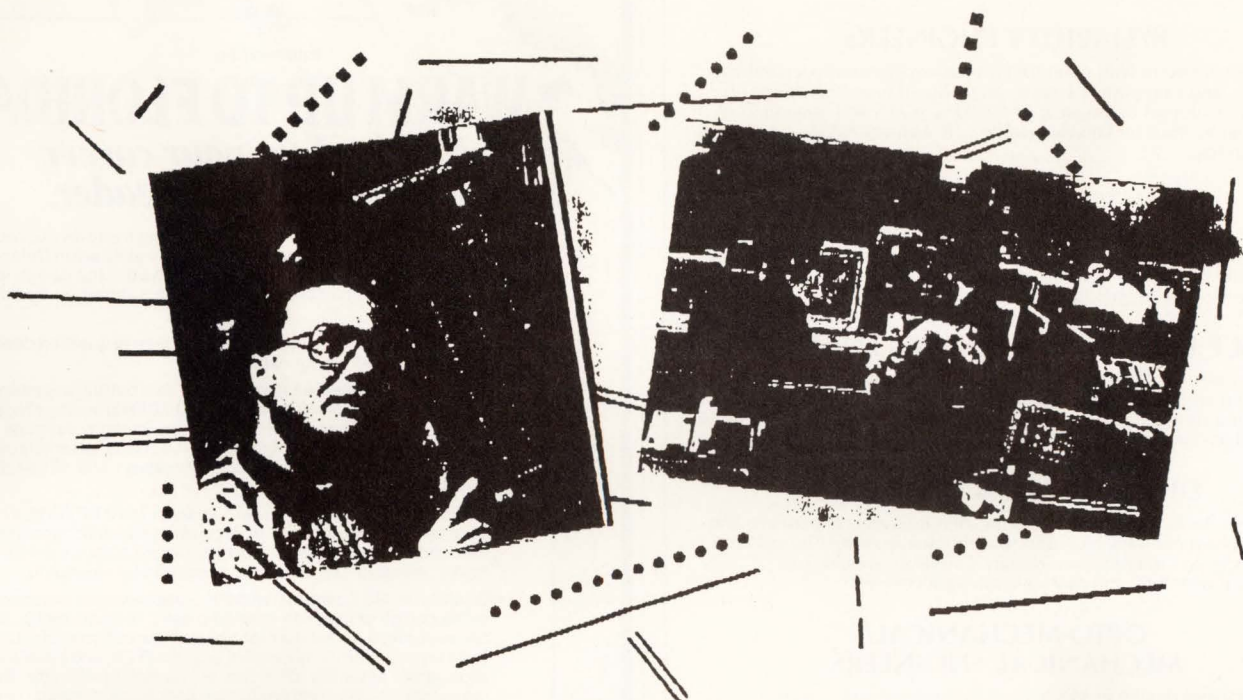
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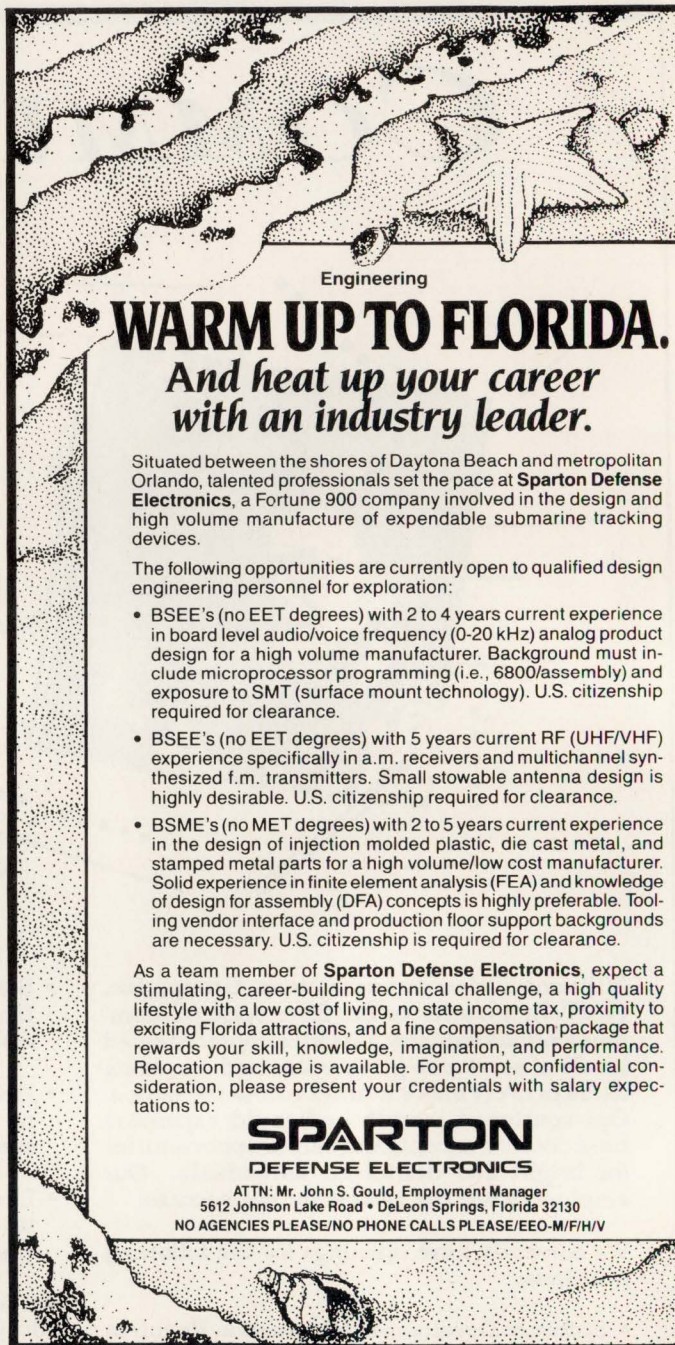
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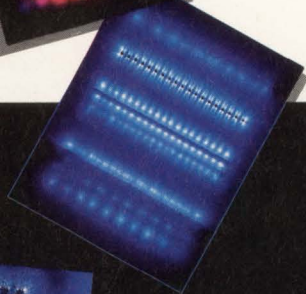
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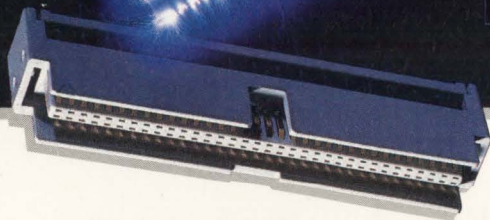
