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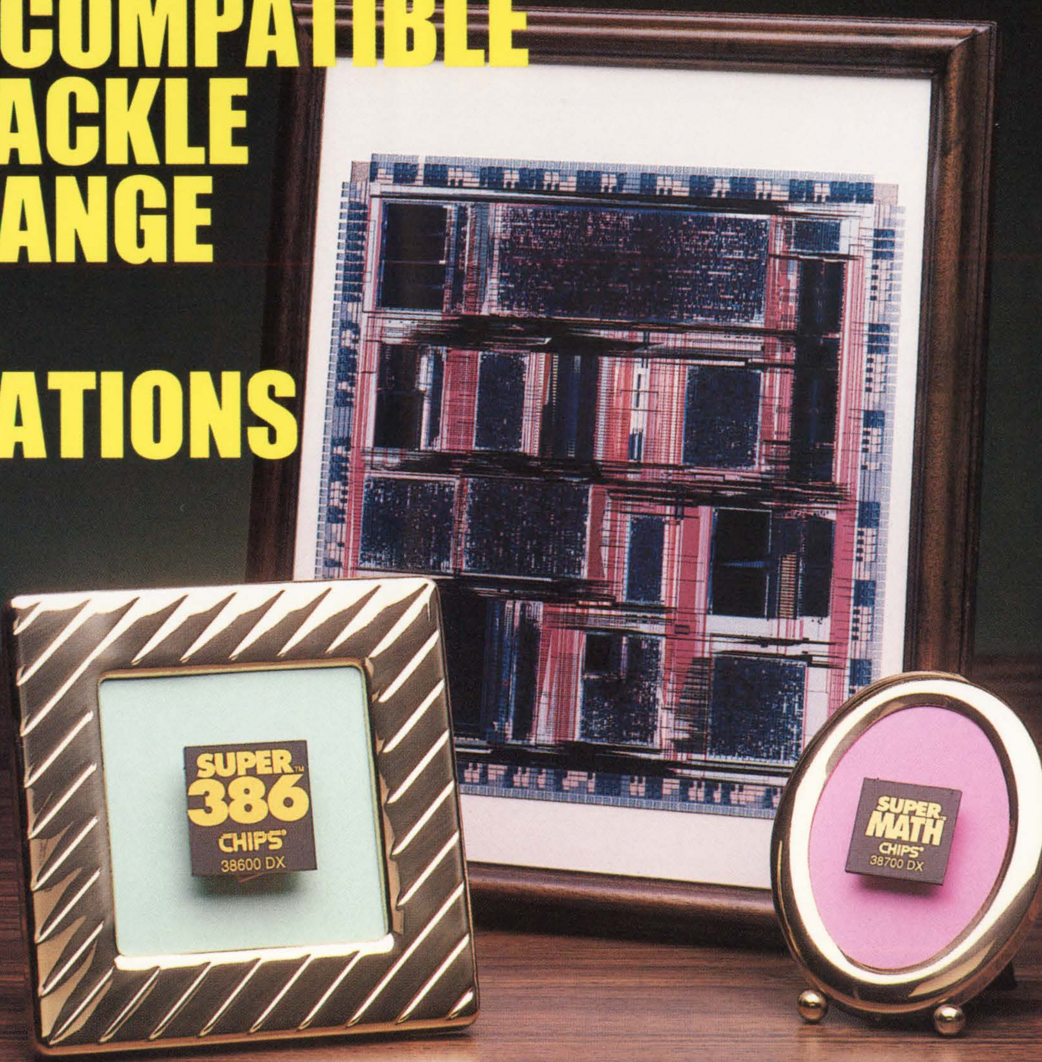

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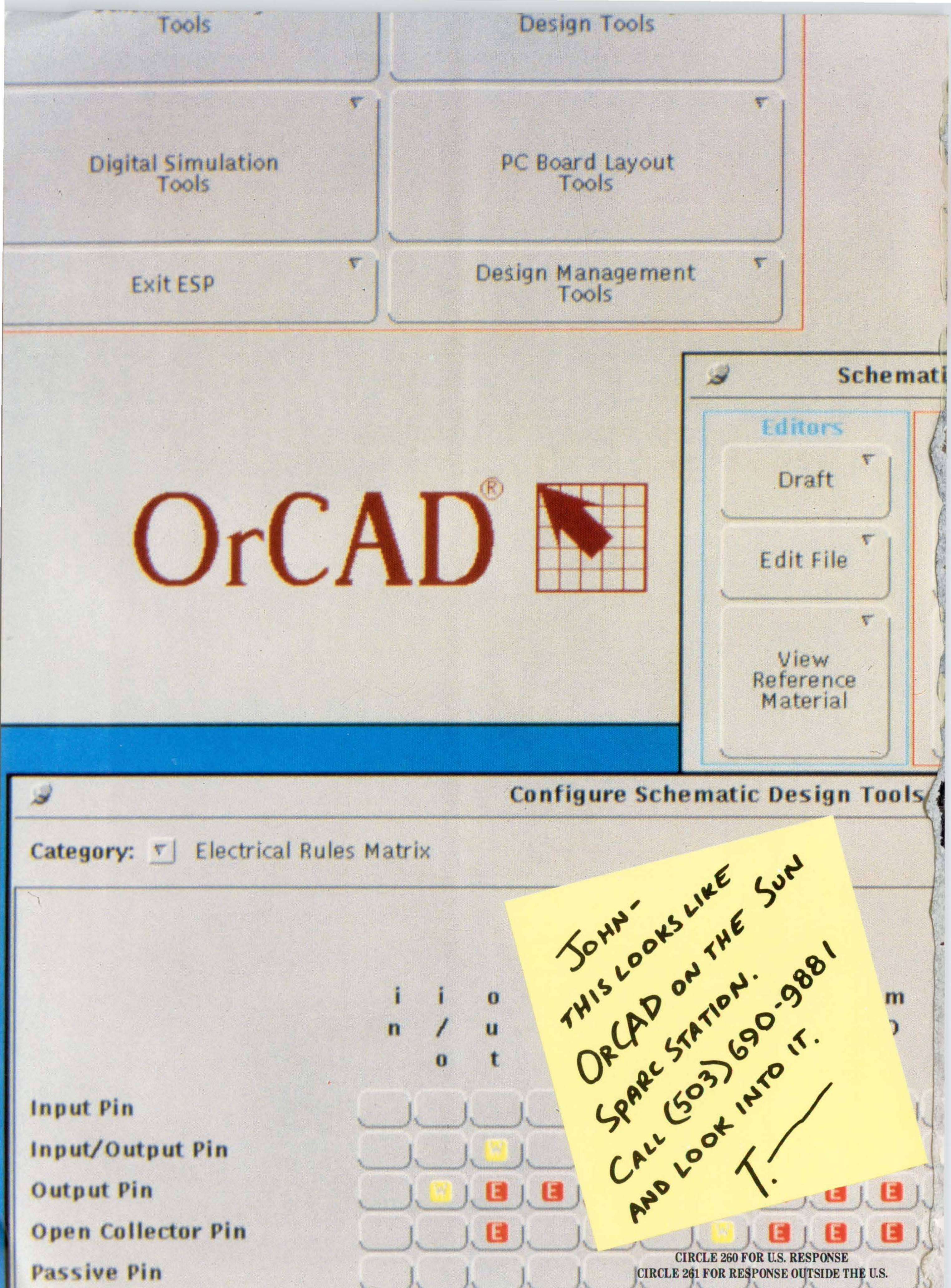
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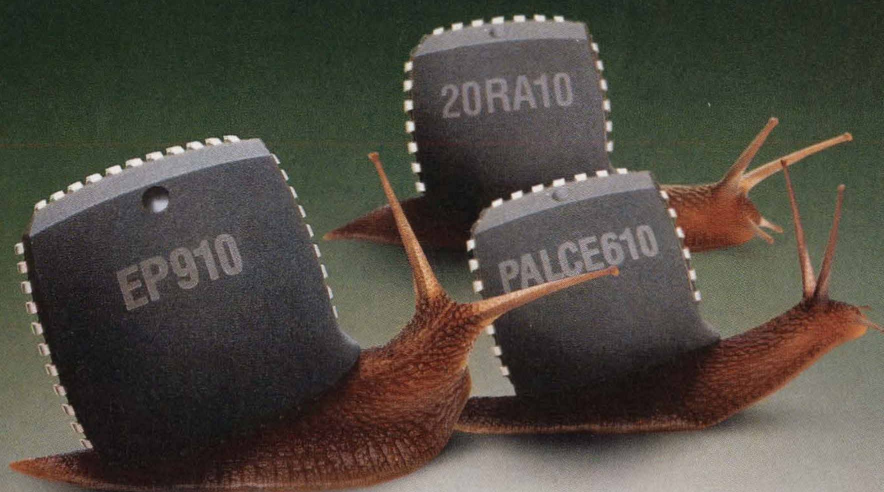

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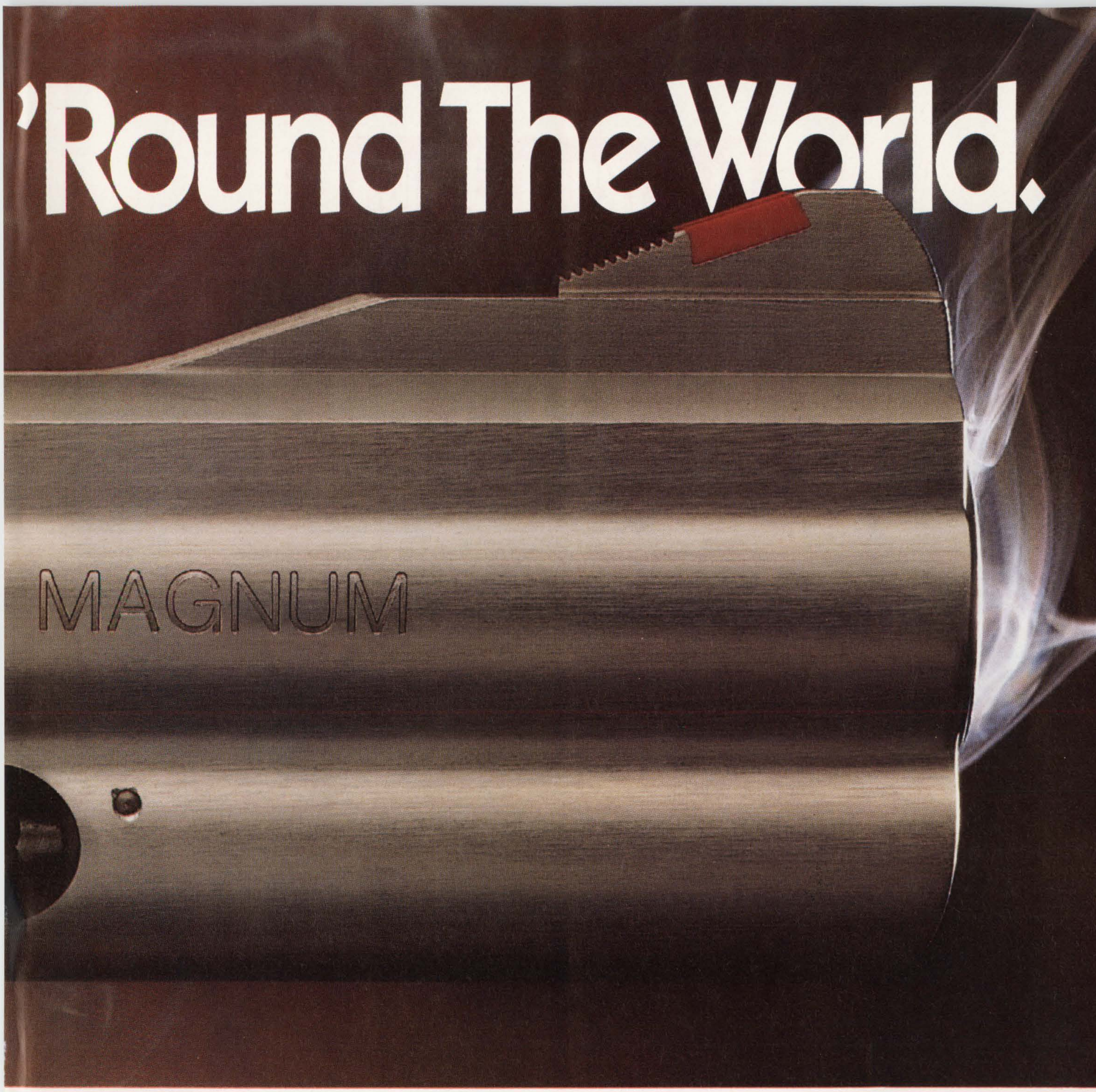

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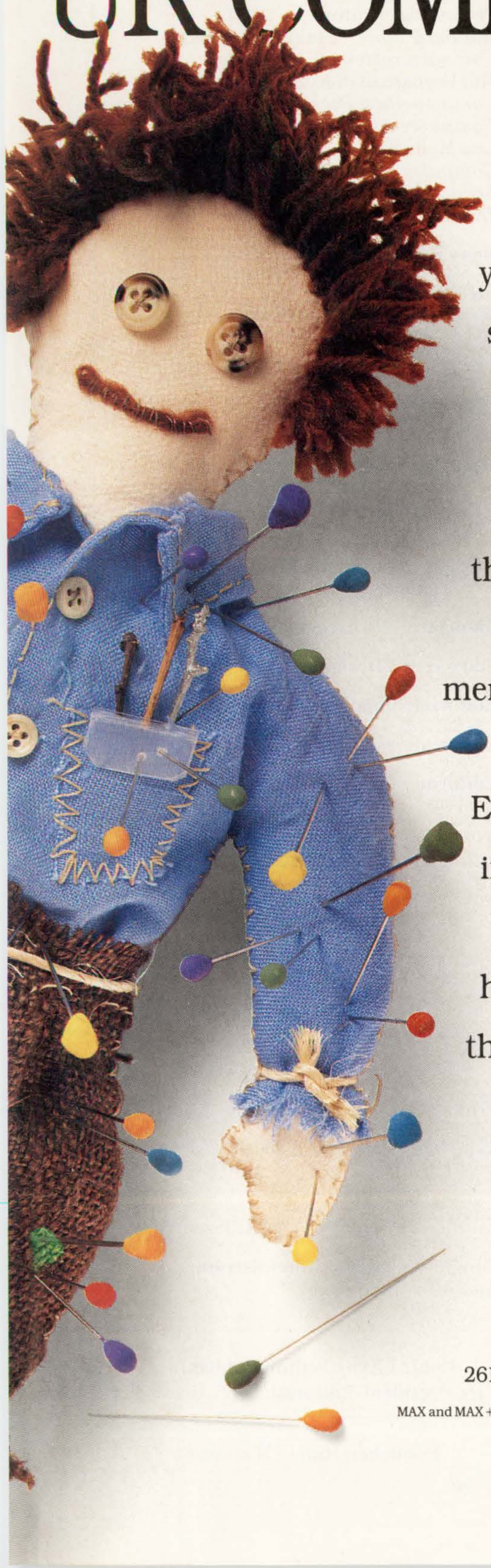

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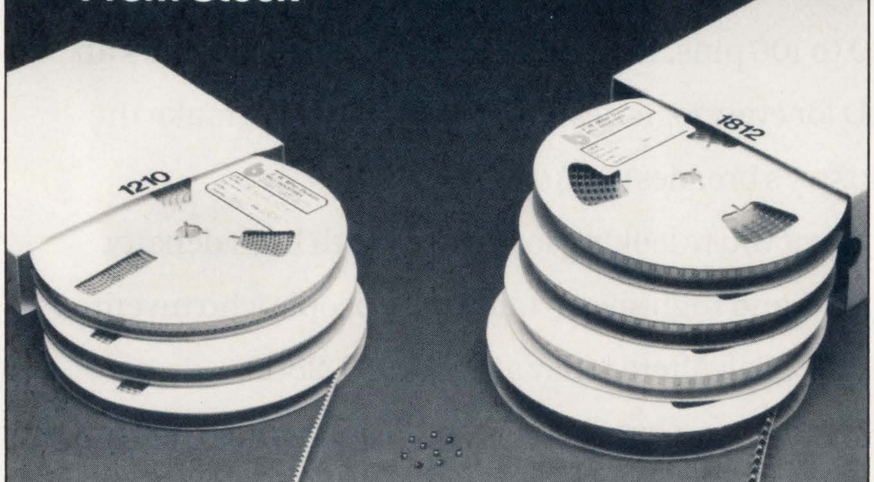

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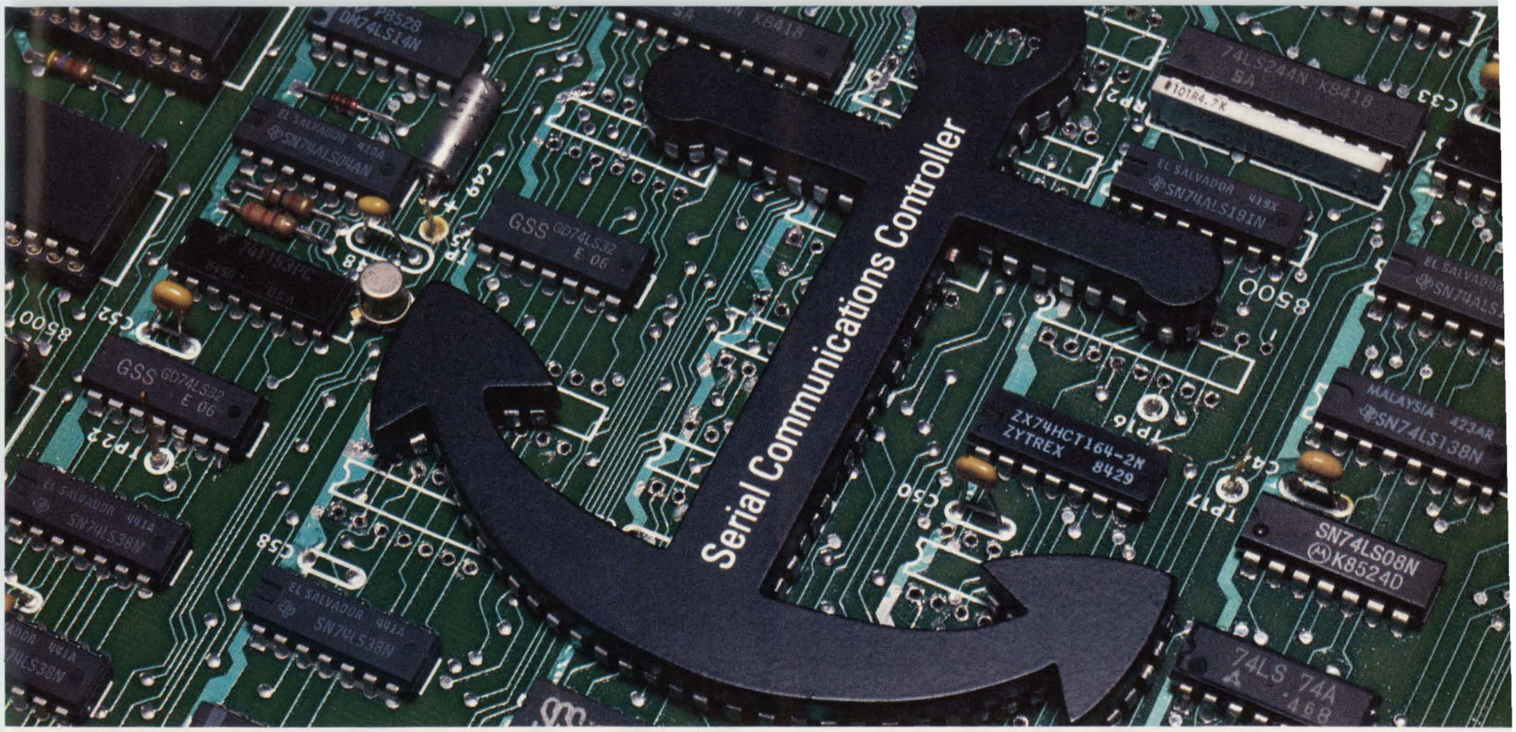

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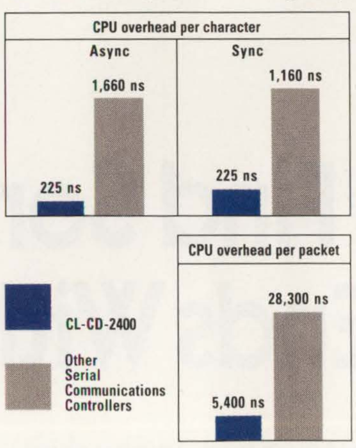

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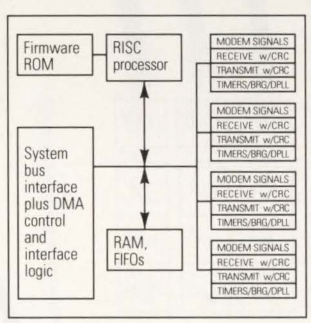

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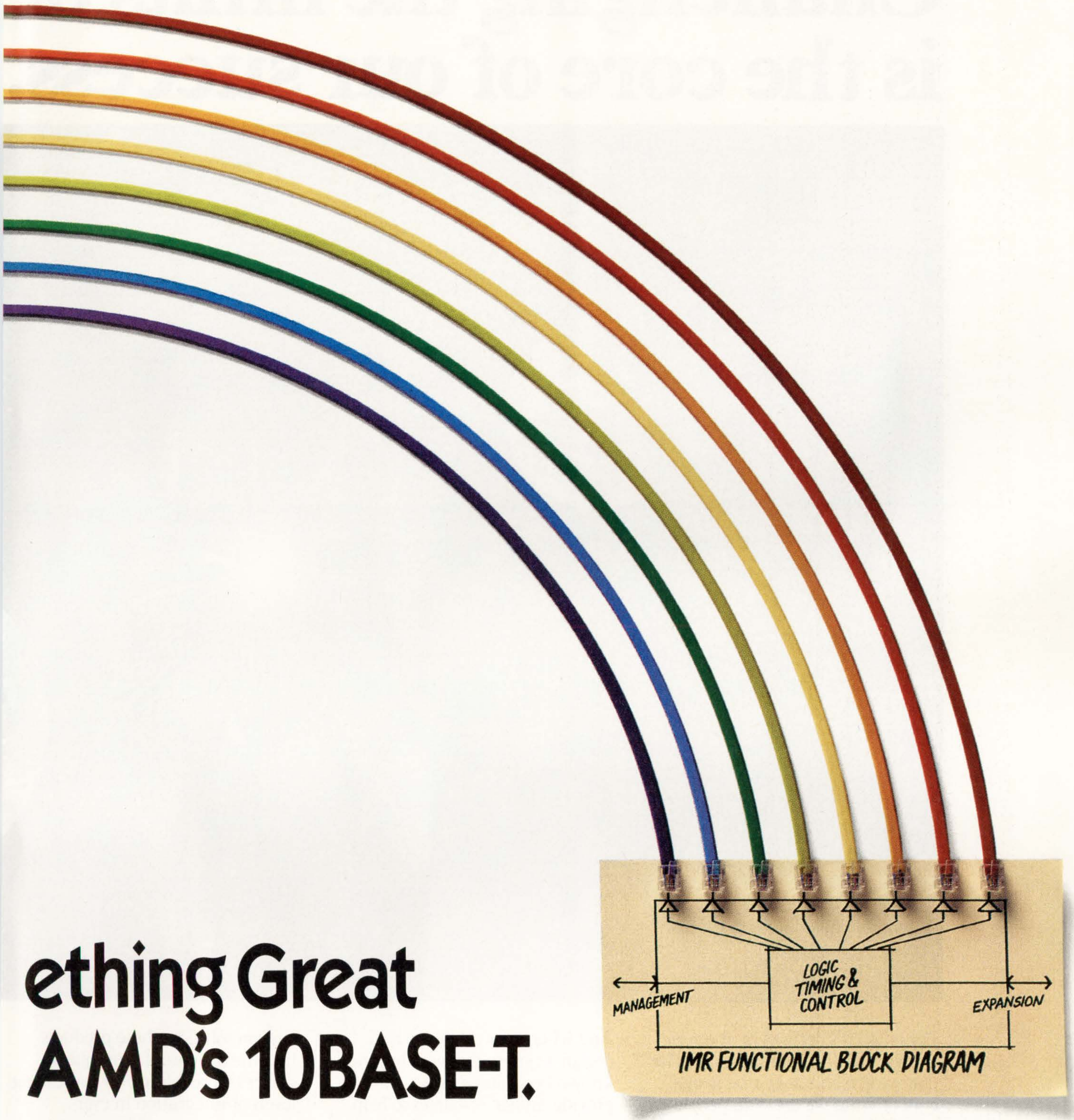

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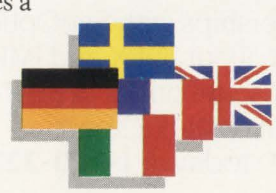

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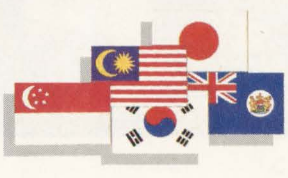

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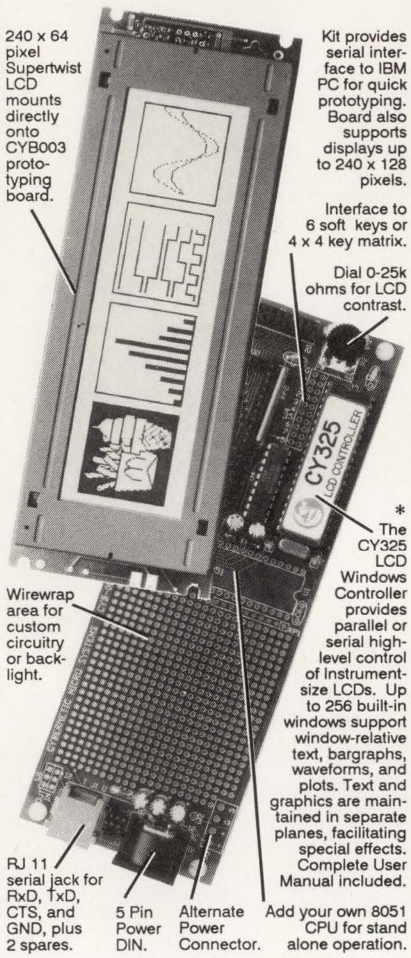

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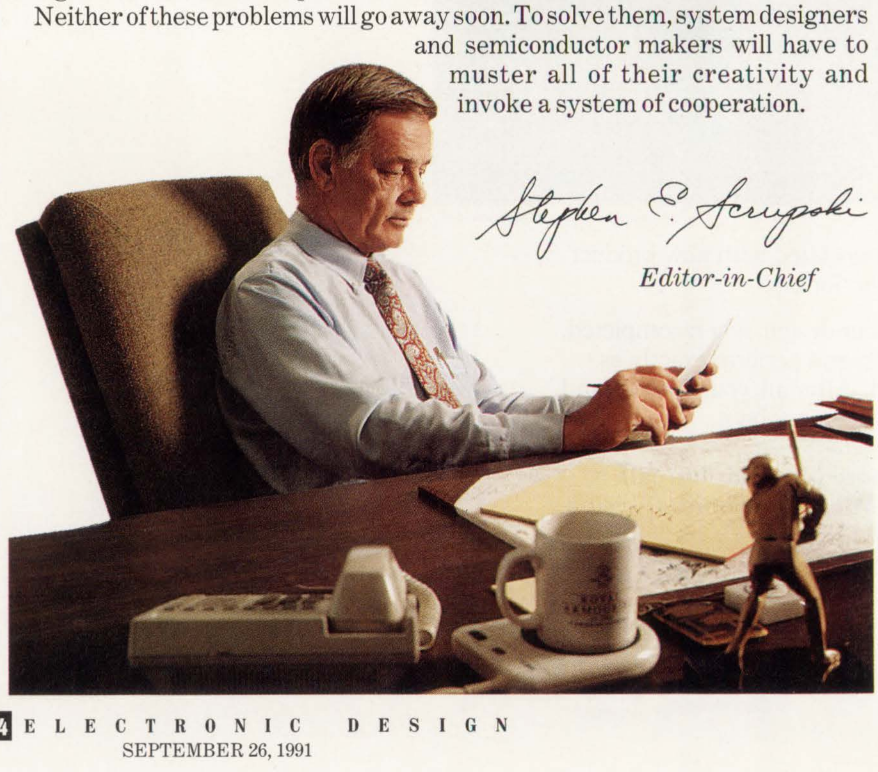
TWO VITAL CHALLENGES

Last month in Dallas, Texas Instruments held its "Tech Trends '91," a series of presentations for the press and financial analysts covering future semiconductor advances and their impact on emerging design challenges in personal computers, hard-disk drives, digital personal communications, and other applications areas. In summarizing the meeting, TI senior vice president Thomas J. Engibous focused on what he called the two most vital challenges facing system designers: shortened time-to-market and increased product differentiation. We feel that Engibous is right on target.

In fact, a message lies here for both system designers and semiconductor makers, because solving these problems will require closer relationships between those two groups. Time-to-market, far from being simply a catch-phrase due for rapid demise, clearly describes a problem that's developing in major equipment areas. It's most notable in the personal-computer area, where product lifetimes are down to one year or even less. Coping with this problem requires changes not only in design tools, but in the design organization itself, as manufacturing and marketing engineers assume an increasing role in the development project. It will also demand more openness between semiconductor suppliers and system designers as they trade information on future product plans to aid rapid new-product development (Electronic Design has covered time-to-market issues for well over a year in Kmet's Korner, authored by design consultant Ron Kmetovicz, in our QuickLook section, p. 133).

Product differentiation is becoming more difficult as VLSI ICs take on more of a system's functionality. How will designers add in features to differentiate their products from that of a competitor's who could very well be using the same VLSI standard chip? Semiconductor makers are already extensively using standard-cell libraries to quickly develop chips for specific market niches, such as modems, laser printers, and disk-drive controllers. Adding extra, custom features to otherwise standard chips also will first require open, detailed disclosure of future product plans from both sides of the desk. Therefore, the semi makers can add in specific functions to their "standard" chips to allow system designers to achieve their product differentiation features.

Neither of these problems will go away soon. To solve them, system designers and semiconductor makers will have to muster all of their creativity and invoke a system of cooperation.



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100-1500MHz	1.1	1.9	1.1	1.7
1500-3000MHz	1.8	2.7	1.8	2.5
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10-100MHz	60	40	60	40
100-1500MHz	40	28	40	30
1500-3000MHz	35	22	35	22
1dB Compression(dBm)	typ.	min.	typ.	min.
10-100MHz	17	6	17	6
100-1500MHz	27	19	27	19
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	1.3	1.6	1.3	1.6
Switching Time (μsec) (from 50% TTL to 90% RF)	typ. 2.0	max. 4.0	typ. 2.0	max. 4.0
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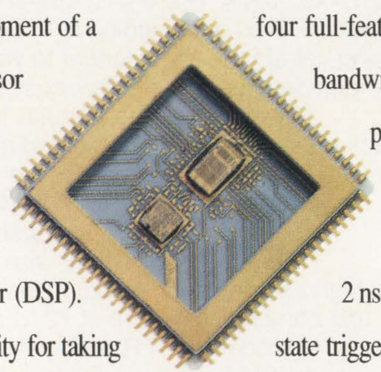

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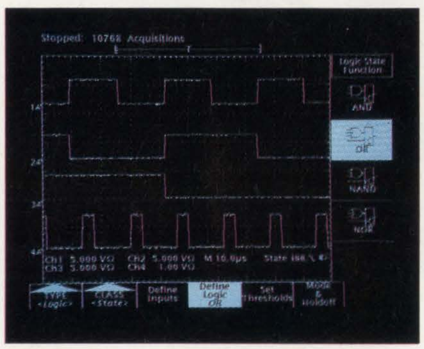

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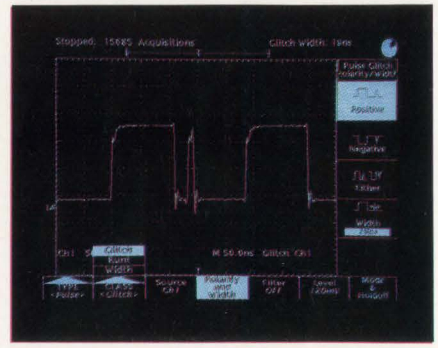

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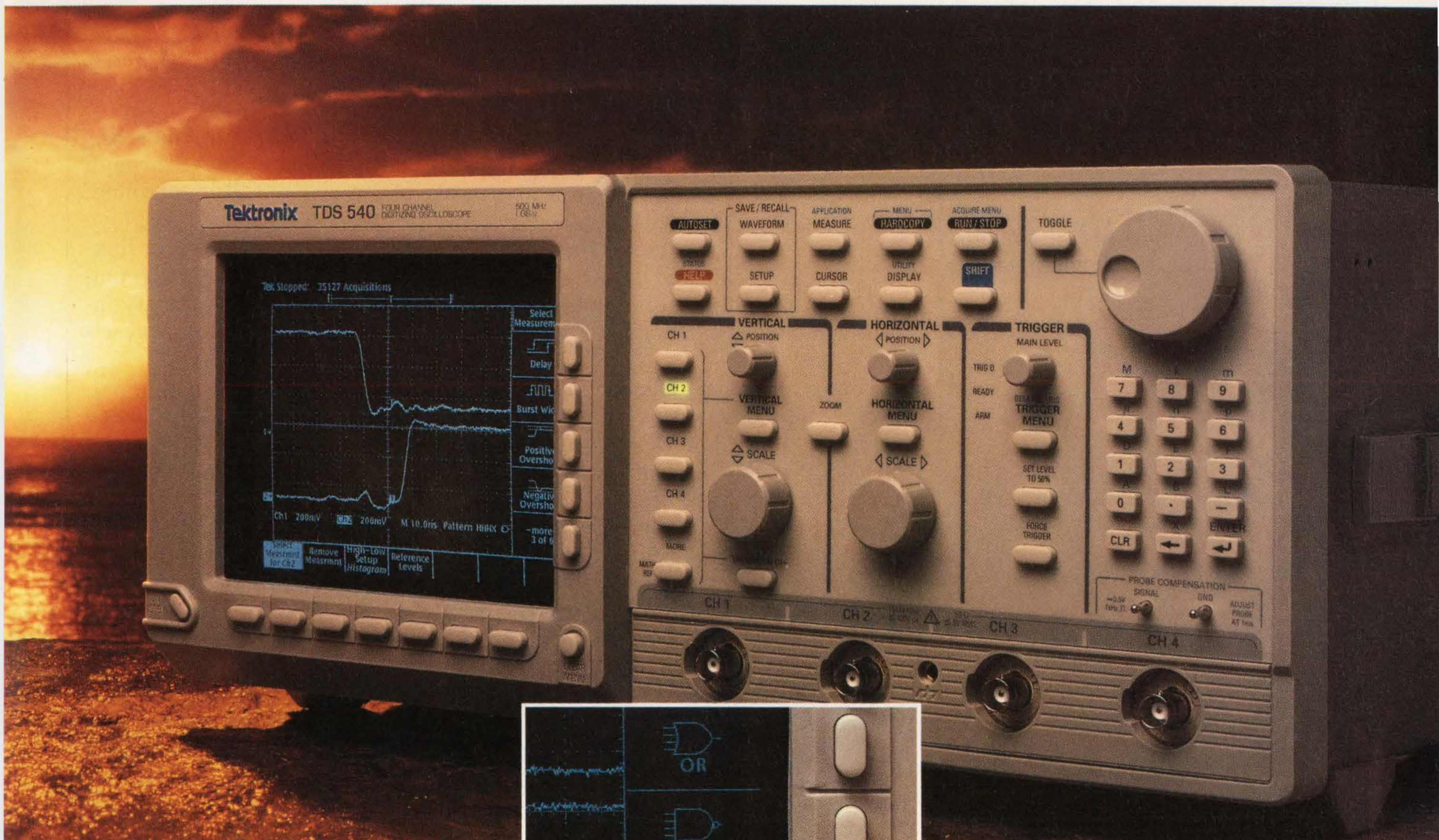

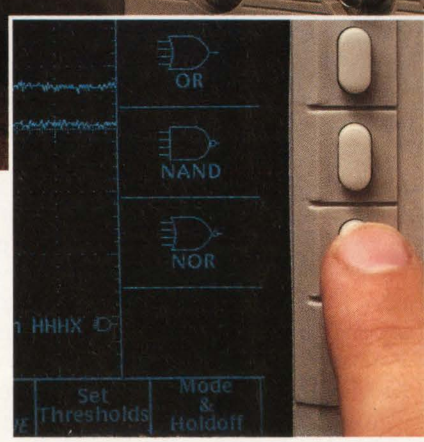

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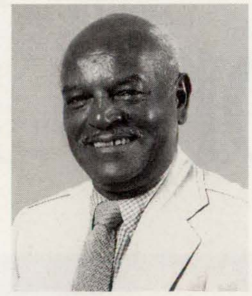

MILT LEONARD
SENIOR EDITOR

Science and industry in the U.S. have long benefitted from technology spin-offs out of the many research programs emanating from the National Aeronautics and Space Administration (NASA). A dramatic example stems from NASA's anticipated need for large-scale remote control of robotic space systems. In a concept called virtual reality (VR), the agency is combining computer, video, image-processing, and sensor technologies so that a human can enter into and react with abstract spaces generated by computer graphics.

The human interface to the computer is made through a network of position sensors attached to an operator. Early investigations in VR technology at NASA's Ames Research Center, Moffett Field, Calif., resulted in the DataGlove, through which advanced robotic hands or fingers can be experimentally controlled. Developed for Ames by VPL Research Inc., Redwood City, Calif., the glove is made of thin Lycra and is fitted with 15 sensors that monitor finger flexion and extension, and hand position and orientation. Connected to a computer through fiber-optic cables, sensor inputs enable the computer to generate an on-screen image of the hand that precisely follows the operator's hand movements.

The glove also has miniature vibrators in the fingertips to provide tactile feedback to the operator from grasped virtual objects. Thus, driven by appropriate software, the system allows an operator to interact with a computer scene by grasping and moving a virtual object within a simulated room while experiencing the "feel" of the object.

VPL Research's VR line also includes the DataSuit and the EyePhone. The DataSuit is an instrumented full-body garment that enables full-body interaction with a computer-generated virtual world. In one application, this product is worn by film actors to give realistic movement to animated characters in computer-generated special effects. The EyePhone is a head-mounted stereo display that shows a computer-generated VR world in full color and 3D.

The EyePhone technology is based on Ames' experimental Virtual Interface Environment Workstation (VIEW) design. VIEW is a head-mounted stereoscopic display system with two 3.9-in. television screens, one for each eye. The display can be a computer-generated scene or a real environment sent by remote video cameras. Sound effects delivered to the headset enhance the realism. Sensors for the DataGlove, DataSuit, and the VIEW headset are supplied by Polhemus Inc., Colchester, Vt.

VR technology is still young and somewhat crude, requiring considerable development and refinement for widespread use. Moreover, as with any frontier technology, cost is still prohibitive for most applications. For example, VPL Research's DataGlove alone sells for about $9000. The company's complete package, called the RB2 Virtual Environment, consists of the DataGlove, the EyePhone, a design-control workstation with processor, and associated software, cables, transceivers, and connections. It costs $45,000. With a computer from Silicon Graphics, Mountain View, Calif., a single-user system is $200,000, and twice that for two users.

However, as computer costs decline, VR enthusiasts foresee such diverse applications as telesurgery, architecture, chemistry, geology, aerodynamics, education, and air-traffic control. In fact, bits and pieces of VR products are already finding practical application. Mattel Toys is using a simplified version of the DataGlove for its Nintendo games. In the medical field, Greenleaf Medical Systems, Palo Alto, Calif., is developing DataGlove applications for sign-language research and to assess hand function and performance.

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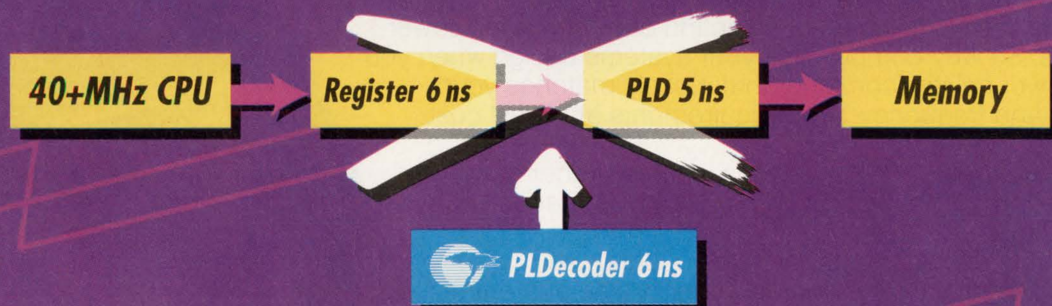

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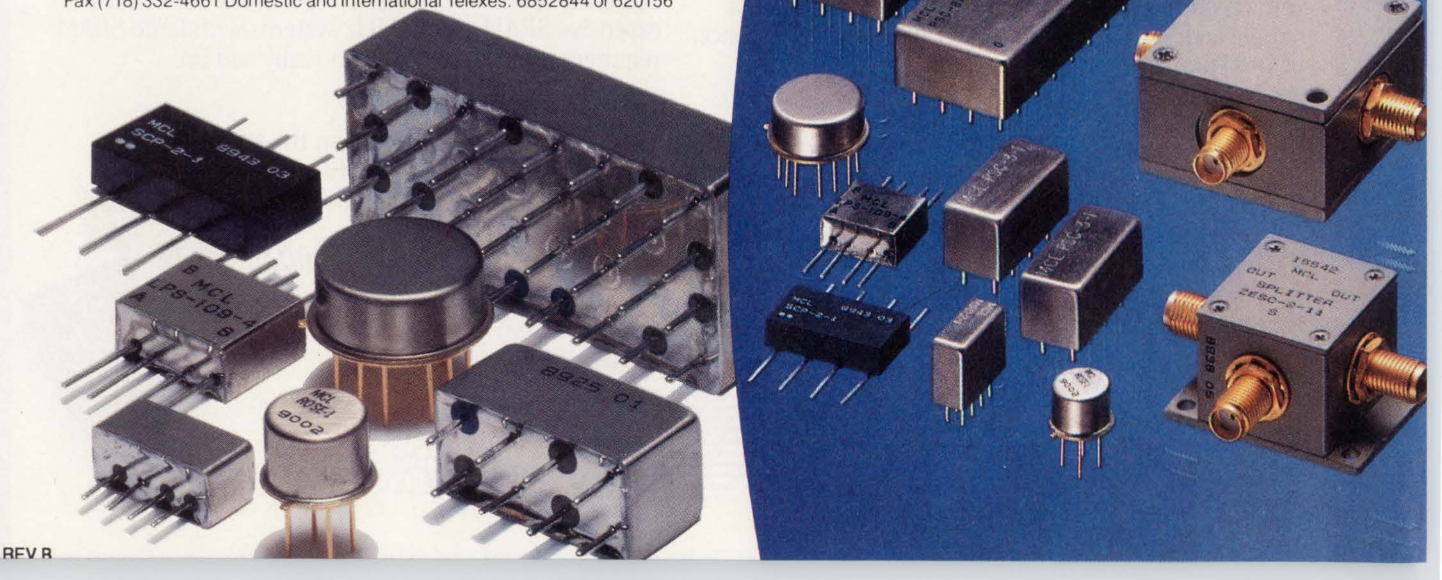

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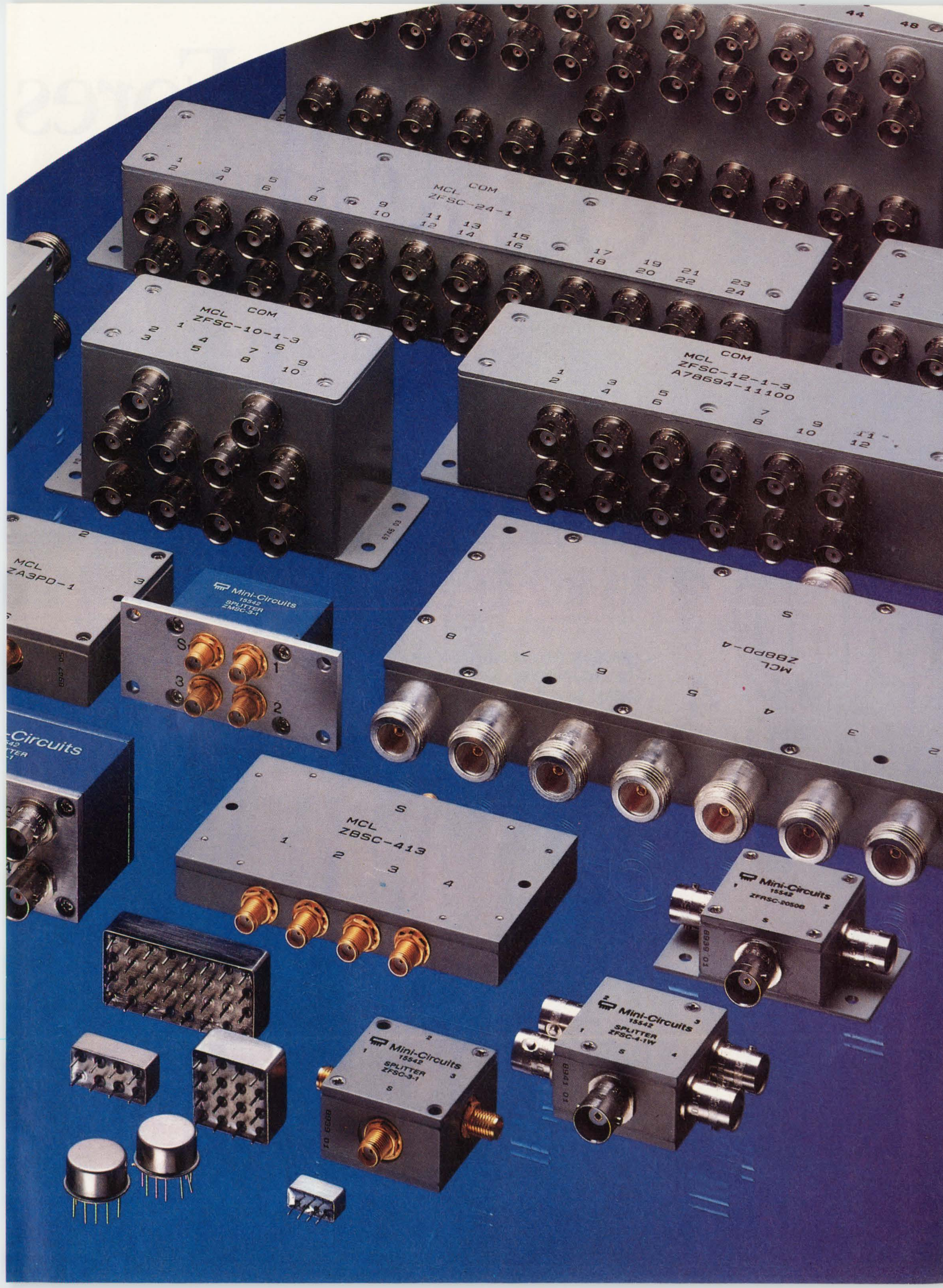
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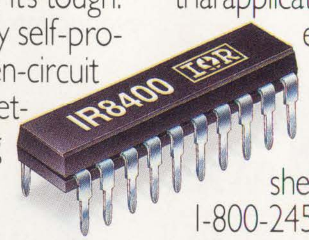

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Fiber Laser May Serve As Wavelength Standard

To satisfy the need for a highly accurate wavelength standard for optical-fiber communications systems, researchers at the National Institute of Standards and Technology (NIST) have built a single-frequency laser that can be tuned from 1.52 to 1.58 μm, and have stabilized the laser's frequency. The new laser, which shows potential for use as a wavelength standard, is a fiber laser, rather than the more common diode type. NIST physicist Sarah Gilbert said she began working with the fiber laser because of its suitability for narrow-line-width operation and tunability. Her goal was a wavelength standard in the 1.5-μm region, which is good for transmission through optical-fiber networks,with 1-MHz reproducibility. The laser uses a 4-cm length of optical fiber made of glass doped with erbium (a lasing medium). The fiber was pumped with green continuous-wave (CW) argon laser light at 528 nm, which produced CW infrared laser light at about 1.5 μm. During this research, it was discovered that no high-frequency noise existed in the fiber laser. The frequency spectrum of noise in diode lasers can extend to well beyond 1 GHz, but the fiber laser's frequency fluctuations were confined to low frequencies that can easily be filtered out. *JN*

Optical Cable Links Transputer Systems

An optical 20-Mbit/s transputer link from the computer firm Parsytec GmbH in Aachen, Germany, interconnects the company's data-processing systems over distances of several thousand meters. Claimed to be the first optical-data-transmission path for transputer-based systems, the link, intended for industrial applications, operates at an 875-nm wavelength and sends data over distances up to 3 km at remarkable quality. Because the link protocol of the participating transputers remains unaffected, transmission security is guaranteed. The link thus offers high reliability even in industrial environments. It uses a standard data-link connector and is completely integrated into Parsytec's RS 422-UniLink standard. *JG*

Initialization Standard Hits IEEE

Open Boot firmware, a standard that originated at Sun Microsystems Inc., Mountain View, Calif., is being studied by the IEEE to determine whether it should be adopted as a standard. The firmware aims at satisfying the need to initialize various I/O devices on separate families of Sun products and on systems networked to those products. Force Computers Inc., Campbell, Calif., announced that it has adopted Open Boot to initialize and configure its single-board products. Force claims it's the first VMEbus vendor to publicly adopt the Open Boot firmware for nonSparc platforms. The company is also actively involved in the process to make Open Boot an IEEE standard. *RN*

One Video Chip Holds 4 Correction Functions

A digital-signal processor now contains four picture-correction functions on one chip for display tubes used in digital TV and computer applications. Based on 1.2-μm NMOS, the Digital Color Transient Improvement processor DTI2250, from the ITT Semiconductors Group in Freiburg, Germany, can be matched to the functions via software. The chip first handles horizontal picture compression, which can be adjusted in 128 steps between 0 and 33%. With, say, a 25% compression factor, picture signals for tubes with a 4:3 aspect ratio can be displayed distortion-free on a 16-to-9-format HDTV screen. The second function is skew compensation, whereby digital color decoders can produce an orthogonal data raster or square pixels—a format used with tubes for computer and multimedia applications. Then there's a compensation function for signal-related run-time differences. Finally, the DTI2250 performs a color-transient improvement function that solves the problem of unsatisfactory reproduction of color contours associated with NTSC, PAL, and SECAM color-TV standards. The device, available now, comes in a 40-pin dual in-line or 44-pin plastic leaded-chip-carrier package. *JG*

Sparc Workstation Clones Challenge PCs

Continuing the trend of dropping workstation prices, Tatung Science and Technology Inc., San Jose, Calif., is now delivering the fully equipped RISC-based workstation for $4990 (a diskless version sells for even less at $4290). The workstation is configured with a 207-Mbyte hard-disk drive, a 15-in. color monitor, 8 Mbytes of RAM, Ethernet and SCSI interfaces, and the Sun Unix operating system and various utilities. Unveiled at the Unix Open Solutions Conference in San Jose earlier this month, the COMPstation 20 delivers a throughput of about 12.5 MIPS; a 25-MHz system offers improved throughputs of over 16 MIPS. Offering a larger display area than even super-VGA displays, the high-resolution 15-in. monitor supports resolutions from 1152-by-900 up to 1280-by-1024-pixels. The system motherboard also contains three SBus card connectors and options to hold up to 64 Mbytes of RAM. Contact Barbara Perna, (408) 435-0140. *DB*

MORE SPARCSTATION CLONES EMERGE

At the recent Sun developer's conference and the Unix Open Systems conference, both held in San Jose, several companies showed their Sparc-based Sun-compatible workstations. In addition to Tatung (see previous story), Afe Computers Ltd., Sutton Coldfield, U.K. (and Charlottesville, Va. in the U.S); CompuAdd Inc., Austin, Texas; and Sampo Corp. of America, Norcross, Ga., unveiled their SparcStation workalikes with monochrome or color graphics. All three claim 100% software compatibility with the Sun SparcStation family. Thus, they can run any of the over 3000 software packages available for Sparc-based systems. The OpenStation S25 from Afe runs at 25 MHz and delivers about 16 MIPS. The base hardware configuration includes a 19-in. color monitor with an 8-bit frame buffer that supports the simultaneous display of 256 colors from a palette of 16.7 million. For accelerated graphics, the company offers a double-width SBus card—OpenVision S007—that employs a custom graphics chip jointly developed with Fujitsu, the MB86900. With that chip, the graphics accelerator can draw 213,000 polygons/s and perform fills at 100 million pixels/s. The CompuAdd SS*1 base implementation runs at 20 MHz and comes with a 19-in. monochrome monitor (1152 by 900-pixel resolution), a "pizza box" style CPU cabinet, and a three-button optomechanical mouse. Housed in a similar cabinet, the Sampo 9020 workstation supports either a 20-in. monochrome or color display with 1152-by-900-pixel resolution in its base configuration. In addition to the Ethernet and SCSI ports, the system has two serial ports, an ISDN interface, and an audio (8-kHz, 8-bit) port. Contact John Shepard of Afe at (804) 974-7801; Bill Jones of CompuAdd at (512) 250-3497; and Sampo at (404) 449-6220. *DB*

IBM'S XGA GRAPHICS CHIPS WILL BE SOLD

To help proliferate its XGA graphics standard, the Entry Systems Div. of IBM Corp. has licensed SGS-Thomson's Inmos division to resell and provide OEM support for the XGA chip set. SGS-Thomson, Carrollton, Texas, will initially sell IBM's XGA chip sets for Micro Channel Architecture adapter cards or motherboards. However, because IBM is transferring the net lists, SGS-Thomson will make the chips with its own 0.8-μm double-level-metal CMOS technology. The two chips—the IMS G200 display controller and the G190 serializer and palette DAC—will sell for less than $200/set in 1000-unit lots. The display controller provides hardware assists to accelerate pixel movement and manipulation, faster line drawing, and sprite (hardware cursor) support.

Furthermore, work has begun on porting the XGA technology so that AT-bus (ISA) compatible versions of the chips can be manufactured at the Inmos facility in the U.K. and the SGS-Thomson facility in Carrollton. AT-bus versions will be ready in the second half of 1992. SGS-Thomson will also license XGA related software, including drivers for the DOS application interface, OS/2 presentation manager, and Microsoft Corp. Windows 3.0, and for the Asian market, double-byte character-set drivers. Contact Raul Diaz at SGS-Thomson's San Jose design center, (408) 452-9122. *DB*

ENHANCED SUNOS TO RUN ON X86-BASED SYSTEMS

An enhanced version of the Sun operating system, SunOS 5.0, incorporates the System V, release 4 implementation of Unix, as well as features like symmetric multiprocessing with multithreading to accelerate time-critical applications. SunOS 5.0 will be included as part of Solaris 2.0, a "shrink-wrapped" software package that will be available for Sparc- or 80X86-based workstations and PC platforms. Enhancements also include improved security features, on-line automatic file backup, and simplified system installation. Slated for release in the second quarter of 1992, the x86-compatible version of Solaris 2.0 will be the first operating-system port from SunSoft Inc., Mountain View, Calif., (Sun Microsystems' software subsidiary) to a non-Sparc CPU. Integrated within the package is the open network computing architecture; OpenWindows version 3; ToolTalk object-oriented application interoperability utility; and the OpenLook desktop metaphor with the DeskSet suite of 15 productivity applications, including multimedia electronic mail and an expanded-help capability. Solaris 2.0 is source-compatible with the existing Solaris 1.0 environment that runs on Sparc workstations. Developer copies of 2.0 are available and Solaris 1.0 is in full release, with single-user prices starting at $795. Contact Steve McKay, (415) 336-0678. *DB*

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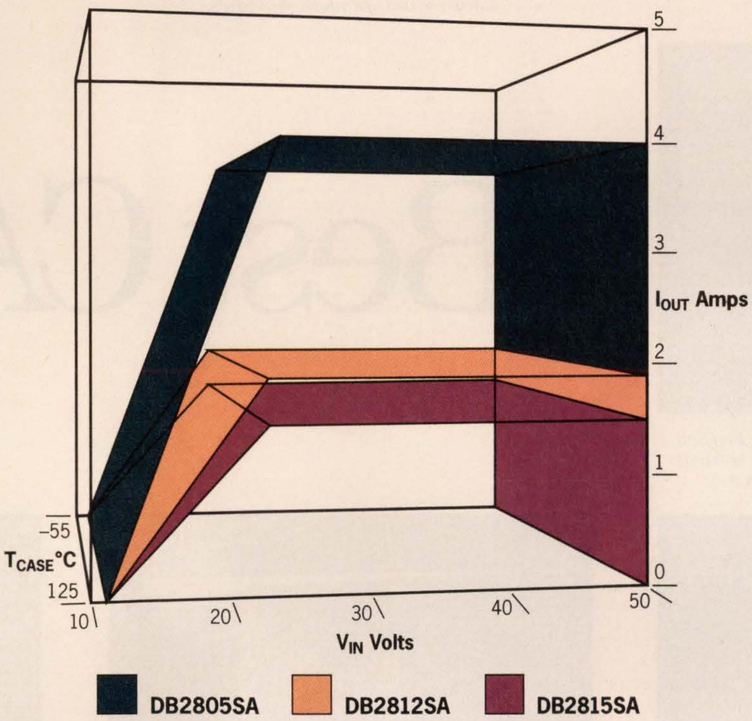

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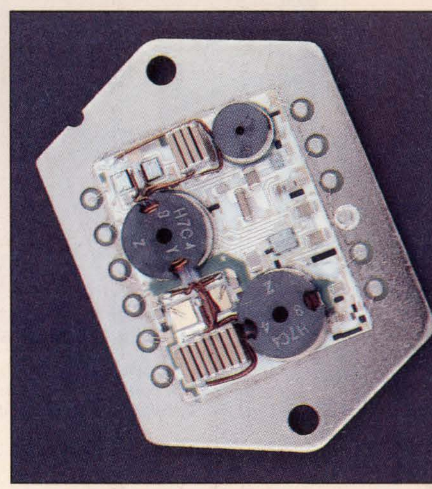

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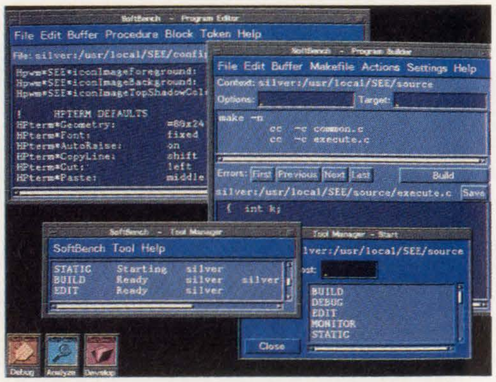

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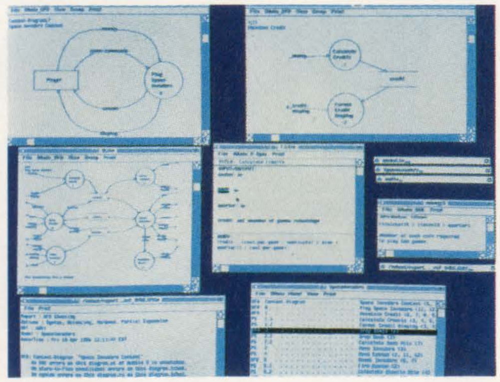

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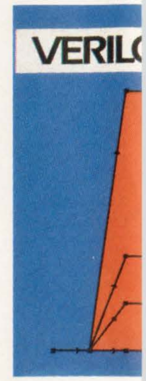

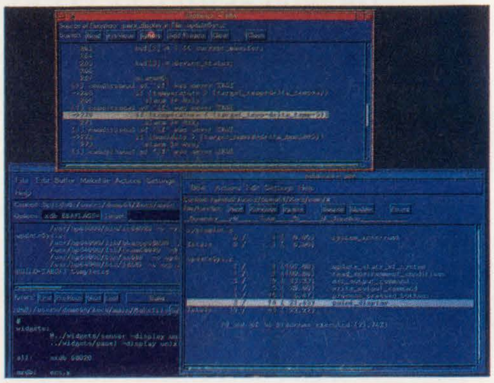

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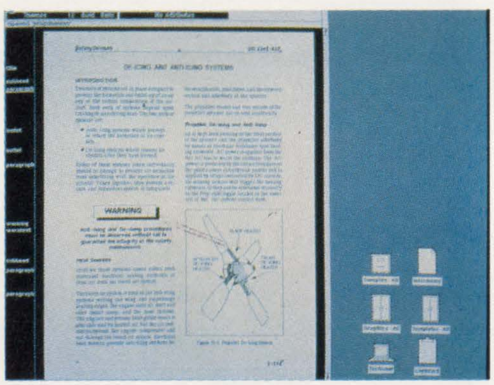

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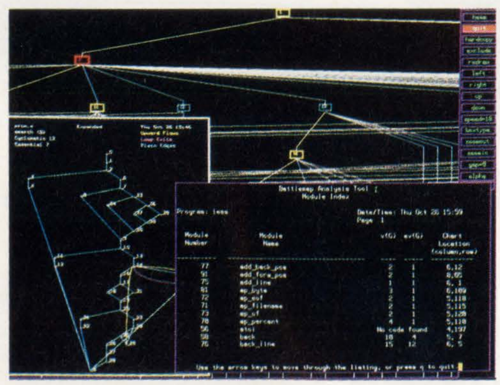

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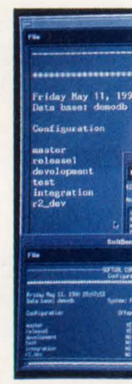

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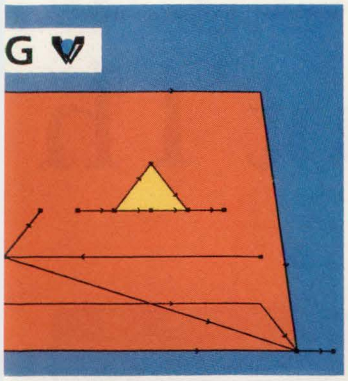

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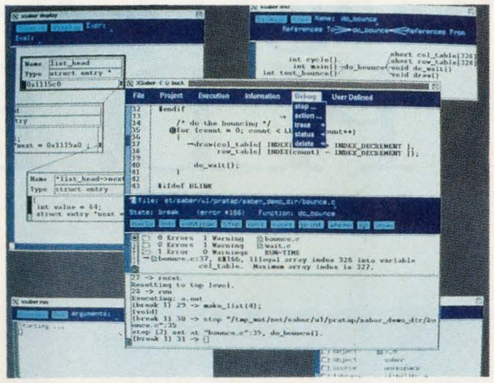
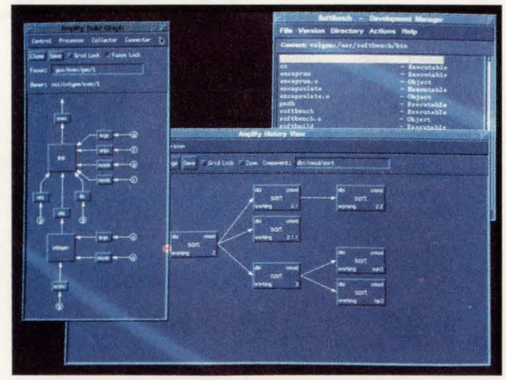


Saber-C: A set of integrated tools for development, testing, maintaining and debugging C programs.



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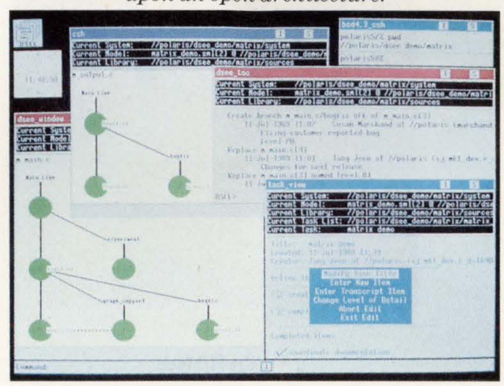

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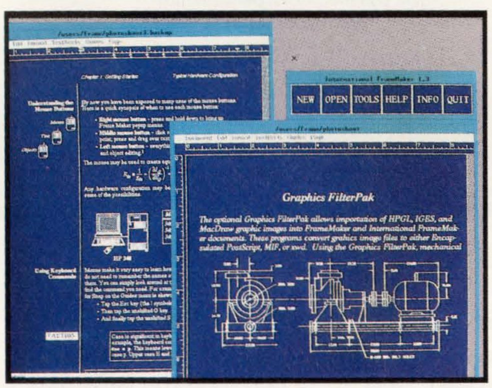

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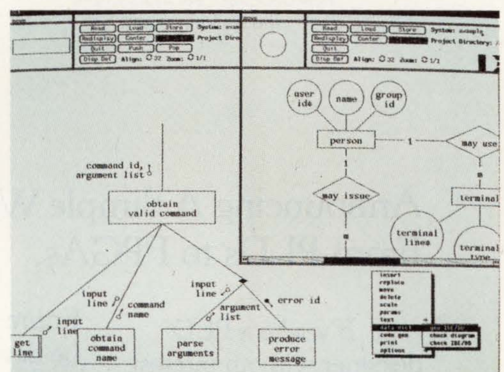

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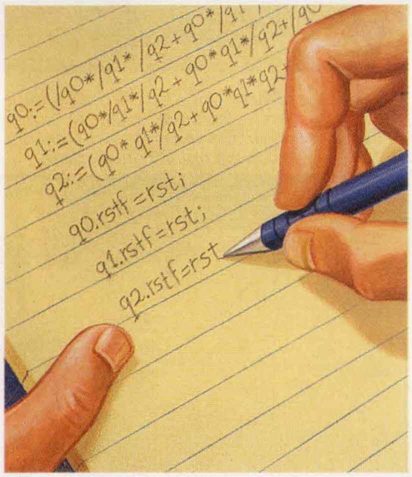

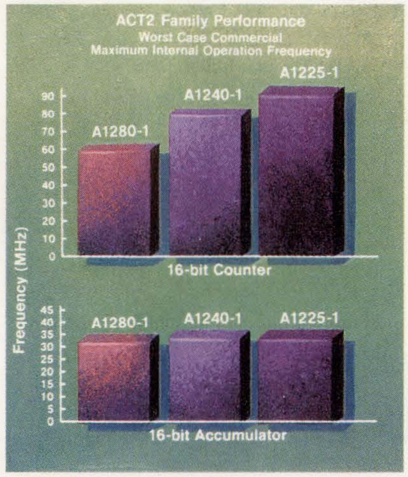

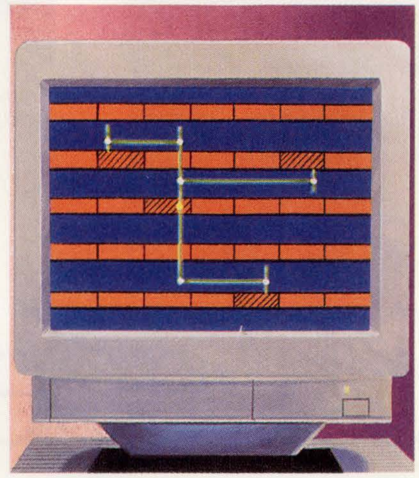

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GAs The Same Way
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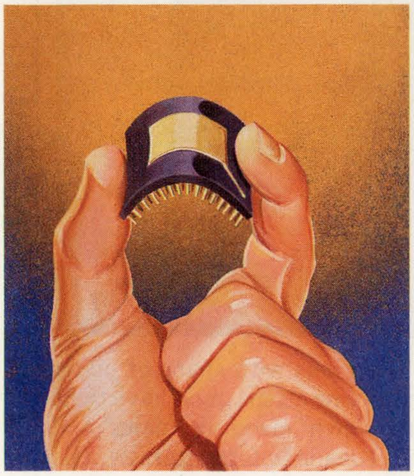

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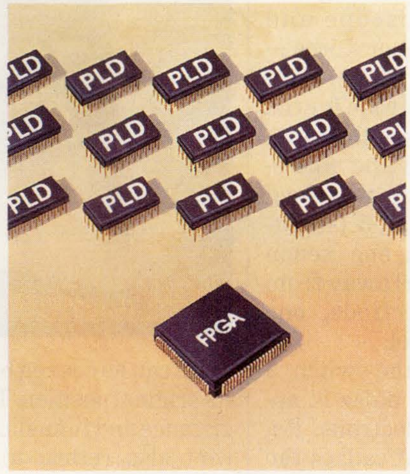

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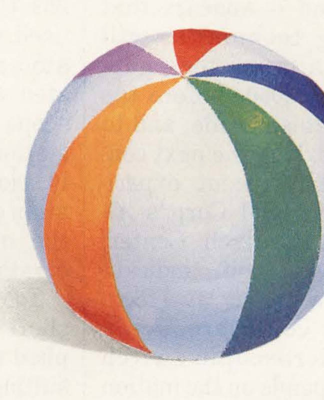

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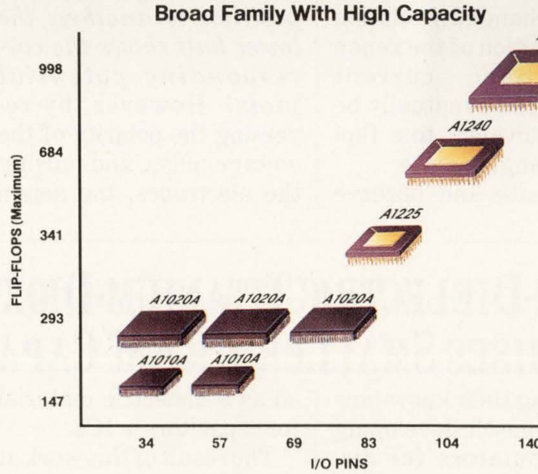


Actel

Risk-Free Logic Integration

CIRCLE 120 FOR U.S. RESPONSE **CIRCLE 121 FOR RESPONSE OUTSIDE THE U.S.**

LOGIC SWITCHES BUILT FROM ATOMS PROMISE THE ULTIMATE MINIATURIZATION

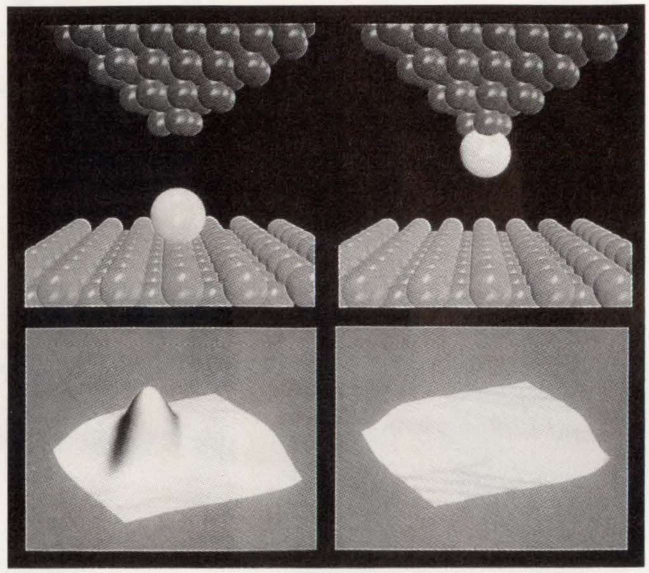
Just how small can a transistor get? Present gate dimensions are in the 5000- r̊ange (0.5 μm), and it appears that scaling techniques will shrink a transistor's gate to about 3000 b̊efore the end of this decade, and to 1000 e̊arly in the next century. But recent experiments at IBM Corp.'s Almaden Research Center, San Jose, Calif., indicate that new atomic-level techniques could produce a sub-microscopic switch that depends on the motion of just one atom, with dimensions of just a few angstroms.

Researchers repeatedly moved one xenon atom back and forth across the gate between two electrodes spaced several atomic diameters apart. With an electrical "tunneling" current flowing between the electrodes, the current changed in relation to the position of the xenon atom. Such current changes can eventually be made equivalent to a flip-flop's changing state.

To create and observe the effect, a special low-temperature scanning tunneling microscope and cryogenic temperatures (–269 °C, liquid helium) were used. One electrode for the atom switch was the tungsten tip from the microscope. That tip was held stationary about 5 (̊slightly more than one xenon atom diameter) away from the other electrode, one crystal of nickel.

To operate the switch, a short voltage pulse is applied to one electrode. Resulting current causes the xenon atom to jump the gap between electrodes and attach itself to the surface of the opposing electrode.

The atom's change in position alters the electrical resistance and the tunneling current between the electrodes *(see the figure: the upper half shows the atom moving from one position to another; the lower half shows the corresponding potential plots)*. However, by reversing the polarity of the voltage pulse, and pulsing the electrodes, the xenon atom can be coaxed back to its original position. The resistance and tunneling current also return to their starting values. Key to the switch's operation is the electrodes' asymmetric geometry—the tungsten tip in the microscope has a very fine point; the nickel electrode is very flat.



Even though it's not clear if anyone could actually build commercially practical atom switches, explains IBM researcher Donald Eigler, the fundamental research will hopefully lay the foundation for future generations of tiny electronic devices. To make such devices practical, the small atomic regions with spans of just a few atoms must have their own electrode pairs and leads to form storage cells or logic functions. Thus far, no fabrication process exists to create such structures on a mass scale. Furthermore, working at cryogenic temperatures isn't a comfortable technology for designers, so experiments are taking place (successfully) at IBM's T.J. Watson Research Center, Yorktown Heights, N.Y., with room-temperature silicon to move single atoms or clusters of atoms. This suggests that room-temperature atom switches might be possible.

DAVE BURSKY

HIGH-DIELECTRIC TITANIUM-DIOXIDE PROMISES SMALLER DRAM CAPACITORS

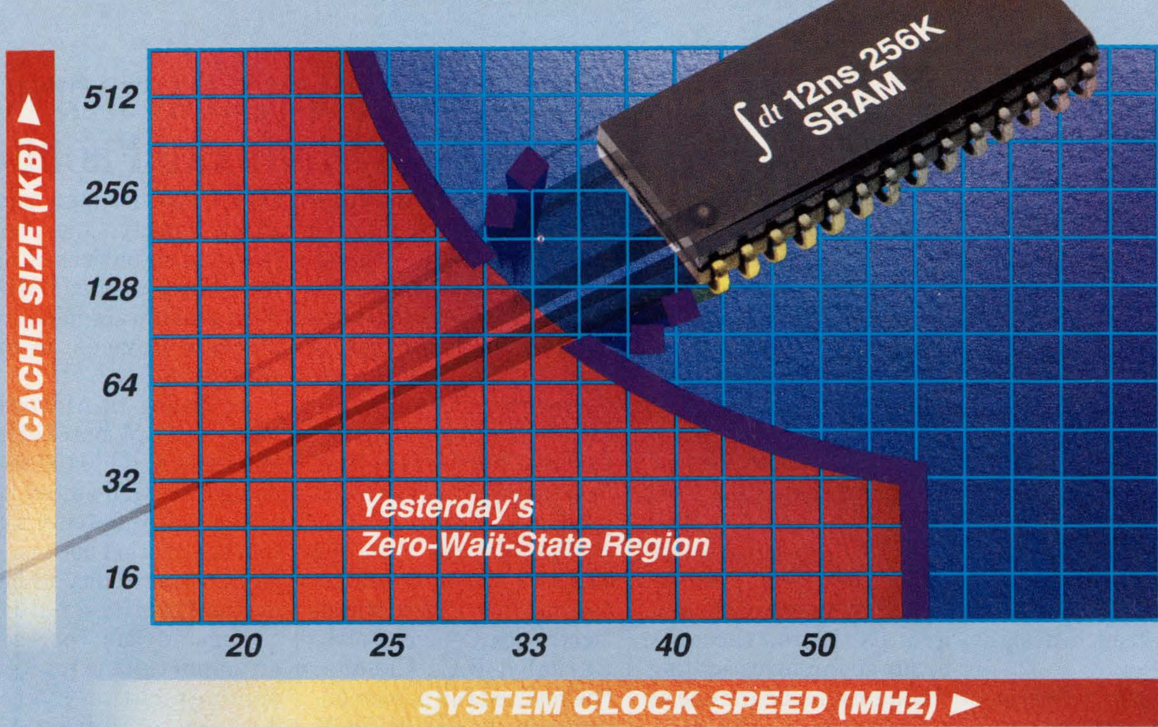
Using their know-how gained in developing insulators for discrete components, researchers at Germany's Siemens AG have produced very thin, high-purity titanium-dioxide layers. The scientists proved that such layers are ideally suited as a dielectric material for capacitors in ICs.

The result of this work at the company's Central Research Laboratories in Munich is expected to significantly impact future DRAM design. Because titanium dioxide has a dielectric constant 20 times higher than that of today's capacitor dielectrics, such as silicon-oxide/silicon-nitride layers, the space requirement for a DRAM's capacitor is considerably smaller—theoretically by a factor of 20—compared with a capacitor using conventional dielectrics.

In DRAMs, information is stored in capacitors, or storage cells, as an electric charge. To be reliable, these devices must have a certain minimum capacity. But with the DRAM density increasing, it's becoming more and more difficult to find the space for the storage cells on the chip.

One solution is to design them as trenches that extend downward into the

Smash the Cache Barrier



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Integrated Device Technology

chip, instead of putting the cells on the chip surface. Such storage cells were first widely used in 4-Mbit DRAMs. Another space-saving approach is to use cells with a high dielectric constant. While occupying the same surface area, such cells can store a charge many times greater than capacitors using today's dielectrics. This is the approach pursued by Siemens. As a result, the design of storage cells would be small enough so that future DRAM generations could be realized using proven non-trench design concepts.

The Siemens researchers feel that titanium dioxide is an excellent dielectric material for DRAM capacitors. The processes involved in handling the material meet the stringent requirements of microelectronic-parts fabrication. Besides a high dielectric constant, titanium dioxide doesn't suffer from the charge losses caused by direct quantum-mechanical tunneling that plague today's silicon-oxide/silicon-nitride dielectric layers.

Capacitors with the new dielectric could find first applications in 256-Mbit DRAMs, according to the Siemens experts. They believe they're one of the few groups, if not the only group so far, investigating titanium dioxide for use as a dielectric in DRAM capacitors.

JOHN GOSCH

MULTICHIP-MODULE PACKAGING ENHANCES A STANDARD PRODUCT

Multichip-module (MCM) technology, fast becoming a key means for computer makers to take the packaging leash off their silicon, is now making its way into telecommunication applications. Not only that, it's doing so for the first time in a standard commercial product.

Within its PM5712 SLIM-12 Sonet line-interface module, Pacific Microelectronics Centre (PMC), Burnaby, B.C., Canada, has realized full implementation of its PM100 MCM technology. That means, among other things, high signal speeds, high packaging density, low crosstalk, and signal losses, and the ability to mix CMOS, TTL, gallium arsenide, and discrete devices on one substrate.

According to Al Kozak, PMC's MCM marketing manager, the PM100 technology is well-suited for telecommunication-system integration because of its inherent ability to handle the 622-MHz serial data stream. MCMs represent an opportunity for telecommunication-system makers to address the changeover from a copper-wire-based network to fi-

How well does Texas Instruments support

ber optics in a way that keeps equipment density to a minimum.

The module, which is the first of a standard series, is a one-package termination for a Sonet STS-12 transmit-receive interface *(see the photo)*. Its capabilities include clock recovery and generation, framing, section and line overhead processing, and multiplexing and demultiplexing of STS-12 to constituent STS-3 frames. The module comes in a 182-pin metallized flat package that measures 2 by 3 in. It dissipates 16 W maximum.

Near-wafer-scale integration is achieved by using wire-bonded bare chips, multilayer metal-polyimide interconnections, and silicon substrates. Active devices occupy more than 35% of the module's footprint area. Comparatively, pc-board solutions take up less than 5%. In the PM100 technology, chips can be mounted directly on the substrate to reduce thermal resistance, or on top of the interconnection layers to minimize substrate area.

The module's performance is largely attributable to its use of polyimide, which has a low dielectric constant k of 3.4. That means higher propagation speeds and less capacitance for each signal net. Propagation delay is 140 ps/in. at 2 GHz. The lower output capacitance on each chip output also means lower power consumption. The polyimide's thickness, which varies from 2.5 to 8 μm, makes it possible to design transmission lines with controlled impedance. Relatively thick 5-μm conductors help reduce resistive losses. The design rules for 66-μm spacing between adjacent conductors hold down crosstalk to better than 40 dB at 1 GHz.

DAVID MALINIAK

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ACOUSTIC-WAVE SENSORS IMPROVE CHEMICAL DETECTION

Most sensors used for detection and measurement of chemicals in industrial processes are limited in their use. That's because a given sensor is made to respond to only one chemical species. Thus, a different sensor is required for each species, and false alarms can be triggered by unwanted responses to other species. Now, researchers have devised a prototype sensor system that enables one sensor to sense and measure concentrations of a variety of chemicals.

The system, developed at Sandia National Laboratories, Albuquerque, N.M., is expected to improve the speed and reduce the cost of chemical sensing in industrial environments. The sensor system has been called a "mass spectrometer on a chip" because it mimics this well-known device's ability to identify chemical species.

"The system could be used to monitor chemicals present in industrial environments, to help engineers adjust processes to reduce wastes and emissions, and to help prevent worker exposure to unsafe chemicals," says Greg Frye, a chemical engineer at Sandia's Inorganic Materials Chemistry Division. The monitors could also verify compliance with environmental regulations for chemical emissions, he adds.

The system is based on coated acoustic-wave (AW) devices, a relatively new class of sensors that measure the behavior of acoustic waves in solids. When acoustic waves interact with solids, liquids, or gases, their properties are altered in measurable ways that can provide information about the materials that the waves encounter.

Sandia engineers devised a way of analyzing data obtained from the AW devices that more quickly and easily identifies chemical species of interest. Earlier methods used multiple sensors to identify a chemical and its concentration level. The Sandia method obtains two independent responses from one sensor. A comparison of the two responses produces a unique "signature" that's compared to the responses of known chemicals to identify an isolated species.

Surface-acoustic-wave (SAW) devices are a type of AW sensor that consists of two interdigital transducers formed on a piezoelectric substrate, such as quartz. When an alternating voltage is applied to the input transducer, an alternating mechanical strain is generated, which launches the acoustic wave. The wave travels along the surface, interacting with a thin film formed on the device surface before converting back into an electrical signal by the output transducer. If the film has absorbed chemicals from the surrounding environment, the velocity and/or attenuation (loss of amplitude) of the acoustic wave will be altered.

Before use, a coated AW device is calibrated by simultaneously monitoring wave velocity and attenuation during exposure to a range of various chemical concentrations of interest. Because the responses are independent, each species generates a unique set of values when attenuation is compared to velocity. When the SAW device responds to an unknown chemical, the two responses are compared to these species-dependent curves to determine molecular identity. Once the chemical is identified, a comparison of either the velocity or amplitude shift to the calibration curve for the species can be used to determine concentration.

This identification capability could have many practical sensor applications. Using AW sensors coated with polymers, Sandia engineers are developing a portable sensor system to monitor the highly regulated chlorinated hydrocarbons (CHCs) in industrial exhausts and in the workplace. Some of the ozone-depleting compounds being tested are trichloroethylene (TCE), trichloroethane (TCA), methylene chloride, and carbon tetrachloride. The system has also been used to identify organics such as toluene, acetone, methanol, ethanol, isopropanol, and hexane. These are common industrial-process chemicals. For field applications where device cost and weight is a consideration, the sensor system could be an effective compromise between a standard gas chromatograph and/or a mass spectrometer.

Sandia is investigating another application for SAW devices—materials characterization. Work is being done on using the devices to determine various properties of thin (0.1-to-10-μm) films, such as surface areas and pore-size distributions of porous coatings.

DAVID MALINIAK

1/2-IN. FLOPPY-DISK DRIVE RESULTS IN DUAL-MEDIA UNIT

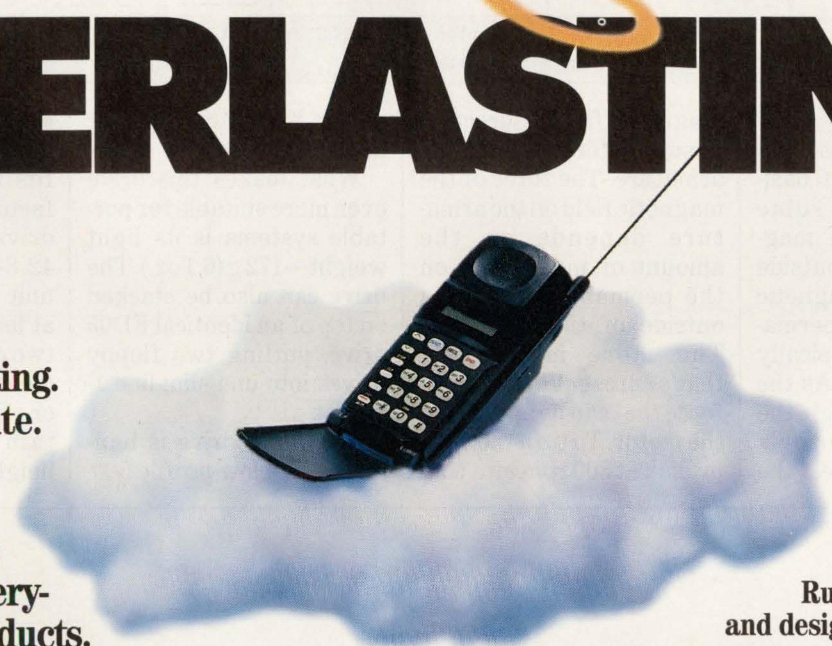
The only 3-1/2-in. floppy-disk drive currently available in a 1/2-in. (12.5-mm) form factor has been built, claims Teac America Inc., Data Storage Products Div., Montebello, Calif. The firm says that the nearest competitive drive to its new FD05 drive is about 2-mm higher.

One innovative idea used to build the drive involved squeezing all of the control electronics into one LSI chip. This part also incorporates most of the drive's discrete circuitry. All of the FD05's electronics fit onto one pc board that measures 1-in.^{2}. Space is also saved by thinning the pc board. The same material used for boards in earlier drives was employed, yet it's 1 mm thinner.

The FD05's thin-profile spindle motor contains a specialized magnet that supplies the power necessary to move the head to within one degree of accuracy. A higher coercivity material was used to give enough strength to the magnet to supply the power needed for the motor. The material can also be produced thinner than pre-

What do LITTLE FOOT p-channel power switches give battery-powered cellular phones?

LIFE EVERLASTING



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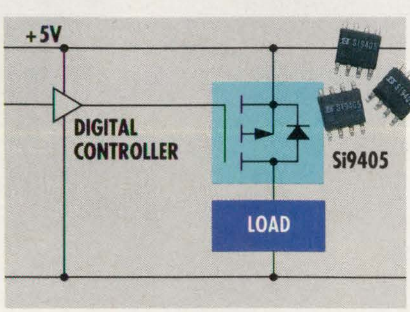

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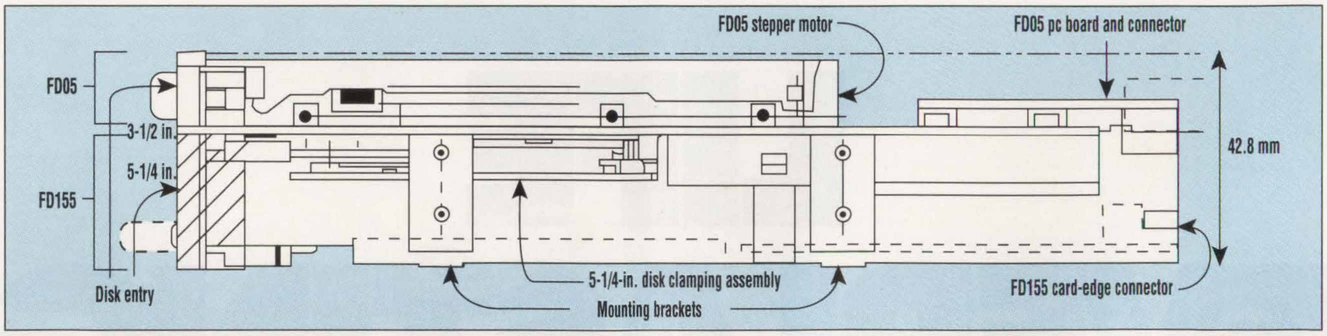


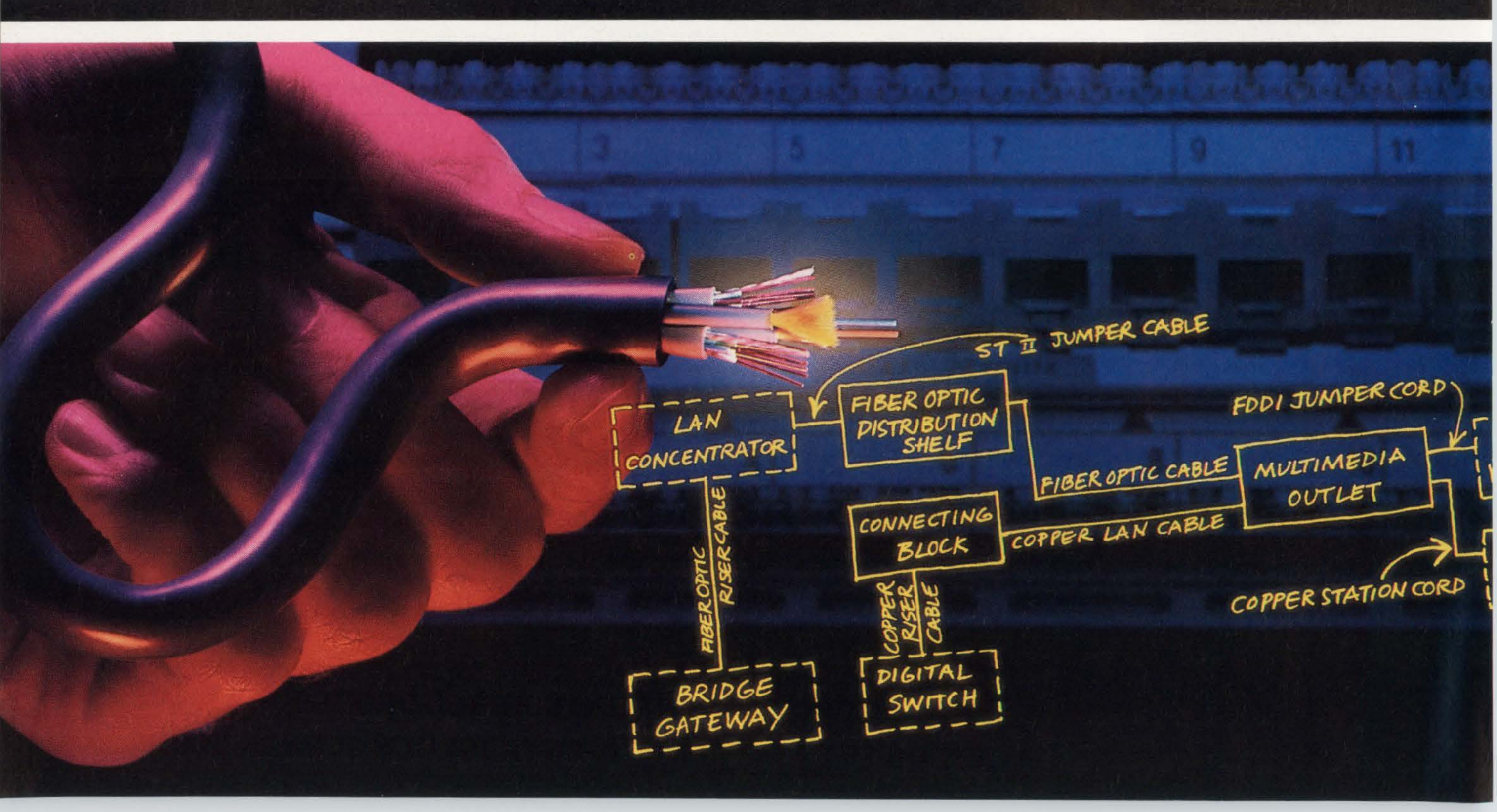
vious magnets.

The motor consists of an armature that itself basically consists of some windings around a magnetic core. On the outside of the core, a magnetic field is created. A permanent magnet is typically used by dc motors. As the current goes through the armature, the motor's commutator changes the magnetic field's direction to supply force to turn the armature. The force of the magnetic field on the armature depends on the amount of magnetism on the permanent magnets outside of the armature. The more magnetism that's present, the more force that can be applied by the motor. To turn the floppy disk at 300 rpm on a consistent basis, ample power must be generated.

What makes this drive even more suitable for portable systems is its light weight—172 g (6.1 oz.). The drive can also be stacked on top of an identical FD05 drive, putting two floppy drives into one slim-line 1-in. slot.

The FD05 drive is bundled with a low-profile 5-1/4-in. drive to form a dual-media drive (FD505) that fits in a half-height form factor. Now the total two-drive package measures 42.8-mm high. The dual unit could have shrunk by at least 4 mm, because the two drives placed together measure 38.1 mm. However, Teac wanted to maintain the standard half-height form factor for the

Every connecting product for every kind



drive *(see the figure)*. Some desktop systems are becoming so small that designers are forced to incorporate only one floppy-disk drive. Using the FD505, they can fit both drives into the same space that previously held one.

Although the FD505 is mounted in one bezel, the host system still sees the dual-media drive as two separate drives, A and B, rather than one unit. By using the FD505 in a desktop format, the system can still house two floppy-disk drives, yet have a half-height slot available for some other type of peripheral, such as an optical, hard-disk, or tape drive.

The 5-1/4-in. version of the dual-media floppy drive, the FD155, is somewhat larger than the FD05. It's actually twice as high as the 3-1/2-in. drive. This is partly due to its motor assembly that goes through the center of the disk—on the 3-1/2-in. drive, the motor assembly just touches the underside of the disk. The 5-1/4-in. unit has a drive cone that goes through the center of the disk and clamps on to the other side to hold the disk in place. And, because the media is larger and contains more friction, the motor needs a higher torque. The higher-torque motor found in the 5-1/4-in. drive is thicker than those found in 3-1/2-in. drives.

Although Teac feels that it has reached the theoretical size limit with its FD05 drive, its engineers are hopeful they can reduce the size of the FD155. Some of the technology that was used on the FD05 will eventually migrate to the FD155, forming an even smaller package.

RICHARD NASS

OXIDIZED SILICON ADVANCES IC HUMIDITY SENSORS

By using oxidized porous silicon as the moisture-absorbing dielectric between two capacitor electrodes, scientists at Sandia National Laboratories, Albuquerque, N. M., successfully fabricated extremely sensitive silicon IC sensors to detect moisture in electronic packages. Accurate humidity sensing in electronic packages is critical in assessing the long-term performance and reliability of ICs that use other types of sensors. Humidity sensors being presently used for IC packages are larger and more costly and do not offer the small size and cost advantages of an IC silicon sensor.

To make the sensor, Sandia researchers Michael J. Kelly, Terry R. Guilinger, David W. Peterson, Melanie R. Tuck, and James N. Sweet used manufac-

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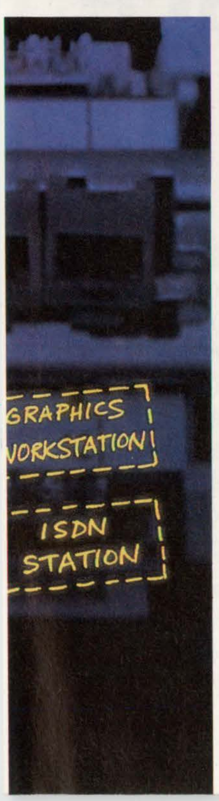

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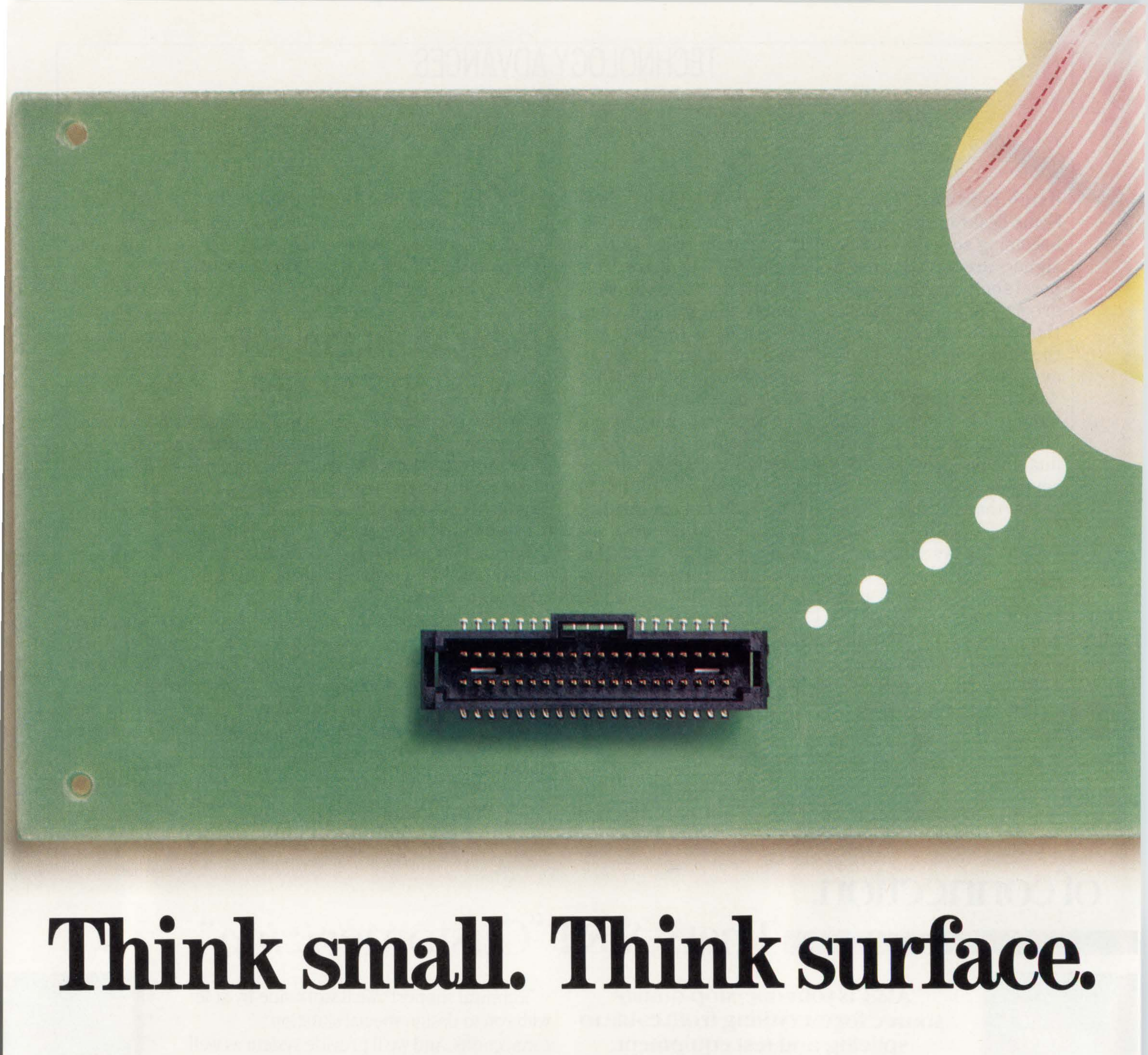

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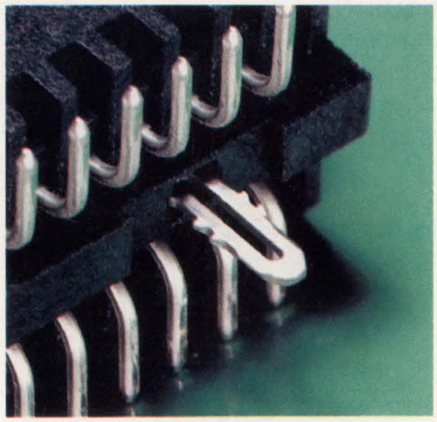

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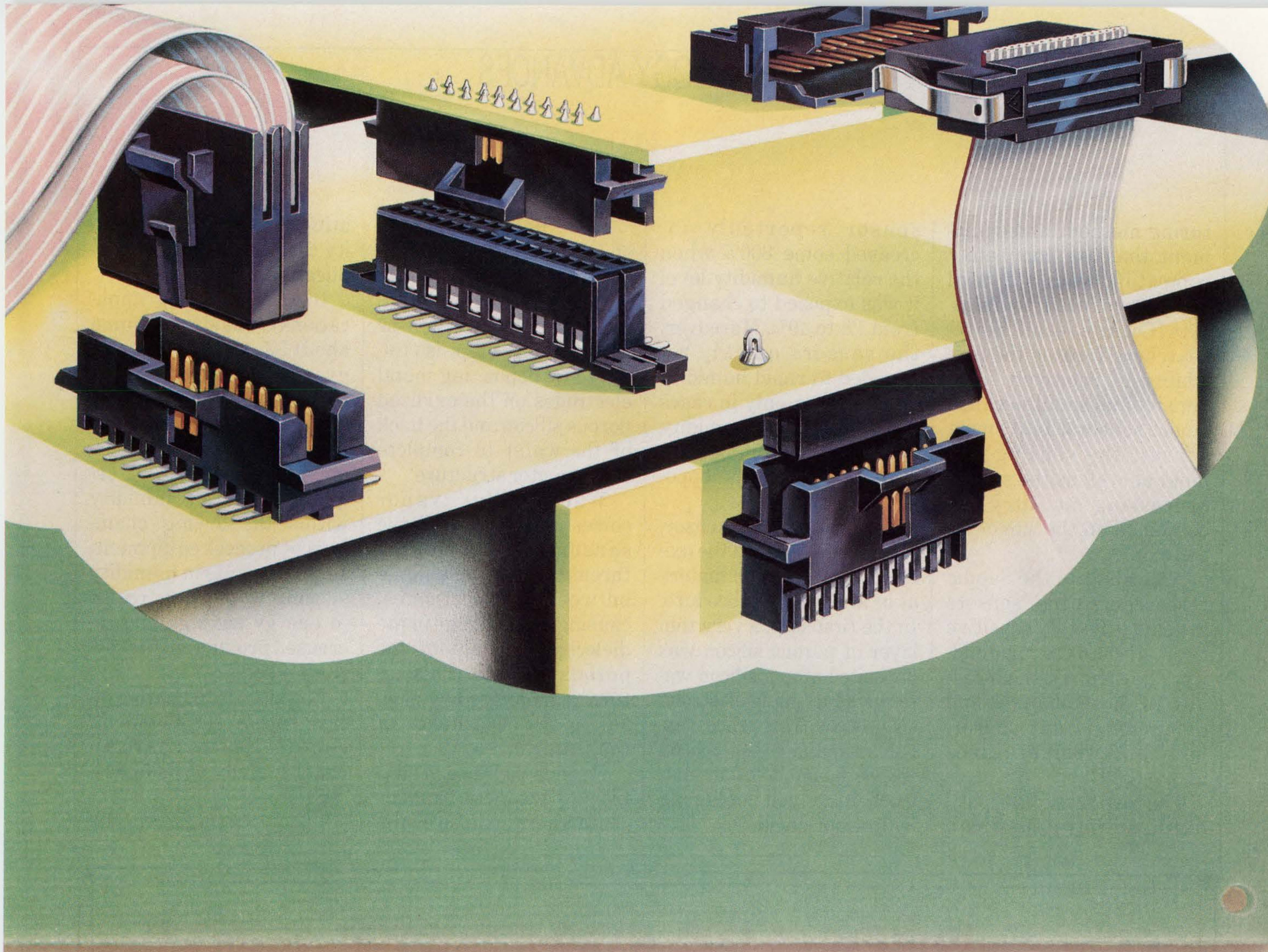

Think system.

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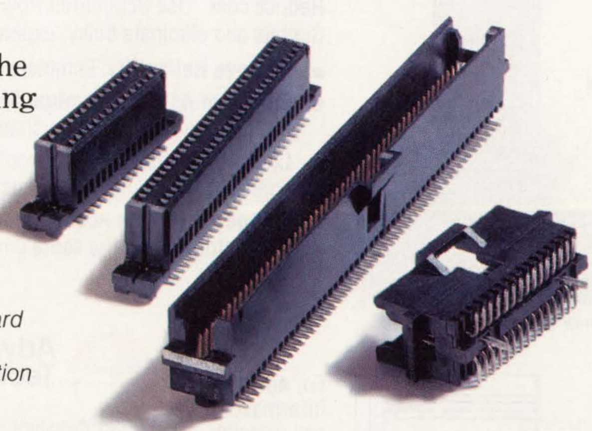

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turing methods and equipment that are completely compatible with standard techniques used to fabricate ICs. As a result, the researchers foresee the possibility of relatively inexpensive and small so-called smart sensors. In a smart sensor, the sensing element as well as the signal-processing circuitry are combined on the same silicon chip.

According to the Sandia researchers, the sensors are said to be very sensitive to small changes in humidity. They also respond rapidly to those changes and offer consistent performance at temperatures above 100°C.

The response of a typical oxidized-porous-silicon sensor reportedly increased some 800% when the relative humidity level it was exposed to changed from 1% to 40%. Moreover, the sensors quickly responded to rapid humidity changes, not only in cases where relatively humidity changes go from low to high, but also in the opposite direction.

In fabricating the sensor, researchers formed the oxidized porous silicon material in a two-step procedure. In the first step, a very thin layer of porous silicon was deposited atop a silicon wafer using a simply electrolysis process. This process involves making the silicon wafer the anode of an electrochemical cell containing hydrofluoric acid.

In the next step, porous silicon material is next oxidized by subjecting it to a high-temperature environment of either oxygen or steam. This step is followed by depositing metal electrodes on the oxidized porous silicon and the back of the wafer to complete the capacitor structure.

When water vapor comes in contact with the sensor, it permeates through the porous volume between the electrodes, causing a net change in the dielectric constant of the porous volume. This, in turn, is monitored by measuring the capacitance of the sensor.

Besides their use in electronic packages, Sandia's researchers are also evaluating the sensor's suitability to industrial drying applications.

Industrial drying applications are said to consume about 5% of the total energy used in the industrial sector each year. Energy experts have estimated that about 10% of this energy is wasted due to inadequate control of humidity within the drying chambers of process equipment. Improvements in humidity sensing would thus result in energy savings and increased productivity levels for this sector.

For more information on this sensor development, contact researcher Michael J. Kelly at (505) 844-4031.

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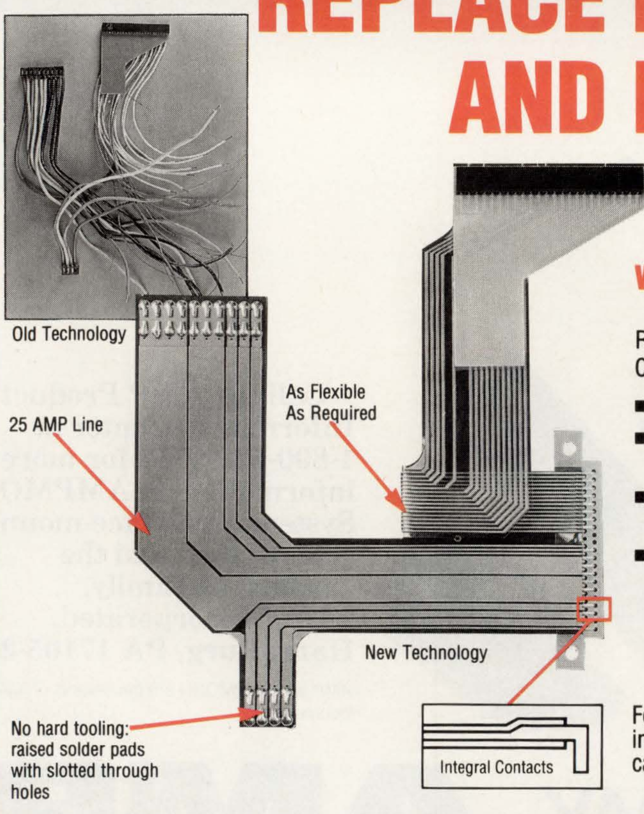

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SPEECH RECOGNITION AND SYNTHESIS PAVE THE WAY TOWARD DIALOGUES BETWEEN MAN AND MACHINES.

SPEECH POISED TO JOIN MAN-MACHINE INTERFACE

MILT LEONARD

Improved speech-processing algorithms coupled with the escalating processing power of affordable VLSI devices are bringing renewed hope for man's ability to converse with machines through speech synthesis and recognition. New developments now in progress promise to topple the last remaining technical obstacles to the younger and more difficult of the two speech technologies to master—speech recognition.

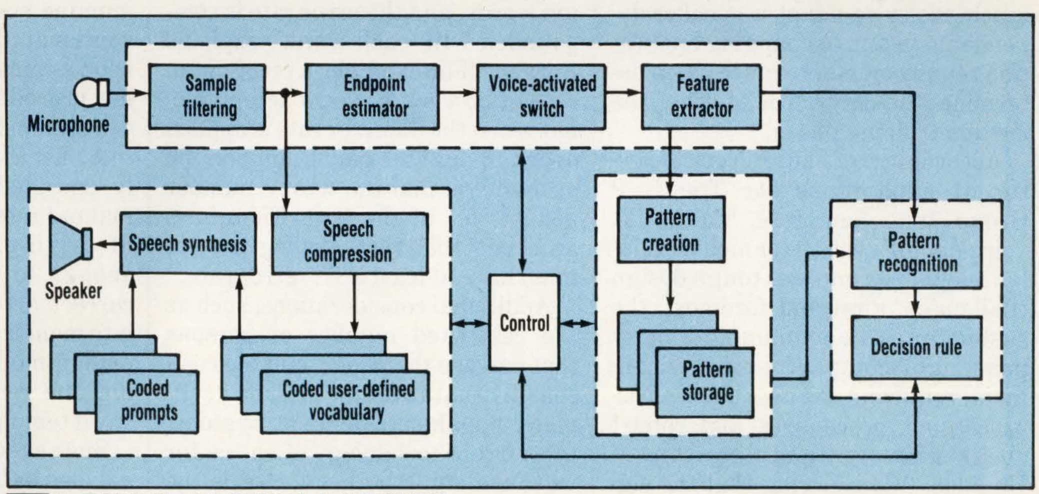
Voice input to and feedback from machines frees the hands and eyes to do other tasks. Moreover, voice can supplement manual operations to perform simultaneous tasks with fewer errors.

Speech synthesis involves a trade-off between the expense of high data rates (large data-storage space) for human-like speech quality, and more economical low data rates and poor speech quality. Fortunately, improved algorithms and more powerful signal-processing chips can produce high-quality speech at low data rates.

Voice-recognition technology, on the other hand, has seen little success as an element of the man-machine interface, due in part to the technology's limited ability to handle large speaker populations, noisy operating environments, continuous speech, and acoustic speech variables like dialects, speaking rate, and loudness. An equally difficult obstacle to overcome has been the high cost of system implementation. As a result, vendors of speech-recognition systems have come and gone, with most sales limited to evaluation units or to cost-insensitive applications.

Now, however, new technologies emerging from their infancy are creating a market demand for speech recognition, spurring on the development of speech-recognition technology to a more mature level. One application begging for more sophisticated recognition technology is mobile cellular telephones.

According to a recent article in the San Jose Mercury News, a study conducted by the American Automobile



1. BUILT AROUND A DSP CHIP from Texas Instruments, an advanced technology under development by The DSP Group performs both speech-recognition and synthesis. Acting as a smart slave of a host processor, the DSP chip performs training, recognition, and synthesis tasks. An ASIC includes control logic to generate clock signals and to support the interface protocol between the digital-signal processor and host. Word templates and user-defined phrases are stored in a 32-kbyte, battery-backed RAM that can handle a 32-word vocabulary. A 32-kbyte ROM stores system prompts obtained with a synthesizer. About 25 seconds of speech can be coded for the synthesizer using 32 kbytes of EPROM.