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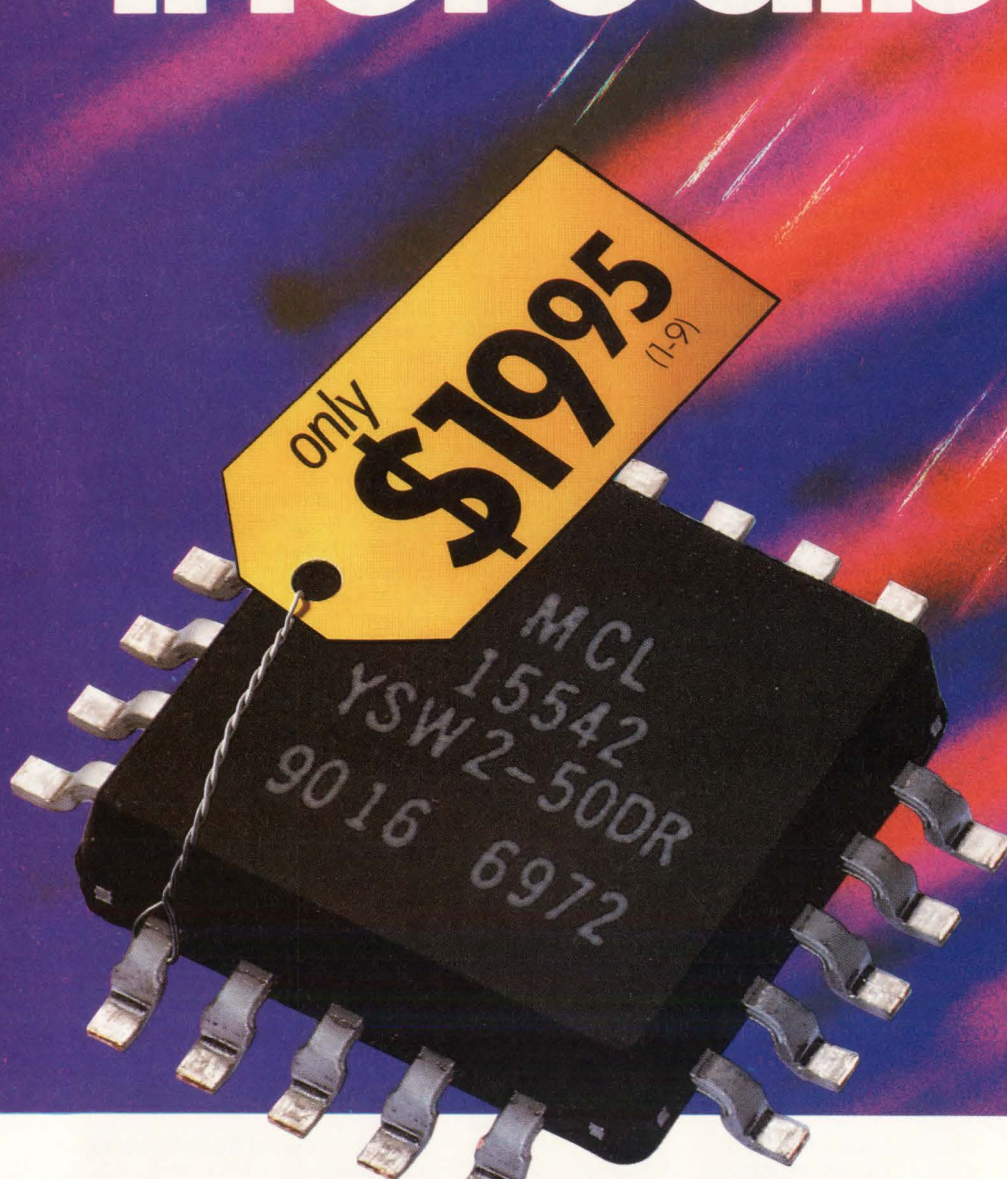
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RF input, max dBm (no damage)	22	22	26
VSWR (on), typ		1.4	
Video breakthrough to RF, typ (mV p-p)		30	
Rise/Fall time, max (nsec)		3.0	