Association Foundation for Traffic Safety in Landover, Md., concluded that a driver's reaction time to road events triples in length while using a phone. This finding is sure to draw the attention of federal and state regulatory bodies for road safety. Safety regulations in many countries prohibit using cellular telephones in road vehicles while driving.

The solution is to offer both hands-free and eyes-free designs through voice-activated dialing to the phone system and synthesized-speech prompts from the system. The choice of a voice-recognition system comes down to either a speaker-dependent or a speaker-independent system.

The speaker-independent system might seem to have more user flexibility, but it presents greater design challenges—it must allow for variances in dialects, accents, speech impediments, and has higher error rates. It also requires more processing power, is less immune to noise, and has a fixed vocabulary. Its practical application is thus years away. Its limitations must be overcome before it can be applied to consumer and communications products.

Speaker-dependent schemes are generally limited to less than four users. Still, they're flexible. It's much easier to adapt a speaker-dependent system to changing application requirements, because users determine the keywords during the system-training phase.

According to Shaul Berger, director of applications for The DSP Group Inc., San Jose, Calif., "A voice-dialing system for mobile cellular telephones imposes tough design challenges. First and foremost, the system must be immune to a noisy passenger-compartment environment, requiring the use of noise preprocessing procedures and robust speaker-recognition algorithms." He adds, "Considering that the signal-to-noise ratio in a car cabin with open windows can dip below 0 dB, unconventional speech-recognition algorithms may be needed to solve the noise problem."

The more noise-robust speaker-dependent approach is preferred over a speaker-independent system for applications involving a limited number of users, as in a mobile cellular telephone. Whether speaker dependent or independent, a voice-recognition system must strike a careful balance between a high recognition rate and a quick response. A system with a high recognition rate but slow response time can be as frustrating to a user as one that responds quickly but with low accuracy.

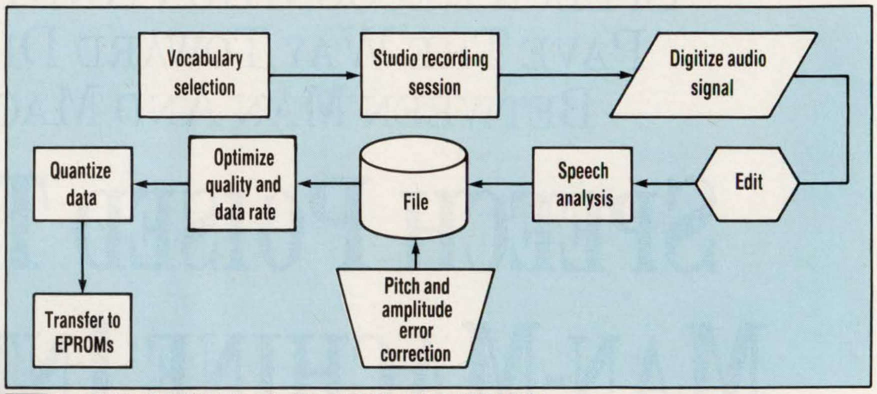
"A high recognition rate is critical, considering that dialing a 10-digit telephone number involves uttering ten words, and the error rate is compounded with each word," explains Berger. "For example, a recognition rate of 95% might seem acceptable, but when the 5% error rate is applied over a 10-digit telephone number, the system will dial the wrong number almost 50% of the time. Therefore, an acceptable voice dialing system must have at least a 97% error rate."

Additional considerations, such as the restricted number of persons that can use the phone, and the cost-sensitive nature of the product itself, make speaker-dependent systems the current technology of choice for voice dialing. Another factor is the ability to create user-defined vocabularies, such as "CALL JOE" or "DIAL MARYANNE." For these reasons, speaker-dependent technology is also being used to control in-vehicle audio systems. Here, noise immunity becomes more important because the audio system itself is a noise source.

A major challenge in recognizing isolated words is detecting word boundaries in noisy environments. Studies show that a 60-ms error during the detection of a word's endpoint causes a 3% average reduction in recognition rates for ten digits. For some specific digits, endpoint deviations can produce a 28% degradation in recognition rate. In extreme noise environment, even the speech detection becomes difficult. Another problem regards extracting noise-immune speech features using conventional algorithms with short response times. However, preprocessing procedures like digital filtering can minimize this problem.

A phone system must also be easily operated to eliminate visual or manual intervention during the act of driving. It should be flexible enough to dial any phone number, correct errors, and store numbers into memory for later recall in speed-dialing modes. Simple system training and retraining of unsuccessful word templates is also required.

Such a technology is now being developed by The DSP Group. The firm is developing an isolated-word, speaker-dependent design that's built around a modified dynamic time-warping (DTW) algorithm *(Fig. 1)*. The algorithm time-aligns words of different lengths, compensates for small variations in natural



2. PROFESSIONAL SPEECH-ENCODING services offer everything from a trained speaker and help with structuring a vocabulary to encoded EPROMs. Speech forms can be individual words, portions of phrases, whole sentences, or a mixture of these. Computer-based speech processing edits the data, removes pauses and extraneous sounds, and corrects inaccuracies.

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speech rates, and constructs each reference template as a series of time-frame sequences. Each time frame is represented by a feature vector. Long words are linearly time-warped to a maximum of 40 frames to keep data-storage requirements and computation time reasonable.

A tested utterance is transformed into a similar series of feature vectors. After the two templates are time-aligned, a local distortion-measurement operation compares the two templates for dissimilarities between one test-feature vector and one reference vector. A speech-specific, voice-activated switch, working with a word-endpoint detector, defines the word boundaries. Speech templates are constructed during a two-stage training mode.

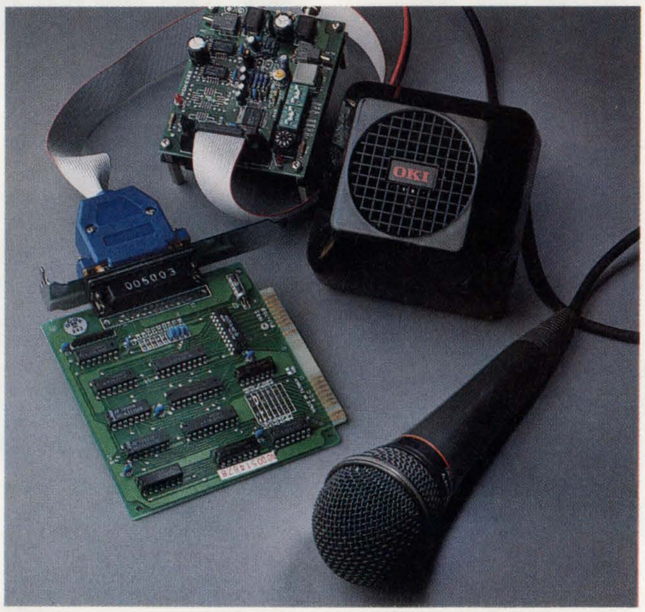
Feature extraction is done by modeling the speech signal with a tenth-order linear-predictive-coding (LPC) algorithm. The LPC algorithm is then converted to cepstrum coefficients and coded in the Parcor domain to minimize storage space. Parcor speech coding uses an all-pole digital filter model to predict the formants (resonant frequencies) in the digitized speech.

The DSP Group's system builds two reference templates per word, one for quiet environments and one for noisy conditions, allowing the decision function to adapt to noise. The system's recognition rate is reportedly greater than 98% for a car-cabin environment and over 99% under laboratory conditions. The system is also being configured to support speech synthesis for both user-prompting and verification. Speech dialing can be digit-by-digit, or in a speed-dialing mode employing such user-defined phrases as "CALL HOME." The number of users supported depends on the amount of memory the application can afford. The system's vocabulary supports 32 words.

Speech recognizers generally work with a microcontroller that handles the user interface. Upon user request, the controller is responsible for such tasks as switching between speakers, selecting the mode of operation for training, and keeping track of trained words.

A speech recognizer being developed by Oki Semiconductor, Sunnyvale, Calif., can distinguish between 256 different speakers using information stored in external static RAM. Expected to be sampled early next year, the speaker-dependent, single-chip recognizer integrates the functions of an earlier board-level product from Oki that exhibited a 98% recognition rate in an automotive environment. Included on the chip are RAM and ROM, a 12-bit successive-approximation analog-to-digital converter, a low-pass filter, and amplifiers for line and microphone inputs. A page of templates for each speaker enables the chip to recognize speaker-specific words and phrases.

Next year may also witness a dramatic departure from conventional approaches to speech-recognition design. Researchers at Motorola Inc., Austin, Texas, are developing a product based on neural-network technology. Designed to work with the company's 8-, 16-, and 32-bit microcontrollers, the technology reportedly could set unprecedented performance levels in recognition speed, throughput, and accuracy.



3. PC-BASED DEVELOPMENT SYSTEMS **can be a cost-effective alternative to professional encoding services for encoding a variety of speech-synthesis vocabularies. This ASE-88 development system from Oki Semiconductor supports the company's line of synthesizers, which use adaptive delta pulse-code modulation. The equipment includes a microphone, speaker, and a demonstration board for use with an IBM PC.**

Where speech recognition is the mechanism for talking to machines, the other side of the coin is speech synthesis. Usually, this technology mimics human speech by using an electronic model of the vocal tract. This approach is taken by the PCF8200 speech synthesizer from Signetics Co., Santa Clara, Calif., where the voiced and unvoiced speech sounds from recorded speech are represented by periodic and noise sources, respectively. These signals are amplified and fed to a formant filter—five cascaded, second-order resonators that individually model each of the five formants within a 5-kHz speech bandwidth—that mimics the vocal tract. Good speech limitation is obtained by adjusting filter response and the amplitude of the periodic and noise sources.

Synthetic-speech systems either use time-domain or frequency-domain algorithms. With data rates ranging upward from 64 kbits/s, time-domain systems produce better-quality speech but require large storage space, which constrains vocabulary size. Time-domain synthesis adds component frequency phases to the speech waveform so that the waveform can be represented using the fewest possible bits.

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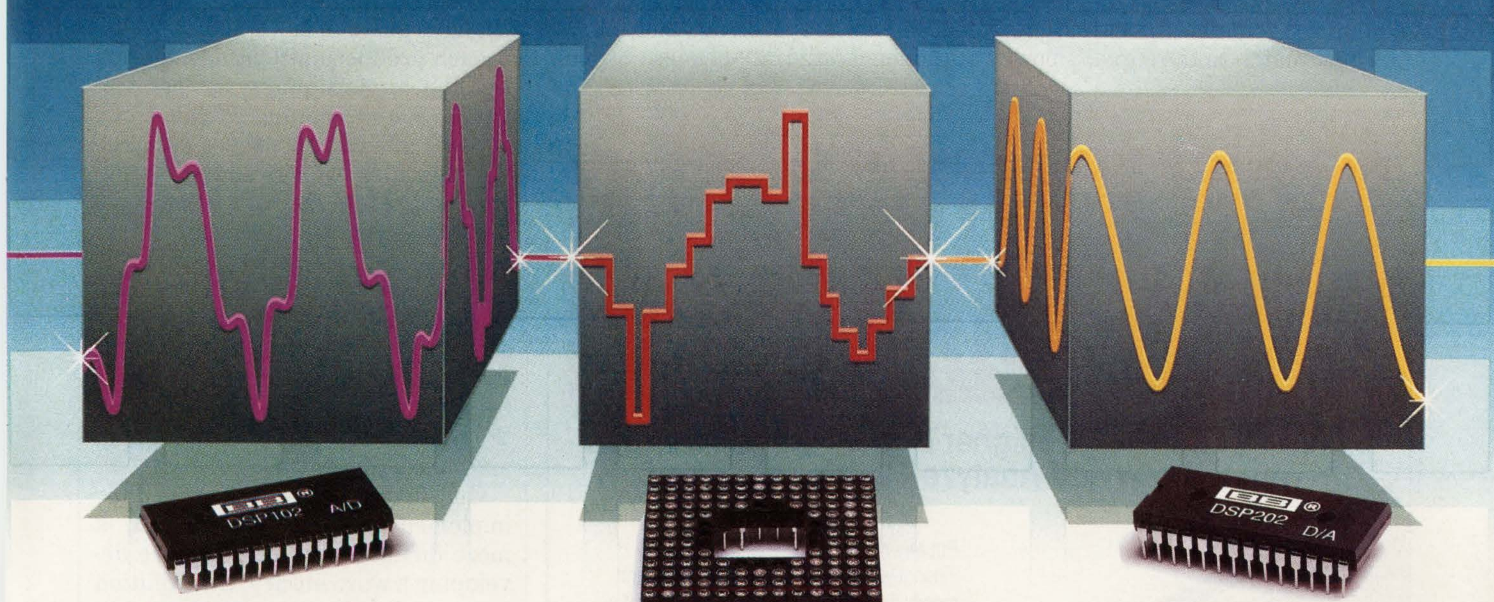

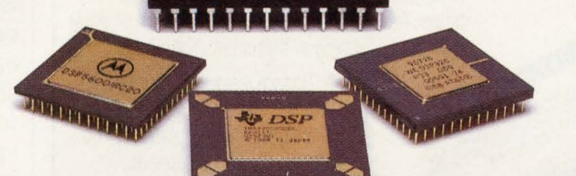

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sand bits/s) of frequency-domain devices like the Signetics' 8200 generate good, intelligible sound while offering much-larger vocabularies. Instead of using phase data, frequency-domain algorithms find the best match to the signal's power spectrum. By using frequency-domain algorithms like formant synthesis, speech can be synthesized without using a vocal-tract model.

Another option is stringing together basic speech building, such as phonemes and allophones, to build words and phrases (a phoneme is the smallest speech unit that distinguishes one utterance from another; an allophone is a phoneme with a different pronunciation when it changes position in a word). This approach produces intelligible speech, but the human quality is lost and words sound robotic. Without the support of a complex set of decision-making rules, words constructed by stringing phonemes and allophones are also prone to mispronunciation of unusual or multisyllabic words.

The performance of future systems will be strongly influenced by artificial-intelligence technology. Research is underway for using AI to analyze the context of speech, pick the right sounds, set proper parsing, and select intonations.

Once a strategy is determined for implementing speech synthesis, a more difficult task may involve developing a word library. One solution is to employ a professional speech-encoding service. Typically, such an operation supports speech synthesizers based on all popular encoding technologies and offers a complete spectrum of services, including finding an appropriate speaker, speech recording, computer processing, editing, and encoding an EPROM *(Fig. 2)*. Speech-encoding services typically range upward in cost from several hundred dollars per word.

A more cost-effective approach, especially where vocabulary development is ongoing, is to use a PC-based development system supplied by the chip maker. One such example is the ASE-88 development system from Oki Semiconductor for editing speech signals for its line of speech synthesizers *(Fig. 3)*. It includes a demo board, microphone, and speaker, and is used with an IBM AT 286-compatible PC running on MS-DOS 3.2 or higher. Similar products are available from other synthesis-chip makers, including Motorola and Texas Instruments.□

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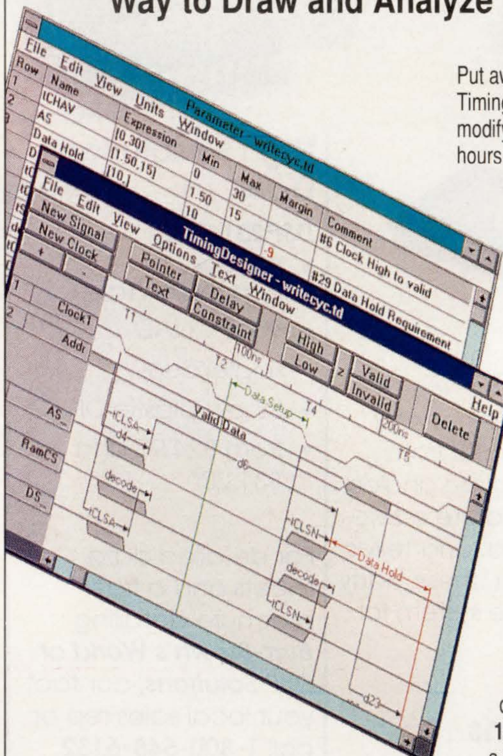

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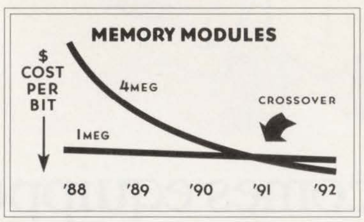

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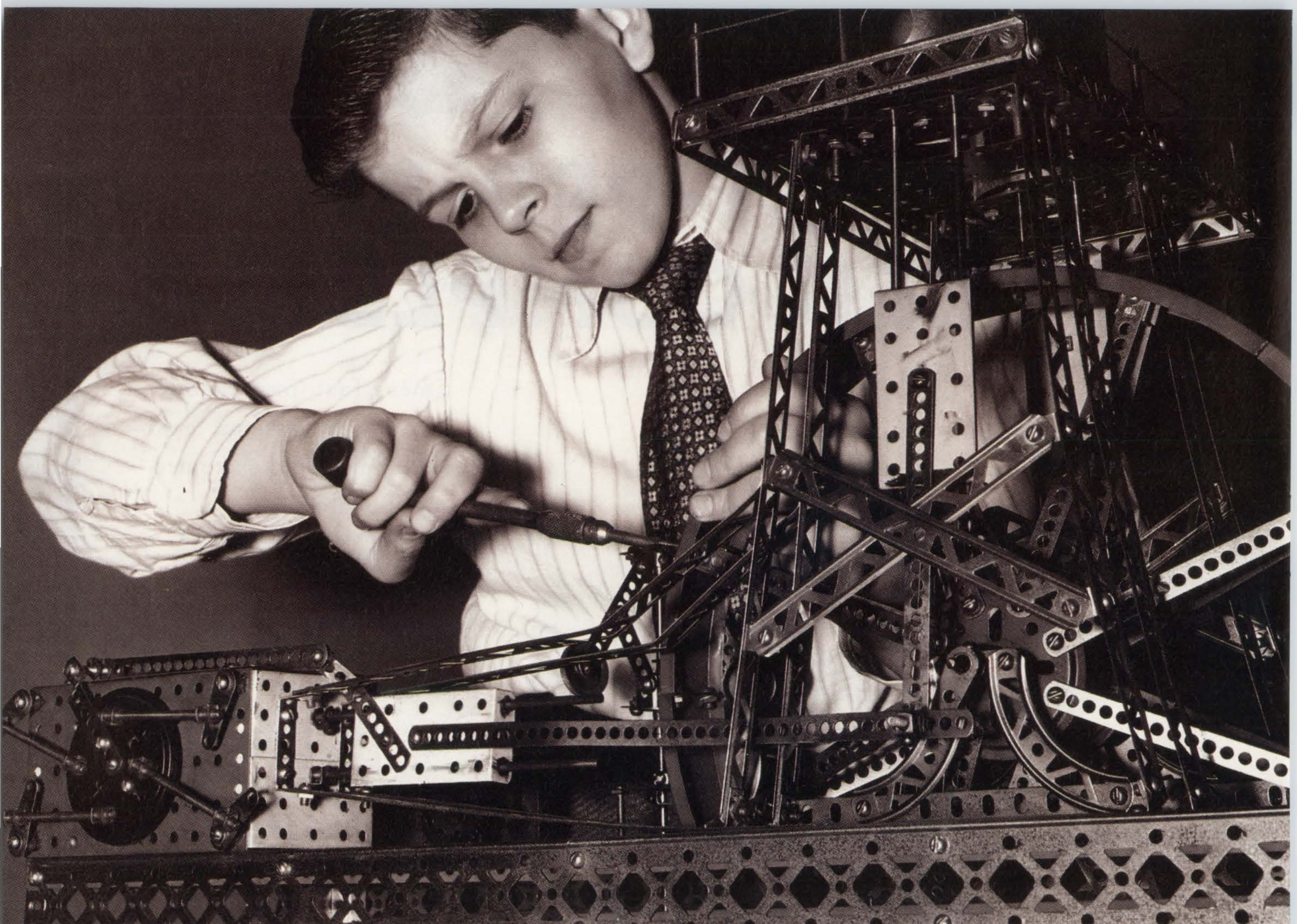

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Boosting System Throughput As Much As 40%, Four 80386-Compatible CPUs And An All-In-One 8086 With 286 Speed Also Add Features.

80X86-Compatible Family Outperforms Original CPUs

Dave Bursky

Though Intel's lock on the 80386 family architecture market has already been broken, the market's size still makes supplying the microprocessor itself an attractive proposition. However, just having workalike CPUs gives system designers and the chip manufacturers little advantage in the marketplace. Designers demand higher performance, new features to give products some value-added aspects, as well as novel hardware to create systems previously not possible.

In its strategy to develop a family of compatible CPUs, Chips and Technologies created CPU and math coprocessor chips that are more than equal in capability to the 386DX, SX and 387SX, DX. What's more, they can run the same programs faster while consuming less power. Also coming from Chips are other processors that are supersets of the CPU, adding new features that further improve performance. And for dedicated applications or pocket-sized computers, the company created an all-in-one version of the 8086 called the F8680. On one chip, the F8680 combines a high-performance 16-bit CPU that delivers 80286-equivalent throughput with a 4-stage pipeline, direct support for memory cards, a 26-bit address space, CGA graphics control for CRT or flat panels, a serial port, real-time clock, a full XT-bus interface, and special software control modes.

Consequently, the Super386 ChipSystem Architecture defined by Chips and Technologies consists of four 32-bit microprocessors,

two math coprocessors and an all-in-one "PC-on-a-chip" CPU. The first two 32-bit processors include the 38600SX and DX, which are pin-compatible with the Intel microprocessors but deliver about 10% higher throughput. The other two 32-bit CPUs, the 38605SX and DX, are supersets and include a 512-byte on-chip instruction cache, which lets them achieve about 40% higher throughput than the equivalent-speed original 80386. Supporting the CPU chips will be an enhanced version of the Peak/DM motherboard chip set, the Peak/DM. When integrated on a motherboard, the Peak/DM chip set with the 40-MHz 38605DX processor and 64 kbytes of 25-ns static RAM for the cache yields a system with an 11-MIPS rating (PowerMeter benchmark).

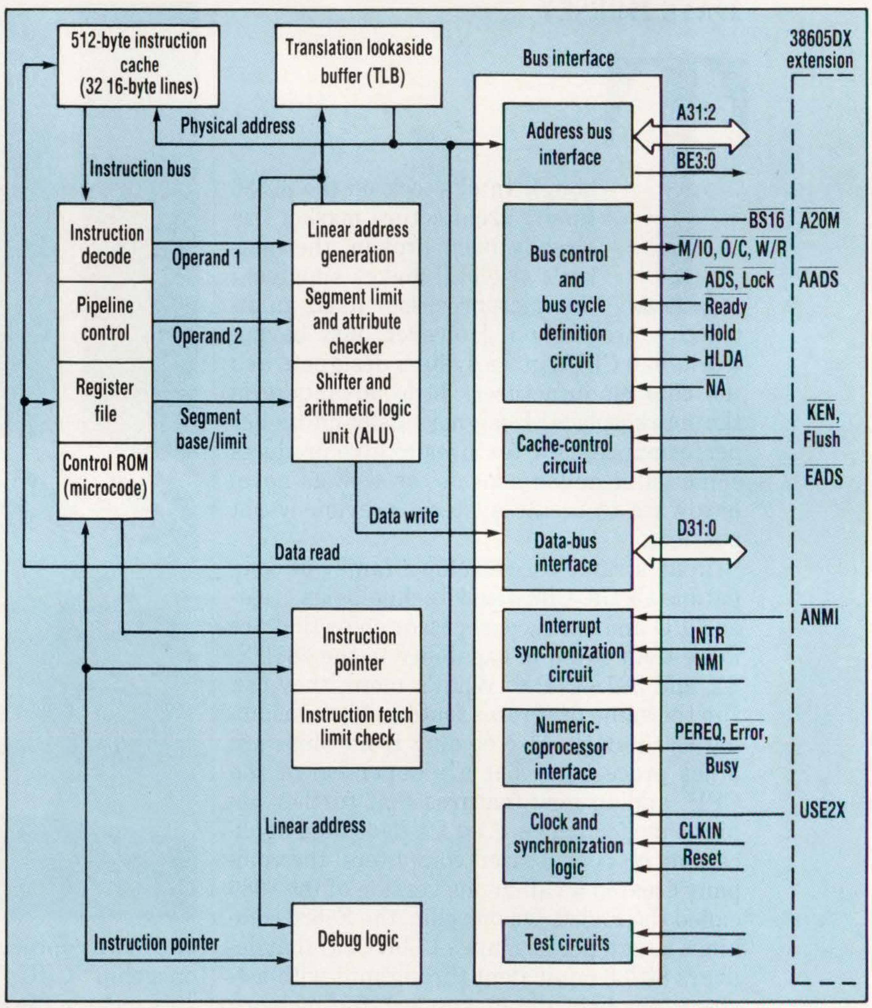
The two superset processors and the F8680 all-in-one chip include a special programming and control mode dubbed SuperState. The SuperState mode can loosely be likened to a brokerage service for hardware resources and becomes the link between the software and hardware, smoothing out current hardware and software incompatibilities. Yet another feature added to each CPU is an Isolate control pin that puts all outputs into their three-state mode and disables all inputs. Furthermore, every Super386 CPU was designed so that all internal registers are scannable to improve system testing.

All four of the 32-bit processors can jump right into existing applications in the desktop and portable PC world. However, new applications that can exploit the SuperState mode or lower operating power—portable instruments, notebook computers with special control capabilities, and other embedded-control applications, promise lots of future growth. Similarly, the highly integrated F8680 has many potential applications, from palmtop personal computers to embedded controllers in medical equipment and portable instruments.

The easiest chips to get familiar with are the 38600SX and DX CPUs, and the SuperMath SX and DX math coprocessors. Totally pin and software-compatible with the Intel 80386-series processors, the 38600SX and DX also boast a fully static design and support a 1X or 2X CPU clock. The fully static design makes it possible for the processors to conserve power because the clock can be totally stopped if no system activity is taking place.

Designers at Chips paid much attention to the efficiency of the coprocessor interface, improving on the math coprocessors while maintaining 100% pin compatibility with Intel's 80387 math chips. The main improvement, however, comes from internal architectural enhancements that improve overall instruction efficiency by as much as 600% over the Intel math chips. For instance, simple operations like stack-to-stack stores require just three clock cycles, while complex instructions, such as a floating-point square-root operation, require as few as 19 clock cycles. In contrast, the original math coprocessors required 11 and 122 cycles, respectively, for the same operations. In addition, static logic design and on-chip power-management circuits minimize chip power consumption. SX versions of the math chips will come in 16-, 20-, and 25-MHz speed grades, while the DX versions will come in those speed grades as well as 33- and 40-MHz options.

Understanding the enhancements Chips applied to the 386 architecture on the 38605SX and DX, and their ramifications, may need a little more explanation. In addition to all of the features of the previously described CPU chips, these superset proces-



1. A FAMILY OF MICROPROCESSORS from Chips and Technologies is available in either a 100% pin-compatible version of the Intel 80386 family, or a superset implementation (shaded regions indicate new features). The 3860X family of microprocessors execute all instructions performed by the Intel 80386 family processors. The superset versions include a 512-byte instruction cache on the chip and boast a 40% improvement in software execution speed. New signal lines were also added on the 38605 superset processors to handle cache control, clock selection, and other functions.

sors include a 512-byte instruction cache and related control logic, and the SuperState system management capability *(Fig. 1)*. Although the chips can run any program written for the 80386, modifications to handle new system features can be done transparently—without touching the original programs—by simply writing routines that execute on the processor when it switches to the SuperState mode.

To add the cache on the chip forced designers at Chips to enhance the CPU pinout so that the 38605SX requires a 132-lead quad-sided flat package (a 32-lead increase over the 38600SX), while the DX version comes in a 144-lead pin-grid array (seven new active pins plus five no-connection pins, for a 12-pin increase over the 38600DX). However, with a simple layout option, the same board can accept either one of the standard CPUs or one of the superset processors, allowing system makers to provide a range of system performance levels with the same motherboard design.

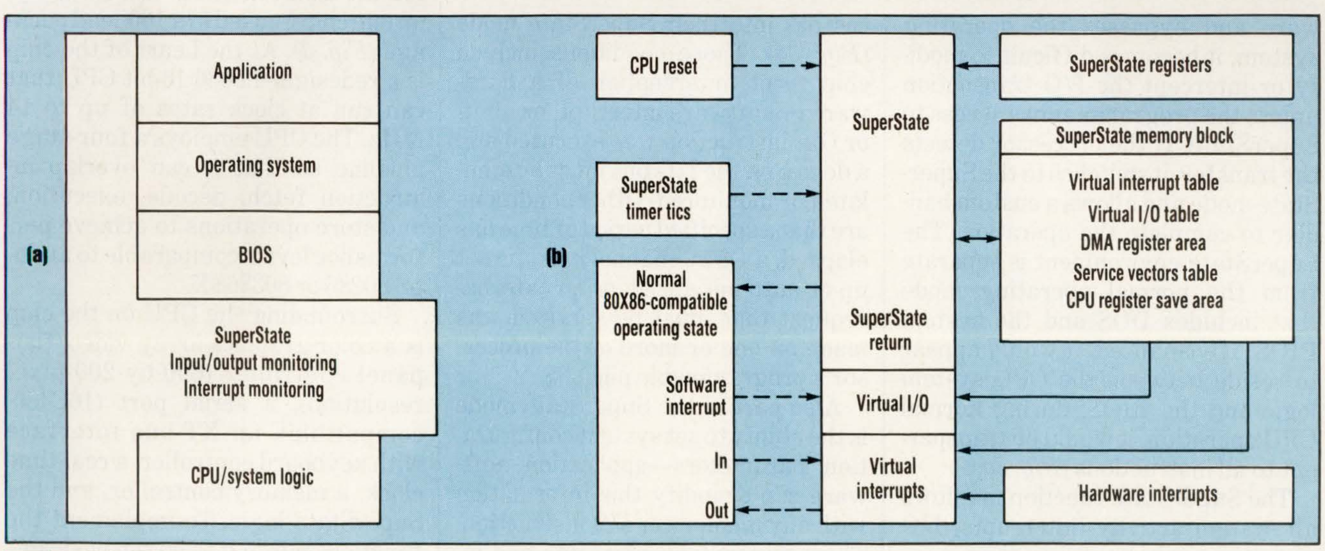
The integrated instruction cache and other CPU enhancements are able to improve overall CPU throughput by as much as 40% over the standard 80386 processors. The instruction flow into the cache saves many external memory references, especially when the processor must execute tight subroutine loops. When a cache miss occurs, either one cache line or the entire cache can be invalidated (one cache line is 16 bytes). If the entire cache is invalidated, the first line of new instruction information bypasses the cache and goes right into the processor's pipeline. Processor throughput is thus improved because the CPU doesn't have to wait until the entire cache is filled. When the instruction starts execution, the rest of the cache is filled. Another improvement was the addition of Jump acceleration hardware that rapidly decodes the Jump operation so that just 2 cycles are required for a Jump when the address is in the cache, and just 5 cycles if out of the cache.

The most novel addition to the CPU definition, the SuperState architecture, provides a transparent interface that ensures compatible communication between hardware and software. SuperState functions actually intercede in the communication process between the software and the hardware to make sure the computer doesn't end up going into an unrecoverable state. Through a virtualization process that brokers the hardware resources, software communications are trapped and then placed in the SuperState environment.

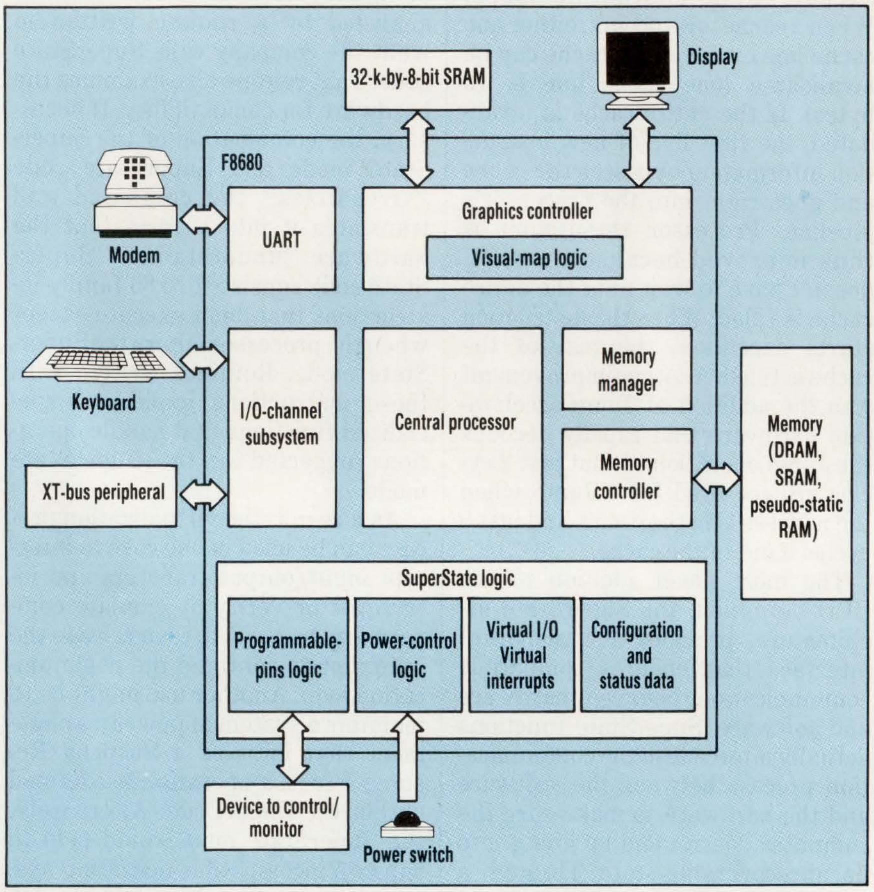
Within the SuperState environment, the software communication is analyzed by a routine written in what the company calls SuperState code. That routine also examines the hardware for compatibility. If necessary, the combination of the SuperState mode and SuperState code "virtualizes" the command and translates it into a form that the hardware "understands." SuperState code consists of x86 family instructions that don't execute except when the processor enters the SuperState mode. Routines written with these instructions implement specialized functions that handle operations expected in the SuperState mode.

As a result, the virtualization process can be used in one case to intercept input/output transfers and interrupts or verify or emulate compatibility as needed, then release the interrupt to continue the communication loop. Another use might be to maintain a system of power management that initiates a Suspend/Resume Process operation as defined within the SuperCode. Alternately, the SuperState mode could help to run two incompatible operating systems simultaneously or add specialized custom features to increase the performance of specific software applications.

For instance, if the driver software is written directly to the hard-



2. WHEN LOOKING AT the standard software model, the SuperState mode must fit transparently between the CPU system logic and the BIOS (a). There are many ways the SuperState mode can be invoked—a CPU reset, external timeout, protected-software operation codes, and software or hardware interrupts (b).



3. EXCEPT FOR A VIDEO MEMORY and the main system memory, one highly-integrated processor chip contains all of the logic for a basic PC with 80286-class performance. In addition to the 8086-compatible CPU core, the F8680 includes a CGA graphics controller, a UART serial port, a keyboard port, an XT-bus interface, a memory controller, power management logic, and many other features.

ware and bypasses the operating system, it becomes difficult to modify or intercept the I/O transaction unless the programmer has access to SuperState. If the processor detects the transfer, it switches to the SuperState mode and allows a custom handler to complete the operation. The SuperState environment is separate from the normal operating mode that includes DOS and the system BIOS. If visualized, it would appear to reside between the CPU system logic and the BIOS; during normal CPU operation, it would be transparent to all instructions *(Fig. 2a)*.

The SuperState function monitors all system activity (interrupts, I/O operations, etc.) and can thus emulate environments without affecting compatibility. Any number of actions or conditions can place the processors into their SuperState mode *(Fig. 2b)*. Those conditions include chip reset, interception of a hardware or software interrupt, or an In or Out instruction was executed and a device on the I/O bus must be emulated or monitored. Other conditions are that a specified period of time has elapsed, a DMA channel must be set up or auto-initialized, or an external request that must be serviced was made on one or more of the processor's programmable pins.

Also part of the SuperState mode is the ability to set system-configuration parameters—application software can't modify this information with any memory or I/O instruction. Thus, SuperState intercepts and interprets other setup programming formats so that previously written setup and BIOS code can be used without modifications. Extensions to the DOS system architecture that include memory cards and other nonstandard items can readily be handled in the SuperState mode. And because the mode automatically monitors the processor activity, the programmer is freed from having to deal with distractions, such as monitoring I/O activity or maintaining I/O access counts. SuperState can also be used during program debugging—it controls a trace buffer that permits the programmer to trace the bug back from the breakpoint, reducing the need for test equipment such as in-circuit emulators.

An enhanced form of the SuperState mode is also included in the PC/Chip F8680 single-chip PC. Called SuperState R, the mode provides a separate operating environment and allows complete I/O-line and interrupt monitoring without BIOS modifications. When responding to interrupts, the virtual interrupt aspect enables any interrupt to be redirected before any operating system, application program, or terminate-and-stay-resident (TSR) program sees the interrupt.

The F8680's most attractive aspects, though, are its high level of integration and high performance. Its designers compressed all functions found in a personal computer, except for the disk controller and memory, on one chip housed in a 160-lead package *(Fig. 3)*. At the heart of the chip is a redesigned 8086 16-bit CPU that can run at clock rates of up to 14 MHz. The CPU employs a four-stage pipeline so that it can overlap instruction fetch, decode, execution, and store operations to achieve performance levels comparable to an Intel 80286 or 80386SX.

Surrounding the CPU on the chip is a color-graphics-array video/flat-panel controller (600-by-200-pixel resolution), a serial port (16C450-compatible), an XT-bus interface with keyboard controller, a real-time clock, a memory controller, and the SuperState logic. To implement the functions missing from the basic PC, a chip like the Chips and Technologies 82C710 can be used with the processor to add a second serial port, a

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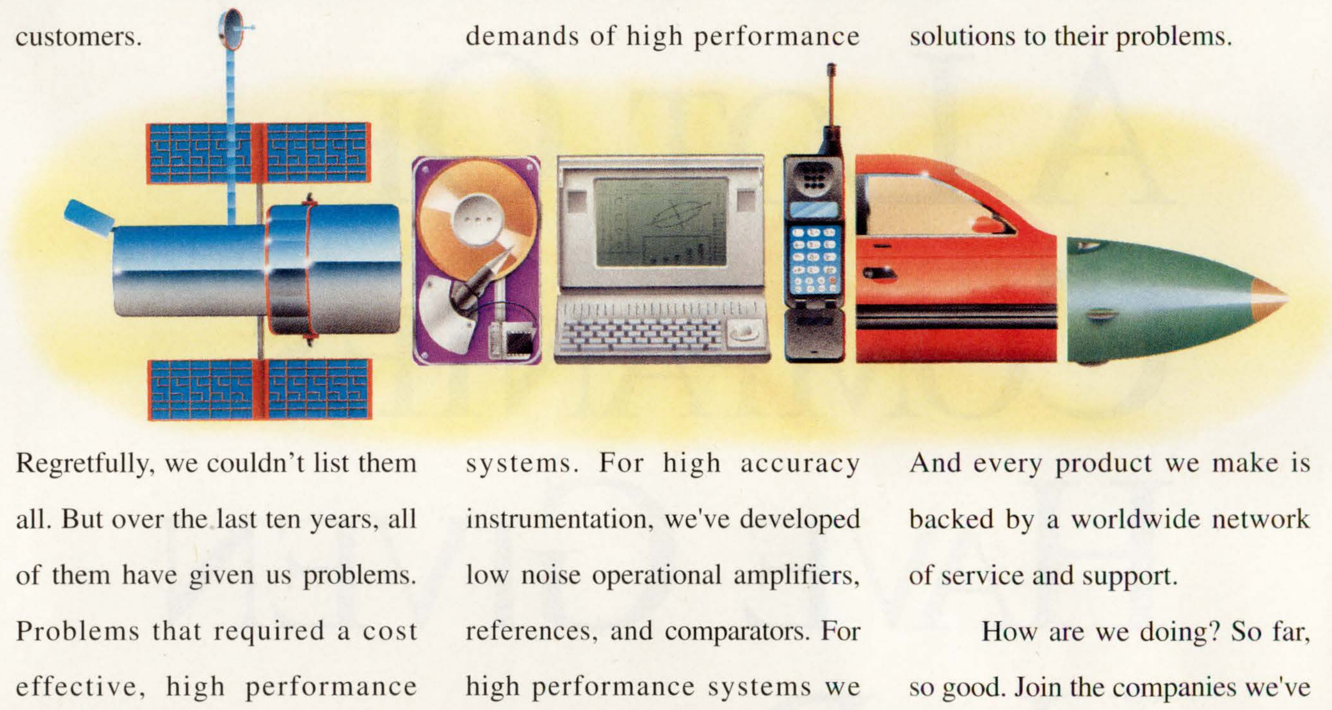

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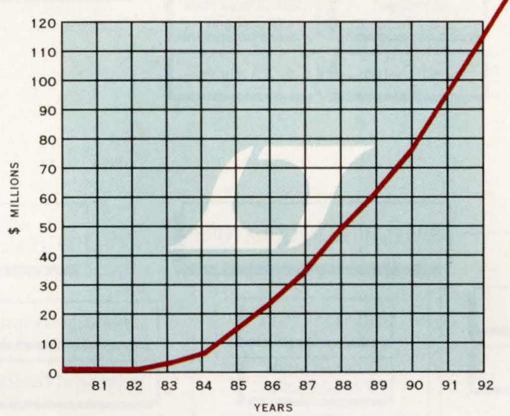

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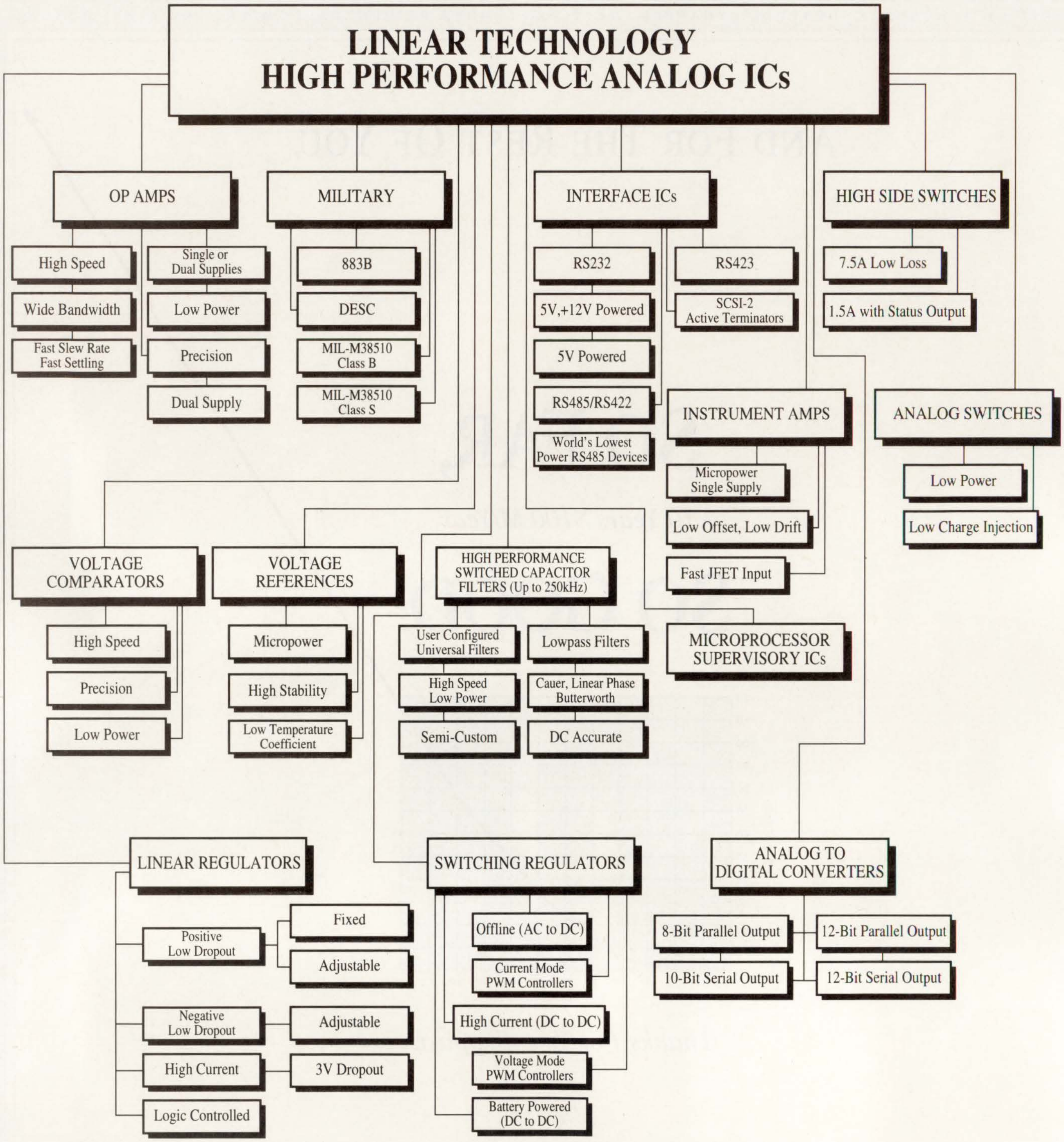

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X86-FAMILY REPLACEMENTS

bidirectional parallel port, an IDE hard-disk interface, floppy-disk controller with analog data separator, a mouse port, and a crystal oscillator.

Because some of the chip's applications will be in portable and palmtop computer systems, the PC/Chip was designed to operate from batteries ranging from 3 to 5 V. When running at 8 MHz, the processor draws just 50 mA and delivers three to five times the throughput of the 8086. All logic was implemented with fully static design techniques. That allows the clock frequency to be reduced to zero without any data loss to minimize power consumption during idle conditions (current drain with the clock stopped drops to just 40 μA maximum). An intelligent sleep mode was also included to reduce the chip's power consumption by 60% and allow direct battery drive.

Many system designers are also considering using memory cards to eliminate the power-hungry floppy or hard-disk drives, extending system battery life. To make it easier to control the memory cards, designers at Chips included support for the Personal Computer Memory Card International Association standard on the processor chip. The interface controls up to three banks of DRAM, SRAM, or pseudo-static RAM, and offers a 26-bit address (64 Mbytes) rather than the 20-bit address provided by the original 8086. Bank switching and high-memory access overcome the 1-Mbyte addressing limitation of the original 8086 and enable both PCMCIA and EMS support.

For the envisioned future applications, designers decided that CGA-level graphics capability would be adequate for most users. And by limiting the graphics to such resolution, a single external 32-kword-by-8-bit SRAM could be used as the video memory. The company's Visual Map gray-scaling algorithm was also incorporated into the chip. Therefore, color images typically shown on a color video monitor could be mapped to 16 gray levels on a monochrome flat-panel display.

System differentiation is one concern for PC makers, because most of the logic is now boiled down to a single chip. Designers made the F8680 very configurable by including over 100 configuration registers that permit system designers to set simple things like the port address for the serial port (Com1 or Com2), to define the memory map, to control power, or to set the XT-bus speed. Or, for example, the CGA controller can be disabled and an external VGA controller added for applications that demand higher-quality images.

Another issue likely to arise is the intellectual property rights that Intel has been protecting. To ensure it didn't copy any aspect of CPU logic or microcode, Chips did all development in a secure area of its laboratory; only project-team members were permitted to enter. No previous Intel employees were allowed to work on the projects. Consequently, the company feels it has implemented totally "clean" versions of the processors.

BIOS software for the PC/Chip, as well as for the 3860X CPUs, will be done by Chips and Technologies; American Megatrends Inc., Norcross, Ga.; Award Software Inc., Los Gatos, Calif.; and Phoenix Technologies Ltd., Norwood, Mass. A ROM-resident debugger for the F8680 is also being developed by Chips. Two evaluation boards were created for the F8680, one that implements a full XT computer motherboard in an area of less than 36 in.^{2}, and the other, a credit-card-size XT (just over 8 in.^{2}) with a PCMCIA-standard memory-card connector for expansion.□

PRICE AND AVAILABILTY

In single-unit lots, prices for the Super Math coprocessors have been set at $149, $159, and $169 each, for the 16-, 20-, and 25-MHz SX versions, respectively. For the Super Math DX, prices are $269, $279, $289, and $299 each, for the 20-, 25-, 33-, and 40-MHz versions, respectively, also in single-unit lots. The F8680 single-chip PC is $35 in lots of 10,000. Prices for the 3860X CPUs will be set in the fourth quarter.

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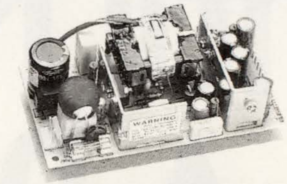

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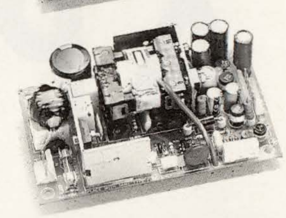

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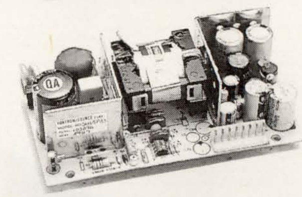

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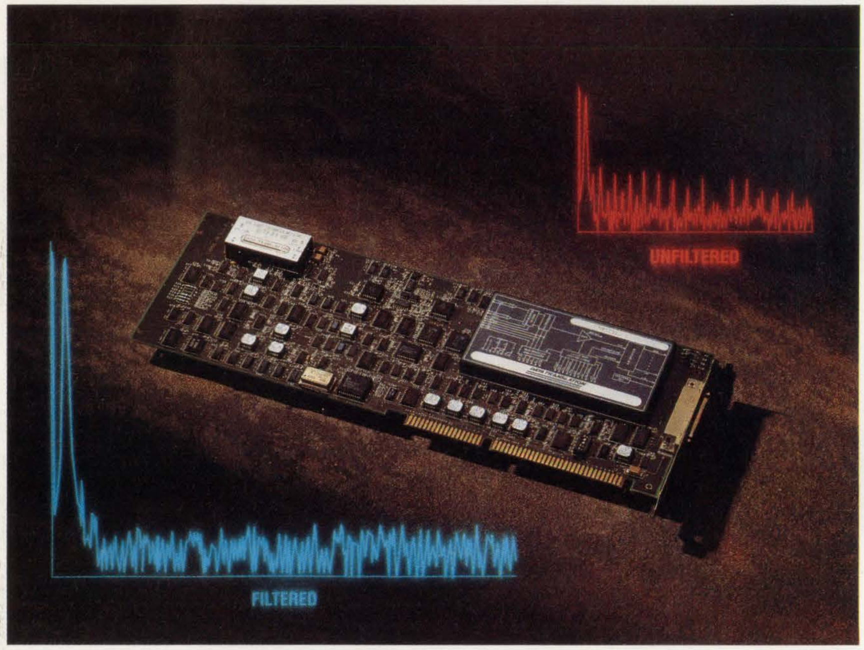

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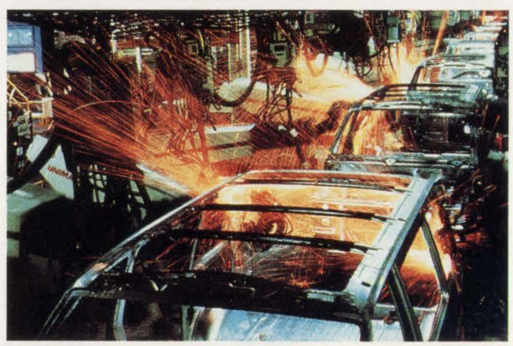

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To Trim Work Queues, Engineers Should Take A Look At Today's Manufacturing Techniques.

Managing The Design Factory

More people from the manufacturing side of the house are joining development teams—and not just on paper. In some companies, the manufacturing people are moving their desks right into the middle of the engineering department. What do they think of this strange new world? What might a top-notch manufacturing manager say when he first observes engineering close up?

a. Let's do more DFM (design for manufacturing)!
b. Wow, this place sure has a lot of inventory!
c. Gee, hasn't anybody here heard about queues?
d. Why do you optimize individual steps instead of the overall process?

The manager might give answer (**a**). In most companies this means "Let's reduce the direct labor on these products." But if he really understands world-class manufacturing, he's more likely to focus on (**b**), (**c**), and (**d**). This article explains why these three areas are the most important breakthrough issues in managing the engineering department.

Invisible Inventory

Most businesses carry a huge invisible burden. Unmanaged design-in-process (DIP) inventory is an enormous drain on earnings. Design-in-process inventory consists of product designs that are in process but not yet in production. It is the product-development equivalent of work-in-process (WIP) inventory. The higher a company's R&D spending and the longer its development cycle, the greater its DIP inventory is likely to be.

Remember, until a product is shipped, money spent on product development represents a huge, invisible, non-earning asset. This asset doesn't appear on any balance sheet, but rises to levels far higher than the manufacturing inventory that most businesses struggle to control. Invisible DIP inventory can easily be two to four times larger than carefully managed manufacturing WIP *(Fig. 1)*.

Why don't we see DIP inventory? Because our accounting systems treat R&D as a one-time expense, not as an investment of ongoing value. Accountants correctly recognize that the future value of R&D spending is so uncertain that it must be written off as incurred. Unfortunately, this removes it from both our balance sheet and our vision.

Yet the accounting treatment should not veil us from economic reality. DIP inventory is very important. Like manufacturing WIP, it's a large bank account that pays no interest.

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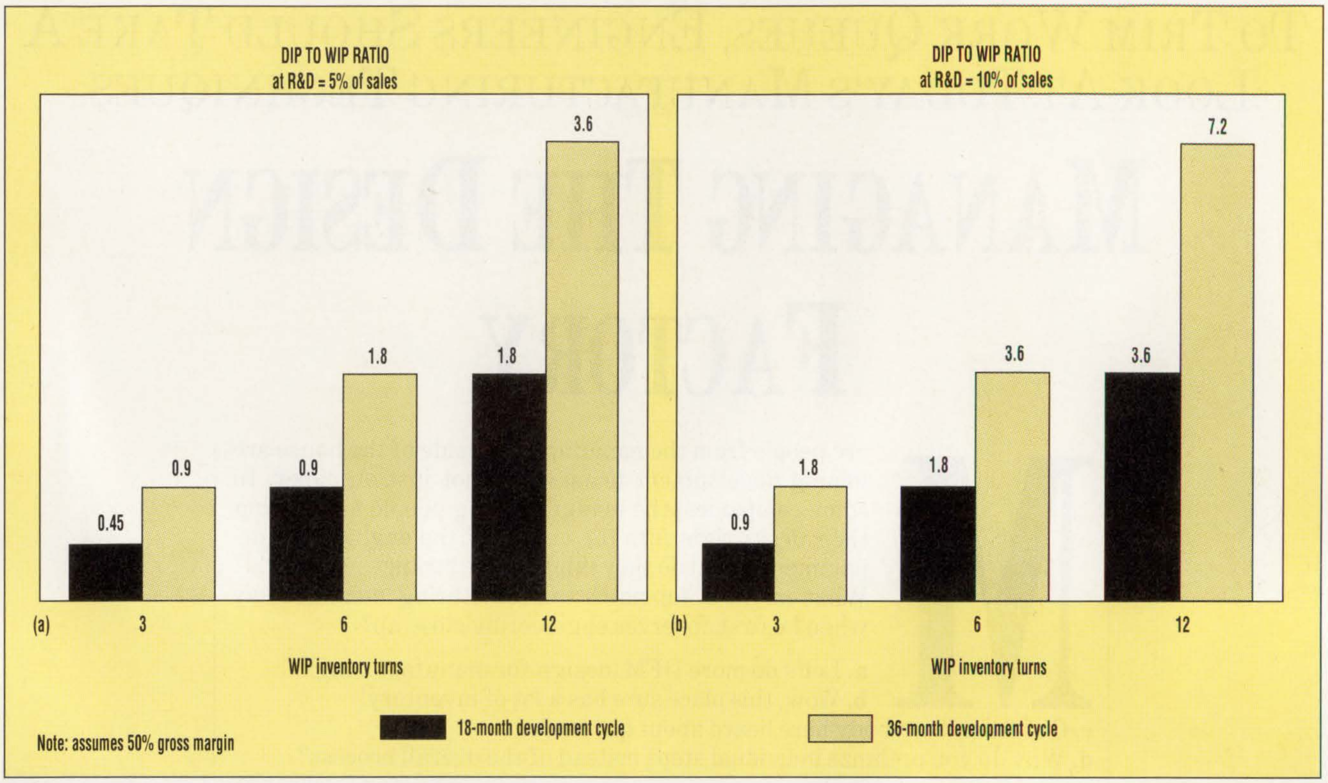

1. DESIGN-IN-PROCESS INVENTORY can be many times larger than well-managed manufacturing work-in-process inventory. However, it receives little attention. It's also directly tied to R&D investment levels.