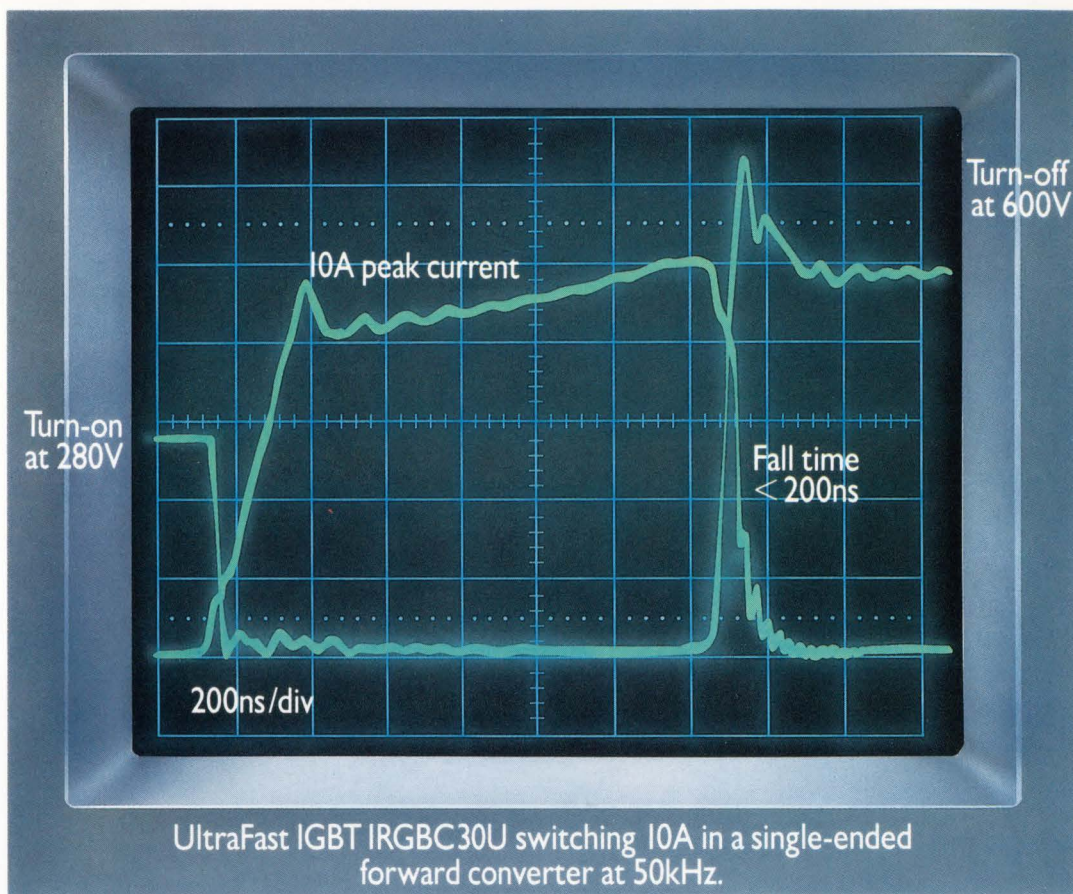
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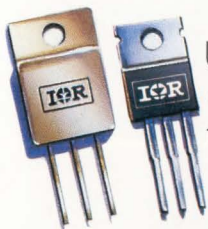
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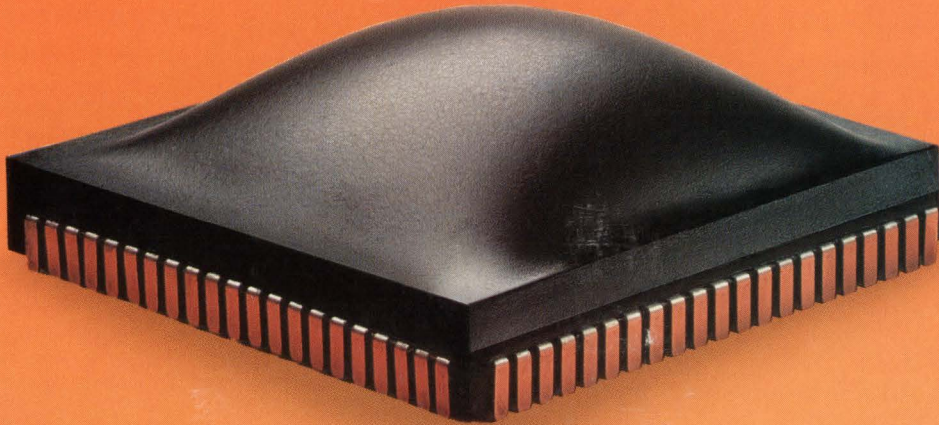
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