In fact, DIP is far more important than manufacturing inventory because it's much more perishable. The failure of a development program to meet its design goals or the introduction of a superior product by a competitor can wipe out DIP overnight. The traditional estimate for annual holding costs of manufacturing inventory is 25% of the inventory's value. In contrast, our analysis suggests that the annual costs of holding DIP ranges from 25% to 75% of its value—up to three times the cost of holding manufacturing WIP.

What Causes DIP?

Because of DIP's high value and its perishability, its total holding costs can be 2 to 12 times higher than those of the WIP we try so hard to manage. As a result, there's enormous financial payoff in managing DIP well.

The size of our DIP is determined by the expense of individual designs and the time it takes to finish them. This is analogous to the way WIP values are determined by the cost of the product and the cycle time through the factory.

In practice, the most important factor is cycle time. Just as manufacturing cycles vary more widely than product costs, design-cycle times vary more widely than design costs.

What causes long design cycles? The biggest culprit is queues. And that's the same problem we find on the factory floor. In the factory, products that take weeks to travel through the factory incur mere hours of actual work. In the engineering department, drawings sit in someone's in-basket for days to receive 15 minutes of review. Because most development time is idle time, the company that manages its queues well manages its design inventory well.

Maintaining the proper relationship between capacity and demand is the key to managing queues. This is even more important in product development than in manufacturing because the manufacturing process is far more predictable than the engineering process. Mathematicians have shown us that a predictable process is amenable to tight scheduling, whereas a random process is far more likely to develop queues.

Unfortunately, it's likely we'll see demand exceed capacity in engineering rather than in manufacturing. In manufacturing, we have to sell something to increase demand; in engineering, we simply have to put a marketing person in a room for two hours—we'll then have enough to do to schedule 200% of available capacity. In fact, it's a rare company that doesn't have 100% of its engineering capacity scheduled at the beginning of the year and 150% by the end of the year. This practice guarantees large queues.

Queues

Queuing theory suggests that such attempts to fully use a resource result in enormous queues. Most of us have experienced this when traveling on a crowded highway at rush hour. Slight increases in traffic density produce dramatic delays. In the extreme case where the duration of

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development tasks is totally random, we can double the length of queues simply by moving from 90 to 95% utilization of capacity.

Of course, doubling the length of queues also doubles the length of the development cycle. This is a enormous schedule penalty in return for a small increase in engineering efficiency. Our emphasis on engineering efficiency and high-capacity utilization can dramatically increase development cycle time *(Fig. 2)*. Our manufacturing manager will probably be far more interested in managing queues than in managing design tasks. His first observation would be that the key to controlling queues is to carefully manage demand.

FLEXIBLE CAPACITY

His second observation would be that engineering needs to make its capacity more flexible. Because workload in product development can be very "lumpy" —the proverbial elephant traveling down a boa constrictor—there is unusual value in being able to handle surges of demand. The manager would point out that we can attain this flexibility either by making our internal capacity flexible or by using outside services. We should evaluate these services on their value in reducing queues, not simply on their cost.

Furthermore, he would suggest that by using more generalists in the engineering department, we can achieve the same results that were achieved by shifting to multipurpose machines on the factory floor. A department of narrow specialists causes the product design to visit too many in-baskets. Even if the specialist works faster than the generalist, often he can't compensate for the delay of being in another queue. Multipurpose individuals reduce queues by allowing us to shift capacity to the part of the process where we need it. We can chase the elephant as it travels down the snake.

His final observation on managing queues would be that we need to organize our design tasks to keep more of them off the critical path. He would point out that manufacturing organizations achieve enormous reductions in setup time by carefully distinguishing between internal and external setups. Internal setups are tasks that require a production machine to be idle, while external setups can be accomplished as a machine is running.

TWO VIEWS OF ENGINEERING

	Deterministic vs.	Stochastic
Key assumption	Engineering tasks are predictable	Engineering task duration cannot be predicted
Battle cry	"We need to schedule better"	"We need to reallocate resources better"
Source of problem	Bad time estimates are a major problem	Queues are a major problem
Solution	Assign more people to scheduling tasks	Add capacity to design team
Likely results	No significant improvement in schedules	Reduction of queues, and with this, reduction in schedules

Similarly, some design tasks must be on the critical path; others can be done before they're needed. We need to do these tasks comfortably ahead of schedule, because engineering tasks can be perversely unpredictable. When they're planned to be done on schedule, they often sneak onto the critical path anyway.

As a result, our manufacturing manager would be quite surprised at our complacent attitude toward queues in the design process. He would claim that we should spend extra time on workload management, on making our capacity flexible, and on organizing design tasks to keep them comfortably off the critical path.

DESIGN AS A SYSTEM

The third area that would surprise our manufacturing manager is how we fail to view the entire design process as a system. Manufacturing, which once focused solely on individual operations, now concentrates on optimizing the overall process. He would argue that design can also be viewed as an overall process.

First, he would observe that we focus too much control effort on the work products of the design process. Our design reviews are analogous to inspecting in quality on the production line. Though our "scrap" costs are low, our rework costs are embarrassingly high.

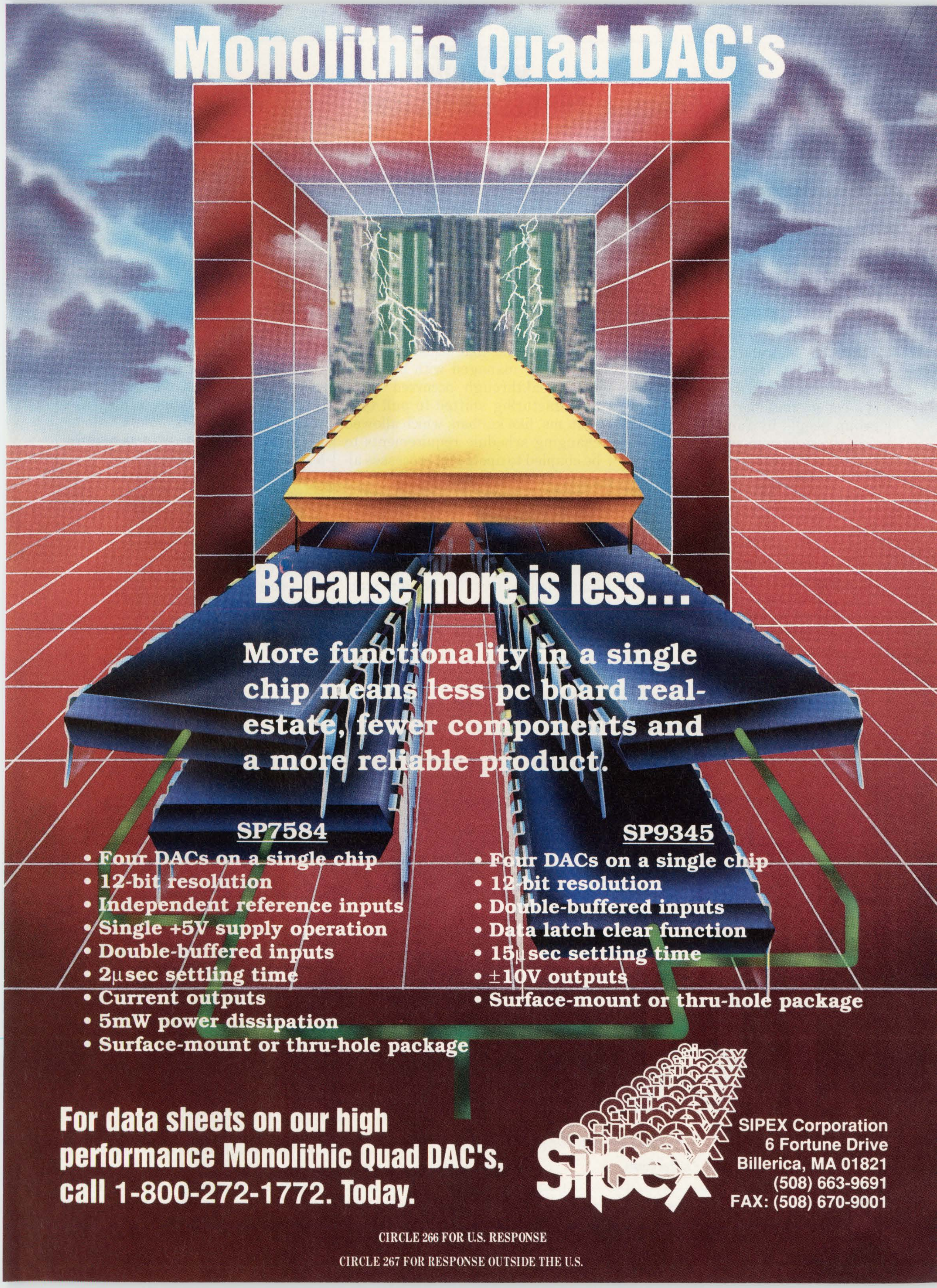
He would recommend that we improve our process control, explaining that predictable quality is achieved by operating within the limits of your processes. Furthermore, he would point out that these process capabilities should be continuously improved. Whenever we ask the design organization to perform tasks in which it has little experience, we're inviting quality problems.

OFFLINE INNOVATION

But how can we innovate without venturing where none have gone before? We simply take our innovation off-line from the development process. Technology development should not get onto the critical path for major development programs. If it does, 1% of the design effort can immobilize the 99% that's completed. We should incorporate the new technology when we have mastered it, not master it in the process of design.

The manufacturing manager would also observe that we pay insufficient attention to upstream processes. He would explain that in manufacturing, we try to chase problems upstream until we reach the root cause.

He would note that the choice of product feature sets and basic system engineering decisions occur very early in the design process. This choice has great implications for the



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MANAGING THE DESIGN FACTORY

difficulty of downstream tasks. If we control these stages effectively, they can pay dividends throughout the entire design process.

The manufacturing manager would also be surprised at our lack of attention to physical layout. At one time, all manufacturing equipment of a certain type used to be grouped together. Now, however, work is organized in cells and continuous flow lines. This has improved quality, reduced queues, and raised productivity. Yet in engineering, we tend to group people by functional specialties, the same way we designed factories in the 1950s.

BRINGING PEOPLE TOGETHER

When people are physically dispersed, communications are both less intense and less frequent. Because the design process requires a great deal of information transfer, this has significant impact on schedules. However, by placing together people who must exchange information, we can improve speed, quality, and productivity.

Our manufacturing manager would also observe that the scheduling systems used in engineering tend to inherently delay the development process. He would note that manufacturing once used such approaches, building schedules months long, and predicting when a product would visit each work center.

However, our manager would go on to explain, such push systems generated a mountain of useless information, and that schedules were frequently managed with hot lists. The breakthrough occurred when manufacturing shifted to pull type systems, like kanban, which allowed changing schedule requirements to be coupled to upstream processes almost instantly.

Pushing programs with schedules imposes an enormous status-reporting burden. As manufacturing people gained confidence that pull systems worked, they increasingly began to let product flow without stopping at every work center to check in with the computer system. People were empowered to manage the process; decisions were made more quickly; and products experienced fewer delays.

Remember that the classic scheduling technique, PERT (Program Evaluation and Review Technique), was originally developed as a tool to communicate progress on the Polaris submarine to Congress. It wasn't invented by designers to help them focus their efforts.

Furthermore, when cycles are shortened and competent people are properly motivated, there's less need to burden the design process with status reporting. Just as our confidence in the process of a just-in-time (JIT) factory allows us to dispense with many "check-in points" along the way, rapid design efforts require less scheduling and reporting.

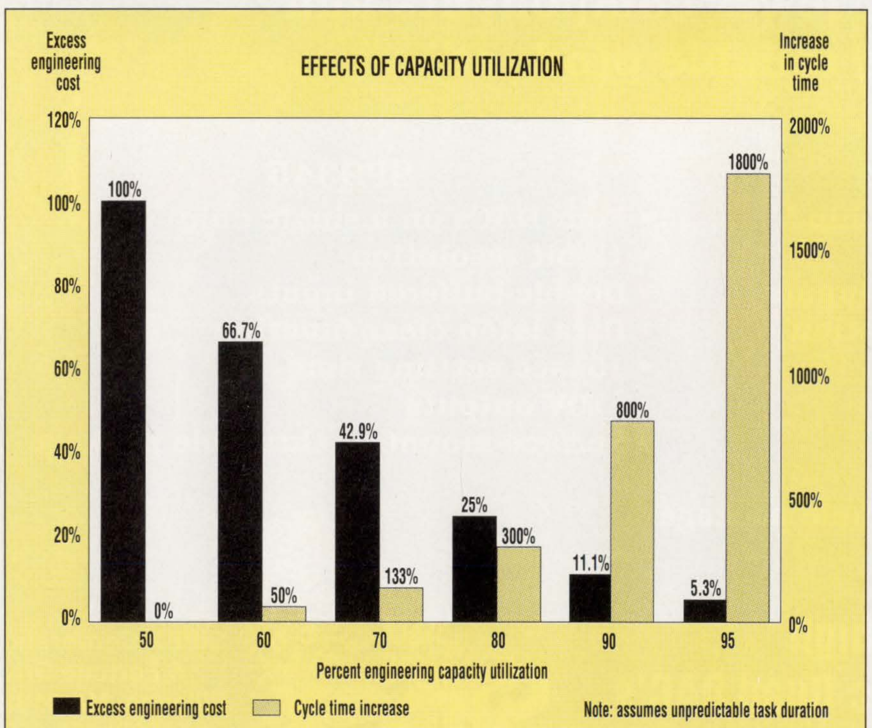
Consequently, our manufacturing manager would assert that we tend to focus too much on individual design tasks and not enough on the overall design system. He would encourage us to fit the design task to the process, to concentrate control on upstream processes, to pay attention to layout, and to rely less on push-type scheduling systems.

AVOIDING WRONG LESSONS

Fortunately, our manufacturing manager is a rather astute fellow. He also recognizes the limits of his comparisons. There are some compelling ways in which engineering is not a factory.

The most critical difference is that engineering is the ultimate job shop. Almost every design is being done for the first time and, as a result, the design is unpredictable in both task content and duration. Many of the world-class manufacturing techniques that focus on reducing variability are simply not applicable in the design process. It can be far more valuable to learn to cope with variability.

This is an important and somewhat subtle point. Many companies devote enormous man-hours to project postmortems and detailed scheduling trying to make the design process less variable. These companies think that if they can just make people better schedulers, projects will come out on time. They fail to see that it is inherently difficult to predict the duration of something that you have never done before. Consid-



2. AS WE TRY TO increase engineering efficiency by raising capacity, we pay a high price in cycle time.

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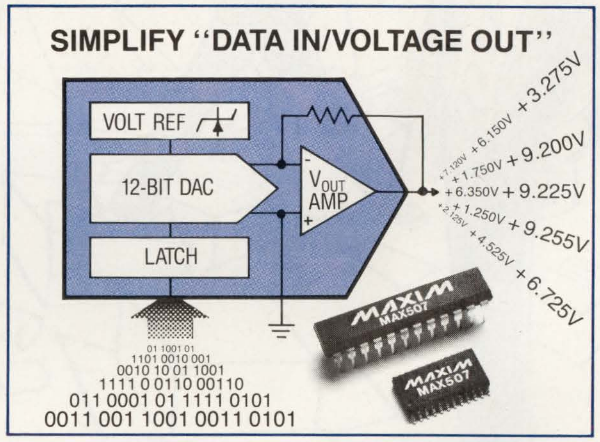

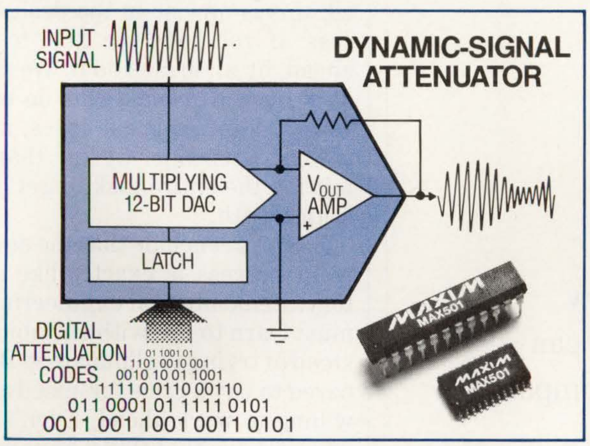

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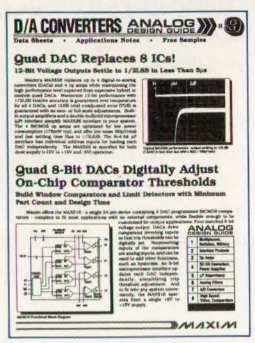

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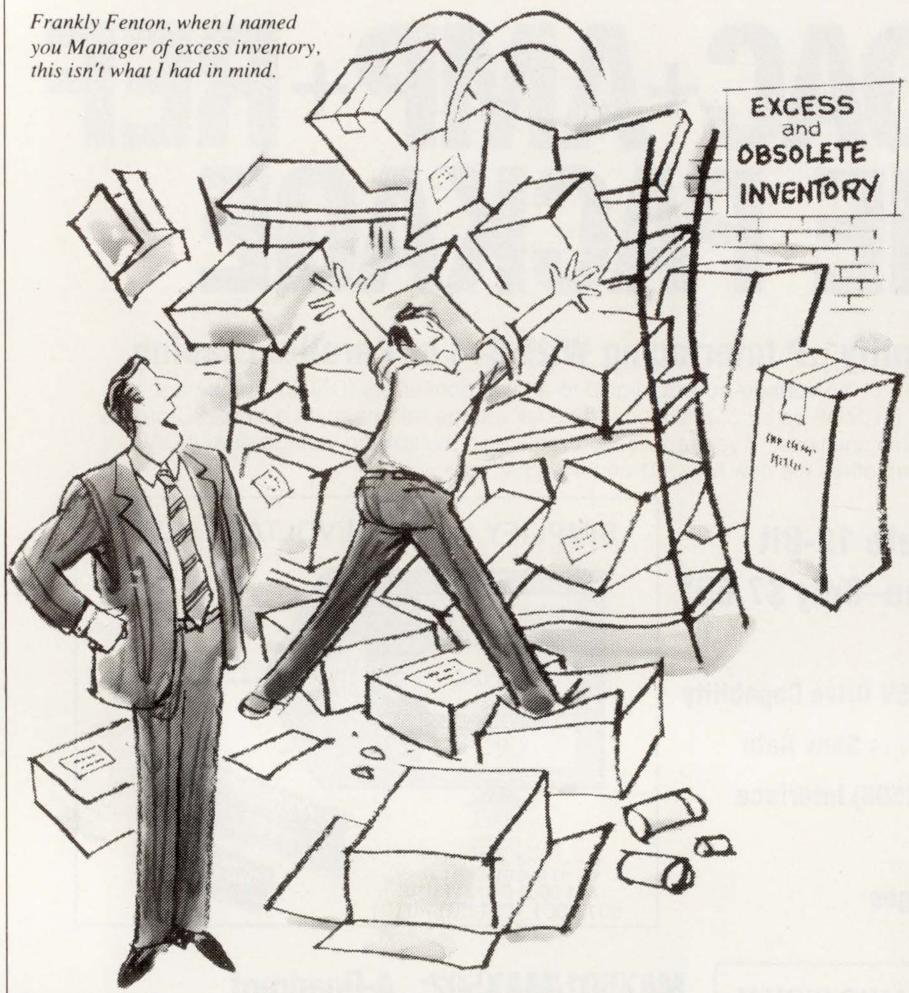

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er instead simply adding extra capacity. Queuing theory suggests that this will have far greater impact on your schedules than all of the scheduling software in the world. The key assumptions behind the deterministic view of engineering will shift the focus to the wrong solution for the problem of lengthy development cycles *(see the table)*.

PRICE TO PAY

A second difference that he would note is that while quality may be free, speed is not. While there are some attractive, low-cost techniques for shortening development cycles, one must ultimately recognize that speed isn't free; the quest for speed must be driven by economic realities. We must calculate what price we can afford to pay for speed and not buy it above that price.

Finally, he would observe that although most JIT factories forbid producing a product before it's needed, this is unwise in the design process. If you have the time to work ahead, by all means do it. We should do it even if it makes us do a little rework later. In most cases, a little rework is cheaper by far than permitting the entire task to get on the critical path.

So don't conclude that the development process is exactly like a factory. Remember, in engineering, we must learn to live with variability instead of trying to eliminate it. Be prepared to pay a price for speed and be willing to work ahead. Even so, it's just possible that those guys over in manufacturing have learned something in the past 40 years.□

Donald Reinertsen heads Reinertsen and Associates, a Redondo Beach, Calif., consulting firm that specializes in product development issues. He cowrote the book, Developing Products in Half the Time, *published by Van Nostrand Reinhold.*

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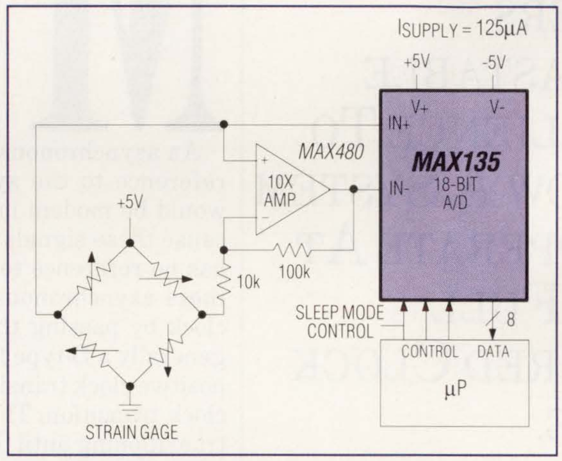

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CONTROL METASTABILITY IN HIGH-SPEED CMOS CIRCUITS

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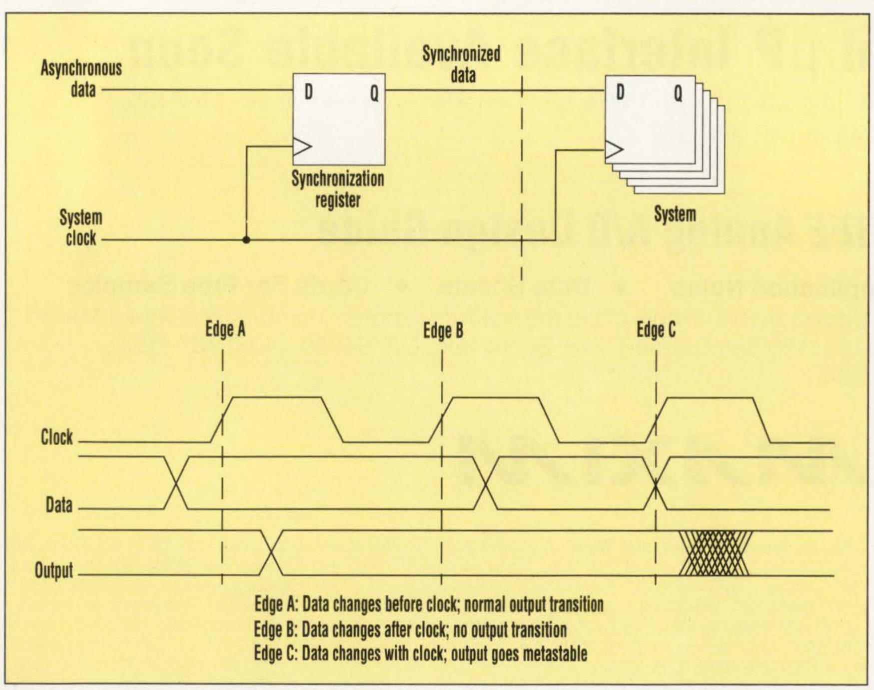
TOM BOWNS
Wyle Laboratories, 15385 N.E. 90th St., Redmond, WA 98052; (206) 881-1150.

Many microprocessor- or embedded-controller-based systems have some sort of asynchronous signal interface. Systems that sample asynchronous inputs may experience random failures due to metastability in the synchronizing registers. Although older logic technologies are susceptible to metastability, new high-speed CMOS Erasable Programmable Logic Devices (EPLDs) coupled with proper design have virtually overcome this problem while still providing high performance.

An asynchronous signal is defined as any signal that transitions without reference to the system clock. Some examples of asynchronous signals would be modem inputs or various signals from a keyboard interface, because these signals are coming into the system from an outside source that has no reference to the system clock. For the system to make good use of these asynchronous signals, they must be synchronized with the system clock by passing them through a synchronizing register. This register is generally a D-type flip-flop, in which the Q output follows the D input at the positive clock transition and remains at that logic level until the next positive clock transition. The register will effectively hold the incoming data from transitioning until there's a system clock transition, so the rest of the system will receive this data synchronized with the system clock.

The components that make up a system—the microprocessor, the memory controllers, the serial communications interface, glue logic, and so on—usually contain registers that are edge-triggered by the common system clock or one of its derivatives. These devices have definite data setup-and-hold times, and demand that their inputs be synchronous with the system clock. In other words, the input transitions must occur at a known point before the next clocking edge, and the registers internal to each device will simply pass the input data through. Consequently, there's a need for signals to be synchronized before they reach these system registers. However, in synchronization registers, input data transitions occur randomly with respect to the clocking edge.



1. DATA WILL TRANSITION in the synchronization register before the clock, after the clock, or right along with the clock. The third scenario can cause metastability.

Manufacturers of all logic devices, whether discrete or integrated, include specifications for their registers pertaining to setup-and-hold parameters. These parameters assert that the incoming data may not change within X nanoseconds before the clocking edge, and must stay sta-

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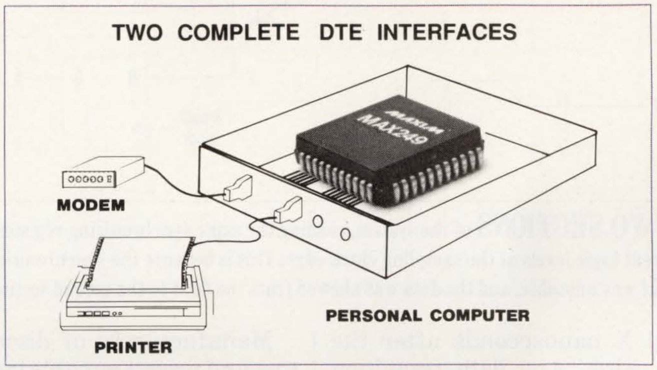

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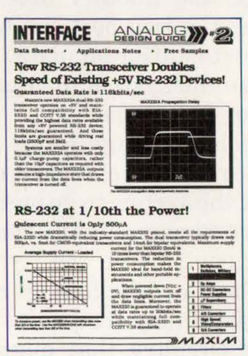
Device	Number of RS-232 Drivers	Number of RS-232 Receivers	External Capacitors	Shutdown & Three-State Outputs	Price*
MAX241	4	5	4 x 1μF	Yes	$3.99
MAX244	8	10	4 x 1μF	No	$7.65
MAX245	8	10	None	Yes	$12.15
MAX246	8	10	None	Yes	$12.15
MAX247	8	9	None	Yes	$12.15
MAX248	8	8	4 x 1μF	Yes	$7.65
MAX249	6	10	4 x 1μF	Yes	$7.65



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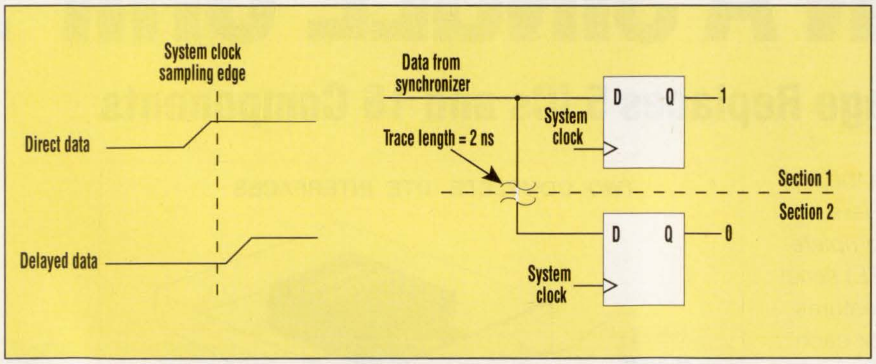

2. TWO SECTIONS of the system, reading the same synchronizing register, receive different logic levels at the sampling clock edge. This is because the synchronizing-register output was unstable, and the data was skewed from the first to the second section by 2 ns.

ble until X nanoseconds after the clocking edge. Any data transition occurring within the setup-and-hold window is considered invalid. Manufacturers don't generally specify what happens at the output of a register when setup-and-hold are violated. When this violation occurs, the register output often enters a metastable state, which is by definition, undefined and unstable *(Fig. 1)*.

Like all digital circuits, registers are constructed out of high-gain transistor amplification circuitry that's not usually operated in the linear range. The register contains two latches, a master and a slave. Data is latched into the master latch when the clock input is low, and latched into the slave latch when the clock input is high.

However, during logic transition of either the data or clock signals, the master/slave feedback loops are operating in the linear region. When the input data transition occurs too close to the transitioning of the clock, the circuitry essentially doesn't get enough of a "kick" to push the slave latch either one way or the other, and the voltages hover in between High and Low. This can cause the actual output of the slave circuit to behave erratically: It can become suspended in between High and Low for an extended period, it may oscillate, or it may go high and then later resolve to low or vice versa. The way a register behaves when it's metastable, whether it oscillates, hangs up, or transitions late, depends on its technology.

Manufacturers of discrete registers and programmable logic devices are now realizing that metastability is an important issue in high-speed system design. They're making the effort to explain metastability and describe their product's characteristics so that users can more confidently design input synchronization circuits. Unfortunately, there's no standard for expressing metastable characteristics. Every manufacturer presenting metastability data for their product has their own way of describing the actual data and how to derive the design-in characteristics.

TAU CURVE

Still, the most commonly cited and accepted method for expressing metastability in registers is by describing the device's tau curve or τ, and failure window or t_W. Metastable occurrence is probabilistic, and therefore not constant or linear. Thus, unlike such constant characteristics as t_{CO} or t_{SU}, the metastable characteristics of any device can't simply be: "In X nanoseconds, the register will have resolved from a metastable state." Unfortunately, designers must instead notice that: "For X percent of metastable occurrences, the register has a Y percent chance of a resolving in Z ns after the data book t_{CO}."

The tau curve of the device is a straight line. The y axis is a logarithmic scale of length of time from one metastable occurrence to the next, and the x axis is a linear scale of time in nanoseconds beyond t_{CO}. The failure window is a constant particular to the device that describes the device's probability entering the metastable state in the first place. In other words, it's how sensitive the device is to setup-and-hold violations.

In designing a system with synchronization of incoming data, designers want the asynchronous incoming data to be synchronized with the system clock. When a particular transition doesn't quite make the nearest clock edge, the designer doesn't care whether the synchronizer's output remains as it was or transitions to the new state, as long as it transitions within the normal t_{CO} specified for the register. The actual data isn't as important in system design as whether the system sees the synchronizer data transition before the next clocking edge.

Under normal operation, the synchronizing register provides data to the rest of the system that transitions in synchronization with the system clock *(Fig. 2)*. The rest of the system, sampling on the same clock edge, sees the data from the synchronizer as always valid, whether high or low. If, however, the synchronizing register goes metastable, the output of this register may vacillate or hang up in limbo for a time, possibly exceeding the period of the system clock. If, due to trace-length delays, the data resolution from the metastable register reaches one portion of the system before the next clock edge and another after the clock edge, the two portions would then react to different data. This could cause the system to crash, or do even worse damage.

Intermediate voltage levels from metastable registers can cause other portions of the system to go metastable, or at worst may actually damage other components in the system. Furthermore, an oscillating metastable register may feed noise data into other circuitry that might be sensitive to high-speed signals, or may erratically clock portions of the system that are edge-triggered.

Several design methods could be used to guard against metastability. Each method considers the fact that no synchronizer is completely meta-

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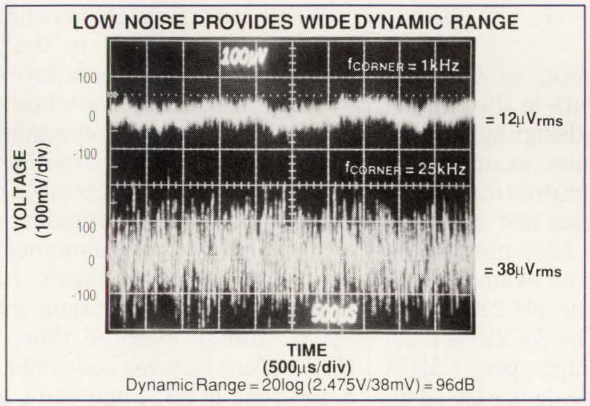

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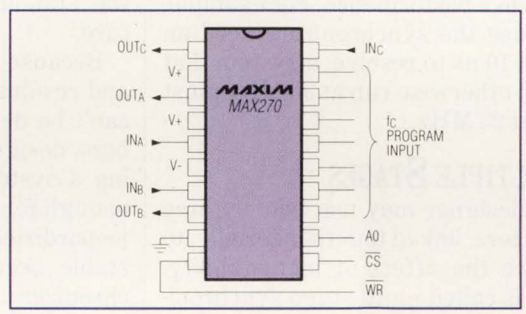

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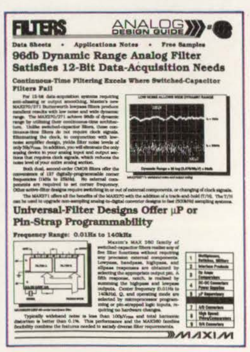

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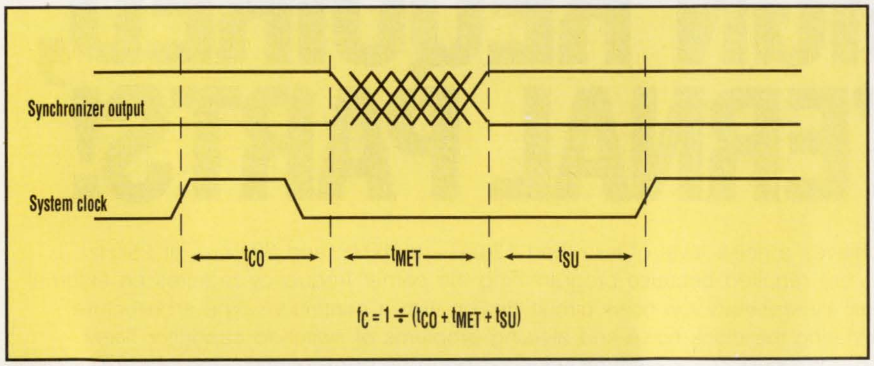


3. THE MAXIMUM SYSTEM-CLOCK FREQUENCY is determined by the synchronizing register's clock-to-output delay, setup time, and the calculated metastable wait time.

stable-hardened, though some manufacturers may make this claim.

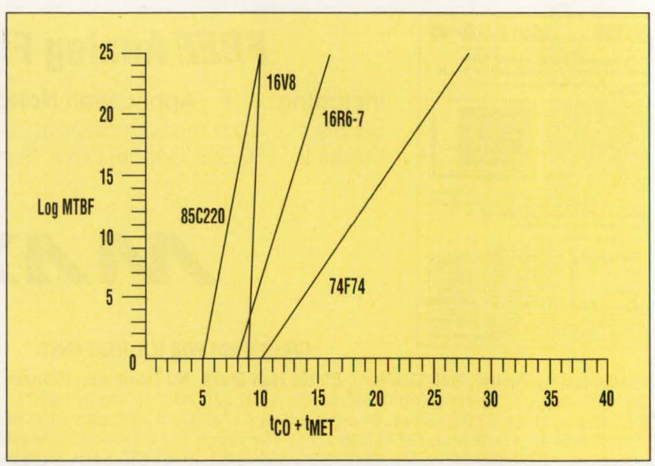
The easiest way to eliminate metastability is to reduce the system clock's speed, allowing plenty of time for the synchronizer to resolve. If the synchronizer's metastability constants are unknown, designers may pad the clock cycle time with a sizable extra period of time to allow for synchronizer resolution. Unfortunately, this directly eats into the system's performance. For example, because the synchronizers need an extra 10 ns to resolve, a system that could otherwise run at 30 MHz must run at 23 MHz.

Multiple Stages

A designer may use two or three registers, linked together serially, to reduce the effect of metastability. This is called multi-stage synchronization. The idea is that if the first register enters metastability, it will most likely resolve before the next register in line is clocked, which supposedly reduces the prospect of metastability by an order of magnitude. However, this idea fails to consider that if the first register doesn't resolve metastability before the next one is clocked, the next register will go metastable as well. The probability of this occurring isn't an additional exponential factor, but a linear one. The doubled or tripled cost for a multi-stage versus a single-stage synchronizer must also be weighed.

The solution that maximizes both board space and cost would be a single-stage synchronizer offering metastable resilience, so that the system could operate at the full desired clock rate. To design such a system, designers must examine the metastable characteristics of the register technologies and choose a register with the best metastable characteristics. As an example, consider the use of the 85C220 μPLD from Intel Corp. The 85C220 is a 20-pin, UV-erasable, high-speed CMOS programmable logic device based on the standard 20-pin PAL architecture.

Because metastable occurrences and resolution are probabilistic and can't be described in concrete numbers, designers may struggle choosing a system clock rate that's fast enough for top performance without jeopardizing the system with metastable occurrences from the synchronizers. These problems are easily solved by applying some mathematical formulas. As mentioned earlier, metastability causes trouble when the synchronizing register is sampled too soon after the specified t_{CO}. Slowing the system clock down accommodates the extra metastable resolution wait time, or t_{MET}.



4. WHEN WORKING WITH various register technologies, use these tau curves to determine their metastability.

To calculate t_{MET}, an acceptable mean time before failure (MTBF), or what would be an acceptable time for the system to operate before seeing any metastability, must be chosen. It's important to note the significance of the term mean time *before* failure. Typically, MTBF stands for mean time between failures, and denotes a hard, or unrecoverable, failure in a device or system. Because this article concerns soft, or recoverable, failures, mean time before failure was chosen to differentiate the two.

When referring to synchronizer metastability, MTBF is the mean time from a metastable failure of one synchronizer to the time when another occurs. Because metastability is probabilistic, MTBF describes the probability that a metastable occurrence will occur. When dealing with a system that has multiple synchronizers, each synchronizer's failure probability must be taken into account. Unlike average time, mean time before failures isn't linear. For a 100-year MTBF, one can't expect 100 years in between each synchronizer failure. Nor can one expect even 50 years. Rather, the probability decreases exponentially over time, and one can expect that in 100 years there's a 63.2% chance of failure occurrence. The equation for MTBF probability is:

$$P = 1 - (e^{(T/MTBF)^{(U/F)}})$$

where P is probability, T is time be-

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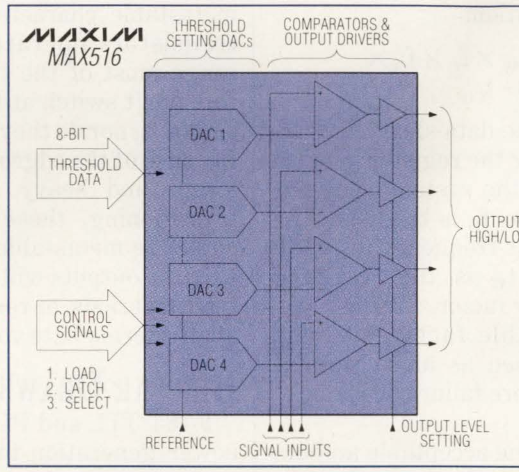

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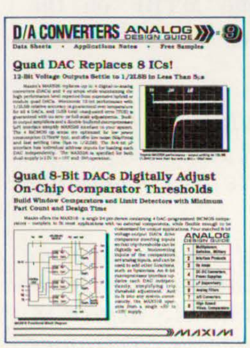

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tween failures in years, MTBF is calculated from device characteristics and system conditions, U is number of synchronizers operating, and F is the number of failures expected. The system designer must heed the probabilistic nature of MTBF to accurately determine system performance when they're given device characteristics, and must choose a value for MTBF.

Once the MTBF is chosen, the device's specifications and metastable characteristics are entered into the following equation:

$$t_{MET} = (\tau \times \ln(t_W \times f_C \times f_D \times MTBF)) - t_{CO}$$

where t_{CO} is the data-sheet clock-to-output time for the register in nanoseconds, f_C is the system clock frequency in MHz, f_D is the asynchronous data input frequency (estimated) in MHz, t_W is the register's failure-window factor, τ is the register's metastable factor tau, and MTBF is chosen as an acceptable mean time before failure, in terms of years.

Therefore, the acceptable amount of time to wait before sampling the output of a synchronizer is the normal t_{CO} plus the t_{MET} time. With this time factor calculated, the maximum clock frequency of the system may be calculated as follows:

$$f_C = 1/(t_{SU} + t_{CO} + t_{MET})$$

where t_{SU} is the register's data-sheet setup time in ns, and all other factors are identical to the previous equation *(Fig. 3)*.

In the case of the 85C220, the data sheet specifies a t_{CO} of 5.5 ns, a t_{SU} of 7 ns, a τ of 0.22 ns, and a t_W of 52. To calculate t_{MET}, 100 years is an acceptable MTBF. The input data frequency, f_D, is roughly 1 MHz. The input clock frequency, f_C, is not yet certain, but it will be at least 33 MHz. Substituting the actual figures:

$$t_{MET} = \{0.22 \times 10^{-9} \times \ln[52 \times (33 \times 10^6) \times 10^6 \times (3.15 \times 10^9)]\} - 5.5 \times 10^{-9}$$
$$= 7.0 \text{ ns}$$

Continuing, the maximum clock frequency for the system is calculated as:

$$f_C = 1/(7 \times 10^{-9} + 5.5 \times 10^{-9} + 7 \times 10^{-9})$$
$$= 1/(19.5 \times 10^{-9})$$
$$= 50 \text{ MHz}$$

So, for an 85C220 with a 100-year MTBF, the maximum clock frequency is 50 MHz.

Various register technologies give rise to different types of metastable failures from synchronizers. For instance, discrete registers built from standard bipolar technology, such as the 74LS74, have the least favorable metastable characteristics. Bipolar transistors operate in the linear range most of the time, and therefore don't switch at full-supply-voltage rails, nor do they switch quickly. Because of the edge rates, transition levels, and heavy loading during transitioning, these devices easily enter the metastable state. As a result, the outputs will oscillate for extended periods, or remain suspended at an intermediate voltage.

BIPOLAR DRAWBACKS

FAST TTL and PLDs based upon newer generation bipolar technology have vastly improved switching characteristics and speed, making them satisfactory as synchronizers. But the technology base is bipolar and has the disadvantages of near-linear operation and heavy loading. Therefore, while characteristics are improved in terms of transition time and pure clock-to-output speed, they're susceptible to oscillation or hanging up in the metastable region.

CMOS devices and programmable logic currently have the best characteristics because of the sharpness of the technology base. The circuitry uses MOS transistors in a complementary configuration, so voltages in the circuits switch from rail to rail and don't remain in the intermediate range of voltages between 0 and 5 V for any appreciable time. In addition, CMOS circuitry gives low node-to-node capacitance; low loading on driving stages; and high gain buffers in between the master and slave, and between the slave and the output stage. This causes the devices to switch from high to low and low to high very quickly. If a register-circuit stage begins to hold at an intermediate voltage, CMOS circuitry tends to resolve out of it quickly.

Intel's CMOS EPLDs have the advantage of a proprietary, high-speed process technology to create very fast internal feedback loops between register-circuit stages. Consequently, they create optimum metastable resolution characteristics. In addition, circuit-design techniques optimize the clock-to-output time, giving Intel CMOS EPLDs the shortest t_{CO} for any CMOS EPLD today. System designers can thus use faster system clock speeds for a given metastable resolution characteristic. This is possible because, according to the aforementioned equations, the total clock period will be shorter due to the shorter t_{CO}.

In the tau curves for the previously discussed technologies, the natural log of the MTBF runs along the Y axis, in terms of seconds multiplied by e to the power listed on the axis *(Fig. 4)*. The synchronizer sample delay $t_{CO} + t_{MET}$ is given along the X axis in terms of nanoseconds. The greater the slope of the line, the better the raw metastable characteristic. In the case of the 85C220, even though the slope is less than that of the GAL16V8A, the t_{CO} and t_{MET} values shift the metastable resolution time well over into the safe range. For a 100-year MTBF, or e^9, the 85C220 allows a $t_{CO} + t_{MET}$ of about 7 ns. For the same MTBF on the GAL16V8A, the $t_{CO} + t_{MET}$ allowed is about 9.5 ns.□

The author would like to thank James Cooper at Intel Corp., Folsom, Calif., for his help in developing this article.

Tom Bowns, field applications engineer for Wyle Laboratories, Seattle, Wash., holds an AS degree in digital and microwave electronics from American River College, Carmichael, Calif.

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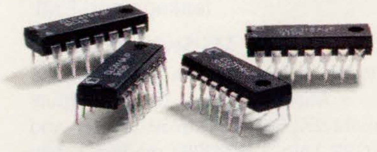

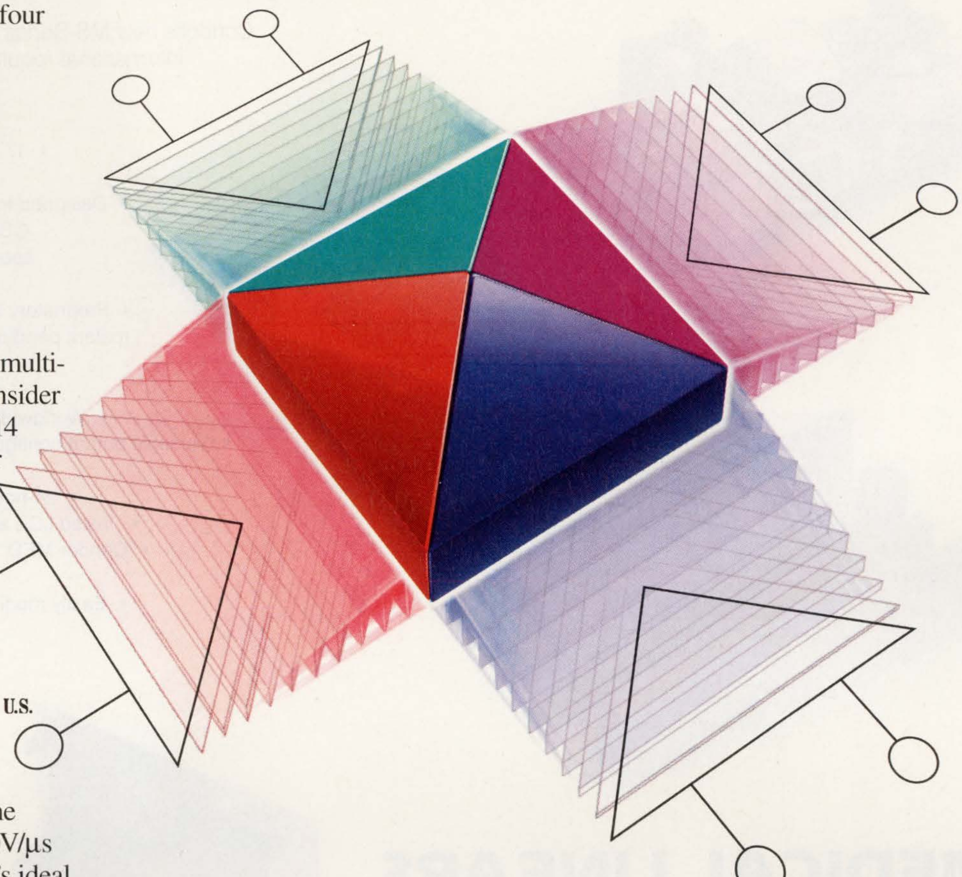

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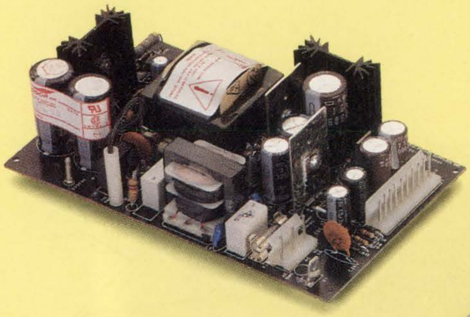

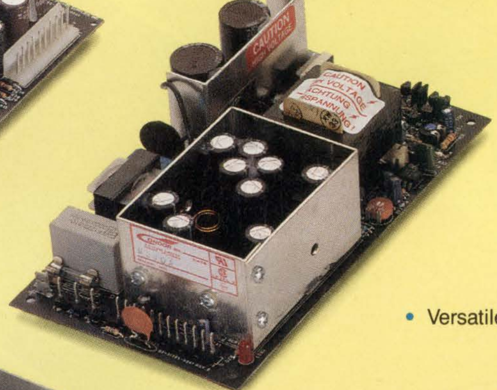

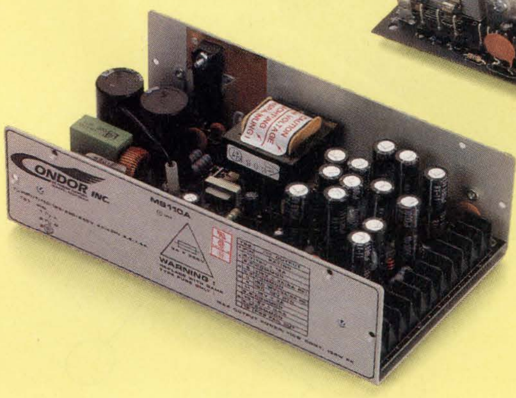

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- Power fail available on 110-watt units
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- Enclosures available for all models
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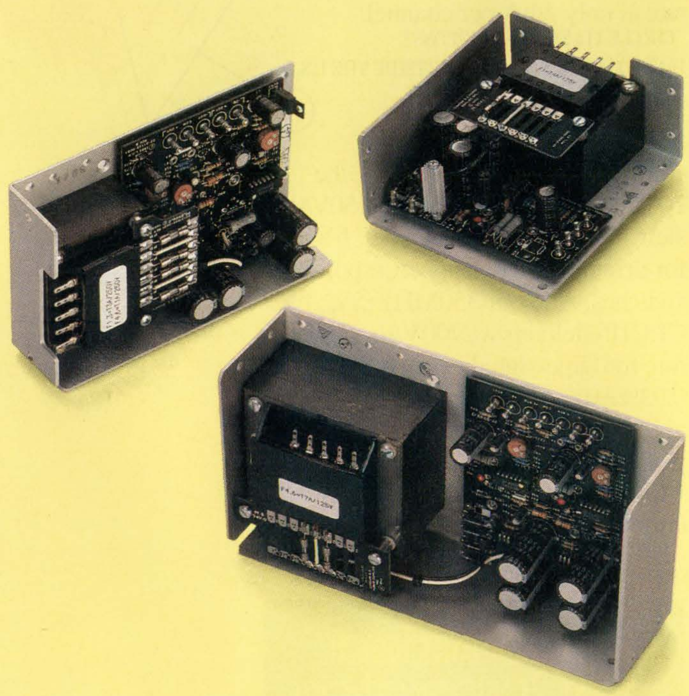

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- Industry-standard packages
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Taking The Mystery Out Of Switching-Power-Supply Noise

Understanding the source of unspecified noise currents and how to measure them can save your sanity.

BY CRAIG MAIER

Hewlett Packard Co., New Jersey Division, 150 Green Pond Rd., Rockaway, NJ 07866; (201) 586-5714.

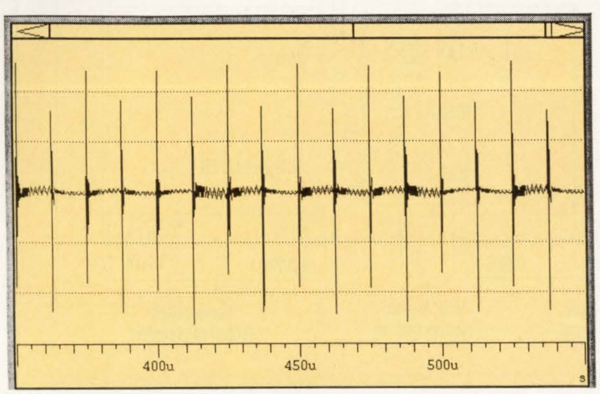
When it comes to purchasing and using a switching-mode power supply, engineers are generally accustomed to coping with normal-mode ripple and noise. This voltage noise is usually acknowledged by power-supply vendors on specification sheets as a worst-case value over a stated bandwidth. Armed with such information, users can readily determine whether or not a particular supply's normal-mode noise performance will fit their application's tolerances.

But there's another source of noise—common-mode current (CMI)—that can mysteriously manifest itself at the power inputs to a circuit when it's hooked up to the supply. Because CMI isn't typically measured or specified by power-supply vendors, users should be aware of how it can affect their circuits, how it originates, and how it can be measured in a standard way.

In most systems, the noise voltage produced by a power supply is measured at the supply's output terminals, typically with a passive resistor load on them. When a circuit or device under test (DUT) is connected to the supply, a common-mode current produced by the supply is transformed into a voltage at the circuit's power inputs. This transformation occurs because of the effects of imbalances in the DUT's common-mode impedance and that of the load (force) leads from the supply to the DUT. As a result, the DUT can be subjected to noise voltages greater than those nominally produced by the supply, and the test results can be unfavorably skewed to indicate that the circuit's noise-voltage tolerance is less than it actually is.

An instance in which common-mode current can wreak havoc with system performance is that of Doppler-radar, missle-guidance systems. In such systems, the difference in frequency between the outgoing and return signal due to the Doppler effect is often in the 10-to-200-kHz range, depending on the relative speed of the object from which the signal is reflected. Unfortunately, a switching-mode power supply can generate CMI with similar frequency characteristics, thus producing a false reading in any system designed without regard for CMI. Similarly, a test system for such radars could falsely reject good units if the common-mode current noise generated by the tester's power supplies was disregarded.

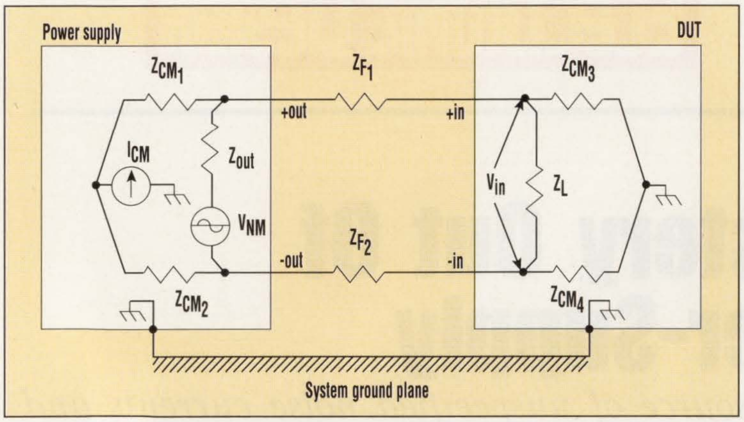
This examples indicates that common-mode current is a factor that must be considered before using a power supply—not only for radar testing, but perhaps for many applications. To understand its potential effect on an application, an engineer should first understand why and how CMI occurs.



1. Common-mode current noise typically shows up as a voltage-spike waveform superimposed on the normal-mode voltage at a circuit's input. Its frequency depends on the power supply's switching rate. Here, Spice simulation shows how a 50-mA common-mode current (CMI) affects a circuit with slight common-mode impedance imbalance. Scale is 5 mV/division.

Typically, common-mode noise current appears at the power inputs of a device connected to a power supply, showing up as voltage spikes superimposed on the normal-mode voltage *(Fig. 1)*. As the figure indicates, common-mode noise can be a greater problem than normal-mode noise, especially because of its high-frequency content.

The predominant source of CMI in a switching power supply is the switching transistors.



2. This model of common-mode current and normal-mode noise sources makes clear the role of impedances in the power supply, leads, and device-under-test in transforming the current into a voltage noise.

In switching, the voltage swing with respect to time (dV/dt) of the transistors generates an E field, which couples from the primary to the secondary of the supply's power transformer. By means of this coupling, unwanted current can flow through the supply's outputs when it is connected to an external system. A model shows how CMI can be transformed into voltage noise by imbalances in the circuit's impedances *(Fig. 2)*. Because the current won't actually flow unless there's a device having pathways to earth ground connected to the supply, CMI will not manifest itself at the output of an unloaded supply as normal-mode noise will.

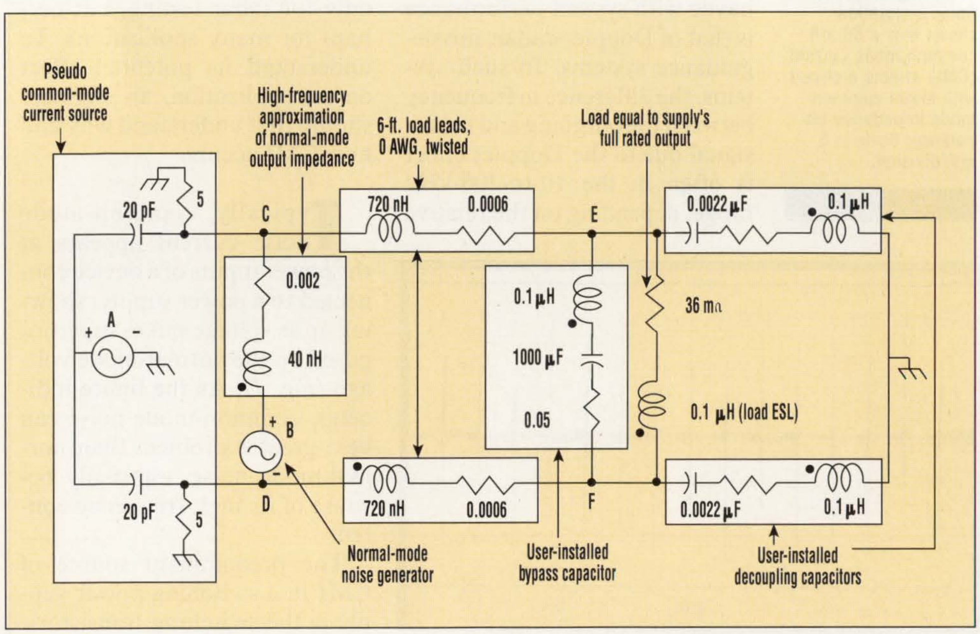
While common-mode current is an important concern with switching-mode power supplies, this is not to say that linear power supplies do not produce CMI as well. But in the case of linear supplies, CMI is usually more benign.

The most troublesome source of CMI in a linear supply is the rectifier diodes. The turn-off characteristics of the diodes can give rise to a common-mode noise spike at the full-wave rectification frequency (120 Hz, or twice the line frequency). If these diodes are not properly snubbed in a high-power linear supply, the resultant noise can be as high as 5 mA pk-pk. But, in general, linear supplies are designed to produce less power than switching-mode supplies, so their diodes operate with relatively low currents. Thus, the diodes tend to turn off with low residual currents and, as a result, the noise they produce tends to be fairly small.

Another mitigating factor in a linear supply is the extremely low-frequency content of the CMI it generates. The magnitude of the voltage developed because of CMI depends on frequency as well as the common-mode impedance, that is, $j\omega L$ for inductance differences and $1/j\omega C$ for capacitance differences. Because the frequency content is low, the magnitude of the noise conversion will also be low. Further, most of today's high-power circuit subassemblies have one or more voltage regulators built into the power-input circuitry. These regulators are able to filter out a linear power supply's 120-Hz noise and mitigate, if not entirely eliminate, the effects of CMI.

The frequency content of the CMI produced by switching supplies, on the other hand, is related to the switching rate of the supply—typically 20 to 200 kHz or higher. At such frequencies, it can easily bypass the regulators. Linear supplies may have a maximum CMI of 5 mA pk-pk, but it is not uncommon to find switching supplies whose CMI ranges from a low of 50 mA pk-pk to a high of 500 mA pk-pk or more. (An exception to this is the new HP 6670 series and 66000 systems power supplies. These switching supplies produce CMI in the 4-to-5-mA pk-pk range.)

The actual effect of CMI on a circuit depends on its configuration. To get a feel for how circuit configuration makes CMI apparent, consider an idealized circuit *(Fig. 3)*. In this figure, a power supply (circuitry to the left of points C and D) provides inputs to a DUT (points E and F), to which a user has added a bypass capacitor and com-



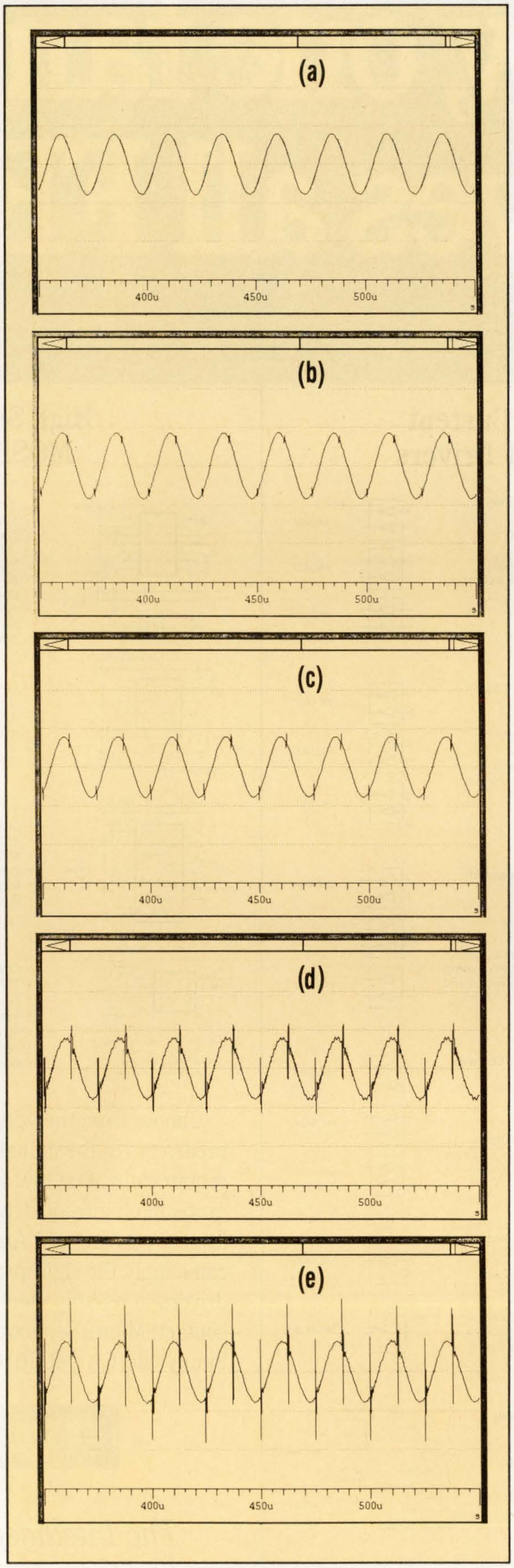
3. An ideal, balanced circuit can show how circuit configuration makes CMI apparent. A power supply is represented by the circuitry to the left of points C and D, which are its outputs. It provides inputs to a DUT, whose inputs are at points E and F.

mon-mode decoupling capacitors, by means of 6-ft-long load leads. The power supply produces a very low CMI of only 1.25 mA, and the common-mode impedances of both the leads and the DUT are balanced with respect to chassis ground. Therefore, when the voltage is measured at the input to the device (across points E and F), only the normal-mode voltage noise appears. The effect of CMI is canceled out due to the balanced-bridge circuit configuration *(Fig. 4a)*.

If there's a slight imbalance in the length of the load leads, CMI will begin to appear at the DUT. If the top lead is one foot shorter and has an inductance of 500 nH, versus the 720 nH inductance of the longer lower lead, a small voltage-spike waveform because of conversion of CMI will be superimposed on the normal-mode voltage noise *(Fig. 4b)*.

It's a common practice to tie the negative rail to ground somewhere in the system. The way in which this is done can make the effects of CMI more or less pronounced. If the negative output of the supply is connected to chassis ground at the power supply end of the load leads (assume the connection has 40-nH inductance), there will be some slight effect of CMI at the DUT *(Fig. 4c)*. If, however, the negative input of the DUT (point F) is connected to chassis ground, there's a more pronounced effect in converting CMI to voltage noise at the DUT *(Fig. 4d)*.

The worst-case situation by far, however, is the effect of a device with unequal impedances between its input terminals and chassis ground. If the paths from the decoupling capacitors in the DUT to chassis ground were of different lengths, say 1.5 in. and 10 in., there would be inductance differences of 30 nH and 200 nH, respectively. The



4. In Spice simulations of the ideal circuit of Fig. 3, all measurements are taken at points E and F, which represent the inputs to the DUT. Scale in all plots is 200 μV/division. Simulation shows that the effects of a small 1.25-mA CMI are balanced out, leaving only normal-mode noise at those points (a). Different lead impedances begin to transform CMI into a voltage (b). Grounding the negative output of the supply (c) is less harmful than grounding the negative input of the circuit (d). The worst noise condition (e) results from a slight imbalance in the circuit-under-test's impedances with respect to ground (30 nH and 200 nH).

CMI noise would be converted to a voltage noise at the DUT inputs, and this common-mode noise would produce a greater peak-to-peak magnitude than the normal-mode voltage noise *(Fig. 4e)*.

While it's often possible to balance the inductance of the load (by ensuring that the leads are equal in length) and control the grounding scheme used, the design of the device under test often mandates an impedance imbalance that must be tolerated, especially when there are parasitics involved. Thus, the CMI of the power supply often becomes the critical aspect in determining the amount of noise that will appear at the device-under-test's inputs.

If a power supply has a CMI of 4 mA pk-pk, then the amount of noise appearing at the input of the unbalanced device described above (with differences in path lengths for the chassis-ground decoupling capacitors) will be 2 mV *(Fig. 5)*. Compare this to the typical noise of 24 mV, which is the noise for the same circuit when the CMI is 50 mA pk-pk *(Fig. 1, again)*. That's the low end of the typical range for switching power supplies. Obviously, one of the most critical aspects of reducing noise effects on a device is making sure that the power source produces very little CMI.

While the conversion of CMI to voltage noise depends upon grounding and impedance im-

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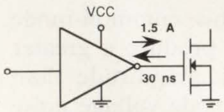

Drives a hex 0 - hex 3 size MOSFET; 400 pF to 3000 pF.

MIC426/7/8 (Original)
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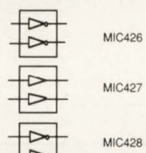
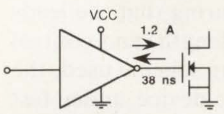
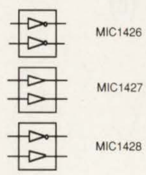
- 4.5 V to 18 V supply
- 1.5 A peak output
- 6 Ω output impedance
- Available in surface mount packages

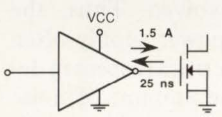




Drives a hex 0 - hex 3 size MOSFET; 400 pF to 3000 pF.

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





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

MIC4426/7/8 (Protected)
- Latch-up protected
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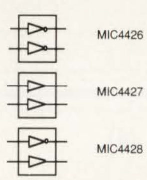
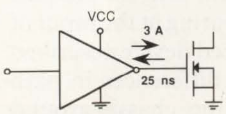
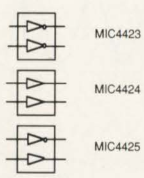
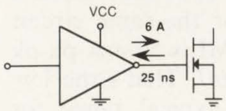




Drives a hex 4 - hex 5 size MOSFET; 6000 pF to 12000 pF.

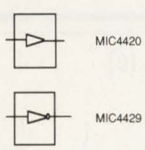
MIC4423/4/5 (High Current)
- Latch-up protected
- 25 nS into 1800 pF
- 4.5 V to 18 V supply
- 3 A peak output
- 3.5 Ω output impedance
- Withstands 5 V negative swing
- Available in surface mount packages

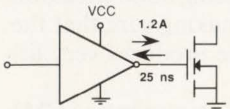




Drives a hex 6 - hex 7 size MOSFET ; 15000 pFto 16000 pF

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





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

MIC4465/6/7/8/9 (Quad)
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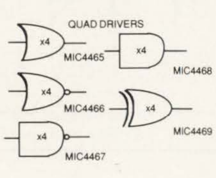
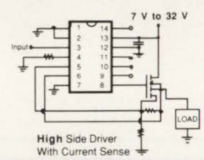
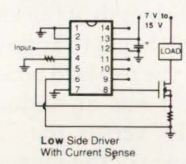
- 25 nS into 470 pF
- 4.5 V to 18 V supply
- 1.2 A peak output
- Available in surface mount packages
- Five logic choices

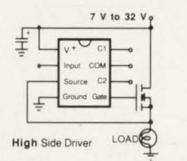


High Side, Protected MOSFET Drivers

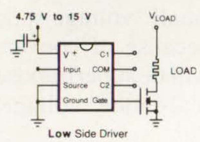


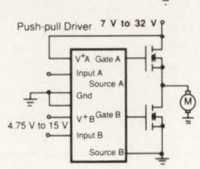
MIC5010
- Full Featured predriver
- Optional speed up caps
- 7 V to 32 V supply
- Internal charge pump
- 60 μS into 1 nF
- Over current sensing
- Fault flag output
- Surface mount packages
- Dynamic sensing threshold



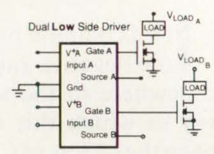


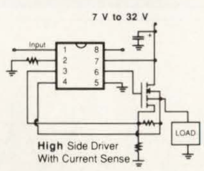
MIC5011
- Minimum parts count
- Optional speed up caps
- 4.75 V to 32 V supply
- Internal charge pump
- 60 μS into 1 nF
- Surface mount packages



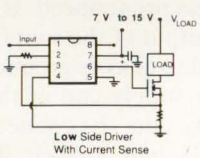


MIC5012
- Dual predriver
- Provides high and low side
- 4.75 V to 32 V supply
- Internal charge pump
- 60 μS into 1 nF
- Surface mount packages





MIC5013
- Over current sensing
- 7 V to 32 V supply
- Fault flag output
- Internal charge pump
- 60 μS into 1 nF
- Surface mount packages
- Dynamic sensing threshold



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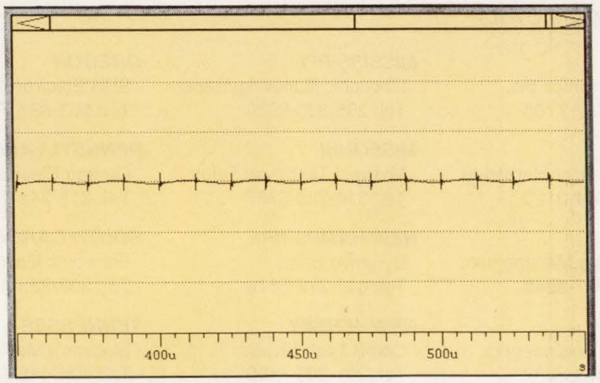
balances of leads and the common-mode impedances of the device, the amount CMI generated is primarily dependent upon the design of the power supply. It should be noted that in an ideal circuit, the power supply's common-mode impedance is balanced between the positive and negative outputs *(Fig. 3, again)*. A balanced common-mode output impedance ensures that the CMI-related voltage noise seen at either output port will be equal and opposite. This is one goal for a good power-supply design.

Another aspect of power-supply design that affects CMI is the supply's switching frequency. As noted, the conversion of CMI to a voltage is frequency dependent, and the lower the switching frequency, the less it will be. Further, limiting the switching speed of the transistors allows slower dV/dt transitions, thereby minimizing common-mode noise.

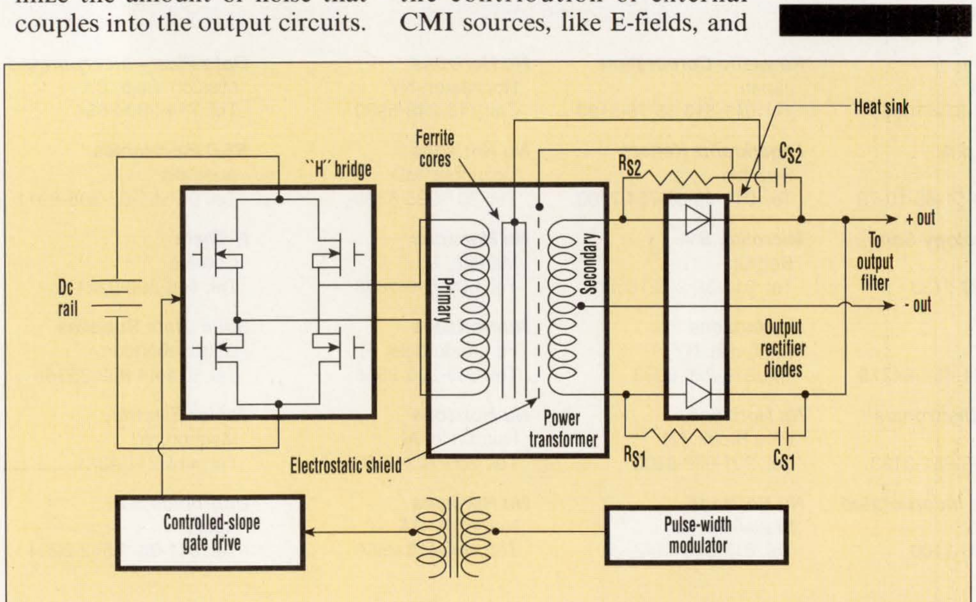
By nature, however, the dV/dt characteristics of the switching devices used in any switcher are bound to create noise fields. That's why it's also important to ensure that the switching segment of the supply is properly isolated from the output to minimize the amount of noise that couples into the output circuits.



5. The best way to minimize the effects of CMI on circuit performance is to use a power supply that produces very little CMI. With a 4-mA CMI, the voltage shown here appears at the input to a circuit-under-test with minimal impedance imbalance. Compare this to the effect of using a supply that produces a 50-mA CMI, as shown in Fig. 1. Scale is 5 mV/division.

Also, it may help to have an electrostatic shield in the power transformer and sufficient primary-to-secondary spacing to minimize capacitance *(Fig. 6)*. Balanced, multiple-pole, common-mode filtering at the supply's output will further ensure that a minimum amount of CMI is injected into the output circuit *(Fig. 7)*.

The design of the power supply's grounding strategy can also affect CMI performance. A single-point ground is better for the output's common-mode filter than a ground plane. This ground point is the quietest point in the supply and can be made available externally for connecting the load-lead shields. The effect is to minimize the contribution of external CMI sources, like E-fields, and other RF sources on the power supply's output noise.



6. Using electrostatic shielding in the design of a power-supply transformer helps prevent CMI from being passed on to the outputs.

Because CMI noise is a rarely specified, yet important specification for many applications, users themselves will often need to make CMI measurements or specify the way in which they are to be made. The overall instrumentation requirements for making measurements of a power supply's CMI noise performance are relatively straightforward *(Fig. 8)*.

The input to the supply comes from a variable transformer tied to the power mains. The transformer lets a test engineer optimally adjust the power-supply input for testing. For example, if the highest tolerance of a nominal 120-V line input is 127 V, the transformer should be adjusted so that it produces 127 V.

Having this adjustment capability permits measurement of the worst-case value of CMI. As already noted, CMI depends on the dV/dt of the switching transistors. Because the switching time, dt, is relatively constant once the power supply has stabilized, the worst-case conditions will exist when dV is greatest. That's when the voltage swing at the switching transistors is largest because of the input voltage.

The variable transformer's output must be monitored to ensure that this condition is achieved and maintained throughout the test. Therefore, ac-input-voltage monitoring is a necessity. The monitoring function has been shown attached to the transformer with dashed lines to reflect the availability of variable transformers with built-in monitors.

The supply's output is connected to an electronic load by means of lead wires wound around toroidal cores to create a current choke. Without this choke, some of the common-mode current could flow through the electronic load to earth ground and would not be measured. But the choke causes

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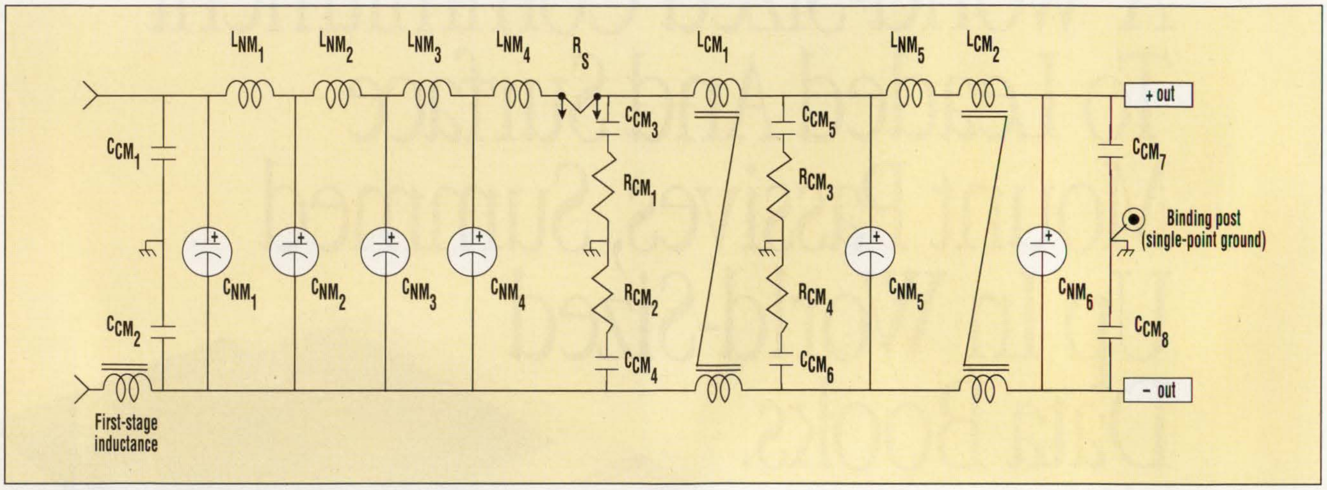


7. Balanced common-mode filtering on the output of a supply is the final stage in reducing CMI.

all CMI to flow through the shunt for measurement.

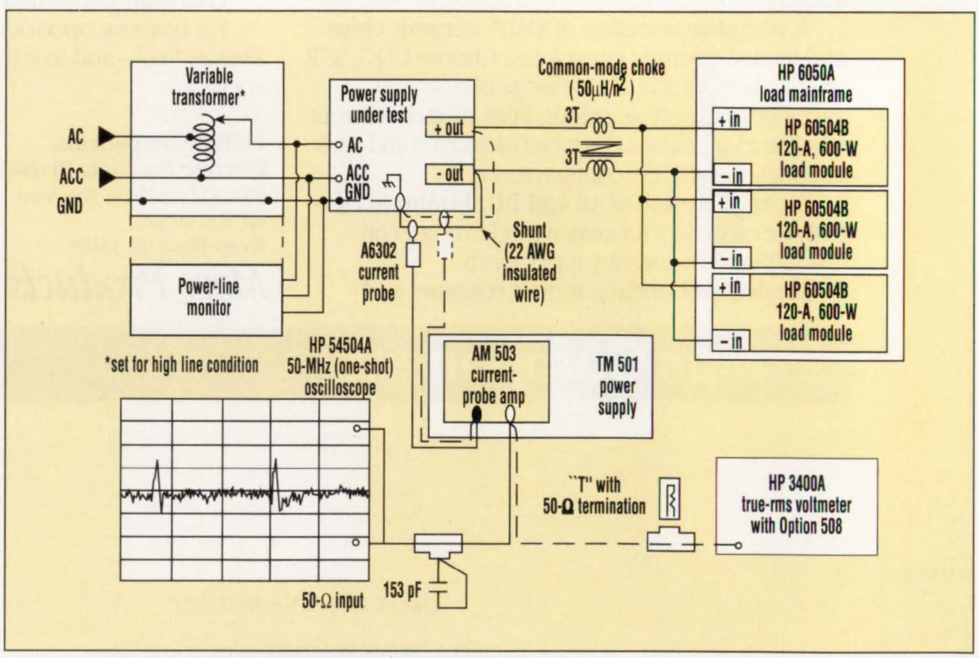
To measure the performance of a 2-kW supply, three TDK toroids of H5C2 material (permeability = 10,000) with three turns through the cores of both load lead wires were used for the choke. The plot of impedance-per-turn-squared (parallel resistance) as it varies with frequency is shown for this family of cores *(Fig. 9)*.

The electronic load is an HP 6050A system with three HP 60504B load modules. Each module is capable of handling about 600 W, and the three modules are used in parallel to accept the output of a 2-kW supply. It is also possible to use a different form of load system. If power resistors capable of withstanding the power can be found, it is possible to use them. That way, no choke system would be needed, because the power resistors present no significant common-mode path to ground. However, the electronic load simplifies taking measurements at several operating points, which is required for CMI testing. Further, the electronic load aids in taking the usual dynamic-characteristic measurements.

Because a supply may not have a balanced common-mode output impedance, and since the signal being measured comes from a psuedo current source, measurements of CMI should be taken separately from the positive and negative outputs of the supply. The current probe and shunt arrangement for taking the negative-output CMI measurement is shown with solid lines, while that for taking the positive-output CMI measurement is shown with dashed lines *(Fig. 8, again)*.

To measure the negative-output CMI, the negative output is connected to the ground plane through a short length of 22 AWG wire used as a current shunt. Because the choke prevents the CMI from flowing to the load, virtually all of the common-mode current flows through the shunt and can be measured there.

The shunt should be as short as possible to minimize impedance to ground. In the case of the 2-kW switcher test, the wire used was only 3.5 in., because a system-ground terminal is available close to the output posts. When making comparative measurements among two or more different supplies, the same shunt should be used for all supplies tested so that any



8. To direct all CMI through a shunt so that it can be measured with a current probe, a common-mode choke prevents any fraction of the CMI from passing to the electronic load system.

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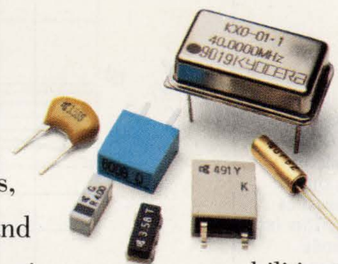

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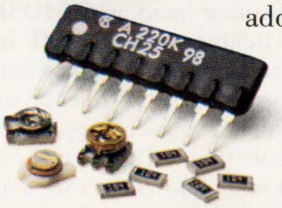

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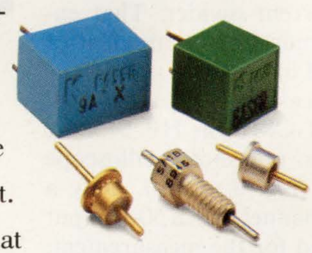

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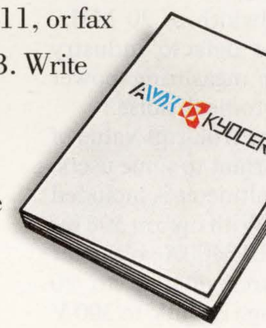

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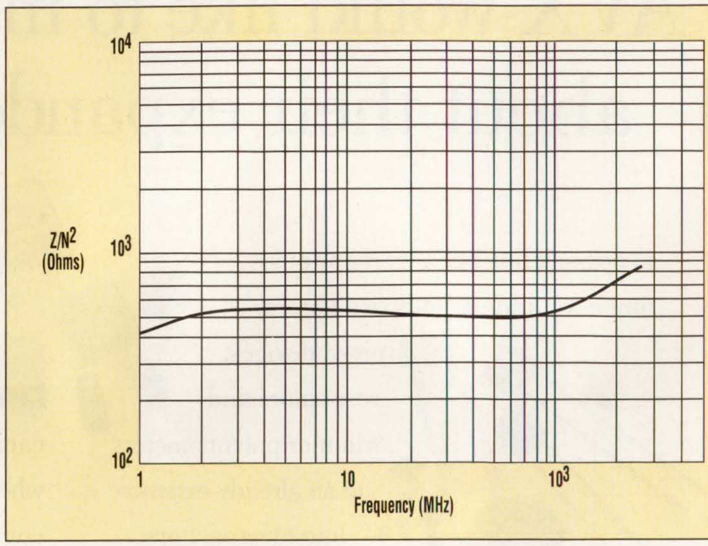
shunt-inductance effects will be identical.

A Tektronix A6302 current probe, used with an AM 503 current-probe amplifier and TM 501 power-module mainframe, senses the current flowing through the shunt. The essential characteristics of the probe, which senses current by means of inductive coupling, are its ability to measure currents as small as 1 mA (up to 50-A peak pulse), a bandwidth over 20 MHz (actual bandwidth is dc to 50 MHz), and its low capacitive loading. The latter feature ensures that the probe doesn't act as a current divider. That enables accurate measurement of the CMI in the shunt.

To measure the peak-to-peak value of CMI, an HP 54504A 50-MHz, one-shot oscilloscope is used *(Fig. 8, again)*. Only a single channel with a 50-Ω input is needed for the measurement; with a minimum deflection of 10 mV/division, the scope easily displays even the smallest CMI measurable with the probe. A 153-pF capacitor limits the scope's bandwidth to 20 MHz, which is the defacto industry standard for measuring power supply peak-to-peak noise.

Because the true-rms value of CMI is important to some users, a true-rms voltmeter is included in the setup. With option 508 installed, the HP 3400A voltmeter takes measurements up to 20 MHz. Its range is 1 mV to 300 V and it handles crest factors of 10:1. A "T" connector with a 50-Ω termination provides the impedance necessary for the voltmeter to work with the current-probe amplifier.



9. The curve for impedance versus frequency for a TDK toroidal core made of H5C2 material shows stable characteristics with frequency. This is the common-mode blocking impedance between the power supply and the load.

With the instrumentation setup described, CMI measurements for a typical power supply should take no more than 10 to 15 minutes. Changes in switching pulse width causes CMI to vary over the output range of the supply, so the most valuable measurement will be the worst-case value over the supply's entire output range. A worst-case measurement lets an engineer make accurate comparisons of the performance of different supplies over a full operating range. The basic methodology for finding the worst-case CMI is to sweep through a number of load settings. One can begin at the maximum power output and work down, or start from the bottom and work up.

While it might seem that there's no reason to measure CMI at zero output power, this isn't the case. Theoretically, the switching circuitry should produce no pulse width at zero power, and hence no CMI. But it doesn't happen that way in practice. Many large switching supplies use a circuit, such as an active downprogrammer, to keep the pulse-width modulator working at zero output. That means it's possible to have some CMI with zero output power.

It may, in some cases, be wise to consider allowing time for power-supply warmup before taking measurements. In the case of switching supplies where ordinary bipolar transistors or insulated-gate bipolar transistors are used, temperature can affect their performance. Initially, when they're cold, such devices tend to switch faster. Because CMI is proportional to switching speed, supplies that use these devices will tend to have a higher CMI when they're cold than when they're hot. On the other hand, with MOSFET-switching designs CMI is not significantly affected by temperature changes. While the way in which a power supply will be used in its final application should influence the way in which it is tested, it should be noted that, in general, power-supply specifications apply after some specified warm-up time.

Acknowledgement:
The author wishes to thank Mike Benes, Robert Bland, and Robert Young for their contributions in developing the concepts presented in this article.

Craig Maier, R&D project manager at Hewlett-Packards's power-supply operation in Rockaway, N.J., holds a BSES degree with a specialization in biomedical engineering from the New Jersey Institute of Technology, Newark.

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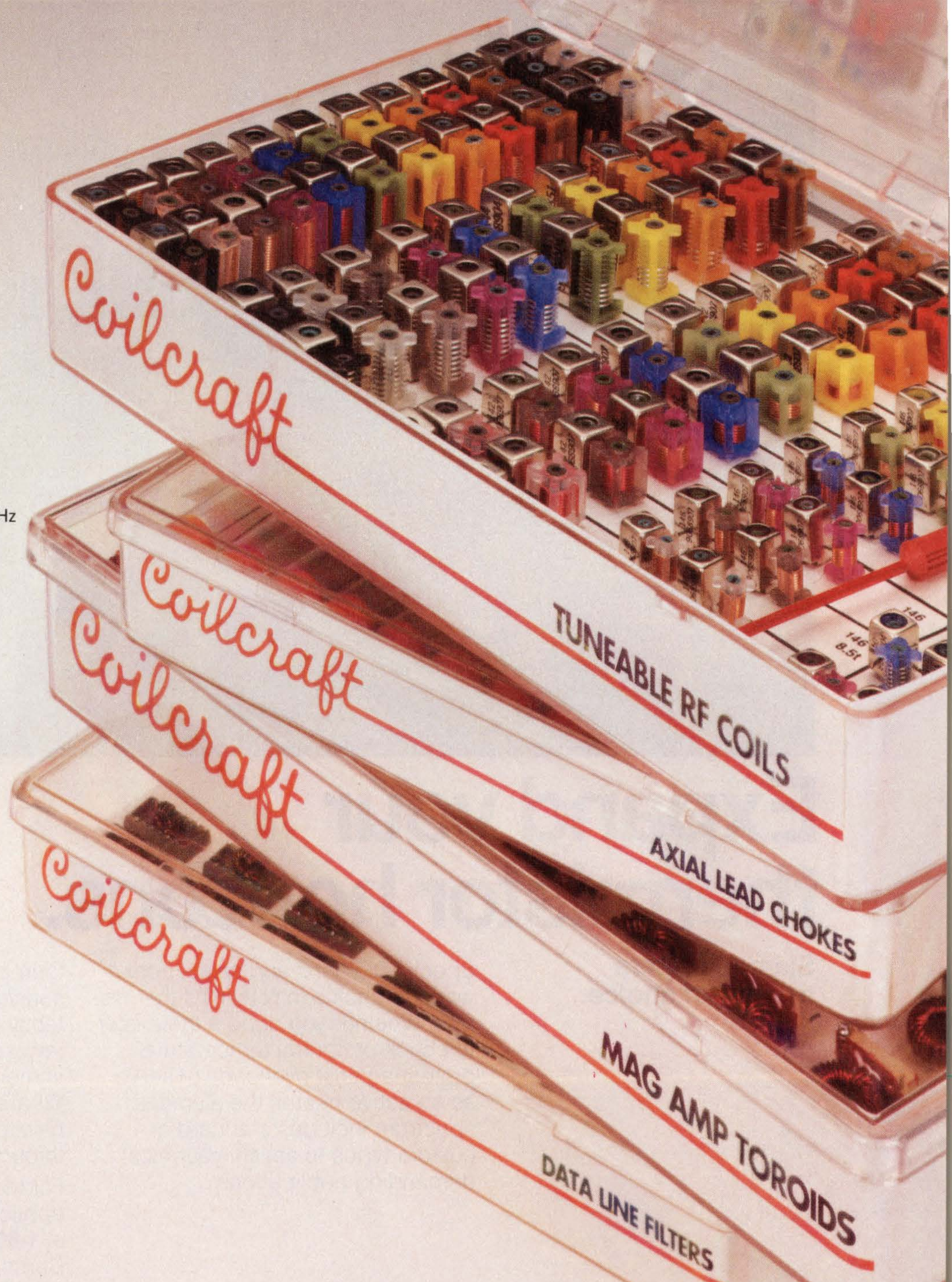

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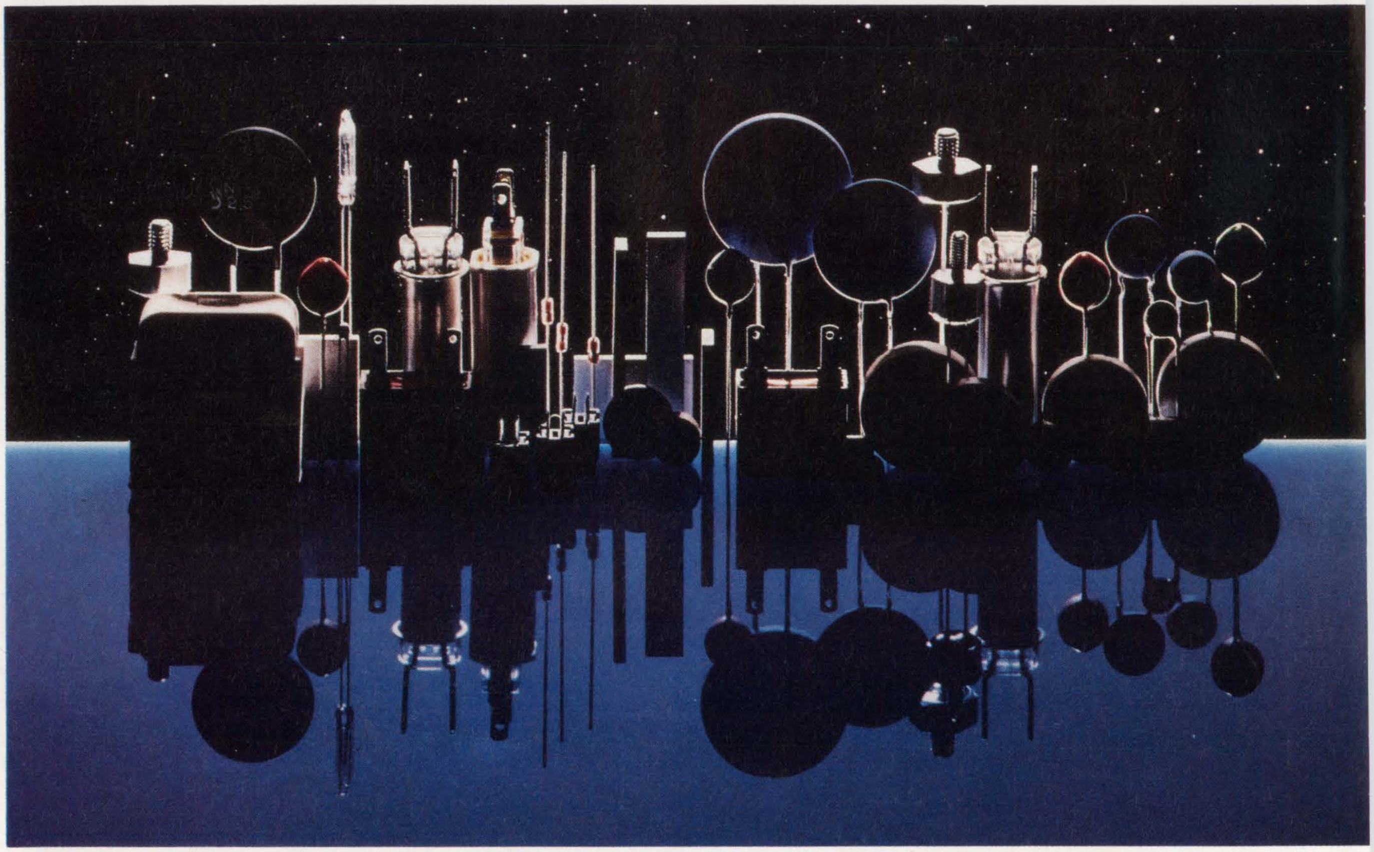

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The Fundamentals Of Thermal Design

Keeping semiconductors from overheating means coming to terms with heat sinks and thermal basics.

BY CHESTER SIMPSON

National Semiconductor, 690 Kifer Rd., Sunnyvale, CA 94086; (408) 721-7501.

When a semiconductor dissipates power, the heat that's generated raises the device's operating temperature. This heat must be conducted away from the die and transferred to the surroundings to keep the die's temperature within safe limits. This article contains information on selecting and specifying heat sinks with emphasis on the most commonly used package types: TO-3 and TO-220. In addition, we'll look at ways to use pc-board copper to dissipate heat in DIP packages and axial-mounted components.

A fundamental law of thermodynamics states that heat always flows from a hotter body to a cooler one. This concept has significant implications that apply in every case where a component dissipates power:

- The junction temperature will always be higher than the case temperature.
- The case temperature will always be higher than the heat-sink temperature.
- The heat-sink temperature will always be higher than that of the surrounding air.

These "rules" follow directly from the fact that the overall direction of heat flow is from the heat generator (which in this case is the die) to its surroundings by whatever means of conduction is available.

A cutaway view of a TO-220-type semiconductor mounted on a heat sink illustrates the concept of heat flow *(Fig. 1)*. The die is the source of the heat, which is shown flowing through the heat sink. Because the middle fin is closer to the source than the outer fins, it would be hotter than the outer fins. Heat is also flowing from the die through the molded plastic into the air on the side away from the heat sink. The heat transfer here would be very poor because the plastic is a very poor thermal conductor (which means it's a good thermal insulator).

In the following sections, precise techniques are developed to quantify "good" and "poor" thermal conductors, as well as calculate heat-sink requirements for specific applications.

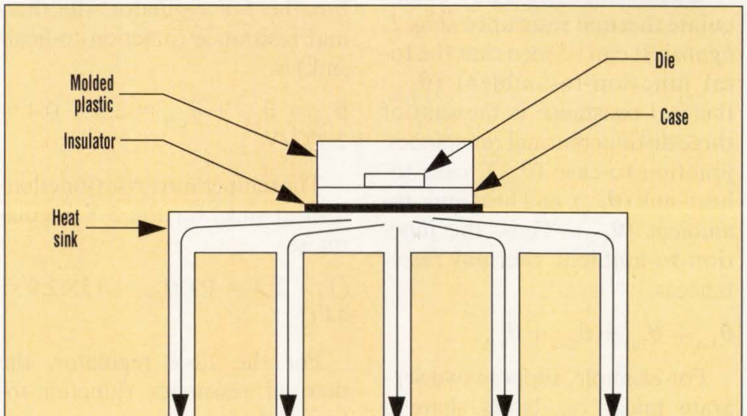
Thermal resistance (θ) represents a measure of how well a material prevents heat from flowing through it. What follows is that a lower value of thermal resistance means a better conductor of heat, and a higher value indicates worse heat conduction.

A simple circuit shows a current, a resistance, and a voltage differential *(Fig. 2)*. The same diagram can model a thermal circuit showing heat flow, thermal resistance, and temperature differential.

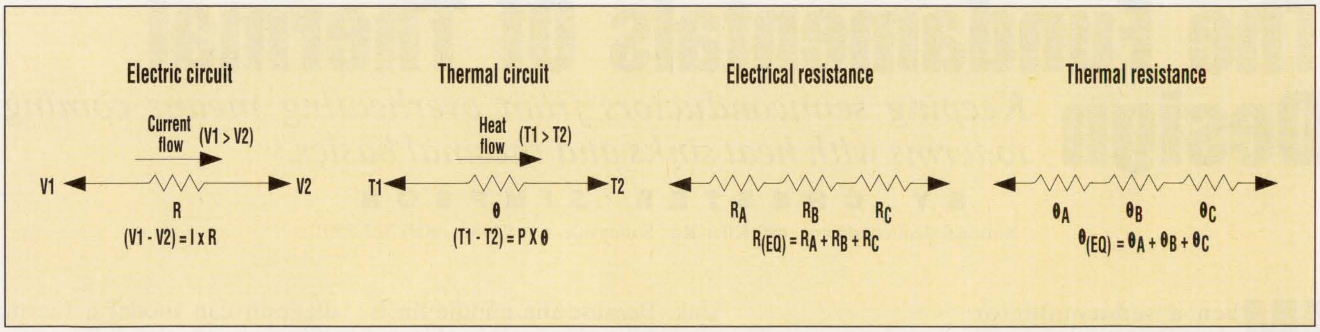
In the electric circuit, it's shown that if a voltage differential is forced across an electrical conductor, a current flows from the higher voltage to the lower voltage. It's equally valid to state that if a current is forced through an electrical conductor, then a voltage differential results across the conductor with the higher voltage being at the source of the current.

In the thermal circuit, a temperature differential forced across a thermal conductor results in heat flowing from the hotter point to the cooler point. Also, if heat is forced to flow through a thermal conductor, a temperature differential results across the conductor with the higher temperature being at the source of heat flow.

Another important similarity is that in either case, the equivalent of a series of resistances is found by simply adding together



1. A cutaway view of a power semiconductor mounted on a heat sink shows the path of heat flow. Starting at the source (the die), the heat flow is primarily through the case and into the heat sink, where it's transferred into the ambient air.



2. Electrical and thermal resistance are completely analogous when modeled. Both types of resistances add algebraically when they're added in series.

each of the individual resistances. Also, in both cases an ideal conductor would be one whose value is zero (because the lower the value, the better the conductor).

An important difference to note is that electrical resistance is in ohms, while thermal resistance is given in °C/W. The term °C/W is convenient for specifying and selecting a heat sink, because the temperature rise for a given power dissipation can be found by multiplying by the power in watts. Always remember that you must use the total thermal resistance from junction-to-ambient to find the total temperature rise for a specific application.

Accurately determining thermal resistance requires evaluation of every thermal interface from point of origin to the ambient air. This is detailed in the following example.

An illustration can be used to demonstrate how to calculate thermal resistance *(Fig. 1, again)*. It can be seen that the total junction-to-ambient ($\theta_{J\text{-}A}$) thermal resistance is the sum of three distinct thermal resistances: junction-to-case ($\theta_{J\text{-}C}$), case-to-heat-sink ($\theta_{C\text{-}S}$), and heat-sink-to-ambient ($\theta_{S\text{-}A}$). Thus, the junction-to-ambient thermal resistance is:

$$\theta_{J\text{-}A} = \theta_{J\text{-}C} + \theta_{C\text{-}S} + \theta_{S\text{-}A}$$

For example, suppose two separate linear regulators share a heat sink. One regulator is an LM309K 5-V regulator in a TO-3 package and the other is an LM7812CT 12-V regulator in a TO-220 package. The following data has been calculated:

$P(5\text{ V}) = 15\text{ W}$
$P(12\text{ V}) = 10\text{ W}$

Problem: Specify the thermal resistance of the heat sink so that the maximum junction temperature of either part doesn't exceed 125°C. The maximum ambient temperature is 30°C. The data sheets specify $\theta_{J\text{-}C}$ as 2.5°C/W for the LM 309K and 4°C/W for the LM 7812CT. Mica insulators with thermal grease are used, which means:

$\theta_{C\text{-}S}(5\text{ V}) = 0.4°\text{C/W}$
$\theta_{C\text{-}S}(12\text{ V}) = 1.6°\text{C/W}$

The best way to solve a case with multiple heat sources is first to calculate the temperature rise (junction-to-case) for each part. Then, use that to determine the maximum allowable heat sink temperature. The thermal resistance of the heat sink is then found using the total power. For the 5-V regulator, the thermal resistance (junction-to-heat-sink) is:

$\theta_{J\text{-}S} = \theta_{J\text{-}C} + \theta_{C\text{-}S} = 2.5 + 0.4 = 2.9°\text{C/W}$

The temperature rise (junction-to-heat-sink) for the 5-V regulator is:

$(T_J - T_S) = P\times\theta_{J\text{-}S} = 15\times 2.9 = 44°\text{C}$

For the 12-V regulator, the thermal resistance (junction-to-heat-sink) is:

$\theta_{J\text{-}S} = \theta_{J\text{-}C} + \theta_{C\text{-}S} = 4 + 1.6 = 5.6°\text{C/W}$

The temperature rise (junction-to-heat-sink) for the 12-V regulator is:

$(T_J - T_S) = P\times\theta_{J\text{-}S} = 10\times 5.6 = 56°\text{C/W}$

The maximum allowable heat-sink temperature is found using the data from the 12-V regulator calculation. Because the temperature rise is greater, it requires a lower maximum heat-sink temperature.

The maximum heat-sink temperature is:

$T_J(\text{MAX}) - (T_J - T_S) = 125 - (56) = 69°\text{C}$

The required thermal resistance of the heat sink can now be found:

$T_S - T_A = P\times\theta_{S\text{-}A}$
$69 - 30 = (15 + 10)\times\theta_{S\text{-}A}$
$\theta_{S\text{-}A} = 1.6\text{ °C/W}$

Note that the total power must be used because one heat sink will have both regulators on it.

A heat sink with an effective thermal resistance of 1.6°C/W is quite large and expensive, and this number may spur the designer to seek a more efficient way of meeting the application's load requirements.

An important point shown by this example is that the part that

TABLE 1: 16-PIN DIP

L (in.)	H (in.)	$\theta_{J\text{-}A}$ (°C/W)
1	0.5	70
2	1	60
3	1.5	58
4	0.19	66
6	0.19	66

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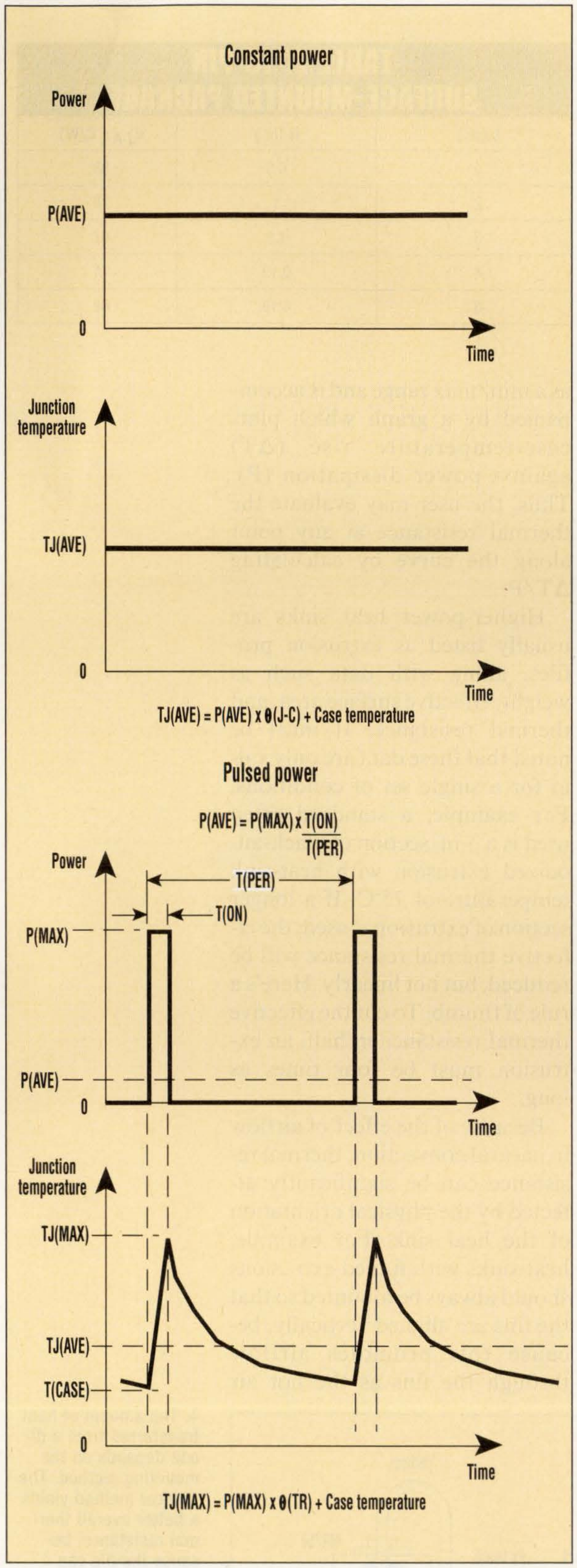
dissipates less power operates at a higher junction temperature. That's because of the TO-220 package's higher thermal resistance compared to the TO-3 package. It also points out an important design tradeoff. Money saved by using a part in a cheaper package must often be spent on a larger heat sink.

Thermal resistances from junction-to-case and from case-to-heat-sink become much more important as power dissipation rises. For example, improving the thermal resistance of a heat sink by 1.5°C/W would require a large increase in size, weight, and cost. However, a 1.5°C/W improvement in the package's thermal resistance can easily be made by going from the TO-220 case to the TO-3 case. Because these thermal resistances add in series, improvements (reductions in thermal resistance) made at any point in the series reduce the total thermal resistance by the amount of that reduction.

When the power dissipated within a semiconductor varies with time, calculating the peak junction temperature requires using the transient thermal resistance. The difference between constant and pulsed power can be illustrated *(Fig. 3)*. In the constant-power case, the power does not vary with time. The junction temperature is also constant, and can be calculated using the equation shown for T_J(AVE).

When the power flows in repetitive pulses, the junction temperature is not constant. The semiconductor die can be modeled as a thermal capacitor, which "charges" when the power pulse is applied, and "discharges" when the pulse ends. The rate at which the junction temperature rises during the charge phase relates to the value of P(MAX). The rate at which the junction temperature falls during the discharge phase depends on the temperature differential between the junction and the case.



3. Power that flows in pulses causes die heating, which results in a junction temperature that's not constant. The shape of the temperature curve follows an exponential rise and decay similar to that of a capacitor's voltage waveform.

The thermal capacitance is sometimes called thermal inertia, because the die mass can not change temperature instantaneously, just as a capacitor can not change voltage instantaneously. This means that for extremely short power pulses, the thermal capacitance has an averaging effect. Similarly, a capacitor averages (filters) voltage pulses applied to it. The thermal capacitor "stores" energy in the form of heat during the power pulse and releases it after the power pulse is over.

The critical parameter to be limited is the maximum junction temperature. The equation used to calculate T_J(MAX) is shown *(Fig. 3, again)*. Note that the transient thermal resistance (thermal response or θ_{TR}) must be found in the manufacturer's data sheet. These curves are usually given for transistors meant for high-frequency, high-power switching applications.

To get a value for the transient thermal resistance, first calculate the power pulse's duty cycle as well as its total time duration. The transient thermal resistance can then be read from the thermal-response graph. If the published data is "normalized," the number read from the graph must be multiplied by the listed junction-to-case thermal resistance to get the required value for the calculation *(Fig. 3, again)*. This is how to calculate the maximum junction temperature when the power flows in repetitive pulses with no power dissipated between the pulses.

The concept of transient thermal resistance should be used whenever justified by the type of power dissipated within the semiconductor. In general, transient analysis is necessary when the dissipated power pulse has a fairly low duty cycle (5% or less), and a pulse longer than about 20 μs. For modern switching bipolar or MOSFET devices, which switch at 40 kHz and high-

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er, the total turn-off transition time is nearly always less than 1 μs. That's why transient analysis is not often needed to calculate the junction temperature of a switching transistor or diode. As noted, the thermal capacitance will "average" the effects of very short power pulses, allowing the power dissipation to be accurately modeled as an equivalent constant (average) power distributed equally through the entire period. The junction temperature is calculated using:

$$T_J = P(AVE) \times \theta_{J\text{-}C} + T_{CASE}$$

Transient thermal analysis can also be applied to the heat-sink assembly. Any heat sink takes time to reach its steady-state temperature after power dissipation begins. That time is longer for heat sinks with larger mass.

In cases where large power dissipation occurs for short, random intervals, the manufacturer may choose to provide only enough heat sinking for discontinuous operation. These cases call for an accurate transient thermal model of the heat sink because operation is in the temperature range well below steady-state condition (where the heat sink's "thermal capacitance" is charging and discharging as power is dissipated).

The thermal resistance (heat-sink-to-ambient) of a heat sink is its figure of merit for effectiveness in conducting heat into the ambient. One might assume that this value is fixed, but in fact it varies slightly with the amount of power being dissipated. In the heat-sink data sheet, the thermal resistance is sometimes specified as a min/max range and is accompanied by a graph which plots case-temperature rise (ΔT) against power dissipation (P). Thus, the user may evaluate the thermal resistance at any point along the curve by calculating $\Delta T/P$.

TABLE 2: 16-PIN SURFACE-MOUNTED PACKAGE

L (in.)	H (in.)	$\theta_{J\text{-}A}$ (°C/W)
1	0.5	83
2	1	70
3	1.5	67
4	0.19	71
6	0.19	69

Higher-power heat sinks are usually listed as extrusion profiles, along with data such as weight, effective surface area, and thermal resistance. It must be noted that these data are only valid for a single set of conditions. For example, a standard often used is a 3-in. section of black-anodized extrusion with heat-sink temperature of 75°C. If a longer section of extrusion is used, the effective thermal resistance will be reduced, but not linearly. Here's a rule of thumb: To cut the effective thermal resistance in half, an extrusion must be four times as long.

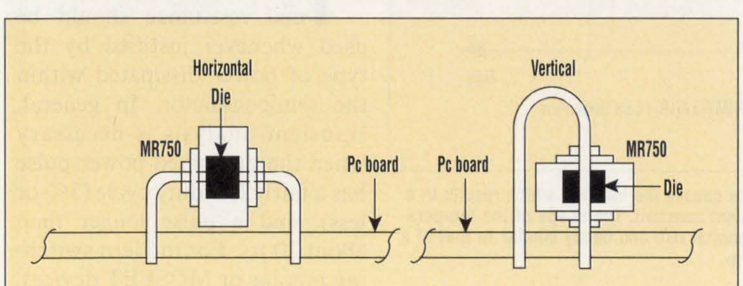
Because of the effect of airflow in natural convection, thermal resistance can be significantly affected by the physical orientation of the heat sink. For example, heat sinks with finned extrusions should always be mounted so that the fins are aligned vertically, because this promotes airflow through the fins as the hot air rises. The heat-sink data sheet should suggest the best mounting orientation for a given heat sink.

Airflow (or the lack of it) can cause a wide variation in the effective thermal resistance of a given heat sink. It's always a good idea to position heat sinks for maximum airflow, whether by forced or natural convection. Many heat-sink data sheets contain curves which show how the effective thermal resistance changes with various rates of airflow. Even if such data is not provided, it can always be assumed that the effective thermal resistance of a heat sink will decrease (improve) if airflow across it is increased.

In high-power assemblies where multiple devices are attached to one heat sink, it's often necessary to use a mating mechanical piece (like an angle extrusion) which has the semiconductors mounted on it. This piece is bolted to the heat sink as an assembly. Always remember that the thermal resistance is increased whenever the power-dissipating source(s) are moved farther from the heat sink. This means the effective $\theta_{S\text{-}A}$ would be higher than the data-sheet specification for the extrusion alone.

Because assemblies continue to shrink in size, significant amounts of power are sometimes dissipated in very small packages (like surface-mounted devices). The wattage that can be safely dissipated within the semiconductor depends on how well heat is removed from the package. Here's how the copper on a pc board can help remove heat from devices whose package isn't easily connected to a typical heat sink.

For example, axial-leaded rectifiers carry current ratings of 10 A or more, which means that considerable power can be dissipated in the rectifier die under continuous-current operation. Fast-recovery rectifiers used in switching applications have the additional problem of dissipating the switching losses which occur every time



4. The amount of heat transferred from a diode depends on the mounting method. The vertical method yields a better overall thermal resistance, because the die can transfer significantly more heat through the shorter lead into the pc-board copper.

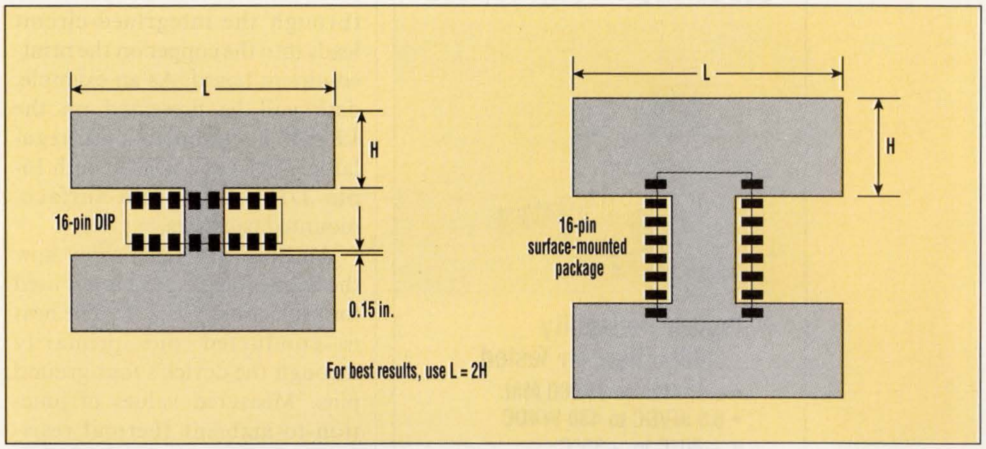
the diode turns off. In many cases, these losses will exceed the power dissipated when the diode is on.

The package of an axial-leaded rectifier can't be easily connected to a heat sink because of its physical shape. In one particular military application, stud-mounted rectifiers were replaced by smaller axial-leaded rectifiers, but the high ambient-temperature specification required more heat sinking than the available pc-board space allowed. Instead, the rectifiers were mounted so that the diode bodies were in contact with an aluminum extrusion and then covered with "thermally conductive" epoxy.

This method of heat sinking proved disastrous for many reasons. Compared with metal, thermally conductive epoxy is not a very good thermal conductor. Also, very little effective heat flow can be obtained through the body of the diode because of its small surface area and high thermal resistance. But the worst part was that vibration was causing the epoxy bond at the heat sink to break away from the metal. This was because there was no strain relief on the diode's leads to the pc board. This story is related in the hope that no reader of this article will make the same mistake.

We can illustrate the power-dissipation capability of several popular axial-leaded diodes. Assuming 0.25-in. effective lead lengths and 80°C lead temperature, the maximum continuous current ratings would be 14 A for the MR750, 6 A for the MR500, and 8A for the 1N5807.

These three diodes were selected to show that the body size of a diode doesn't determine how much current or power it can handle. The diode body is a very poor heat conductor because it's made of molded plastic or epoxy and has a very small surface area through which it can conduct heat. The primary means of transferring heat from the die to the heat sink is through the leads. This also means that because the



5. When DIP or surface-mounted packages are used for power semiconductors, heat is conducted out of the part through ground pins and into the pc-board copper. The inherent thermal resistance of the leadframe (inside the part) limits the maximum practical power dissipation to about 2 W.

[redacted]

leads represent the major portion of the junction-to-ambient thermal resistance in a typical pc-mounted diode, they must be kept as short as possible.

Two methods of pc-board mounting for axial-leaded diodes are the most common *(Fig. 4)*. In most cases, the vertical method provides a lower (better) thermal resistance from junction-to-heat-sink (which is a copper plane on the pc board). To understand why this is so, we need to compare the thermal resistances of the vertical and horizontal cases.

In comparing the two mounting methods, it can be seen that for the horizontal case, the die sees two parallel and equal thermal resistances from the die to the heat sink (because the lead lengths are equal). In the vertical case, the two parallel thermal resistances are very unequal. To see which mounting method is better, compare two typical cases. We'll assume the thermal resistance of the leads to be 40°C/W per inch and $\theta_{J\text{-}C} = 2$ °C/W.

In the horizontal case, the minimum lead length (assuming bend radius of one lead diameter and 0.050-in. board clearance) is 0.3 in. The thermal resistance of each lead is $0.3 \times 40 = 12$°C/W.

Total thermal resistance (each side) $= \theta_L + \theta_{J\text{-}C} = 12 + 2 = 14$°C/W

Effective lead thermal resistance (for both leads paralleled) $= 0.5 \times 14 = 7$ °C/W

In the vertical case, the minimum lead length (shorter lead) is 0.1 in. The thermal resistance is $0.1 \times 40 = 4$°C/W (for shorter lead only).

Total thermal resistance (short lead side) $= 4 + 2 = 6$°C/W

Minimum lead length (longer lead) = 1.3 in.

Thermal resistance $= 1.3 \times 40 = 52$°C/W (for longer lead only)

Total thermal resistance (long lead side) $= 52 + 2 = 54$°C/W

Effective lead thermal resistance (for both leads paralleled) = 5.4°C/W

From this example, it's clear that the vertical-mounting method creates a lower thermal resistance from the die to the heat sink. Also, it can be seen that in the vertical case about 80% of the heat will flow through the shorter lead (assuming the board's copper plane is properly sized).

Remember this when designing the pc-board layout, because most of the copper area available for heat sinking should be used near the pad connected to the shortest lead. If the horizontal-mounting method is used, the board's copper areas should be equal. That's because the thermal resistances are the same through each lead.

The heat from power dissipation within DIP and surface-mounted devices must be transferred from the die through the

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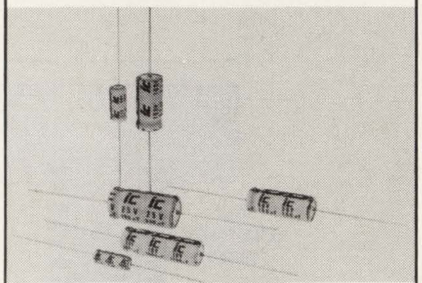

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lead frame (inside the part) and through the integrtaed-circuit leads into the copper on the printed-circuit board. As an example, data will be presented on the LP2953 low-dropout linear regulator. This part comes in both 16-pin DIP and 16-pin surface-mounted packages.

An illustration can show how the copper on the pc board is used for heat sinking *(Fig. 5)*. The heat is conducted out primarily through the device's four ground pins. Measured values of junction-to-ambient thermal resistance are given for various lengths and widths of pc board. All data is for 1-oz. copper weight pc board *(Tables 1 and 2)*.

The ability of the pc-board copper to conduct heat away from the die in an axial-mounted diode is quite limited. Power levels of 4 or 5 W are the upper limit in most practical cases. Higher power could be realized by using either forced airflow across the board or fluid immersion (such as oil) of the board in a sealed assembly, but the cost would be prohibitive.

The data presented for the LP2953 can be used to explain how and why these power limits exist *(Tables 1 and 2, again)*. In the data for the 16-pin DIP, it can be seen that increasing the heat sink area by a factor of 9 yields a reduction in overall thermal resistance of only about 16% (compare L = 1 and L = 3).

In analyzing the heat flow, note that the pc-board heat sink is essentially "one-sided." The heat is conducted into the ambient air primarily on the copper surface away from the pc board. The other copper side, which is glued to the board, can not conduct much heat into the air because the fiberglass or epoxy printed-circuit-board material is such a poor heat conductor.

The power-dissipating element appears as a "point source," which means the heat spreads outward from the point of origin. As the heat spreads, it passes through the thermal resistance of the copper itself. The copper is extremely thin, and this "spreading resistance" reduces the efficiency of the heat sink as the area grows very large.

Another significant factor limiting the effective thermal resistance is the thermal resistance of the lead frame inside the part. The thermal resistance from the die through the lead frame to the copper surface is in series with the thermal resistance of the copper heat sink. This means that as the copper area is increased (and the thermal resistance of the heat sink is reduced), the thermal resistance of the lead frame becomes dominant.

For the LP2953 16-pin DIP data, the point of diminishing returns for increasing copper area is about 4 in.^{2} (total), shown where L = 2. The data for L = 3 has a heat-sink area more than double that of L = 2, but the reduction in thermal resistance is very small. This shows that further increases in heat sink area would not be "seen" by the die, and the overall thermal resistance would change very little.

The thermal resistance can be improved by using 2-oz. copper weight on the pc board. This doubles the cross-sectional area of the copper plane, which reduces the spreading resistance. In data taken on the LP2953, improvements in overall thermal resistance of about 20% were seen comparing 1-oz. and 2-oz. copper heat sinks with areas in the range of 1 to 10 in.^{2} (data not listed).

Chester Simpson, a senior application engineer in National Semiconductor's Power Products Group, holds a BSEE from California State University at Sacramento.

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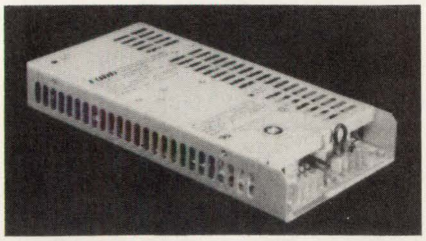

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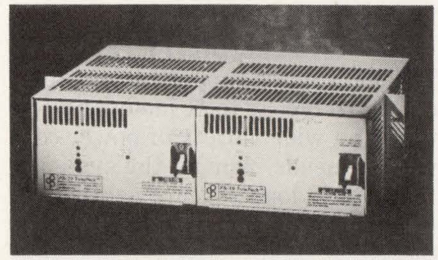

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Electronic Systems Div.
P.O. Box 3999, M/S 9F-UF
Seattle, WA 98124-2499
(206) 657-7474
(50S) (51S) (500S) (10S) (11S) (200S) (RM) (CV) (PR) (MD) (50R) (51R) (500R) (10R) (11R) (200R) (SW) (MU) (ML) (50C) (51C) (500C) (10C) (11C) (200C) (DC) (AC) (MO)
CIRCLE 628

Brandt Electronics Inc.
815 E. Middlefield Rd.
Mountain View, CA 94043
(415) 967-4944
(50S) (51S) (500S) (10S) (11S) (200S) (RM) (CV) (MD) (50R) (10R) (LI) (SW) (ML) (50C) (51C) (500C) (10C) (11C) (200C) (DC) (MO) (MI)
CIRCLE 629

Burr-Brown Corp.
Power Convertibles Corp.
3450 S. Broadmont, #128
Tucson, AZ 85713
(800) 548-6132
(50C) (51C) (10C) (11C) (DC) (MO) (IC)
CIRCLE 630

Burr-Brown Corp.
P.O. Box 11400
Tucson, AZ 85734
(602) 746-7754
(50C) (DC)
CIRCLE 631

CEC Electronics Corp.
1324 Motor Pkwy.
Hauppauge, NY 11788
(516) 582-4422
(50S) (51S) (500S) (10S) (11S) (200S) (LA) (RM) (CV) (PR) (MD) (SW) (MU) (ML) (50C) (51C) (10C) (11C) (200C) (DC) (AC) (MO) (MI)
CIRCLE 632

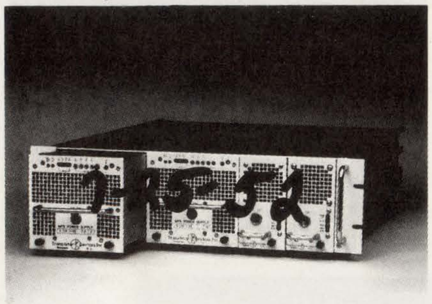
Cal-Tek Engineering
UPS Div.
P.O. Box 202
Kingston, MA 02364
(617) 585-5666
(50S) (11S) (RM) (CV)
CIRCLE 633

(see p. 111 for key)
(continued on p. 102)

POWER SUPPLIES

▼ MODULAR SUPPLIES OFFER FLEXIBILITY

The MPS Series supplies are custom-configurable, ac-to-dc modular units that fit a wide variety of power-conversion needs. Among the system's features is load-sharing parallel redundancy that comes from N+1 con-

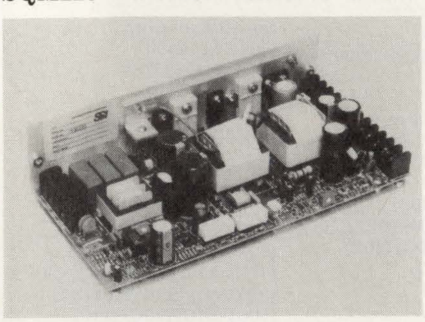


figurations. In addition, each 5.25-in.-high module offers power-factor correction. A hot-bus plug-in capability permits modules to be quickly changed without shutting the system down. Modules can be mixed and matched in a 19-in. rack with up to 3000 W of output power.

Transistor Devices Inc.
85 Horsehill Rd.
Cedar Knolls, NJ 07927
(201) 267-1900
▶ CIRCLE 824

▼ QUAD-OUTPUT SWITCHER PACKS AUXILIARY POWER

A quad-output, 225-W (300-W peak) switcher is designed for applications calling for larger power requirements from auxiliary outputs with minimal main-output loading. The SQM225 switcher features a 5-V



main output at 30 A. Up to three auxiliary outputs are available. Pricing in lots of 100 is $228. Small quantities ship within four weeks.

Switching Systems International
500 Porter Way
Placentia, CA 92670
(714) 996-0909
▶ CIRCLE 825

POWER-SOURCE MANUFACTURERS

Calex Mfg. Co. Inc.
3355 Vincent Rd.
Pleasant Hill, CA 94523
(415) 932-3911
(50S) (10S) (11S) (RM) (CV) (50C) (10C) (11C) (DC) (MO)
CIRCLE 634

California Instruments Corp.
5125 Convoy St. #201
San Diego, CA 92111
(619) 279-8620
(51S) (LA) (RM) (PR) (RP)
CIRCLE 635

Caritronics Inc.
P.O. Box 821
West Caldwell, NJ 07007
(201) 575-8916
(50C) (51C) (500C) (10C) (11C) (DC)
CIRCLE 636

Catalyst Research Corp.
3706 Crandall Ln.
Owings Mills, MD 21117
(301) 356-2400
(LT)
CIRCLE 637

Central Semiconductor Corp.
145 Adams Ave.
Hauppauge, NY 11788
(516) 435-1110
(BT) (TH)
CIRCLE 638

Cherry Semiconductor Corp.
2000 South County Trail
Warwick, RI 02818
(401) 885-3600
(50R) (10R) (LI) (SW) (ID) (PC)
CIRCLE 639

Clary Corp.
Precision Instruments Div.
320 W. Clary Ave.
San Gabriel, CA 91776
(818) 287-6111
(200S) (LA) (RM) (OF) (CV) (PR) (RP) (MD) (200C) (AC) (MO) (MI)
CIRCLE 640

Computer Power Inc.
124 W. Main St.
High Bridge, NJ 08829
(908) 638-8000
(50C) (51C) (500C) (AC) (BT) (MF) (RE) (TH) (LC) (NC)
CIRCLE 641

Computer Products
Tecnetics
6287 Arapahoe Ave.
Boulder, CO 80306
(303) 442-3837
(50S) (51S) (500S) (10S) (11S) (200S) (MD) (50C) (51C) (500C) (10C) (11C) (200C) (DC) (MI)
CIRCLE 642

Computer Products Inc.
Power Conversion
3797 Spinnaker Ct.
Fremont, CA 94538-6563
(415) 657-6700
(50S) (51S) (10S) (11S) (200S) (OF) (CV) (50C) (10C) (11C) (200C) (DC) (MO)
CIRCLE 643

Condenser Products Corp.
2131 Broad St.
Brooksville, FL 34609
(904) 796-3561
(500S) (10S) (CV)
CIRCLE 644

Contact East Inc.
335 Willow St.
North Andover, MA 01845
(508) 682-2000
(50S) (11S) (LA) (RM) (CV) (RP) (LI) (SW) (AL)
CIRCLE 645

Controlled Power Co.
1955 Stephenson Hwy.
Troy, MI 48083
(313) 528-3700
(50S) (51S) (500S) (10S) (11S) (200S) (50R) (51R) (500R) (10R) (11R) (SW)
CIRCLE 646

Conversion Devices Inc.
15 Jonathan Dr.
Brockton, MA 02401
(508) 559-0880
(50C) (51C) (10C) (11C) (DC) (MO) (IC) (MI)
CIRCLE 647

Current Technology
Power Supplies Div.
1400 S. Sherman
Richardson, TX 75081
(214) 238-5300
(50S) (51S) (RM) (OF) (50R) (51R) (11R) (200R) (SW) (MU) (50C) (51C) (200C) (DC) (AC) (MO)
CIRCLE 648

Custom Power Systems
33 Comac Loop
Ronkonkoma, NY 11779
(516) 467-5328
(50S) (51S) (500S) (10S) (11S) (200S) (LA) (RM) (OF) (CV) (RP) (MD) (50C) (51C) (500C) (10C) (11C) (200C) (DC) (MO) (MI)
CIRCLE 649

Cyberpak Co.
Custom Design
251 S. Frontage Rd. #23
Burr Ridge, IL 60521
(800) 328-3938
(11S) (200S) (OF) (CV) (11R) (200R) (SW) (11C) (200C)
CIRCLE 650

D&B Power Inc.
204 N. Fehr Way
P.O. Box 40M
Bayshore, NY 11706
(516) 586-5955
(50S) (10S) (11S) (OF) (CV) (MD) (50R) (10R) (11R) (LI) (50C) (11C) (MI)
CIRCLE 651

Datel Inc.
11 Cabot Blvd.
Mansfield, MA 02048
(508) 339-3000
(50C) (10C) (11C) (DC) (MO)
CIRCLE 652

Delta Products Corp.
3823 Spinnaker Ct.
Fremont, CA 94538
(415) 770-0660
(50S) (51S) (10S) (11S) (200S) (OF) (50R) (51R) (SW) (50C) (DC) (AC)
CIRCLE 653

Deltron Inc.
290 Wissahickon Ave.
North Wales, PA 19454
(215) 699-9261
(50S) (11S) (200S) (RM) (OF) (50C) (200C) (DC)
CIRCLE 654

Duracell Inc.
Berkshire Industrial Pk.
Bethel, CT 06901
(203) 791-3274
(AL) (LT) (ZA)
CIRCLE 655

EG&G Power Systems
1330 E. Cypress St.
Covina, CA 92635
(818) 967-9521
(50S) (51S) (11S) (200S) (MD) (LI) (SW) (ML) (50C) (11C) (200C) (DC) (AC) (MI)
CIRCLE 656

EMCO High Voltage Co.
11126 Ridge Rd.
Sutter Creek, CA 95685
(209) 223-3626
(50S) (51S) (500S) (10S) (11S) (LA) (RM) (OF) (CV) (RP) (MD) (50R) (51R) (500R) (10R) (11R) (LI) (SW) (MU) (ID) (ML) (50C) (51C) (500C) (10C) (11C) (DC) (MO) (IC) (MI)
CIRCLE 657

EPSCO Inc.
1115 Hilltop Dr. Unit 2A
Itasca, IL 60143
(708) 250-0410
(50S) (51S) (LA) (RM) (MD) (LI)
CIRCLE 658

East Penn Mfg. Co. Inc.
Deka Rd.
Lyon Station, PA 19536
(215) 682-6361
(LC)
CIRCLE 659

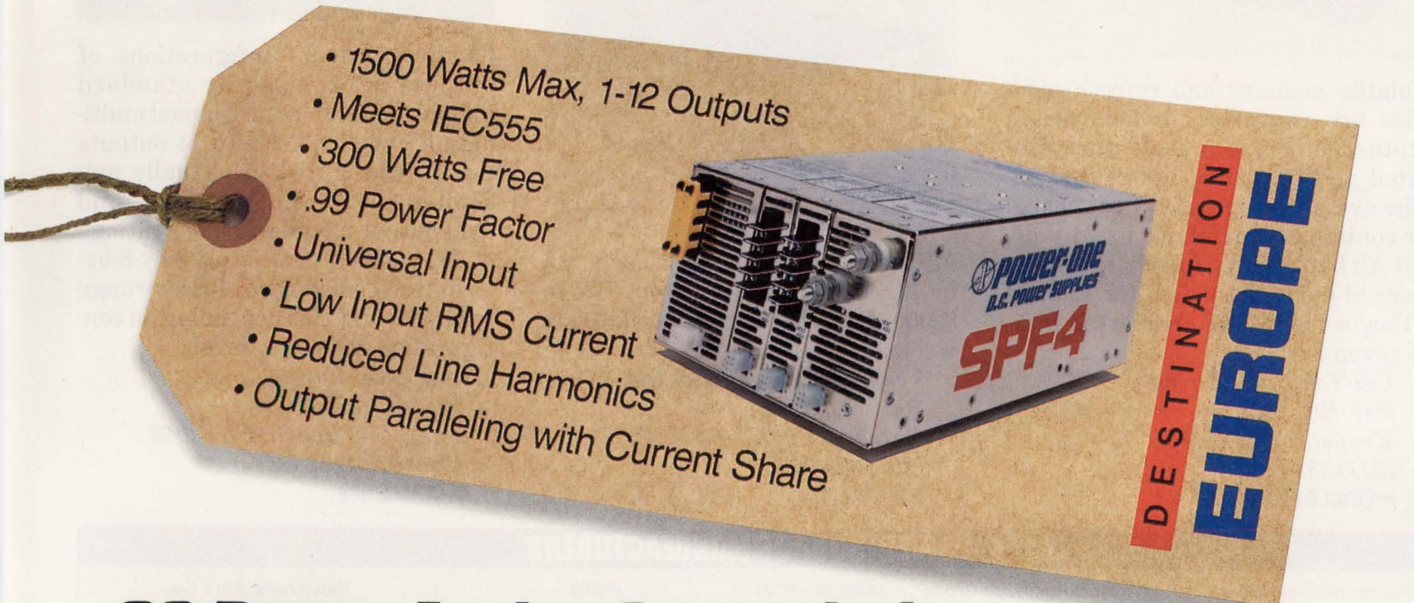
Elantec Inc.
1996 Tarob Ct.
Milpitas, CA 95035
(408) 945-1323
(PI)
CIRCLE 660

Electrochem Industries
10000 Wehrle Dr.
Clarence, NY 14031
(716) 759-2828
(LT)
CIRCLE 661

Electroid Co.
45 Fadem Rd.
Springfield, NJ 07081
(201) 467-8100
(51S) (11S) (CV)
CIRCLE 662

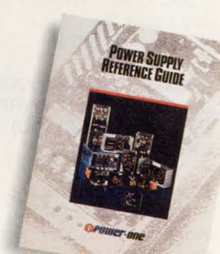
(see p. 111 for key)
(continued on p. 104)

Your Ticket To Europe POWER-ONE's SPF4



.99 Power Factor Corrected And Meets Europe's New Standard IEC555

Selling in Europe...a Tough New Challenge. Beginning in 1992, Europe's stringent IEC555 line Harmonic Disturbance Standard may greatly restrict – or even eliminate – your international sales. However, POWER-ONE's new SPF4 power supply, featuring 0.99 Power Factor Correction with reduced line harmonics easily solves the problem while providing up to 1500 watts from a 180-264 VAC input.



Up to 12 Configurable Outputs. The SPF4's fully regulated single and multiple output modules, ranging from 2 to 48 VDC, satisfy every standard output requirement. Plus, all single output modules are parallelable for true current sharing.

Meets Other International Requirements. The SPF4 operates continuously over an input range of 85-264 VAC, eliminating costly selector switches and strapping. All applicable International Safety and EMI Standards are met as well.

Attracts New Domestic Customers, too. Rewiring a building, larger circuit breakers, new service panels, higher capacity wire – they're all time-consuming and expensive for your customers. If your system uses POWER-ONE's new SPF4, most of these costs can be avoided. With its high efficiency and 0.99 Power Factor, the SPF4 not only operates from a standard 115 VAC 15 A outlet, but can provide your system with up to 300 watts of additional power over competitive non-corrected power supplies.

Get complete details today!
Call our Toll Free LITERATURE HOT LINE for our new Catalog! (800) 678-9445

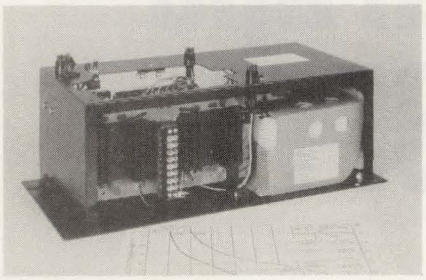
"Innovators in Power Supply Technology"

Power-one
D.C. POWER SUPPLIES

POWER-ONE, INC.
740 Calle Plano • Camarillo, CA 93012-8583
Phone: (805) 987-8741 • TWX: 910-336-1297
FAX: (805) 388-0476

CIRCLE 164 FOR U.S. RESPONSE   CIRCLE 165 FOR RESPONSE OUTSIDE THE U.S.

ON-LINE DC UPS PROTECTS MEMORIES

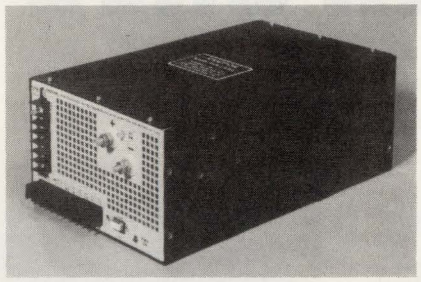


Volatile memory and refresh modules are converted to non-volatile status by the 2719A dual-output, isolated and regulated power system. The system's regulated float charger continually maintains its 24-V dc, 2.5-Ah batteries at full charge in the normal mode. A system for 10 to 24 PCs goes for $1197. Delivery is within seven weeks.

Cal-Tek Engineering
P.O. Box 202
Kingston, MA 02364
(617) 585-5666
▶CIRCLE 826

OFF-LINE SWITCHERS BOAST HIGH POWER

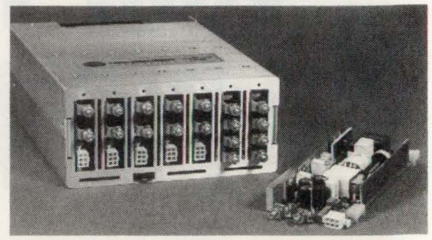
Power levels from 500 to 2000 W are offered by a line of off-line switchers with up to three outputs. The line features six optional modules that enable users to custom-configure their supply. Power factor is from



97% to 99%. The units measure 8 by 5 by 12.5 in. Prices range from $525 to $2000. Delivery is from stock to six weeks.

Technology Dynamics Inc.
100 School St.
Bergenfield, NJ 07621
(201) 385-0500
▶CIRCLE 827

MULTI-OUTPUT SWITCHERS OFFER FLEXIBILITY



Flexible custom configurations of outputs is provided by standard plug-in modules in the Unimod multi-output switchers. Up to 14 outputs can be configured in virtually any combination from 16 single- and dual-output modules. Power ratings of 400 to 800 W come in a 3.8-by-8-by-11-in. fan-cooled case. Prices range from $650 to $1130 depending on configuration and power level.

Unipower Corp.
2981 Gateway Dr.
Pompano Beach, FL 33069
(305) 974-2442
▶CIRCLE 828

POWER-SOURCE MANUFACTURERS

Electronic Devices Inc.
21 Gray Oaks Ave.
Yonkers, NY 10710
(914) 965-4400
(RE)
CIRCLE 663

Electronic Measurements Inc.
405 Essex Rd.
Neptune, NJ 07753
(201) 922-9300
(50S) (51S) (500S) (200S) (LA) (RM) (OF) (CV) (RP) (50C) (51C) (11C) (DC)
CIRCLE 664

Elenco Electronics Inc.
150 W. Carpenter St.
Wheeling, IL 60090
(708) 541-3800
(50S) (LA) (CV)
CIRCLE 665

Elgar Corp.
Test & Measurement
9250 Brown Deer Rd.
San Diego, CA 92121
(619) 450-0085
(51S) (200S) (LA) (RM) (PR) (RP) (51R) (200R) (LI) (51C) (200C) (MO)
CIRCLE 666

Elpac Electronics Inc.
Elpac Power Systems
3131 S. Standard Ave.
Santa Ana, CA 92705
(714) 979-4440
(50S) (OF)
CIRCLE 667

Endicott Research Group Inc.
P.O. Box 267
Endicott, NY 13760
(607) 754-9187
(50R) (LI) (SW) (50C) (10C) (11C) (DC) (AC)
CIRCLE 668

Entran Devices Inc.
10 Washington Ave.
Fairfield, NJ 07004
(201) 227-1002
(50S) (LA) (RM) (CV)
CIRCLE 669

Ericsson Components Inc.
Power Products
403 International Pkwy. #500
Richardson, TX 75081
(214) 997-6561
(50S) (11S) (200S) (RM) (OF) (CV) (50C) (10C) (11C) (DC) (MO)
CIRCLE 670

Exide Electronics
8521 Six Forks Rd.
Raleigh, NC 27615
(919) 872-3020
(200S) (UN) (LC)
CIRCLE 671

Fiskars Electronics Corp.
P.O. Box 1490, Newton Rd.
Littleton, MA 01460
(508) 486-9551
(51S) (200S) (LA) (RM) (CV) (PR) (MD) (50C) (51C) (11C) (200C) (DC) (AC)
CIRCLE 672

Fujitsu Microelectronics
3545 N. First St.
San Jose, CA 95134-9044
(408) 922-9000
(SW) (BT) (PI) (PC)
CIRCLE 673

Gamma High Voltage Research
1096 N. U.S. Hwy. #1
Ormond Beach, FL 32174
(904) 677-7070
(51S) (500S) (10S) (11S) (200S) (LA) (RM) (CV) (RP) (51C) (500C) (10C) (11C) (200C) (DC) (MO)
CIRCLE 674

Gates Energy Products Inc.
P.O. Box 861
Gainesville, FL 32602
(904) 462-3911
(LC) (NC) (NH) (NM)
CIRCLE 675

Gennum Corp.
P.O. Box 489, Station A
Burlington, Ontario
Canada, L7R 3Y3
(416) 632-2996
(PC)
CIRCLE 676

Georator Corp.
9617 Center St.
Manassas, VA 22110
(800) 523-9938
(200S) (OF) (PR) (MD) (51C) (200C) (MI) (AT)
CIRCLE 677

Germanium Power Devices Corp.
P.O. Box 3065, SVS
Andover, MA 01810-3065
(508) 475-5982
(REC)
CIRCLE 678

Glassman High Voltage
P.O. Box 551, Route 22
Whitehouse Station, NJ 08889
(908) 534-9007
(500S) (200S) (LA) (RM) (CV) (RP)
CIRCLE 679

HC Power Inc.
17032 Armstrong Ave.
Irvine, CA 92714-5716
(714) 261-2200
(50S) (200S) (RM) (MD) (50R) (200R) (SW) (50C) (200C) (DC)
CIRCLE 680

Harris Semiconductor
IC Products Div.
1301 Woody Burke Rd.
Melbourne, FL 32902
(407) 724-3886
(50R) (51R) (LI) (SW) (ID) (50C) (DC) (IC) (PC)
CIRCLE 681

Harris Semiconductor
724 Rte. 202, P.O. Box 591
Somerville, NJ 08876
(201) 685-6920
(50S) (51S) (10S) (11S) (OF) (CV) (MD) (50R) (51R) (10R) (11R) (LI) (SW) (MU) (ID) (ML) (50C) (51C) (DC) (AC) (IC) (BT) (MF) (RE) (TH) (PI) (PC)
CIRCLE 682

Hewlett-Packard Co.
Power Supplies
19310 Pruneridge Ave.
Cupertino, CA 95014
(800) 752-0900
(50S) (51S) (10S) (11S) (200S) (LA) (RM) (CV) (RP)
CIRCLE 683

Hitachi America Ltd.
Semiconductor & IC Div.
2000 Sierra Point Pkwy.
Brisbane, CA 94005-1819
(415) 589-8300
(SW) (BT) (MF) (PI) (PC)
CIRCLE 684

Hitran Corp.
Power Systems Div.
362 Hwy. 31
Flemington, NJ 08822
(908) 782-5525
(50S) (51S) (200S) (CV) (51C) (200C) (AC)
CIRCLE 685

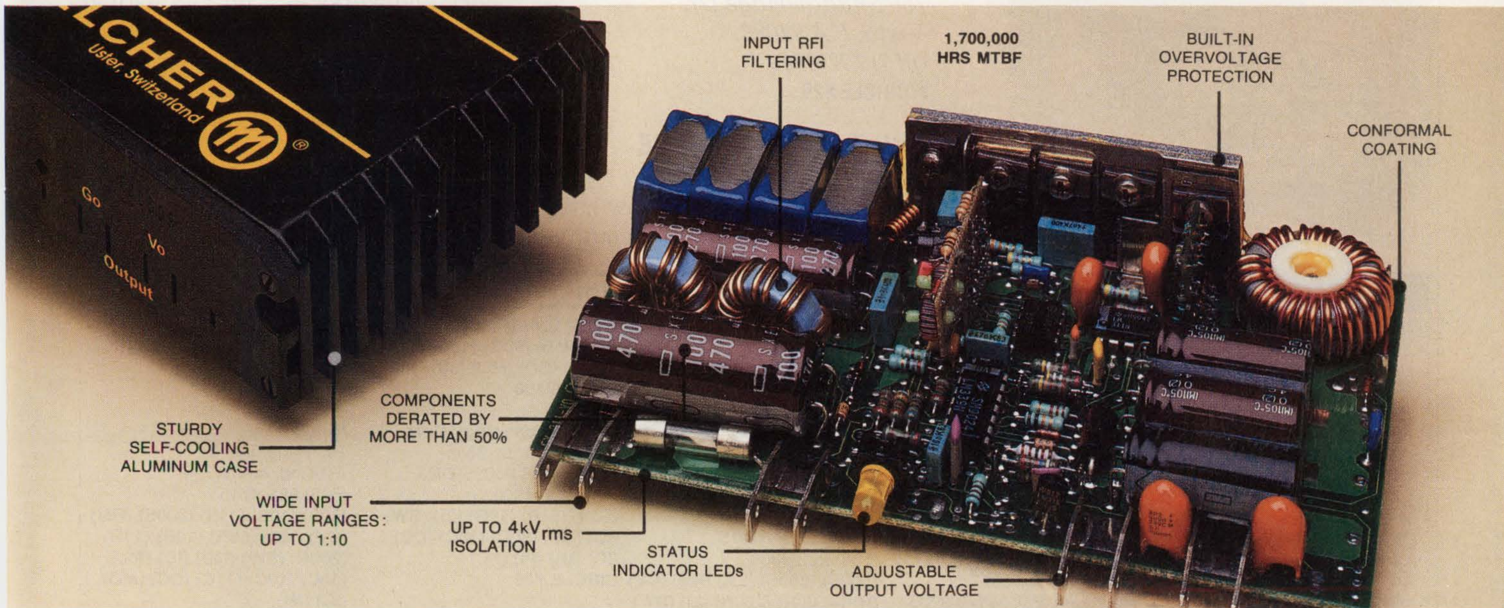
Hokuriku USA Ltd.
8145 River Dr.
Morton Grove, IL 60053
(708) 470-8440
(50C) (DC) (MO)
CIRCLE 686

Hydrocap Corp.
975 NW 95th St.
Miami, FL 33150-2095
(305) 696-2504
(LC)
CIRCLE 687

(see p. 111 for key)
(continued on p. 106)

MELCHER Industrial Power Supplies

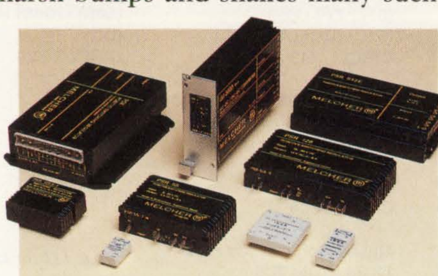
Guaranteed* to function to the outer limits of *heat, cold, voltage & vibration*



When you can't compromise on your power supply, start your search with MELCHER . . . because for almost 20 years, the world's most demanding OEMs have depended on MELCHER's remarkable ability to handle their wide temperature fluctuations, intense shock and vibration and input voltage surges. In fact, MELCHER industrial power supplies can maintain full load capability over an ambient temperature range of −40 °C to +85 °C!

Each MELCHER unit is a total power supply solution — in its own compact, self-cooling, EMI/RFI-shielded aluminum case ready for mounting. And, because shock and vibration tolerance are critical in telecommunications and mobile applications such as rail, air, and shipborne systems, MELCHER power supplies are tested in strict accordance with MIL STD 810 to ensure they'll endure the harsh bumps and shakes many such environments impose. They are also designed with ultra-sophisticated voltage protection mechanisms to guard against surges and transients which so easily push less extraordinary power supplies well beyond their limits. Actual field data confirms MELCHER PSR units perform reliably with an average MTBF of almost 2 million hours!

There is a great deal more to tell about MELCHER performance and quality in the finest Swiss tradition, and also about our in-depth customer service and applications engineering programs. We invite you to call our 800 number for a copy of our fact-filled, full line catalog where, among other things, you'll learn about MELCHER's 24-hour 100% burn-in testing . . . just one of the vital steps in MELCHER's total Quality Management Program.



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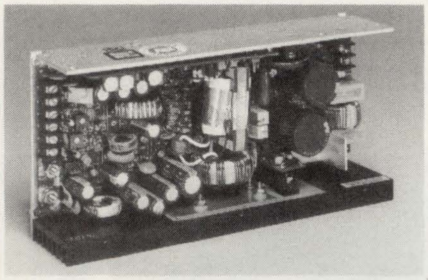
MELCHER INC., 200 Butterfield Drive, Ashland, MA 01721
Fax (508) 881-5082

* ALL MELCHER POWER SUPPLIES CARRY A FULL YEAR WARRANTY AGAINST ALL MANUFACTURING DEFECTS

CIRCLE 236 FOR U.S. RESPONSE **CIRCLE 237 FOR RESPONSE OUTSIDE THE U.S.**

▼ AUTO-RANGING SWITCHERS FEATURE EMI FILTERS

Nine power levels from 175 to 500 W are included in the AR Series of quad-output switchmode power supplies. The auto-ranging supplies' input circuitry is automatically configured for 90 to 132 V ac or 180 to 264 V ac with no jumpers or other hardware changes. All models carry four fully regulated, adjustable outputs. Prices range from $0.70 to $1/W.



Xentek Inc.
760 Shadowridge Dr.
Vista, CA 92083
(619) 727-0940
▶CIRCLE 829

▼ WINDOWS SOFTWARE MONITORS POWER

Microsoft Windows users now have an easy way to monitor their system's power at all times. The Power Sleuth software can signal power problems even when other applications are running. Its icon can be set to flash and beep if a disturbance occurs. The software requires Windows 3.0 and uses one free serial port, and works best on PCs with at least an 80286 CPU. Power Sleuth, which is designed for use with Sola's UPS systems, goes for $99.

Sola, a unit of General Signal
1717 Busse Rd.
Elk Grove Village, IL 60007
(800) BUY-SOLA
▶CIRCLE 830

POWER-SOURCE MANUFACTURERS

ILC Data Device Corp.
105 Wilbur Pl.
Bohemia, NY 11716
(516) 567-5600x390
(50S) (51S) (11S) (200S) (MD) (50C) (51C) (11C) (200C) (DC) (MO) (MI)
CIRCLE 688

IMC Magnetics Corp.
Florida Div.
14025 NW 60th Ave.
Miami Lakes, FL 33014
(305) 822-2558
(51S) (500S) (RM) (OF) (CV) (51C) (500C) (DC)
CIRCLE 689

IXYS Corp.
2355 Zanker Rd.
San Jose, CA 95131-1109
(408) 435-1900
(MF) (RE) (TH) (PI) (PC)
CIRCLE 690

Integrated Power Designs Inc.
9C Princess Rd.
Lawrenceville, NJ 08648
(609) 896-2122
(50S) (11S) (200S) (OF) (CV) (50R) (10R) (11R) (SW) (50C) (10C) (11C) (DC) (MO)
CIRCLE 691

International Power DC
373 Dawson Dr.
Camarillo, CA 93012
(805) 987-7900
(11S) (OF) (LI)
CIRCLE 692

International Power Devices
155 N. Beacon St
Brighton, MA 02135
(617) 782-3331
(50S) (51S) (10S) (11S) (200S) (RM) (CV) (50C) (51C) (10C) (11C) (200C) (DC) (MO) (IC)
CIRCLE 693

International Power Sources
200 Butterfield Dr.
Ashland, MA 01721
(508) 881-7434
(50S) (51S) (10S) (11S) (200S) (LA) (RM) (OF) (SW) (50C) (51C) (10C) (11C) (200C) (DC) (MO) (IC)
CIRCLE 694

International Rectifier
233 Kansas St.
El Segundo, CA 90245
(213) 772-2000
(PI)
CIRCLE 695

Interpoint
Power Products
10301 Willows Rd.
Redmond, WA 98073-9705
(206) 882-3100
(50C) (10C) (11C) (DC) (MI)
CIRCLE 696

Intronics Inc.
150 Dan Rd.
Canton, MA 02021
(617) 828-4992
(LA) (RM) (OF) (CV) (SW) (50C) (DC) (MO) (IC)
CIRCLE 697

Jameco Electronics
1355 Shoreway Rd.
Belmont, CA 94002
(415) 592-6718
(11S) (200S) (RM) (OF) (CV) (PR) (BT) (RE) (LT) (NC)
CIRCLE 698

Jerome Industries
730 Division St.
Elizabeth, NJ 07201
(201) 353-5700
(50S) (10S) (11S) (CV) (50R) (LI) (SW) (50C)
CIRCLE 699

Jeta Power Systems Inc.
2675 Junipero Ave.
Signal Hill, CA 90806
(213) 427-0095
(50S) (200S) (CV)
CIRCLE 700

John Fluke Mfg. Co.
Philips T & M Group
P.O. Box 9090
Everett, WA 98203
(206) 356-6157
(50S) (51S) (LA) (RM) (CV) (RP)
CIRCLE 701

Joule Power Inc.
Summer Rd.
Boxborough, MA 01719
(508) 263-9712
(50S) (11S) (200S) (OF) (RP) (SW)
CIRCLE 702

Kaiser Systems Inc.
126 Sohier Rd.
Beverly, MA 01915
(508) 922-9300
(500S) (200S) (LA) (RM) (CV) (RP) (500R) (200R) (LI) (SW) (500C) (200C)
CIRCLE 703

Keltec Florida Inc.
84 Hill Ave.
Fort Walton Beach, FL 32548
(904) 244-0043
(50S) (51S) (500S) (10S) (11S) (200S) (MD) (50C) (11C) (DC) (MI)
CIRCLE 704

Kepco Inc.
131-38 Sanford Ave.
Flushing, NY 11352
(718) 461-7000
(50S) (51S) (500S) (10S) (11S) (200S) (LA) (RM) (OF) (CV) (PR) (RP) (LI) (SW) (MU) (50C) (10C) (11C) (200C) (DC) (MO)
CIRCLE 705

LH Research Inc.
14402 Franklin Ave.
Tustin, CA 92715
(714) 730-0162
(50S) (11S) (200S) (RM) (OF) (CV) (50R) (11R) (200R) (LI) (SW) (50C) (200C) (DC)
CIRCLE 706

LZR Electronics Inc.
8051 Cessna Ave.
Rockville, MD 20855
(301) 921-4600
(50S) (51S) (LA) (OF) (CV) (PR) (50C) (51C) (DC) (AC)
CIRCLE 707

Lambda Electronics Inc.
515 Broad Hollow Rd.
Melville, NY 11747-3700
(516) 694-4200
(50S) (51S) (10S) (11S) (200S) (LA) (RM) (OF) (CV) (RP) (MD) (50C) (10C) (11C) (200C) (DC) (MO) (MI)
CIRCLE 708

Linear Technology Corp.
1630 McCarthy Blvd.
Milpitas, CA 95035-7487
(408) 432-1900
(50R) (51R) (10R) (LI) (SW) (ID) (ML) (50C) (10C) (DC) (IC) (MI) (PI) (PC)
CIRCLE 709

Logitek Inc.
101 Christopher St.
Ronkonkoma, NY 11779
(516) 467-4200
(50S) (51S) (11S) (200S) (MD) (50C) (51C) (11C) (200C) (DC) (MI)
CIRCLE 710

M.S. Kennedy Corp.
8170 Thompson Rd.
Clay, NY 13041
(315) 699-9201
(50R) (51R) (10R) (11R) (LI) (ML)
CIRCLE 711

MIL Electronics Inc.
106 Perimeter Rd.
Nashua, NH 03063
(603) 882-3200
(50S) (51S) (10S) (11S) (CV) (50R) (51R) (500R) (10R) (11R) (SW) (ML) (500C) (10C) (11C) (DC) (MO) (MI)
CIRCLE 712

Marathon Power Technologies
P.O. Box 8233
Waco, TX 76714-8233
(817) 776-0650
(51C) (DC) (AC) (NC)
CIRCLE 713

Marconi Circuit Technology
160 Smith St.
Farmingdale, NY 11735
(516) 393-8686
(BT) (TH) (PC)
CIRCLE 714

Maxell Corp. of America
22-08 Route 208
Fair Lawn, NJ 07410
(201) 794-5938
(AL) (CZ) (LC) (LT) (NC) (SO) (ZC)
CIRCLE 715

Melcher Inc.
200 Butterfield Dr.
Ashland, MA 01721
(508) 881-4715
(50S) (10S) (11S) (200S) (RM) (CV) (MD) (50R) (10R) (11R) (200R) (SW) (MU) (ID) (ML) (50C) (10C) (11C) (DC) (MO) (IC) (MI)
CIRCLE 716

Micrel Semiconductor
560 Oakmead Pkwy.
Sunnyvale, CA 94086
(408) 245-2500
(PI) (PC)
CIRCLE 717

Micro Linear Corp.
2092 Concourse Dr.
San Jose, CA 95131
(408) 433-5200
(SW) (PC)
CIRCLE 718

Micropac Industries Inc.
905 E. Walnut St.
Garland, TX 75040
(214) 272-3571
(50S) (51S) (10S) (11S) (CV) (MD) (50R) (10R) (11R) (LI) (MU) (ML) (50C) (51C) (10C) (11C) (DC) (MO) (MI)
CIRCLE 719

Modular Devices Inc.
Power Supplies
4115 Spencer St.
Torrance, CA 90503
(213) 542-8561
(50S) (200S) (OF) (CV) (50C) (DC)
CIRCLE 720

(see p. 111 for key)
(continued on p. 108)

One Shop Stopping.

	Monolithic/Hybrid ICs	Laser Diodes	Optoelectronics	Transistors	Diodes	Resistors	Capacitors	GaAs FETs	Printheads
ROHM	✓	✓	✓	✓	✓	✓	✓	✓	✓
ALLEN BRAD.						x			
ALPS						x			
BOURNS						x	x		
DALE						x	x		
FUJITSU	x	x		x	x			x	
G E				x	x			x	
G I				x	x		x		
HITACHI	x	x	x	x	x			x	
HOKURIKU						x			
H P	x			x	x				
ITT				x	x				
KOA						x			
KYOCERA			x			x	x		x
LITE-ON			x		x				
MITSUBISHI		x		x	x			x	
MOTOROLA	x		x	x	x				
NATIONAL	x			x	x				
NEC	x	x		x	x			x	
OPTOREX			x						
PANASONIC	x		x	x		x		x	x
PHILLIPS	x			x	x				
SHARP	x	x	x		x				
SIEMENS	x		x	x	x				
STACKPOLE						x			
STANLEY			x						
TDK		x	x	x	x				
TOSHIBA	x	x	x	x	x			x	
TRW			x	x	x	x			

For vendor reduction. Think about it—ROHM has the broadest product line in the industry. Even broader than Motorola, Panasonic, or Siemens.

We've got the resistors, capacitors, and discretes you need every day, with AQLs in parts-per-*billion*. You can wring out your costs and save mountains of time.

But we're more than a jellybean store. Just look at our dense hybrids, with component counts up to 50/cm^3. And our modules, printheads, flat panels and displays—subassemblies that can shave precious days off your time-to-market, or ease the hit on development budgets.

ROHM puts you in the super-market!

ROHM

ROHM Corporation
ROHM Electronics Division
8 Whatney
Irvine, CA 92718
Telephone (714) 855-2131
FAX (714) 855-1669

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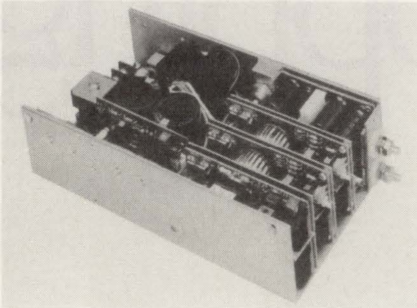
CIRCLE 160 FOR U.S. RESPONSE CIRCLE 161 FOR RESPONSE OUTSIDE THE U.S.

POWER SUPPLIES

▼ AC AND DC INPUTS HIGHLIGHT SWITCHER LINE



Power ratings of 400 to 750 W are offered for the M Series of ac-input switchers. The DM Series dc-input versions come in ratings of 400 or 600 W. Single- and multiple-output models are available. Both feature 120-kHz MOSFET design and current-mode control. All outputs are adjustable, fully regulated, and floating. In quantities up to nine, pricing starts at $390 for M Series units and at $465 for DM Series supplies. Delivery is within two weeks.

Deltron Inc.
290 Wissahickon Ave.
North Wales, PA 19454
(215) 699-9261
▶ **CIRCLE 831**

▼ UPS SYSTEM PROTECTS EQUIPMENT

The Powerware Plus 12 UPS system delivers clean, consistent power to sensitive electronics such as data-processing systems, networks, file servers, telecommunication equipment, and medical and lab systems. The 17-by-28-by-26-in. unit comes in three kVA ratings and is field-upgradeable from 8 kVA to 10 or 12 kVA. Pricing starts at $11,195. Call for delivery.

Exide Electronics
8521 Six Forks Rd.
Raleigh, NC 27615
(919) 870-3239
▶ **CIRCLE 832**

POWER-SOURCE MANUFACTURERS

Modular Devices Inc.
One Rone Rd. Brookhaven
Shirley, NY 11967
(516) 345-3100
(50S) (51S) (500S) (10S) (11S) (200S) (RP) (MD) (50R) (51R) (500R) (10R) (11R) (200R) (LI) (SW) (MU) (ID) (ML) (50C) (51C) (500C) (10C) (11C) (DC) (AC) (MO) (IC) (MI)
CIRCLE 721

Modupower Inc.
374 Turquoise St.
Milpitas, CA 95035
(408) 263-6115
(50S) (10S) (11S) (OF) (50R) (10R) (LI) (SW) (MU) (ID) (50C) (10C) (11C) (DC) (MO) (IC)
CIRCLE 722

Motorola Inc.
Semiconductor Products Sector
5005 E. McDowell Rd.
Phoenix, AZ 85008
(602) 244-6900
(BT) (MF) (RE) (TH) (PI) (PC)
CIRCLE 723

Multi Products International
250 Lackawanna Ave.
West Paterson, NJ 07424
(201) 890-1344
(50S) (51S) (10S) (11S) (LA) (CV) (50R) (10R) (11R) (LI) (SW) (MU) (50C) (51C) (10C) (11C) (DC) (AC) (MO)
CIRCLE 724

NH Research Inc.
16601 Hale Ave.
Irvine, CA 92714
(714) 474-3900
(50S) (51S) (200S) (RM) (CV) (PR) (RP) (MD) (SW) (MU) (50C) (51C) (200C) (MO) (MI)
CIRCLE 725

National Semiconductor
2900 Semiconductor Dr.
Santa Clara, CA 95052
(408) 721-2641
(50R) (10R) (11R) (LI) (SW) (MU) (ID) (ML) (50C) (10C) (11C) (DC) (IC) (MI) (BT) (MF) (PI) (PC)
CIRCLE 726

OECO Corp.
4607 S.E. International Way
Milwaukie, OR 97222
(503) 659-7932
(50S) (51S) (500S) (200S) (OF) (CV) (PR) (RP) (MD) (50C) (51C) (500C) (11C) (200C) (DC) (MI)
CIRCLE 727

Omnirel Corp.
205 Crawford St.
Leominster, MA 01453
(508) 534-5776
(50R) (10R) (11R) (LI) (SW) (ML) (BT) (MF) (TH) (PI) (PC)
CIRCLE 728

Onan Power/Electronics
9713 Valley View Rd.
Minneapolis, MN 55344
(612) 943-4642
(50S) (51S) (10S) (11S) (200S) (OF) (50R) (51R) (10R) (11R) (200R) (LI) (SW) (50C) (51C) (10C) (11C) (200C) (DC) (AC)
CIRCLE 729

Optek Technology Inc.
1215 W. Crosby Rd.
Carrolton, TX 75006
(214) 323-2469
(BT) (RE)
CIRCLE 730

PC Power & Cooling Inc.
31510 Mountain Way
Bonsall, CA 92003
(619) 723-9513
(50S)
CIRCLE 731

PDS Technologies
875 Bridgeport Ave.
Shelton, CT 06484
(203) 925-0123
(50S) (11S) (200S) (LA) (RM) (OF) (CV) (MD) (50R) (11R) (200R) (LI) (SW) (MU) (ML) (50C) (11C) (200C) (DC) (MI)
CIRCLE 732

Panasonic Industrial Co.
Battery Sales
Two Panasonic Way 7A-1
Secaucus, NJ 07094
(201) 348-7000
(AL) (CZ) (LC) (LT) (ME) (NC) (SO) (ZA) (ZC)
CIRCLE 733

Panasonic Industrial Co.
Power Supplies Div.
Two Panasonic Way 7H-1
Secaucus, NJ 07094
(201) 348-7000
(50S) (10S) (11S) (200S) (OF) (CV) (50R) (11R) (SW) (MU) (50C) (11C) (MO)
CIRCLE 734

Perma Power Electronics Inc.
5601 W. Howard St.
Chicago, IL 60648
(312) 763-0763
(11S) (200S) (CV) (PR)
CIRCLE 735

Philips Components
2001 W. Blue Heron Blvd.
Riviera Beach, FL 33404
(407) 881-3308
(BT) (MF) (RE) (TH)
CIRCLE 736

Phoenix Contact Inc.
P.O. Box 4100
Harrisburg, PA 17111
(717) 944-1300
(50S) (10S) (11S) (CV) (50R) (10R) (11R) (LI) (MU) (50C) (10C) (11C) (DC) (AC) (MO)
CIRCLE 737

Pico Electronics Inc.
453 N. MacQuesten Pkwy.
Mount Vernon, NY 10552
(914) 699-5514
(50R) (51R) (10R) (11R) (LI) (SW) (50C) (51C) (500C) (10C) (11C) (DC) (MI)
CIRCLE 738

Pioneer Magnetics Inc.
1745 Berkeley St.
Santa Monica, CA 90404
(800) 233-1745
(200S) (RM) (PR) (200R) (SW) (200C) (DC) (AC) (MO)
CIRCLE 739

Plainview Batteries Inc.
23 Newtown Rd.
Plainview, NY 11803
(516) 249-2873
(AL) (LC) (LT) (NC)
CIRCLE 740

Polytron Devices Inc.
P.O. Box 398
Paterson, NJ 07544
(201) 345-5885
(50S) (LA) (RM) (CV) (MD) (50R) (LI) (SW) (MU) (ML) (50C) (DC) (MO) (IC) (MI)
CIRCLE 741

Power Components
Div. of Vanguard Electronics
1480 W. 178th St.
Gardena, CA 90248
(213) 323-8120
(50S) (10S) (11S) (200S) (RM) (OF) (CV) (50C) (DC)
CIRCLE 742

Power Conversion Products Inc.
42 East St.
Crystal Lake, IL 60014
(815) 459-9100
(50S) (51S) (10S) (11S) (RM) (OF) (CV) (PR) (MD) (50R) (51R) (10R) (11R) (LI) (SW) (MU) (ML) (50C) (10C) (11C) (DC) (AC) (MO) (MI)
CIRCLE 743

Power General
Unitrode Corp.
152 Will Dr., P.O. Box 189
Canton, MA 02021
(617) 828-6216
(50S) (11S) (OF) (SW) (MU) (50C) (51C) (11C) (DC) (AC)
CIRCLE 744

Power Integrations Inc.
411 Clyde Ave.
Mountain View, CA 94043
(415) 960-3572
(PI)
CIRCLE 745

Power Switch Corp.
50 Graphic Pl.
Moonachie, NJ 07074
(201) 641-4544
(50S) (200S) (OF)
CIRCLE 746

Power Systems Inc.
45 Griffin Rd. South
Bloomfield, CT 06002
(203) 726-1300
(50S) (51S) (500S) (10S) (11S) (200S) (OF) (CV) (50R) (51R) (500R) (10R) (11R) (200R) (SW) (50C) (51C) (11C) (200C) (DC) (AC)
CIRCLE 747

(see p. 111 for key)
(continued on p. 109)

▼ RINGER POWER SUPPLIES SUIT TELECOM NEEDS

A family of four single- and dual-output ringer power supplies comes in low-profile, open-frame packages. The single-output RP Series supplies provide 24 VA of ac output power at a frequency of 20/30 Hz. Dual-output models provide 12 VA and a talk voltage of 24 V or 48 V with full-load output power of 50 W. Pricing starts at $119 in lots of 1000.

Viking Industrial Products
720 Farm Rd.
Marlboro, MA 01752
(508) 481-4600
▶ **CIRCLE 833**

▼ DEDICATED SUPPLY MEETS VXIBUS NEEDS

A dedicated power supply is available that meets the extra voltage requirements defined in the VXIbus specifications. The BVM 350VXI supply features automatic universal input-voltage selection. Four outputs are available: –5.2 V at 25 A, –2 V at 10 A, 24 V at 3 A, and –24 V at 3 A. Pricing is $600. Delivery is from stock to four weeks.

BICC-VERO Electronics
1000 Sherman Ave.
Hamden, CT 06514
(203) 288-8001
▶ **CIRCLE 834**

▼ 1500-W SUPPLY CORRECTS POWER FACTOR

International applications where standards for harmonic distortion (IEC 555-2) and stringent EMI limits for conduction (VDE 0871 level B) are crucial are met by the model PS 2141 power supply. The 1500-W, four-output unit features power-factor correction for a 99% power factor and 82% efficiency. Pricing is under $1 per watt in OEM quantities.

Modular Devices Inc.
4115 Spencer St.
Torrance, CA 90503-2489
(213) 542-8561
▶ **CIRCLE 835**

POWER-SOURCE MANUFACTURERS

Power Tech Inc.
0-02 Fair Lawn Ave.
Fair Lawn, NJ 07410
(201) 791-5050
(BT) (TH)
CIRCLE 748

Power Ten Inc.
486 Mercury Dr.
Sunnyvale, CA 94086
(408) 738-5959
(50S) (51S) (500S) (200S) (LA) (RM) (CV) (RP) (MD)
CIRCLE 749

Power Trends Inc.
1101 N. Raddant Rd.
Batavia, IL 60510
(708) 406-0900
(50R) (10R) (11R) (SW) (MU) (50C) (10C) (11C) (DC) (MO)
CIRCLE 750

Power-One Inc.
740 Calle Plano
Camarillo, CA 93010-8583
(800) 678-9445
(50S) (OF) (CV) (50R) (10R) (11R) (200R) (LI) (SW) (MU) (50C) (MO)
CIRCLE 751

Power-Sonic Corp.
3106 Spring St.
Redwood City, CA 94063
(415) 364-5001
(LC) (NC)
CIRCLE 752

Powercard Corp.
393 Totten Pond Rd.
Waltham, MA 02154-2014
(617) 890-6789
(AL) (CZ) (LT)
CIRCLE 753

Powercube Corp.
18810 N. Glenville #102
Richardson, TX 75081
(214) 480-9281
(50S) (51S) (10S) (11S) (200S) (MD) (50R) (51R) (10R) (11R) (200R) (LI) (SW) (MU) (ML) (50C) (51C) (10C) (11C) (200C) (DC) (MO) (MI)
CIRCLE 754

Powerex Inc.
Hillis St.
Youngwood, PA 15697
(412) 925-7272
(BT) (MF) (RE) (TH)
CIRCLE 755

Preferred Electronics Inc.
Main Line Dr., P.O. Box 248
Westfield, MA 01086
(413) 568-2301
(50S) (500S) (10S) (OF) (CV) (MD) (50R) (51R) (11R) (200R) (LI) (SW) (50C) (11C) (200C) (DC) (MO)
CIRCLE 756

Qualidyne Systems Inc.
3055 Del Sol Blvd.
San Diego, CA 92154
(619) 575-1100
(50S) (51S) (11S) (200S) (RM) (OF) (CV) (50R) (51R) (11R) (200R) (LI) (SW) (MU) (50C) (51C) (11C) (200C) (DC) (MO)
CIRCLE 757

RO Associates Inc.
246 Caspian Dr.
Sunnyvale, CA 94089
(408) 744-1450
(50S) (11S) (200S) (LA) (RM) (OF) (CV) (MD) (50R) (11R) (200R) (LI) (SW) (MU) (ML) (50C) (11C) (200C) (DC) (MO) (MI)
CIRCLE 758

Rantec Microwave & Electronics
1173 Los Olivos Ave.
Los Osos, CA 93402
(805) 528-5858
(500S) (10S) (11S) (OF) (CV) (MD)
CIRCLE 759

Rantec Microwave & Electronics
9401 Oso Ave.
Chatsworth, CA 91311
(818) 885-8223
(50S) (51S) (500S) (11S) (200S) (OF) (CV) (MD) (50R) (51R) (500R) (11R) (200R) (LI) (SW) (MU) (ML) (50C) (51C) (500C) (11C) (200C) (DC) (MO) (MI)
CIRCLE 760

Rayovac Corp.
601 Rayovac Dr.
Madison, WI 53711
(608) 275-4932
(AL) (CZ) (LT) (ME) (NC) (SO) (ZA)
CIRCLE 761

Reich Associates Inc.
Rte. 4 Box 4620
Lakehills, TX 78063
(512) 751-3220
(50S) (51S) (500S) (10S) (11S) (200S) (LA) (RM) (OF) (CV) (MD) (50R) (51R) (500R) (10R) (11R) (200R) (SW) (ML) (50C) (51C) (500C) (10C) (11C) (200C) (DC) (AC) (MO) (MI) (BT) (MF) (PI) (PC)
CIRCLE 762

Reliance Comm/Tec
Lorain Products
1122 F St.
Lorain, OH 44052
(216) 288-1122
(50S) (200S) (RM) (OF) (50R) (200R) (SW) (MU) (51C) (200C) (DC)
CIRCLE 763

Resonant Power Technology Inc.
3350 Scott Blvd. Bldg. 42/01
Santa Clara, CA 95051
(408) 982-0200
(51S) (OF) (PR) (RP) (MD) (SW) (MU) (ML) (50C) (DC)
CIRCLE 764

Ritz Electronics Ltd.
196 Queens St. N.
New Dundee, Ontario, Canada NOB 2EO
(519) 696-2616
(50S) (51S) (10S) (11S) (200S) (LA) (RM) (OF) (CV) (PR) (MD) (50R) (51R) (10R) (11R) (200R) (LI) (ML) (50C) (DC) (AC)
CIRCLE 765

SGS-THOMSON Microelectronics
1000 E. Bell Rd.
Phoenix, AZ 85022
(602) 867-6100
(50R) (LI) (SW) (MU) (ID) (DC) (MO) (BT) (MF) (RE) (TH) (PI) (PC)
CIRCLE 766

Samsung Semiconductor
3725 N. First St.
San Jose, CA 95131-1708
(408) 954-7264
(50R) (LI) (SW) (BT) (MF) (PI) (PC)
CIRCLE 767

Schaeffer Inc.
200 Butterfield Dr.
Ashland, MA 01721
(508) 879-8658
(50S) (51S) (RM) (LI) (SW) (50C) (51C) (DC)
CIRCLE 768

Sem Tech Corpus Christi
121 International Blvd.
Corpus Christi, TX 78406
(512) 289-0403
(50R) (10R) (11R) (200R) (LI) (SW) (MU) (ID) (ML) (BT) ((PI) (PC)
CIRCLE 769

Semiconductor Circuits Inc.
49 Range Rd.
Windham, NH 03087
(603) 893-2330
(50S) (11S) (RM) (50C) (11C) (DC) (MO) (IC)
CIRCLE 770

Semikron Inc.
11 Executive Dr. P.O. Box 66
Hudson, NH 03051
(603) 883-8102
(BT) (MF) (TH)
CIRCLE 771

Shindengen America Inc.
5999 New Wilke Rd., #406
Rolling Meadows, IL 60008
(708) 593-8585
(50S) (51S) (10S) (11S) (200S) (OF) (CV) (50C) (10C) (11C) (DC) (MO) (BT) (MF) (RE) (PI) (PC)
CIRCLE 772

Shogyo International Corp.
287 Northern Blvd.
Great Neck, NY 11021-4799
(516) 466-0911
(50S) (10S) (RM) (OF) (PR) (50R) (10R) (LI) (MU) (50C) (10C) (DC) (AC) (MO)
CIRCLE 773

Siemens Components Inc.
Integrated Circuit Div.
2191 Laurelwood Rd.
Santa Clara, CA 95054
(408) 980-4647
(MF) (PI) (PC)
CIRCLE 774

Sierra West Power System
2615 Missouri Ave. Bldg. 5
Las Cruces, NM 88001
(505) 522-8828
(50S) (51S) (10S) (11S) (200S) (RM) (OF) (CV) (RP) (MD) (50R) (51R) (10R) (11R) (200R) (LI) (SW) (MU) (ID) (ML) (50C) (51C) (500C) (10C) (11C) (200C) (DC) (MO) (IC) (MI)
CIRCLE 775

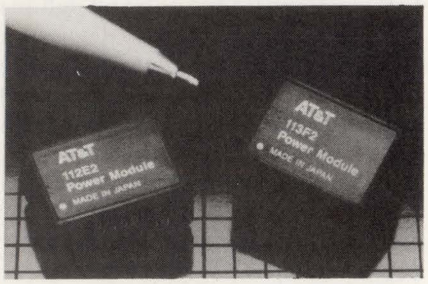
Silicon General Inc.
Semiconductor Div.
11861 Western Ave.
Garden Grove, CA 92641
(714) 898-8121
(50R) (10R) (LI) (SW) (MU) (ID) (ML) (BT) (PI) (PC)
CIRCLE 776

Silicon Transistor Corp.
BBF
2 Katrina Rd.
Chelmsford, MA 01824
(508) 256-3321
(BT) (MF) (RE) (TH)
CIRCLE 777

Siliconix Inc.
2201 Laurelwood Rd.
Santa Clara, CA 95054-1516
(408) 970-5697
(MF) (PI) (PC)
CIRCLE 778

(see p. 111 for key)
(continued on p. 110)

▼ MINI POWER MODULES DRIVE TELECOM TASKS



High-reliability power for digital and telecommunication applications is delivered by the 112-Series and 113-Series power modules. The +5-V-input non-isolated switching regulators require minimal external filtering. Positive output voltages of 12 V, 15 V, and 25 V are provided by the 112-Series units; while –5 V, –12 V, –15 V, and –130 V modules make up the 113-Series.

AT&T Microelectronics
Dept. 52AL040420
555 Union Blvd.
Allentown, PA 18103
(800) 372-2447
▶ **CIRCLE 836**

▼ DC POWER SUPPLIES OFFER PROGRAMMABILITY

ATE system, service, or lab applications are served by the four PPS Series power supplies. Controlled either through the front-panel keyboard or the GPIB interface by com-

puter, the supplies offer a full set of programmable features. Output voltage and current may be programmed and read back through a DVM. Overvoltage and overcurrent protection guards against component failure. Pricing starts at $495.

American Reliance Inc.
9241 E. Valley Blvd.
Rosemead, CA 91770
(818) 287-8400
▶ **CIRCLE 837**

POWER-SOURCE MANUFACTURERS

Sola Electric
a unit of General Signal
1717 Busse Rd.
Elk Grove Village, IL 60007
(708) 439-2800
(50S) (51S) (10S) (11S) (200S) (RM) (OF) (PR) (UN) (50R) (51R) (500R) (10R) (11R) (200R) (LI) (SW) (MU)
CIRCLE 779

Solidstate Controls Inc.
875 Dearborn Dr.
Columbus, OH 43085
(614) 846-7500
(200S) (PR) (200R) (LI) (51C) (200C) (AC)
CIRCLE 780

Sorensen Company
5555 N. Elston Ave.
Chicago, IL 60630
(312) 775-0843
(50S) (51S) (500S) (11S)200S) (LA) (RM) (OF) (CV) (RP) (MD) (500R) (LI)
CIRCLE 781

Speco/Emco Electronics
1172 Rt. 109
Lindenhurst, NY 11757
(516) 957-8700
(50S) (LA)
CIRCLE 782

Spellman Electronics
7 Fairchild Ave.
Plainview, NY 11803
(516) 349-8686
(500S) (10S) (11S) (200S) (LA) (RM) (CV) (RP) (500C) (10C) (11C) (DC) (MO)
CIRCLE 783

Sprague Semiconductor
363 Plantation St.
Worcester, MA 01613
(508) 7995-1300
(BT) (PI) (PC)
CIRCLE 784

Square D Co.
Power Protection Systems
9192 Topaz Way
San Diego, CA 92123-1165
(619) 279-0111
(51S) (51R) (500R)
CIRCLE 785

Stanford Research Systems
1290 D Reamwood Ave.
Sunnyvale, CA 94089
(408) 744-9040
(500S) (LA) (RM) (CV) (RP)
CIRCLE 786

Superior Electric Co.
383 Middle St.
Bristol, CT 06010
(203) 582-9561
(51S)
CIRCLE 787

Supertex Inc.
1225 Bordeaux Dr.
Sunnyvale, CA 94088
(408) 744-0100
(MF)
CIRCLE 788

Switching System International
500 Porter Way
Placentia, CA 92670
(714) 996-0909
(50S) (11S) (200S) (OF) (CV) (50C) (11C) (DC)
CIRCLE 789

TNR Technical Inc.
279 Douglas Ave.
Altamonte Springs, FL 32714
(407) 682-4311
(AL) (CZ) (LC) (LT) (NC)
CIRCLE 790

Tadiran Electronic Industries
Batteries Div.
40 Seaview Blvd.
Port Washington, NY 11050
(516) 621-4980
(AL) (LT) (SO)
CIRCLE 791

Taltronics Corp.
P.O. Box 339
Davidson, NC 28036
(704) 892-8872
(50S) (10S) (11S) (200S) (OF) (CV) (50C) (DC)
CIRCLE 792

Tamura Corp. of America
1150 Dominguez St.
Carson, CA 90746-3518
(213) 638-1790
(50S) (10S) (11S) (200S) (OF) (CV) (50R) (10R) (11R) (200R) (LI) (SW) (MU) (ID) (50C) (10C) (DC) (AC) (IC)
CIRCLE 793

Tauber Electronics Inc.
4901 Morena Blvd. #314
San Diego, CA 92117
(619) 274-7242
(AL) (CZ) (LC) (LT) (ME) (NC) (SO) (ZA) (ZC)
CIRCLE 794

Technology Dynamics Inc.
100 School St.
Bergenfield, NJ 07621
(201) 385-0500
(50S) (51S) (500S) (10S) (11S) (200S) (LA) (RM) (OF) (CV) (RP) (MD) (50C) (51C) (500C) (10C) (11C) (200C) (DC) (MO) (MI)
CIRCLE 795

Teledyne Components
1300 Terra Bella Ave.
Mountain View, CA 94039
(415) 968-9241
(50R) (10R) (11R) (LI) (SW) (MU) (ID) (ML) (50C) (DC) (IC) (MI) (BT) (MF) (RE) (PI) (PC)
CIRCLE 796

Texas Instruments
8360 LBJ Freeway
Dallas, TX 75380-9066
(214) 997-5469
(51R) (10R) (11R) (LI) (SW) (ID) (ML) (BT) (PI) (PC)
CIRCLE 797

Todd Products Corp.
50 Emjay Blvd.
Brentwood, NY 11717
(516) 231-3366
(50S) (51S) (11S) (200S) (OF) (CV) (RP) (50C) (51C) (11C) (200C) (DC)
CIRCLE 798

Toko America Inc.
1250 Feehanville Dr.
Mount Prospect, IL 60056
(708) 297-0070
(50S) (10S) (11S) (RM) (OF) (CV) (PR) (50C) (10C) (11C) (DC)
CIRCLE 799

Toshiba America
Electronic Components
9775 Toledo Way
Irvine, CA 92718
(714) 455-2000
(BT) (MF) (RE) (TH) (PI) (PC)
CIRCLE 800

Total Power International
418 Bridge St.
Lowell, MA 01850
(508) 453-7272
(50S) (RM) (OF) (RP) (50R) (LI) (SW) (MU) (ID) (50C) (10C) (11C) (DC) (AC) (MO) (IC)
CIRCLE 801

Transistor Devices Inc.
85 Horsehill Rd.
Cedar Knolls, NJ 07927
(201) 267-1900
(50S) (51S) (500S) (10S) (11S) (200S) (LA) (RM) (CV) (PR) (RP) (MD) (50C) (51C) (500C) (10C) (11C) (200C) (DC) (AC) (MO) (MI)
CIRCLE 802

Tri-Mag Inc.
1601 N. Clancy Ct.
Visalia, CA 93291
(209) 651-2222
(50S) (51S) (10S) (11S) (200S) (OF) (CV) (MD) (50R) (10R) (11R) (SW) (50C) (51C) (10C) (11C) (DC) (AC) (MO) (MI)
CIRCLE 803

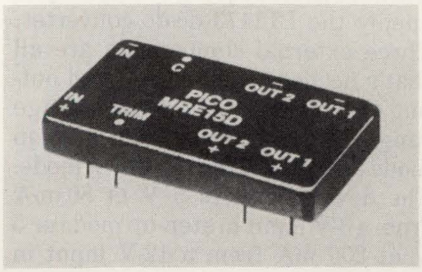
U.S. Elco Inc.
2930 Scott Blvd.
Santa Clara, CA 95054
(408) 980-5144
(50S) (10S) (11S) (200S) (OF) (RP) (SW) (50C) (10C) (DC)
CIRCLE 804

Unipower Corp.
2981 Gateway Dr.
Pompano Beach, FL 33069
(305) 974-2442
(50S) (RM) (CV) (50C) (DC)
CIRCLE 805

Unitrode Integrated Circuits
7 Continental Blvd.
Merrimack, NH 03054-0399
(603) 424-2410
(SW) (ID) (ML) (PI) (PC)
CIRCLE 806

(see p. 111 for key)
(continued on p. 111)

▼ MILITARY CONVERTERS TAKE WIDE INPUTS

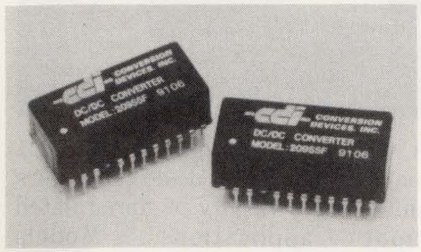


A wide input range, output power up to 2.5 W, and a regulated output are features of the MR series of military dc-dc converters. The devices come in a 0.300-in. package with optional MIL-STD-883 environmental screening available. Six-sided shielding and 32-pin-DIP compatibility combine with input-to-output isolation to suit these converters to military needs.

Pico Electronics Inc.
453 N. MacQuesten Pkwy.
Mt. Vernon, NY 10552
(800) 431-1064
▶ **CIRCLE 838**

▼ HIGH-DENSITY CONVERTER FILLS LAN NEEDS

Conversion of power from the main bus to an isolated output voltage for transceiver chips is the task of the F Series dc-dc converters. Two models offer a single output in a 24-pin DIP-compatible package. The units operate from a 5- or 12-V dc input and provide 9 V dc at 250 mA for Cheapernet applications. Pricing for the F Series starts at $8.60 in lots of 100. Delivery is from stock.



Conversion Devices Inc.
15 Jonathan Dr.
Brockton, MA 02401
(508) 559-0880
▶ **CIRCLE 839**

▼ MILITARY CONVERTER BOASTS LOW PROFILE

The lowest height for any standard military-aerospace-grade dc-dc-converter—0.27 in.—is featured in the MSA series of 5-W converters. The thick-film hybrids are built in a MIL-STD-1772 facility and are rated for full-power operation over the –55-to-125°C military range. Power density in the 1.065-in.^{2} devices is 16 W/in.^{3}. Prices start at $225 in lots of 100. Call for delivery.

Interpoint
P.O. Box 97005
Redmond, WA 98073-9705
(206) 882-3100
▶ **CIRCLE 840**

POWER-SOURCE MANUFACTURERS

Universal Voltronics
27 Radio Circle Dr.
Mount Kisco, NY 10549
(914) 241-1300
(50S) (200S) (LA) (RM) (OF) (CV) (RP) (MD) (500R) (200R) (LI) (SW) (ML) (500C) (200C) (DC) (MI)
CIRCLE 807

VSR Corporation
4609 S. 33rd Pl.
Phoenix, AZ 85040
(602) 243-6200
(50S) (51S) (10S) (11S) (200S) (LA) (RM) (CV) (PR) (RP) (MD) (50R) (51R) (10R) (11R) (200R) (LI) (MU) (ML) (50C) (51C) (10C) (11C) (200C) (AC) (MI)
CIRCLE 808

Valor Electronics
6275 Nancy Ridge Dr.
San Diego, CA 92121
(619) 458-1471
(50S) (OF) (50C) (10C) (DC)
CIRCLE 809

Vicor Corp.
23 Frontage Rd.
Andover, MA 01810
(508) 470-2900
(50S) (11S) (200S) (CV) (RP) (MD) (SW) (MU) (ML) (50C) (11C) (200C) (DC) (MO) (MI)
CIRCLE 810

Viking Industrial Products
729 Farm Rd.
Marlboro, MA 01752
(508) 481-4600
(50S) (51S) (11S) (200S) (OF) (CV) (PR) (50R) (LI) (SW) (50C) (51C) (11C) (200C) (DC) (AC)
CIRCLE 811

Viteq Corp.
10000 Aerospace Rd.
Lanham, MD 20706
(301) 731-0400
(51S) (200S) (PR)
CIRCLE 812

Voltex Co. Inc.
3460 Great Neck Rd.
N. Amityville, NY 11701
(516) 842-2772
(50S) (51S) (500S) (10S) (11S) (200S) (RM) (OF) (CV) (RP) (50R) (51R) (500R) (10R) (11R) (200R) (LI) (SW) (50C) (51C) (500C) (10C) (11C) (200C) (DC) (MO)
CIRCLE 813

Walker Scientific Inc.
Walker Magnetics Group
Rockdale St.
Worcester, MA 01606
(508) 852-3674
(50S) (51S) (500S) (200S) (LA) (CV)
CIRCLE 814

Wall Industries Inc.
5 Watson Brook Rd.
Exeter, NH 03833
(603) 778-2300
(50S) (10S) (11S) (CV) (50C) (51C) (500C) (10C) (11C) (200C) (DC) (MO) (IC)
CIRCLE 815

Wells-Gardner Electronics
2701 N. Kildare
Chicago, IL 60639
(312) 252-8220
(50S) (51S) (OF) (CV) (50R) (51R) (SW) (50C) (51C)
CIRCLE 816

Westcor Corp.
485-100 Alberto Way
Los Gatos, CA 95032
(408) 395-7050
(50S) (10S) (11S) (200S) (LA) (RM) (MD) (50C) (10C) (11C) (DC) (MO) (MI)
CIRCLE 817

Xentek Inc.
760 Shadow Ridge Dr.
Vista, CA 92083
(619) 727-0940
(50S) (RM) (OF) (CV) (MD) (50R) (LI) (SW) (50C) (DC)
CIRCLE 818

Yuasa-Exide Inc.
9728 Alburtis Ave.
Santa Fe Springs, CA 90670
(213) 949-4266
(LC) (NC)
CIRCLE 819

Zenith Electronics Corp.
1000 Milwaukee Ave.
Glenview, IL 60025
(708) 391-8510
(50S) (11S) (200S) (OF) (50C) (11C) (DC)
CIRCLE 820

Zytronics Inc.
Zytron
70 Tirrell Hill Rd.
Bedford, NH 03054
(603) 623-8888
(51S) (500S) (10S) (11S) (200S) (LA) (RM) (OF) (CV) (PR) (RP) (51R) (500R) (10R) (11R) (200R) (LI) (SW) (MU) (51C) (500C) (10C) (11C) (200C) (DC) (AC) (MO)
CIRCLE 821

KEY

Power Supplies

Output

(50S)	To 50 V
(51S)	51 to 500 V
(500S)	Over 500 V
(10S)	To 10 W
(11S)	11 to 200 W
(200S)	Over 200 W

Types

(LA)	Laboratory
(RM)	Rack mounting
(OF)	Open-frame OEM
(CV)	Constant voltage/current
(PR)	Precision ac output
(RP)	Remote programming
(MD)	Military designs
(UN)	Uninterruptible

Power Converters

Output

(50C)	To 50 V
(51C)	51 to 500 V
(500C)	Over 500 V
(10C)	To 10 W
(11C)	11 to 200 W
(200C)	Over 200 W

Types

(DC)	Dc to dc
(AC)	Dc to ac
(AT)	Ac to dc
(MO)	Modular
(IC)	IC DIP
(MI)	Military designs

Power Regulators

Output

(50R)	To 50 V
(51R)	51 to 500 V
(500R)	Over 500 V
(10R)	To 10 W
(11R)	11 to 200 W
(200R)	Over 200 W

Types

(LI)	Linear
(SW)	Switching
(MU)	Modular
(ID)	IC DIP
(ML)	Military designs

Batteries

Output

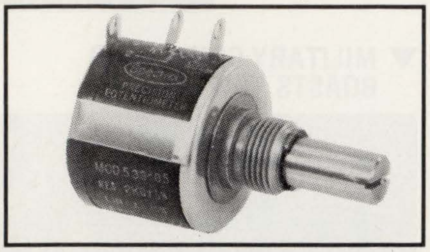
(AL)	Alkaline
(CZ)	Carbon zinc
(LC)	Lead acid
(LT)	Lithium
(ME)	Mercury
(NC)	Nickel cadmium
(NH)	Nickel hydrogen
(NM)	Nickel metal hydride
(SO)	Silver oxide
(ZA)	Zinc air
(ZC)	Zinc chloride

Power Semiconductors

Output

(BT)	Bipolar transistors
(MF)	MOSFETs
(RE)	Rectifiers
(TH)	Thyristors
(PI)	Power ICs
(PC)	Power-control ICs

Low-Cost Multi-Turn Precision Pots From Spectrol



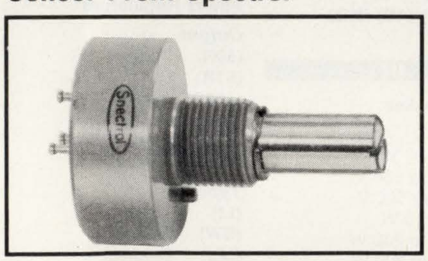
Spectrol's low noise, 7/8" diameter wirewound pots are well suited for industrial panel controls or position sensing applications. The three-turn model 533, five-turn model 535 and ten-turn model 534 are available with a choice of English or metric shaft/bushing sizes and a hybrid resistor element. The model 536 is a lower cost ten-turn version offering a choice of plastic or metal shaft. Other specifications include a 50Ω to 100KΩ resistance range, 0.25% linearity and −55°C to +125°C operating temperature range. Custom modifications are welcome when the quantity warrants.

Spectrol®

Spectrol Electronics Corporation
4051 Greystone Drive, Ontario, CA 91761
Phone: (714) 923-3313 Fax: (714) 923-6765

CIRCLE 102 FOR U.S. RESPONSE
CIRCLE 104 FOR RESPONSE OUTSIDE THE U.S.

Low-Cost Industrial Position Sensor From Spectrol



Spectrol offers a low-cost, high-quality conductive plastic pot with features that are normally associated with more expensive devices. This rugged design is ideal for sensing applications in industrial, off-road and agricultural equipment. The Model 157 features a 7/8 inch diameter bushing or servo mount machined aluminum housing, ground stainless steel shaft and 2,000,000 shaft revolution life. Specifications include a 1KΩ to 50KΩ resistance range, 2% linearity (0.25% available) and an operating temperature of −55°C to +125°C. Center taps, shaft seals and special resistance values are among the available options.

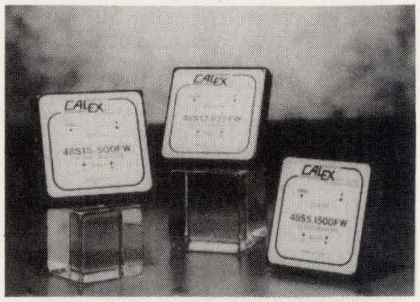
Spectrol®

Spectrol Electronics Corporation
4051 Greystone Drive, Ontario, CA 91761
Phone: (714) 923-3313 Fax: (714) 923-6765

CIRCLE 103 FOR U.S. RESPONSE
CIRCLE 105 FOR RESPONSE OUTSIDE THE U.S.

CONVERTERS

▼ WIDE INPUT RANGE SUITS CONVERTERS



A wide input-voltage range of 2:1 makes three 7.5-W dc-dc converters suited for a variety of unregulated input applications. Models 48S5.1500FW, 48S12.625FW, and 48S15.500FW are designed for low-noise telecommunication, industrial-control, and medical tasks. All are 120-kHz, MOSFET-based designs with tight line and load regulation. Each operates from 48-V inputs. Pricing is $62.90 in lots of 100.

Calex Mfg. Co. Inc.
3355 Vincent Rd.
Pleasant Hill, CA 94523
(800) 542-3355
▶ **CIRCLE 841**

▼ HIGH EFFICIENCIES OFFERED IN CONVERTER

Efficiency of up to 85% is featured in the 2PKV series of 2.5- and 3-W dc-dc converters. The units accept wide input ranges of 9 to 36 V dc and 18 to 72 V dc. Standard output voltages are 5, 12, and 15 V dc in single and dual versions. Call for pricing and delivery.

Ericsson Components Inc.
403 International Pkwy. #500
Richardson, TX 75081
(214) 997-6561
▶ **CIRCLE 842**

▼ 100-, 150-W TYPES JOIN CONVERTER LINE

A standard line of encapsulated dc-dc converters has been expanded to include 100- and 150-W units. The PD series of low-profile converters delivers those power levels at a fixed frequency of 150 kHz. A high input-voltage range (up to 400 V dc) accommodates off-line applications. Prices range from $160 to $180 in lots of 100.

Wall Industries Inc.
5 Watson Brook Rd.
Exeter, NH 03833
(800) 321-WALL
▶ **CIRCLE 843**

▼ DC-DC CONVERTER CONSUMES TINY CURRENT

Only 110 μA is required in standby to supply the LT1173 dc-dc converter. Three external components are all that's needed to deliver a fixed output of 5 V or 12 V. Supply voltage ranges from 2 to 12 V in step-up mode and to 30 V in step-down mode. The device delivers 5 V at 80 mA from a 3-V input in step-up mode or 5 V at 200 mA from a 12-V input in step-down mode. Switch current limit can be programmed with just one resistor. An auxiliary gain block is configurable as needed. Call for pricing and delivery.

Linear Technology Corp.
1630 McCarthy Blvd.
Milpitas, CA 95035-7487
(408) 432-1900
▶ **CIRCLE 844**

▼ HIGH ISOLATION SETS CONVERTER APART

A high isolation voltage of 3000 V pk test is featured in the HPR4XX Power Convertible dc-dc converter. The device's power density is 10 W/in.^{3}. Output power is 750 mW with efficiencies as high as 80%. Fifteen single- and dual-output models are available in SIP configurations. Pricing in lots of 1000 is $7.45 for dual-output units and $6.90 for single-output types. Delivery is from stock to four weeks.

Burr-Brown Corp.
Power Convertibles
P.O. Box 11400
Tucson, AZ 85734
(800) 548-6132
▶ **CIRCLE 845**

▼ 10-W DC-DC CONVERTERS BUILT ON CERAMIC

The XWR series of dc-dc converters is built directly on ceramic using low-profile surface-mounted components and thick-film hybrid techniques. The high-frequency, current-mode converters deliver up to 10 W of regulated, low-ripple power with efficiencies to 84%. Input voltage ranges of 4.7 to 7 V, 9 to 18 V, and 18 to 72 V dc are available. Call for pricing and delivery.

Datel Inc.
11 Cabot Blvd.
Mansfield, MA 02048
(508) 339-3000
▶ **CIRCLE 846**

The last thing an enclosure should be is confining

When you've engineered an innovative electronic system, it deserves better than to get packaged in a not-quite-perfect cabinet. That's why, in working to meet your enclosure requirements, Equipto Electronics believes that flexibility and versatility are no less important than reliability and quality.

So how do we provide you with that flexibility?

First, by offering cabinets, consoles and work stations in several lines so extensive you can usually find exactly what you need. You can choose panels 19," 24" or 30" wide, up to 36" deep with panel openings up to 84" high.

You can choose from hundreds of accessories in thousands of sizes. And you can choose enclosures especially engineered to provide maximum shielding effectiveness in meeting EMI/RFI, seismic, severe shock and vibration requirements.

Color? Our 12 standard colors are available in any combination on any of our enclosures. Or, specify a custom color without extra charges or delay in delivery.

But, if we don't have what you need on hand, we don't expect you to compromise.

One of our design engineers can consult with you by phone or Fax, at no charge. And, if needed for evaluation—even for destructive testing—we'll send you a standard enclosure free.

We offer this extra level of service so you can get all the flexibility you need from a single source. And get it fast. The most popular choices from our extensive catalog can be shipped in 5 working days. And anything you order from our catalog ships in 5 weeks, assembled to your specifications at no extra charge, no surprises, damage free.

When Equipto Electronics started manufacturing enclosures nearly three decades ago, we made a commitment to the combination of quality products and quality service that helps you design and create without confinement.

Phone or Fax for our newest 304-page catalog, on a diskette or in the printed version, including extensive technical data. Contact Equipto Electronics Corporation, 351 Woodlawn Avenue, Aurora, Illinois 60506-9988. Phone now (708) 897-4691, or Fax [708] 897-5314.

FREE Engineering Design Kit

Equipto Electronics Corporation ®

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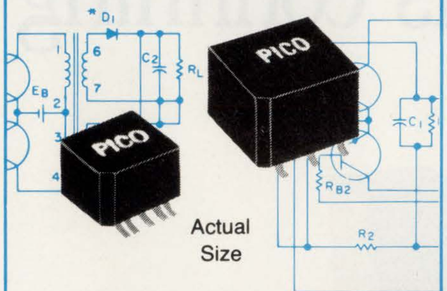
See our catalog pages C-1040 through C-1045

CIRCLE 134 FOR U.S. RESPONSE

CIRCLE 135 FOR RESPONSE OUTSIDE THE U.S.

ULTRA-MINIATURE

SURFACE MOUNT



DC-DC Converter Transformers and Power Inductors

These units have gull wing construction which is compatible with tube fed automatic placement equipment or pick and place manufacturing techniques. Transformers can be used for self-saturating or linear switching applications. The Inductors are ideal for noise, spike and power filtering applications in Power Supplies, DC-DC Converters and Switching Regulators.

- ***Operation over ambient temperature range from −55°C to +105°C***
- ***All units are magnetically shielded***
- ***All units exceed the requirements of MIL-T-27 (+130°C)***
- ***Transformers have input voltages of 5V, 12V, 24V and 48V. Output voltages to 300V.***
- ***Transformers can be used for self-saturating or linear switching applications***
- ***Schematics and parts list provided with transformers***
- ***Inductors to 20mH with DC currents to 23 amps***
- ***Inductors have split windings***

Delivery—stock to one week

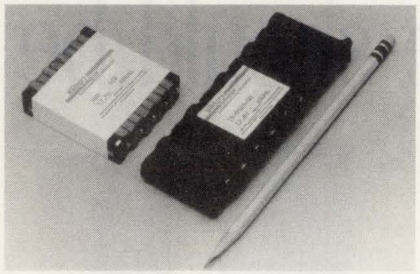
SEE EEM, THOMAS REGISTER OR SEND DIRECT FOR FREE PICO CATALOG

PICO Electronics, Inc.
453 N. MacQuesten Pkwy. Mt. Vernon, N.Y. 10552
***Call Toll Free* 800-431-1064**
IN NEW YORK CALL **914-699-5514**

CIRCLE 204 FOR U.S. RESPONSE
CIRCLE 205 FOR RESPONSE OUTSIDE THE U.S.

BATTERIES

▼ BATTERY-PACK DESIGN BOOSTS EFFICIENCY



The Hed-Line series of packaged prismatic, sealed nickel cadmium batteries offers volume efficiencies up to 60% higher than standard cylindrical batteries. For example, a 12-V, 600-mAh battery pack occupies only 3.75 in.^{3} compared to 6.05 in.^{3} using standard cylindrical cells. Also, electrode improvements boost the capacity of each integral cell by 20% to 30%. A 12-V, 600-mAh pack goes for $60 in lots of 100. Delivery is three to four weeks.

The Battery Source
7069-1/2 Vineland Ave.
N. Hollywood, CA 91605
(800) 228-5239
▶ CIRCLE 839

▼ BATTERY MAKER WORKS CLOSELY WITH OEMS

Tough OEM battery problems can be solved by a battery manufacturer with a long history of working closely with OEMs. Experienced battery engineers and technical experts will work one-on-one with OEM designers to develop application solutions. Battery systems include Duracell alkaline batteries, as well as lithium and zinc-air batteries in a wide range of configurations. Call with application requirements.

Duracell Inc.
Berkshire Industrial Park
Bethel, CT 06801
(800) 431-2656
▶ CIRCLE 840

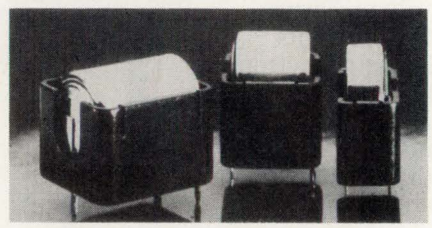
▼ NICKEL-METAL HYDRIDE CELLS REACHING OEMS

A family of nickel-metal hydride batteries with twice the run time of standard nickel cadmium cells is now available to OEMs. The nickel-metal hydride batteries also offer important environmental advantages compared with traditional rechargeable cells. Samples are being provided to OEMs in the portable-computer, portable-communication, and other selected markets. The line includes AA cells at 1100 mAh, 2/3A at 900 mAh, 4/5A at 1400 mAh, A at 1600 mAh, and Cs (sub-C) at 2700 mAh. Initially, nickel-metal hydride cells will cost about twice as much as nickel cadmium cells of equivalent amp-hour capacities.

Gates Energy Products Inc.
P.O. Box 114
Gainesville, FL 32602
(904) 462-3911
▶ CIRCLE 841

▼ BATTERY HOLDER IS ALSO ASSEMBLY MODULE

The PBAM battery holder/assembly module comes in two models. One holds the Z2A65, a 2.4-V, 65-mAh cell, and the other holds the Z3A65, a 3.6-V, 65-mAh cell. Both permit soldering of the battery holder to a pc



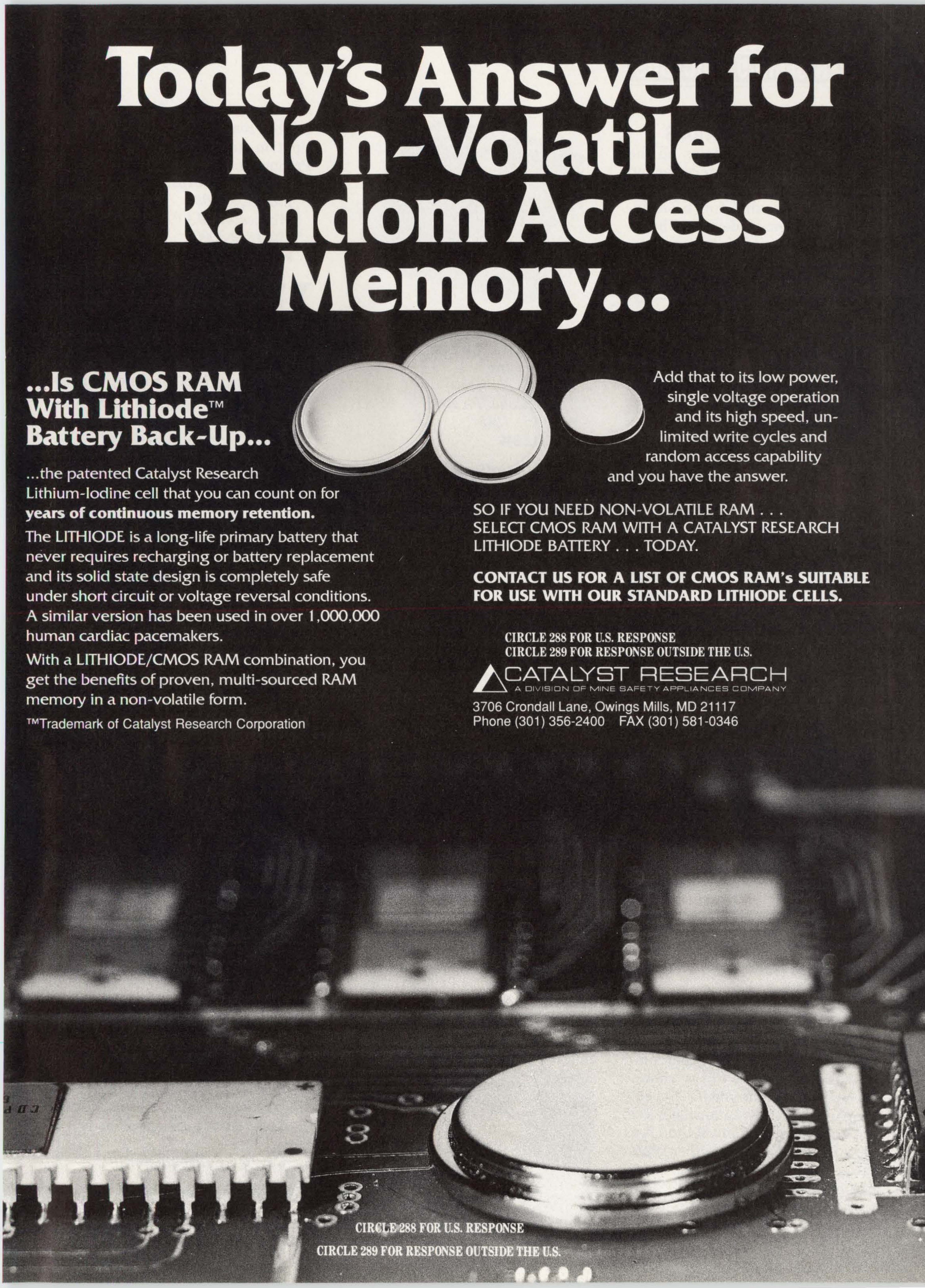
board as either a through-hole or surface-mounted component. Later in the assembly process, the battery can be added. Consumers will also be able to replace the battery without desoldering. Call for pricing and delivery.

Plainview Batteries Inc.
23 Newtown Rd.
Plainview, NY 11803
(516) 249-2873
▶ CIRCLE 842

▼ SEALED-LEAD BATTERY SHRINKS UPS SYSTEMS

Thanks to a 60% improvement in volumetric energy density compared with conventional batteries, the Genesis sealed-lead battery lets designers significantly reduce the size and weight of their UPS battery cabinets. The first cell in the line, the G12V120W15, provides 120W/cell for 15 minutes, which is 20% more power than a typical 38-Ah battery. Call for pricing and delivery.

Gates Energy Products Inc.
P.O. Box 114
Gainesville, FL 32602
(904) 462-3911
▶ CIRCLE 843


Today's Answer for Non-Volatile Random Access Memory...
...Is CMOS RAM With Lithiode™ Battery Back-Up...
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The LITHIODE is a long-life primary battery that never requires recharging or battery replacement and its solid state design is completely safe under short circuit or voltage reversal conditions. A similar version has been used in over 1,000,000 human cardiac pacemakers.
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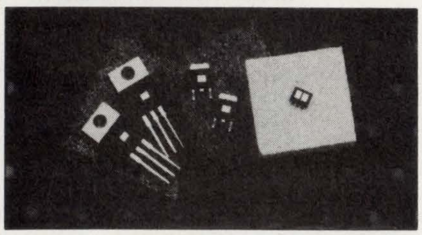
A DIVISION OF MINE SAFETY APPLIANCES COMPANY
3706 Crondall Lane, Owings Mills, MD 21117
Phone (301) 356-2400 FAX (301) 581-0346
CIRCLE 288 FOR U.S. RESPONSE
CIRCLE 289 FOR RESPONSE OUTSIDE THE U.S.

▼ BATTERY-BACKUP IC INTEGRATES FUNCTIONS

A single chip now contains all the functions needed for battery-backup control. The MB3780A device is designed specifically for SRAMs, ROMs, and logic-IC devices. The IC automatically switches to two alternate power sources—either a nonrechargeable primary battery or a rechargeable secondary battery—during dc power losses or disturbances. In lots of 1000, the devices cost $1.15 and $1.50 in 16-pin plastic DIPs or 16- or 20-pin plastic flat packs, respectively. Delivery is from stock.

Fujitsu Microelectronics Inc.
3545 N. First St.
San Jose, CA 95134-1804
(408) 922-9000
▶CIRCLE 844

▼ DUAL-MOSFET FAMILY ADDS TO SMT LINE

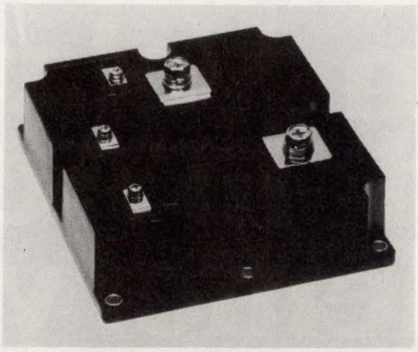


Three additions have been made to a surface-mounted family of MOSFETs for motor control and power switching. The Si9952DY, Si9953DY, and Si9955DY each contain two MOSFETs in an 8-pin small-outline package, and each replaces two discrete MOSFETs in the DPAK or TO-220 package. In lots of 100,000, unit prices start at $0.92. Lead times for production lots are about eight to 12 weeks.

Siliconix Inc.
2201 Laurelwood Rd.
Santa Clara, CA 95054
(800) 554-5565
▶CIRCLE 845

▼ BIPOLAR TRANSISTORS CUT DRIVE NEEDS

The High Beta family of bipolar power transistors lets users reduce drive-power requirements by 90% compared with conventional devices. The family requires only 0.1 to 1 A as opposed to 1 to 10 A for other types. Ratings are from 10 to 600 A and voltages are 600/1000 V and 1200 V. A pricing example is $878.87 for 10 pieces of the 1200-V, 1000-A



KS62121KHB. Prototypes are available in eight to 16 weeks.

Powerex Inc.
Hillis St.
Youngwood, PA 15697
(800) 451-1415
▶CIRCLE 846

▼ TO-240 POWER MODULES USE DIRECT COPPER BONDS

A proprietary direct copper bonding process is used in a family of thyristor-diode power modules. The process improves the current-carrying and power-cycling capabilities of power modules while reducing thermal resistance. The family consists of 12 members: six dual thyristors (MCC19/26/44/56/72/95) and six thyristor-diodes (MCD19/26/44/56/72/95). Current ratings range from 40 to 180 A rms and voltage ratings run to 1600 V. Pricing ranges from $20.95 to $44.65 in lots of 100.

IXYS Corp.
2355 Zanker Rd.
San Jose, CA 95131-1109
(408) 435-1900
▶CIRCLE 847

▼ SPINDLE-MOTOR DRIVERS CONTROL HARD DRIVES

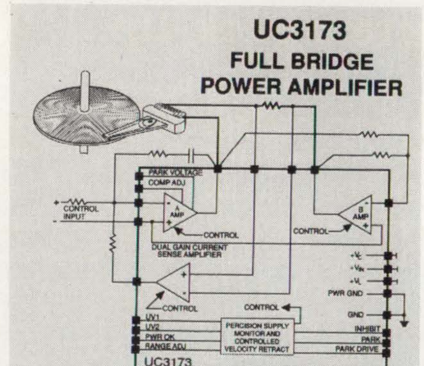
Three mixed-signal ICs drive the three-phase brushless dc spindle motors used in hard-disk drives. The A8901CLB, A8902CLB, and A8903CLB ICs combine back-EMF sensing with power-DMOS outputs and programmable control logic for control and flexibility. Each IC's power-DMOS output stage specifies

a dc output current of 1.5 A and a 1-Ω total on-resistance for low power dissipation and maximum headroom. Pricing starts at $6 in lots of 1000.

Allegro Microsystems Inc.
P.O. Box 15036
Worcester, MA 01615
(508) 853-5000
▶CIRCLE 848

▼ VOICE-COIL DRIVER TARGETS LAPTOP DRIVES

A power amplifier is available to address the needs of space- and power-limited servo applications in high-density disk drives for laptop or notebook computers. The UC3173 full-



bridge power-amplifier IC integrates auxiliary functions such as a current-sense amplifier for load-current monitoring, a dual-input undervoltage comparator, and a head-parking circuit. Prices start at $3.55 in lots of 1000. Call for delivery.

Unitrode Integrated Circuits Corp.
7 Continental Blvd.
Merrimack, NH 03054-0399
(603) 424-2410
▶CIRCLE 849

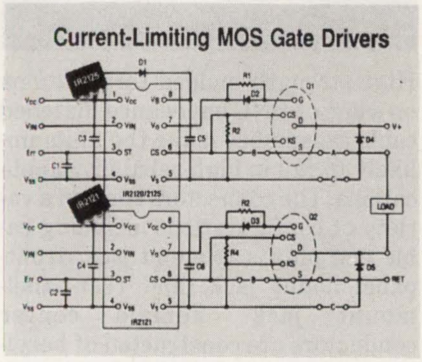
▼ SPINDLE-MOTOR DRIVER SAFEGUARDS DATA

A spindle-motor driver IC for 3.5-in. disk-drive motors features a dynamic braking capability that prevents head crashes during power outages. The SP-440 IC effects dynamic braking by forcing the motor windings to ground after the head is extracted. The device is available from stock in a 15-lead SIP. It costs $6.95 in lots of 1000.

Harris Semiconductor
P.O. Box 883
Melbourne, FL 32901
(800) 4-HARRIS

▼ 500-V GATE DRIVER LIMITS CURRENTS

Driving MOS-gated power transistor is easier than ever with a pair of ICs that provides both higher voltage (to 500 V) and current limiting on one chip. The 500-V/20-V pair of MOS gate drivers, the IR2125 and IR2121, free designers from dis-



crete-based solutions to circuits needing current protection and from low-voltage drivers. The IR2125 and IR2121 cost $4.80 and $2.48, respectively, in lots of 1000. Delivery is from stock.

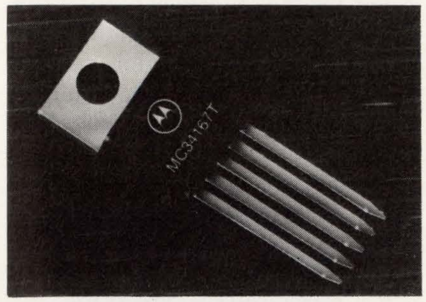
International Rectifier
233 Kansas St.
El Segundo, CA 90245
(213) 772-2000
▶ CIRCLE 850

▼ QUAD-GATED DRIVERS TAKE AUTOMOTIVE HEAT

Two quad-gated inverting power drivers feature 125°C ambient operation for automotive applications. The CA3262A and CA3272 drivers contain four gated power switches to interface low-level logic to inductive and resistive loads such as solenoids, ac and dc motors, heaters, incandescent displays, and vacuum-fluorescent displays. The CA3262A switches 700 mA of load current. Each individual output is protected with overcurrent and overtemperature limiting features. The CA3272 switches 400 mA and has a fault-mode flag output. A sequential-addressing capability identifies shutdown channels. Both come in 16-lead DIPs and 28-lead PLCCs. Pricing starts at $2.20 in lots of 1000 for the CA3262A in a DIP.

Harris Semiconductor
P.O. Box 883
Melbourne, FL 32901
(800) 4-HARRIS, ext. 1251
▶ CIRCLE 881

▼ SWITCHING REGULATOR EASES CONVERTER DESIGN

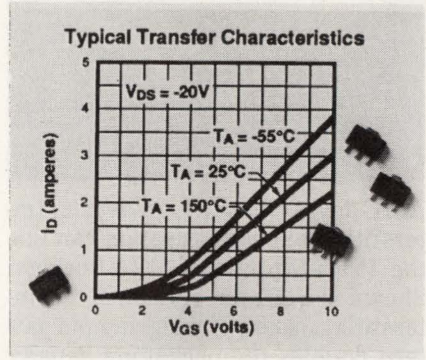


A monolithic power switching-regulator IC offers an on-chip output switch that controls currents greater than 5 A. The MC34167 regulator comes in a 5-pin TO-220 plastic package and contains the primary functions needed in step-down and voltage-inverting configurations. Pricing starts at $2.03 in lots of 10,000. OEM quantities have stock-to-six-week lead times.

Motorola Inc.
2100 E. Elliot Rd.
Tempe, AZ 85284
(602) 897-3615
▶ CIRCLE 851

▼ P-CHANNEL MOSFETS HAVE LOW THRESHOLD

A low-threshold p-channel MOSFET is available in an SOT-89 package. The TP2510N8 carries a drain-to-source breakdown voltage of 100 V

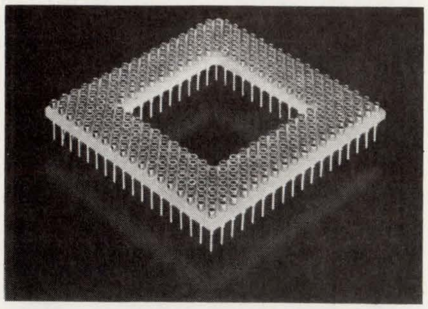


minimum and an on-resistance of 3.5 Ω maximum at $V_{GS} = 10$ V and $I_D = 1$ A. The gate-threshold voltage is guaranteed at 2.4 V maximum. Pricing is $0.53 in lots of 1000.

Supertex Inc.
1225 Bordeaux Dr.
Sunnyvale, CA 94088-3607
(408) 744-0100
▶ CIRCLE 852

CIRCLE 252 FOR U.S. RESPONSE CIRCLE 253 FOR RESPONSE OUTSIDE THE U.S.

▼ PGA SOCKETS KEEP FORCE LOW, DENSITY HIGH

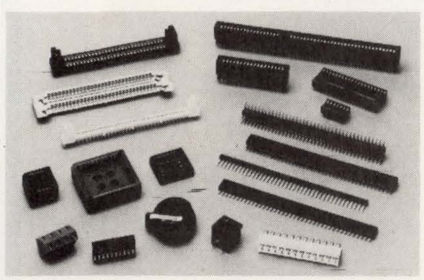


ASIC devices with a high-density (interstitial) pin configuration can use the Preci-Dip line of PGA sockets. Shown is a 391-pin version of the interstitial socket. The zig-zag pin pattern doubles the packaging density compared with traditional 0.100-in. grid patterns. The socket's insulator is molded FR-4 epoxy, which is suitable for all forms of soldering and assembly. Ultra-low-force contacts prevent pin damage to high-lead-count devices. Call for pricing and delivery.

Mill-Max Mfg. Corp.
P.O. Box 300
Oyster Bay, NY 11771-0300
(516) 922-6000
▶ **CIRCLE 853**

▼ STAMPED SOCKETS COMPLEMENT LINE

A series of stamped and formed sockets and edge-card connectors complements an existing line of screw-machine products. The series includes PLCC sockets in patterns

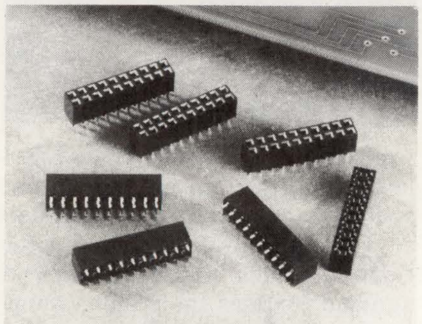


from 28 to 100 pins, DRAM sockets, standard DIP sockets, coin-cell battery holders, mini-DIN connectors, terminal blocks, SIMM sockets, headers, and more. Pricing in OEM quantity starts at $0.002 per pin. Delivery is from stock.

Andon Electronics Corp.
4 Court Dr.
Lincoln, RI 02865
(401) 333-0388
▶ **CIRCLE 854**

▼ DUAL-ROW CONNECTOR KEEPS LOW PROFILE

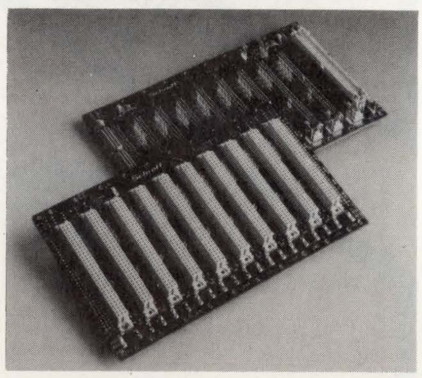
A low-profile, dual-row vertical connector is just 0.250-in. high, which satisfies dense packaging requirements. The connector comes in from two to 40 positions per row (four to 80 circuits) on a 0.100-in. grid. Tail



lengths of 0.050 and 0.120 in. are available. The connector is end-to-end or side-to-side stackable. Call for pricing and delivery.

Methode Electronics Inc.
Interconnect Products Div.
1700 Hicks Rd.
Rolling Meadows, IL 60008
(800) 323-6864
▶ **CIRCLE 855**

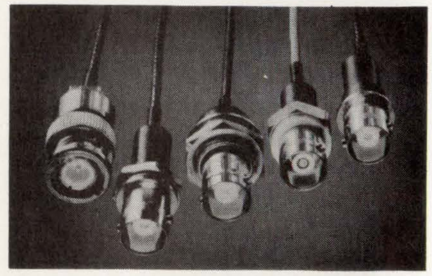
▼ VME BACKPLANES REDUCE NOISE



Optimized placement of capacitors reduces noise and power dissipation in the ON-Board J1 VME backplanes. The units are offered in standard sizes from three to 20 slots in a four-layer design. The current source for switchable "active" terminations are two op amps, which limits power dissipation and prevents misplaced jumpers. Pricing starts at $173.60. Call for delivery.

Schroff Inc.
170 Commerce Dr.
Warwick, RI 02886
(800) 451-8755
▶ **CIRCLE 856**

▼ BNC CABLE ASSEMBLIES FEATURE HIGH STRENGTH

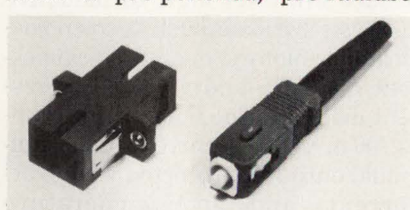


High-strength molded terminations on a line of BNC impedance-matched cable assemblies make the units unlikely to fail in high-reliability applications. The connectors come in a variety of configurations including cable end plug, cable end jack, front-panel-mount jack, and rear-panel-mount jack. Female center conductors are constructed of beryllium copper or phosphor bronze. A 12-in., double-ended BNC assembly with a cable end plug and 50-Ω coaxial cable costs $9.52 for 1000 pieces.

Meritec
1359 W. Jackson St.
Painesville, OH 44077
(216) 354-3148
▶ **CIRCLE 857**

▼ STREAMLINED CONNECTOR TERMINATES FASTER

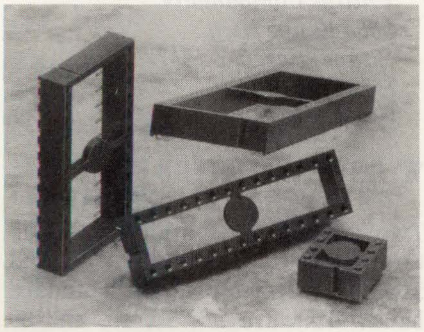
With fewer components than the standard NTT-style connector, the 86061 Series SC fiber-optic connector permits faster and easier field termination without affecting performance. The connector is compatible with all SC-type hardware and features a pre-polished, pre-radiused



PC ferrule. Typical insertion loss is 0.15 dB in the multimode version and 0.17 dB in the single-mode version. Pricing depends on style, ferrule material (alumina or zirconia), and quantity.

Molex Fiber Optic
Interconnection Technologies
2111 Oxford Rd.
Des Plaines, IL 60018
(708) 803-3600
▶ **CIRCLE 858**

▼ DIP SOCKETS SUIT SMT TASKS



A line of DIP sockets for surface mounting has three-finger contacts that approach screw-machined quality. The ICF Series sockets come in 0.300-in. row spacing from eight to 28 pins and in 0.600-in. row spacing from 24 to 40 pins. Pricing is from $0.11 per pin.

Samtec Inc.
P.O. Box 1147
New Albany, IN 47151-1147
(800) SAMTEC-9
▶ **CIRCLE 859**

▼ PRINTED-CIRCUIT CARD SIMPLIFIES PROTOTYPING

The Model 100 printed-circuit card is for building prototype analog and/or small logic circuits. It can also be used for short production runs of special circuits. The card has hole patterns for 16- and 8-pin DIPs, potentiometers, resistors, capacitors, diodes, and transistors. It also has hole patterns for wire-wrap pins. Pricing is $29.50.

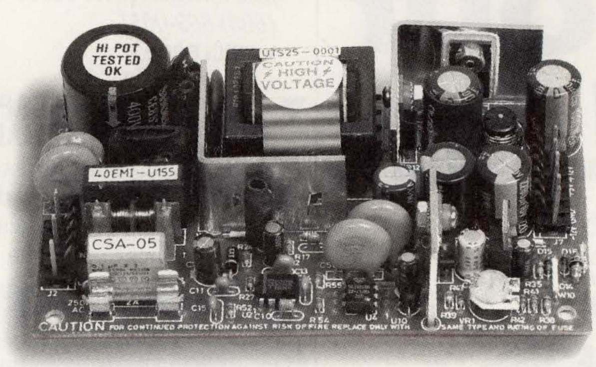
Calex Mfg. Co. Inc.
3355 Vincent Rd.
Pleasant Hill, CA 94523
(800) 542-3355
▶ **CIRCLE 860**

▼ CABLE ASSEMBLIES KEEP CROSSTALK LOW

Factory-programmed coaxial cable assemblies are said to perform better than planar-ribbon transmission assemblies. They offer low crosstalk, low attenuation, and minimum propagation delay. The assemblies mate with standard eject headers or pin fields with 0.025-in.^{2} posts on 0.100-by-0.100-in. centerline spacing.

AMP Inc.
P.O. Box 3608
Harrisburg, PA 17105-3608
(800) 522-6752
▶ **CIRCLE 861**

PURE GOLD IS NOW $20.00*



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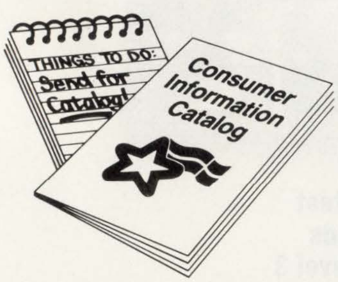
Golden Power Systems

DISCOVER THE NEW GOLD STANDARD IN OEM POWER SUPPLIES.

CIRCLE 198 FOR U.S. RESPONSE
CIRCLE 199 FOR RESPONSE OUTSIDE THE U.S.

Put Our List On Your List



Our list can help you do the other things you have on your list. Such as buy a car. . . estimate social security. . . start the diet. . . check out investments. . .

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Pueblo, Colorado 81009

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PASSIVES

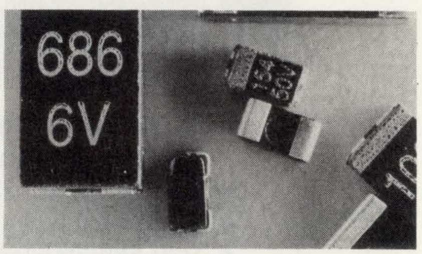
▼ RESISTORS, COILS SHIP IN A HURRY

A wide range of resistor products is now available within two to seven days thanks to the Swift (ship within 52 hours) quick-delivery program. Delivery is guaranteed in one week or less for almost any type of resistor, including commercial and precision metal-film types, SMT chip resistors, power wirewounds, ultraprecision types, and more. Accuracies are as tight as 0.01% or 2 ppm/°C. Call for pricing and samples.

RCD Components Inc.
520 E. Industrial Park Dr.
Manchester, NH 03109
(603) 669-0054
▶ **CIRCLE 862**

▼ TANTALUM CHIP CAPACITOR BOASTS HIGH RELIABILITY

The TAZ HRC5000 Series of tantalum chip capacitors is designed, built, and tested for medical and life-support applications. The units are



intended for human-implantable applications that must operate continuously for up to 10 years. These applications include pacemakers, defibrillators, hearing aids, nerve stimulators, and others. Eight molded-case sizes are offered. Call for pricing and delivery.

AVX Tantalum Corp.
69 Landry St.
Biddeford, ME 04005
(207) 282-5111
▶ **CIRCLE 863**

▼ SMT FERRITE BEADS SUPPRESS TRANSIENTS

EMI/RFI suppression is the purpose of two surface-mounted ferrite beads. The beads come in 0.335-in. (8.9-mm) and 0.160-in. (4.6-mm) sizes and are made of 4S2 ferrite material. The beads' impedances match those of the most-frequently used tape-and-reeled beads on wire. Construction consists of a piece of flat tinned copper wire passed through and crimped on the rectangular beads. Samples are available. Call for pricing.

Philips Components
5083 Kings Hwy.
Saugerties, NY 12477
(914) 246-2811
▶ **CIRCLE 864**

▼ CRYSTAL FILTERS COME IN SEVERAL BANDWIDTHS

Two series of monolithic crystal filters are centered at 10.7 MHz and 21.4 MHz. In each series, standard bandwidths are 7.5, 12, 15, and 30 kHz. Two-, four-, six-, and eight-pole designs are offered with ultimate attenuation of 90 dB. Features include low pass-band ripple and excellent spurious-response rejection. Call for pricing and delivery.

OPT Industries Inc.
300 Red School Lane
Phillipsburg, NJ 08865
(908) 454-2600
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Torrance, CA 90505
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▼ LIGHTED PUSHBUTTONS INCLUDE 11,008 OPTIONS

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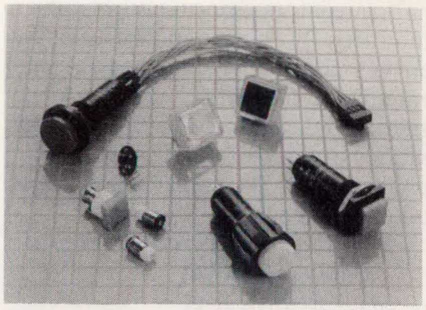
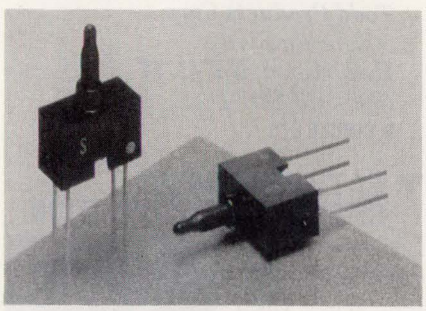


bilities, and snap-in front-panel installation. Any of the Series 20 models fits in a 5/8-in.-diameter panel hole. High-density mounting is possible on 3/4-in. centers when required. SPST to DPDT switching functions are available. Call with application requirements.

Electro-Mech Components Inc.
1826 N. Floradale Ave.
South El Monte, CA 91733
(818) 442-7180
▶ **CIRCLE 868**

▼ SUBMINI OPTICAL SWITCH FEATURES LONG LIFE



A subminiature, optoelectronic pin-plunger switch offers longer service life and higher reliability than traditional mechanical switch designs. The EE-SA105 switch has no contact mechanism. Instead, it relies on an infrared LED and phototransistor combination that works with an actuator to alter the switch's output level for activation. Contact bounce and wear is eliminated. Pricing starts at $0.99 in lots of 5000. Call for delivery.

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12525 Daphne Ave.
Hawthorne, CA 90250
(213) 777-0077
▶ **CIRCLE 871**

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(213) 777-0077
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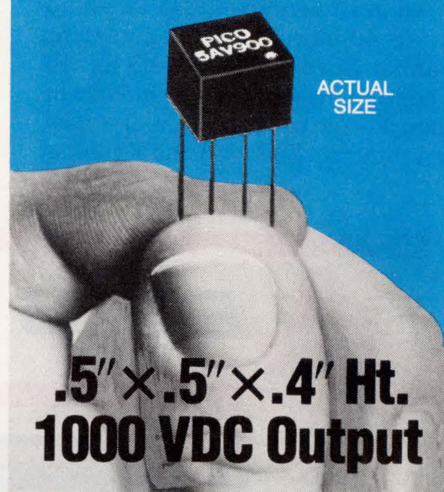

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▼ RELAY BULLETIN UPDATES MANY PRODUCTS

A wide range of general-purpose and heavy-duty power relays are featured in Bulletin No. 1845-12, an updated 40-page relay engineering manual. Coverage includes 5- and 10-A continuous-duty types, compact industrial-control relays, 35-A types, and others. Specs include contact configurations, amperage ratings, coil voltages, resistance, and nominal coil power. Drawings, schematics, and performance data is included.

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2745 S. 19th St.
Milwaukee, WI 53215
(414) 671-6800
▶ **CIRCLE 873**

▼ DISCRETE DEVICES DETAILED IN DATABOOK

A large variety of discrete semiconductor devices are specified in a 278-page databook. Complete technical information is provided on MOSFETs, power transistors, small-signal transistors, triacs, and rf-power modules. Device-characteristic curves and dimensional diagrams round out the entries. A reference section details procedures for automatic handling of the devices. An alphabetical index helps locate parts quickly and easily.

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25621 Redhill Ave.
Tustin, CA 92680
(714) 259-0368
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▼ FULL SWITCHER LINE POWERS COLOR CATALOG

Dozens of switching power supplies in a wide range of outputs are described in a full-color, 32-page catalog. Featured is a power-supply locator chart that matches applications to solutions. Dimensional diagrams are included as are complete specifications for each series of supplies. Output power ranges from 150 to 1000 W.

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▼ DISCRETE-SEMI LINE FILLS 206-PAGE BOOK

A full line of small-signal leaded, power, rf/microwave, surface-mounted, and optoelectronic devices is detailed in a 1991 selector guide and cross reference. The 206-page book contains an alphanumeric index, comprehensive cross-reference information, packaging specs, and outline drawings. Reply cards facilitate requests for additional data.

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Riviera Beach, FL 33404
(800) 447-3762
▶ **CIRCLE 877**

▼ HIGH-POWER SWITCHERS RANGE UP TO 4000 W

A catalog outlines high-power switching supplies ranging from 500 to 4000 W with from one to five outputs and power-factor correction. The reference guide contains a concise overview of the line and is supplemented by product data sheets and performance specifications. Eight standard supply lines are covered as are specialty product lines.

HC Power Inc.
17032 Armstrong
Irvine, CA 92714-5716
(714) 261-2200
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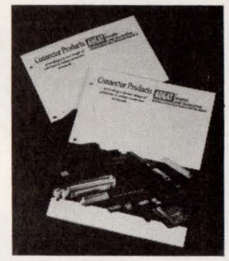
▼ OVER 36,000 SENSORS FILL LARGE CATALOG

A 268-page product catalog features over 36,000 sensors in eight basic technology groups. The new edition is 22% larger than the company's previous catalog and features "flap technology," which means color-coded indexed foldouts for each product section. Also included are two new product lines: the IDEX identification and communication system, and a family of thin-film pressure sensors and transducers. Complete technical data is included.

Baumer Electric Ltd.
122 Spring St., C-6
Southington, CT 06489
(203) 621-2121
▶ **CIRCLE 879**

▼ CONNECTOR PRODUCTS IN FULL-LINE CATALOG



A broad range of interconnection products including board-to-board connectors such as press-fit, modular printed-wiring-board headers, receptacles and IDC types, card edge, DIN, ribbon-cable headers, fiber-optic connectors, controlled-impedance types, and others are featured in a 120-page catalog. Product descriptions, performance characteristics, features, benefits, photographs, and engineering drawings are included along with specs and applications.

Augat
Interconnection Products Division
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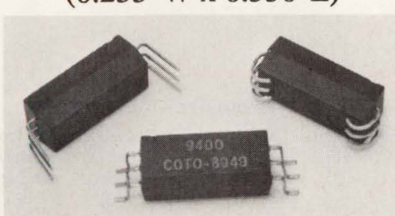
▶ **CIRCLE 880**

2 GHz

Micro Miniature Reed Relays

(0.255"W x 0.550"L)



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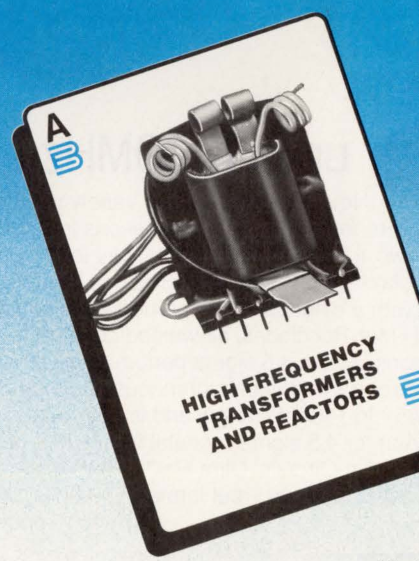

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LRMS-2L	800-1000	DC-200	+3	6.6	24	6.95
LRMS-1	0.5-500	DC-500	+7	6.4	45	6.25
LRMS-1W	2.0-750	DC-750	+7	5.8	45	6.75
LRMS-2	5-1000	DC-1000	+7	6.8	38	6.95
LRMS-2D	5-1000	DC-1000	+7	6.8	40	7.25
LRMS-2U	10-1000	10-1000	+7	6.5	46	11.45
LRMS-5	5-1500	DC-1000	+7	6.0	41	13.95
LRMS-11A	1400-1900	40-500	+7	7.0	25	16.95
LRMS-1LH	2.0-500	DC-500	+10	5.8	47	7.95
LRMS-2LH	5-1000	DC-1000	+10	6.6	40	8.95
LRMS-5LH	10-1500	DC-900	+10	5.4	38	14.95
LRMS-1MH	2.0-500	DC-500	+13	5.7	44	8.95
LRMS-2MH	5-1000	DC-1000	+13	6.6	44	9.95
LRMS-5MH	10-1500	DC-900	+13	5.8	46	15.95
LRMS-1H	2.0-500	DC-500	+17	6.3	44	10.95
LRMS-2H	5-1000	DC-900	+17	7.2	36	11.95
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CIRCLE 521

Low-Cost Iso Amp Has High Precision

JAMES WONG
Analog Devices Inc., 1500 Space Park Dr., Santa Clara, CA 95052; (408) 727-9222.

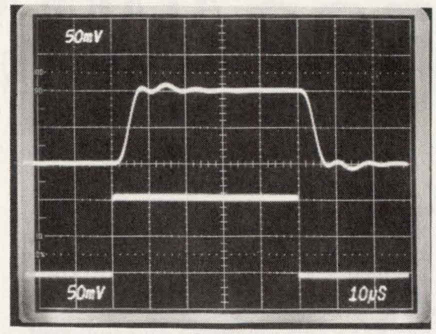
An isolation amplifier that can work across a 5000-V barrier with a maximum dc gain error of only 0.1% can be built using a bifurcated linear optocoupler at a parts cost of about $7 or $8 *(Fig. 1)*. The amplifier is at least as good as most commercial units, which cost up to $100.

Key to the amplifier's operation is the optocoupler, which contains one LED and two nominally identical photodiodes. One of the photodiodes is on the same side of the 5000-V isolation barrier as the LED. It's used in a feedback loop to ensure a linear relationship between the amplifier's input voltage, V_{in}, and the photocurrents in the two photodiodes, independent of temperature variations and long-term drift of the LED's output.

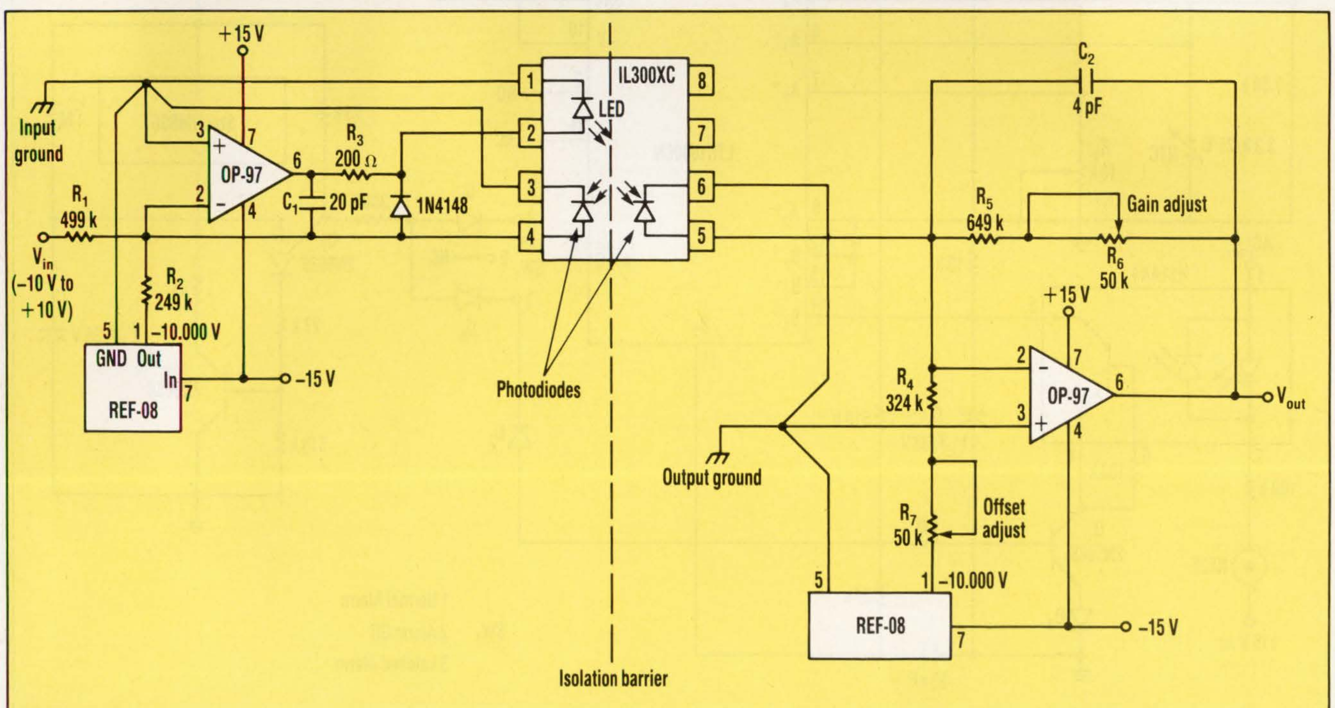
The amount of light received by the second LED is linearly proportional to the amount received by the first one; hence its photocurrent is also proportional to V_{in}. That photocurrent is converted back into a voltage by the output op amp. The isolation amplifier requires two separate, isolated power supplies: one for the input circuitry, and one for the output.

Because current can flow through the optocoupler's LED in only one direction, the input op amp is biased by a −10.000-V reference supply, through R_2. Consequently, the amplifier can handle bipolar input signals in the range of ±10-V. It exhibits a linearity of better than 0.05% over that range. To minimize the errors generated by the isolation amplifier's relatively high circuit resistances, the op amps were chosen for their low input bias currents and low temperature-drift characteristics. Thus, the overall amp can maintain its dc gain at 1.000 ±0.001 from 0° to 70° C.

The amplifier has two simple adjustments—offset and gain. The offset pot (R_7) is adjusted for zero output with 0 V applied to the input. The gain pot (R_6) is trimmed for −10.000 V out, with −10.000 V in. Repeat the sequence until no further adjustment is needed. The amplifier has a respectable 3-dB bandwidth of 85 kHz *(Fig. 2)*.□



2. THIS SCOPE PHOTO of the amplifier's small-signal pulse response (input on lower trace, output on upper trace) demonstrates the unit's bandwidth characteristics. The amplifier's response extends out to 85 kHz.



1. THE "EXTRA" photodiode on the input side of the optocoupler provides feedback, which gives the isolation amplifier its excellent (0.05%) linearity. Note that the amplifier requires independent power supplies for its isolated input and output circuits.

CIRCLE 522

Alarm Monitors Temp And Voltage

JOHN A. HAASE
Colorado State University, Fort Collins, CO 80523; (303) 491-5545.

Send in Your Ideas for Design
Address your Ideas-for-Design submissions to Richard Nass, Ideas-for-Design Editor, Electronic Design, 611 Route 46 West, Hasbrouck Heights, NJ 07604.

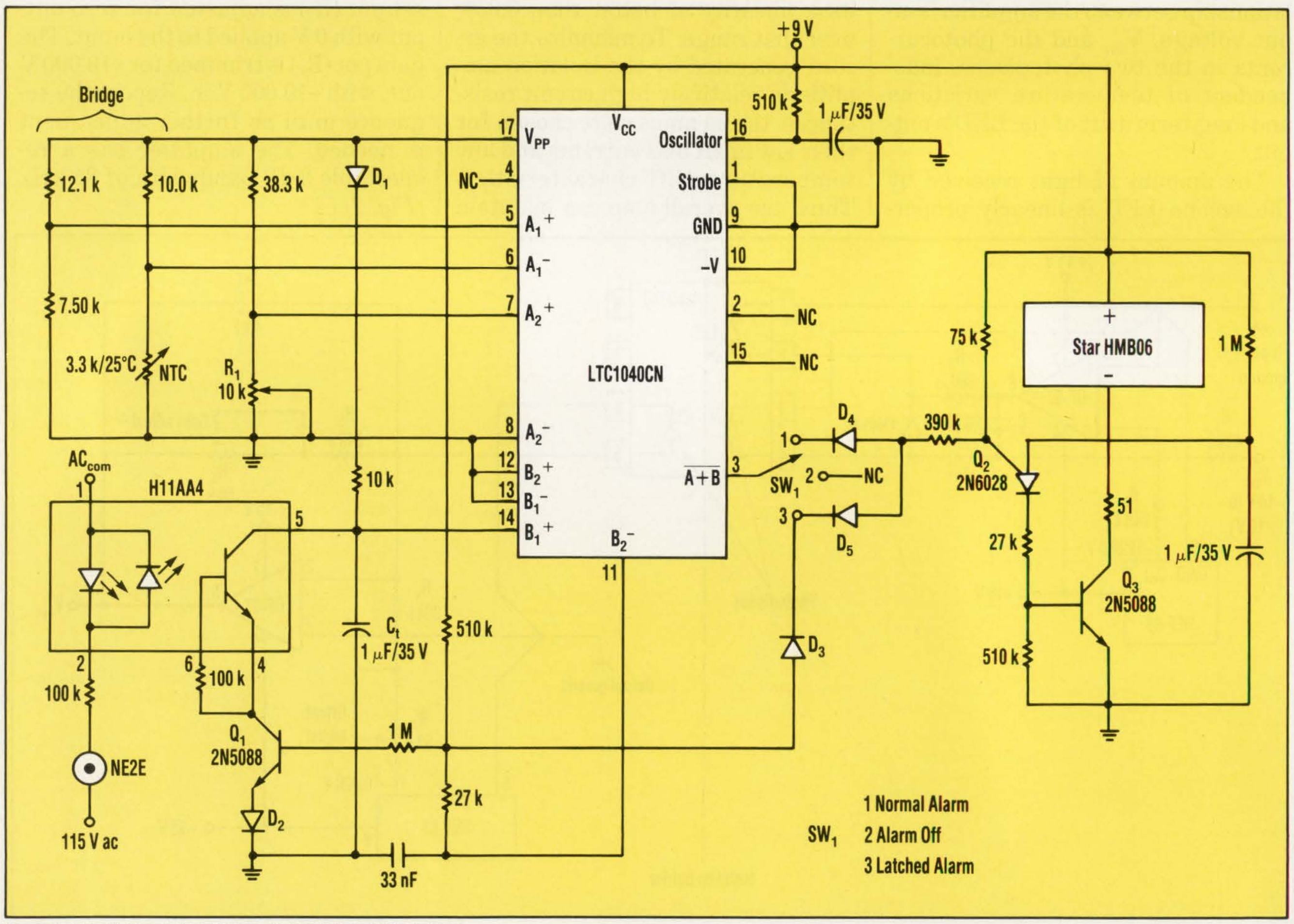
Designed to provide timely warning of problems with refrigeration equipment, this low-power circuit monitors both temperature and line voltage. The circuit's alarm sounds if the temperature rises above a preset value or if the line voltage drops out for more than five minutes—a condition that often precedes a rise in temperature.

Unlike many commercial monitors, the circuit uses very little power, thanks to the sampled data techniques used in the CMOS LTC1040CN dual micropower comparator *(see the figure)*. Power consumption is low because the device's pulsed voltage source at pin 17 turns on for a mere 80 µs. Moreover, the monitor's ratiometric design means that its accuracy is unaffected by declining battery potential.

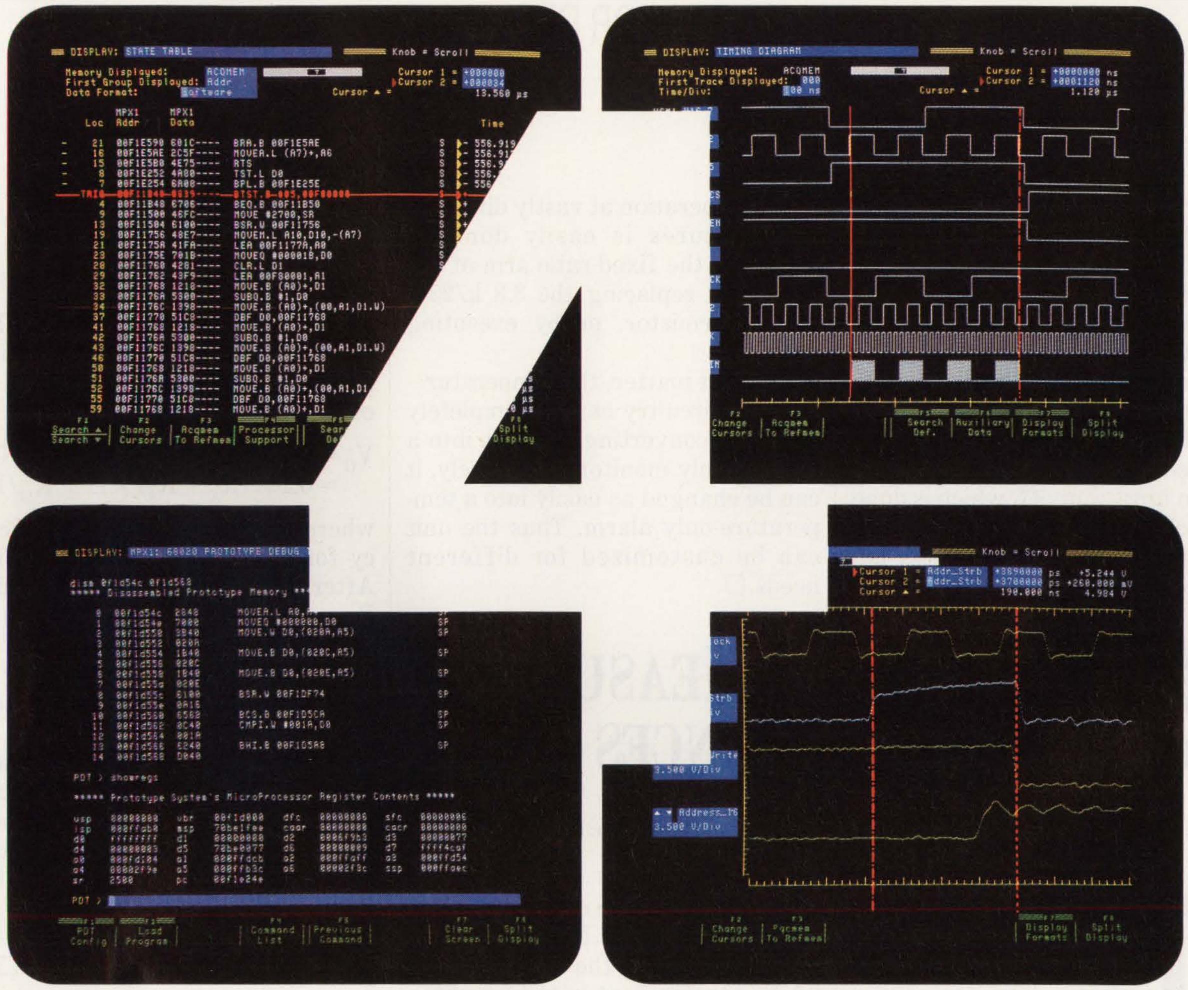
If the temperature rises above the setpoint (0°C for the values in the diagram), comparator 'A' in the 1040 drives pin 3 low, which enables Q_2, a PUT. The PUT is a relaxation oscillator whose load is the Star Micronics HMB06 piezotransducer. That transducer is driven by a short tone burst every two seconds and draws no standby current, further contributing to battery life.

A neon lamp serves both as a pilot light and as a current exciter for the H11AA4 ac optocoupler. As long as there's ac power, capacitor C_t finds a discharge path via the optocoupler, Q_1, and D_2 twice every cycle. Once per second, a charging current through D_1 attempts to raise the voltage at pin 14.

If the ac power fails, the opto-



THIS REFRIGERATION MONITOR sounds its alarm when power is lost for more than five minutes or when the temperature rises above 0°C. Its single switch, SW_1, provides two operating modes (latched and unlatched), plus an Off state to silence the alarm.



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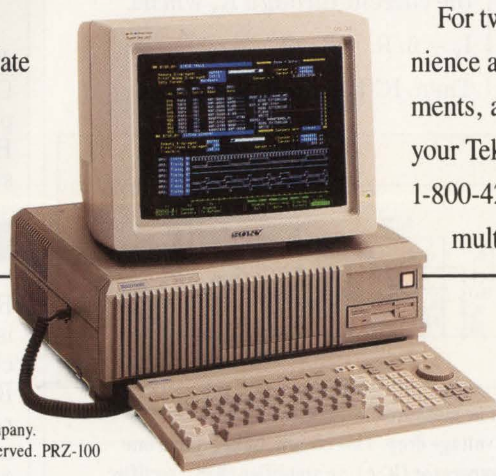

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CIRCLE 170 **for Literature (U.S. Response)**

CIRCLE 171 **for Literature (Response Outside U.S.)**

CIRCLE 172 **for Sales Contact (U.S. Response)**

CIRCLE 173 **for Sales Contact (Response Outside U.S.)**

coupler gets cut off and the voltage at pin 14 begins a staircase ascent. After about five minutes, it reaches the threshold level of about 6 V set by the biasing resistors at the base of Q_1 and triggers the alarm.

When switch SW_1 is set in position 1, the alarm is automatically shut off when the condition that caused it is corrected. In position 3, it latches and stays on until shut off, which is done by switching to position 2.

The temperature setpoint is adjusted over a ±10°C range by 15-turn pot R_1. Operation at vastly different temperatures is easily done by changing the fixed-ratio arm of the bridge or replacing the 3.3 k/25°C NTC thermistor, or by executing both.

For that matter, the temperature-sensing circuitry can be completely disabled, converting the unit into a voltage-only monitor. Conversely, it can be changed as easily into a temperature-only alarm. Thus the unit can be customized for different needs.□

CIRCLE 523

AC SCHEME MEASURES LOW RESISTANCES

YONGPING XIA
West Virginia University, Dept. of Electrical and Computer Engineering, Morgantown, WV 26506.

Measuring low-value resistors can be tricky. One method is to measure the voltage drop across the unknown resistor and then calculate its value. Because the drop depends on the current through the resistor, the current should be large enough to supply measurable voltage. For example, the voltage drop is only 10 mV if the measured resistor is 0.1 Ω and current through the resistor is 100 mA. Large currents supply large voltage drops. However, in many cases, the measured components don't let large currents pass through. Or, the heat generated by the components due to the large current may cause some measurement error.

This problem can be solved by amplifying the voltage drop so that less current is needed. If the amplifier has a 60-dB gain, the output will be 0.1 V if the current is 1 mA and the resistor is still 0.1 Ω. Typically, op amps have a dc input offset voltage. This offset causes an error when the input level is very low. An ac amplifier technique, however, can sidestep the problem *(see the figure)*.

IC-A, C_1, and R_{1-4} form a square waveform generator with a frequency around 300 Hz. D_1 regulates the square wave to be a 6-V pk-pk source. Because the values of the measured resistor (R_X) and additional resistor (R_A) are much less than R_6, the current through R_X will be:

$$I_X = 6/R_5 = 2\text{ mA}.$$

Then, IC-B's input is:

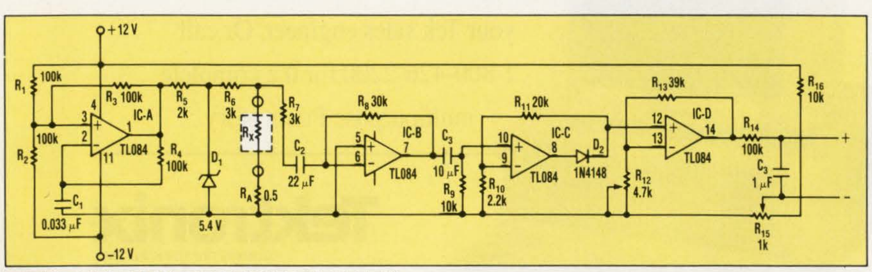
$$V_{in} = 0.002 \times (R_X + R_A).$$

IC-B supplies the ac gain—$R_8/R_7 = 10$. IC-C and D_2 convert the ac signal to a dc signal with gain of $1 + R_{11}/R_{10} = 10$. IC-D is a dc amplifier with a gain of $1 + R_{13}/R_{12}$. As a result, the output is:

$$\begin{aligned} V_O &= 0.5 \times V_{in} \times 10 \times 10 \times (1 + R_{13}/R_{12}) \\ &= 0.1 \times (R_X + R_A) \times (1 + R_{13}/R_{12}) \end{aligned}$$

where 0.5 is the conversion efficiency for a 50% duty-cycle waveform. After the dc output is smoothed by R_{14} and C_4, a digital voltmeter can measure R_X.

R_A supplies a base signal for the amplifiers. When $R_X = 0$, R_A sends a 1-mV pk-pk signal to IC-B. If $R_A = 0$ and R_X is very small, IC-B's noise may "eat" the weak input. To compensate for the output offset due to R_A, R_{15} calibrates the digital voltmeter to zero when $R_X = 0$. Adjusting R_{12} makes the scale 1Ω/V. Thus, a 2-V digital voltmeter can measure resistances from 0.001 to 1.999 Ω.□



LOW RESISTANCE VALUES can be measured by injecting an ac current through them and amplifying the resultant voltage drop. This circuit, built around one TL084 chip, includes a 300-Hz square-wave generator (IC-A), ac amplifier (IC-B), rectifier (IC-C), and dc amplifier (IC-D).

IFD WINNER

IFD Winner for May 9, 1991

Michael J. English, National Semiconductor Corp., 2900 Semiconductor Dr., P.O. Box 58090, Santa Clara, CA 95052; (408) 721-5000. His idea: *"Voltage Limiter Is Adjustable."*

IFD Winner for May 23, 1991

Jim Williams, Linear Technology Corp., 1630 McCarthy Blvd., Milpitas, CA 95035; (408) 954-8400. His idea: *"Build Low-Cost Precision Barometer."*

VOTE!

Read the Ideas for Design in this issue, select your favorite, and circle the appropriate number on the Reader Service Card. The winner receives a $150 Best-of-Issue award and becomes eligible for a $1,500 Idea-of-the-Year award.

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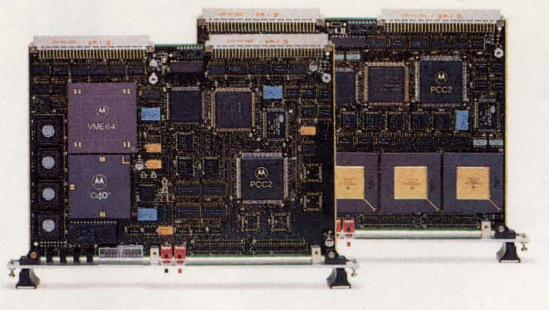

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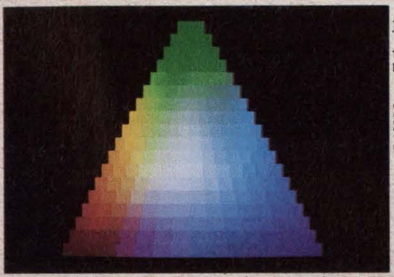

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TRW's dedication to quality always stands up to the test.

Take for example our third Color Palette DAC in the last year – the TMC0458. This stand-alone triple 8-bit DAC doesn't require a costly companion synchronization chip. Yet it's pin-compatible with the industry-standard 458's.

San Diego Zoo Photo/Ron Garrison.

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ELECTRONIC DESIGN

QUICK LOOK

EDITED BY SHERRIE VAN TYLE

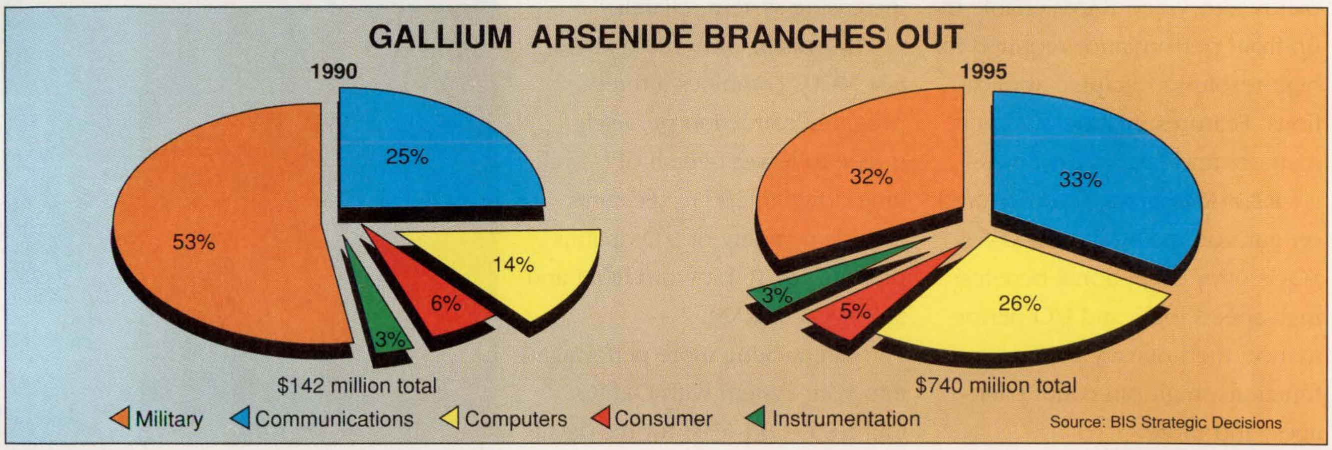
MARKET FACTS

Once the domain of the military, gallium arsenide ICs are branching out into new areas. As a result, GaAs chips are enjoying strong sales growth. From $142 million in 1990, the merchant GaAs IC market is expected to reach $740 million by 1995, according to BIS Strategic Decisions. Fueling the growth is improved manufacturing, resulting in lower cost and wider diversity of applications for the ICs, according to the Luton, England, market researcher.

Sales to the military remain brisk. In 1990, the military accounted for about 53% of merchant revenues. Sales of analog/microwave GaAs ICs should grow from $87 million in 1990 to $358 million by 1995. Fast growing areas are GaAs MMICs (monolithic microwave ICs) used in global positioning system (GPS) receivers, VSATs (very small aperture terminals), and DBS (direct broadcast satellite) TV receivers.

Nonetheless, enough GaAs chips will find their way into high-performance computers, communications, and consumer products, to shrink the military share to 32% by 1995. In computers, digital GaAs offers the advantages of high speed and lower power dissipation on a par with advanced silicon devices. Indeed sales of digital GaAs Ics are forecast to increase from $55 million in 1990 to $382 million by 1995.

Another hot area is fiber-optic telecommunication and data networking. GaAs chips are going into high-speed equipment conforming to Sonet and FDDI standards.



QUICKLOOK COMING EVENT

From propulsion to pocket calculators, batteries and the circuits with which they are managed are very much in the news these days. Batteries and their controlling ICs will be the subjects of a two-day conference and exhibition to be staged in London on April 7 and 8, 1992. The event is sponsored by research and test specialist ERA Technology Ltd. (ERA Technology is a newly privatized state-controlled research establishment. The company was formerly known as the Electrical Research Association.)

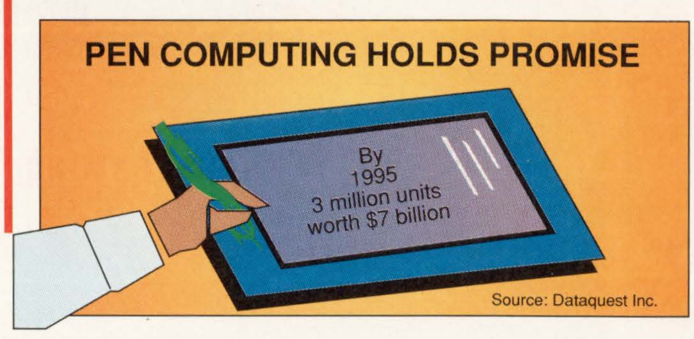
Besides reviewing the latest developments in battery technology, attendees at the conference will also consider proposals for recycling battery components. Also, those attending the conference are expected to consider the possibility of international legislation for the protection of the environment.

Engineers interested in the conference can obtain more details from Linda Jelly; phone +44 (0)372 374151 extension 2393. The association's address is ERA Technology Ltd, Cleeve Road, Leatherhead, Surrey KT22 7SA, United Kingdom.

DID YOU KNOW?

. . . that the Asia-Pacific electronics market, excluding Japan but including Korea, Taiwan, and Singapore, was worth $6.9 billion last year. It is expected to grow 13.7% to hit $7.9 billion this year; $9.6 billion in 1992 (21.7%); $11.1 billion in 1993 (15.9%); and $12.2 billion (10.4%) in 1994.

Semiconductor Industry Association



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Speech Synthesis. For high-quality performance you can hear, no one matches Oki's RealVoice™ speech synthesizers. With on-chip filter and D/A, these chips reduce design time and IC count while increasing system reliability.

16-Bit MCU. Oki's nX family of fast MCUs combines a three-program instruction pre-fetch queue to lower overall CPU cycle time down to 200 ns. Features include a variety of I/O options plus 16K of 16-bit word ROM and 512 bytes of RAM.

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MSM10S0000	0.8μm SOGs, true 82xx, UARTs, memories, standard 24ma drive, 300ps, >500MHz logic
MSM6388	Solid-state recorder/IM serial register I/F
MSM67620	16-bit MCU with 16KB ROM, 512B RAM, 56 I/Os, 3 x 16-bit timers, 2 x 8-bit timers

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OFFERS YOU CAN'T REFUSE

Designers working with active devices for which noise models are not readily available may wish to send for a free demo disk of Microwave Harmonica. The software includes an element that can model up to six user-defined correlated noise current, voltage (or combination) sources.

The program's developer, Compact Software, has improved Harmonica's computation speed in linear and nonlinear simulations. Demo disks are available for SuperCompact for PCs and workstations, Microwave Success—systems simulator, and Using Microwave Harmonica for High-Speed Interconnect Design. Contact Compact Software, 483 McLean Blvd., Paterson, NJ 07504; (201) 881-1200; fax (201) 881-8361. CIRCLE 451

A series of free seminars around the U. S. this fall demonstrates the latest oscilloscope measurement techniques. Hands-on labs, using modern analog and digitizing oscilloscopes, are oriented to common applications. The seminar includes tips on SMT probing, isolating metastable conditions, and triggering on noisy signals. Contact Tektronix at (800) 426-2200, ext. 579. CIRCLE 452

Information on IBM's RISC System/6000 family of Unix workstations is available on a free videotape. With AIX Version 3 as an operating system, the family of workstations executes up to 25.2 MFLOPS and 72.2 SPECmarks. In terms of graphics, the workstations can be equipped to deliver 990,000 3D vectors/s and 120,000 shaded polygons/second. For a copy of the RISC System/6000 video, contact (800) IBM-6676, ext. 838. CIRCLE 453

Just 15% of U. S. scientists and engineers are female. To encourage women to enter science and engineering professions, the U. S. Department of Energy's Argonne National Laboratory offers a free booklet, "Graduate School and Beyond." The booklet draws on a panel discussion held at the laboratory in which panelists offered guidance on selecting a graduate school, supporting oneself through school, choosing a thesis advisor, combining a career with family life, and fulfilling seminar commitments.

Write to Graduate School and Beyond, Division of Educational Programs, Argonne National Laboratory, 9700 S. Cass Ave., Argonne, IL 60439. CIRCLE 454

QUICK NEWS: CONFERENCES

With a $450 million budget for fiscal 1991, the 11-agency federal government Small Business Innovation Research (SBIR) program has supported 3000 small, high-technology companies in its nine years. These companies often have ideas that have government and commercial application, yet have trouble financing them.

To remedy the situation, three conferences will be held in the U. S.—in San Diego, Oct. 30–Nov. 1, in Detroit, Nov. 19–21, and in Atlanta, April 27–29. Conferences gather in one place at the same time all federal R&D agencies and many major prime contractors.

Contractors map specific technology areas at the conference; among the companies participating in the past are General Dynamics, IBM, Texas Instruments, and TRW. Basic seminars give information on proposal preparation, government procurement, patents, and negotiations for defense contracts. Advanced seminars cover marketing, U. S. and foreign licensing, venture financing, strategic alliances, foreign markets, and follow-on funding.

The $105 fee covers sessions, conference documents, and meals. For more information or to register, contact Foresight Science and Technology Inc., 3165 NW 15th St., Delray Beach, FL 33445; (407) 274-4005. Foresight is contactor to the National Science Foundation and the Department of Defense for the National SBIR Conferences. CIRCLE 455

KMET'S KORNER

...Perspectives on Time-to-Market

BY RON KMETOVICZ
President, Time to Market Associates Inc.
Cupertino, Calif.; (408) 446-4458; fax (408) 253-6085

Can you remember a new product development effort you worked on that did not have major changes in management personnel while it was in its execution phase? If you are like me, it will be easy to think of individuals whose departure had an effect on the effort. You should also find it quite easy to remember the effects produced by their replacements!

By their very nature, cross-functional, concurrent product-development programs have a number of managers actively involved with each effort. The probability of having the entire management structure remain intact for the duration of the execution phase is slight. Management change cannot be stopped or brought into full control; this change must be anticipated and managed.

What can be done to minimize negative impact on time to market? A complete task network that identifies the work taking place within functional groups and the resources assigned to do the work is of great value to adjust to the change of a key manager on the team. From the network data is produced an item-by-item list of work that the manager's work group is responsible to perform. Knowing what must be done and who is doing the work within a particular group contributes to promptly identifying and selecting a replacement. During the transition, someone is appointed acting manager of the work group until the new person assumes responsibility.

The replacement manager has access to information on all task activity going on in his/her group sorted by the individuals responsible for the work. They step into the job running. In effect, an up-to-date plan that is accurately tracked makes it very easy to move managers into and out of the project/program.

Another subtle effect of organizational change sometimes requires that the product's definition, or the original plan, be slightly modified to accommodate desires of new management. When this happens, the effects of the change can be added to the plan and results communicated with the organization. The ability to accurately forecast the effect makes it all the more valuable to have a solid base from which to draw comparisons. Most of the time, small changes that do not affect major milestone completion dates will be accepted, while those that lead to major delay will be rejected.

QUICKLOOK

QUICK REVIEWS

Electromagnetic compatibility (EMC) is an issue growing in significance in Europe. Tough pan-Euopean legislation intended to control emission and protection is expected to be introduced in the next few years. Already a directive from the European Commission insists that all electronic and electrical equipment meet stringent EMC design criteria.

Now the British Institution of Electrical Engineers (IEE) has compiled an information package for designers that summarizes the technical standards and regulations in the UK, Germany, and other European countries and the U. S. and lists test houses and procedures, along with designs for screening and filtering. It costs £36 ($21.60 US) and is available from the IEE's Publication Sales Department at P. O Box 96, Stevenage, Hertfordshire, SG1 2SD, UK. Phone +44 (0)438 313311.

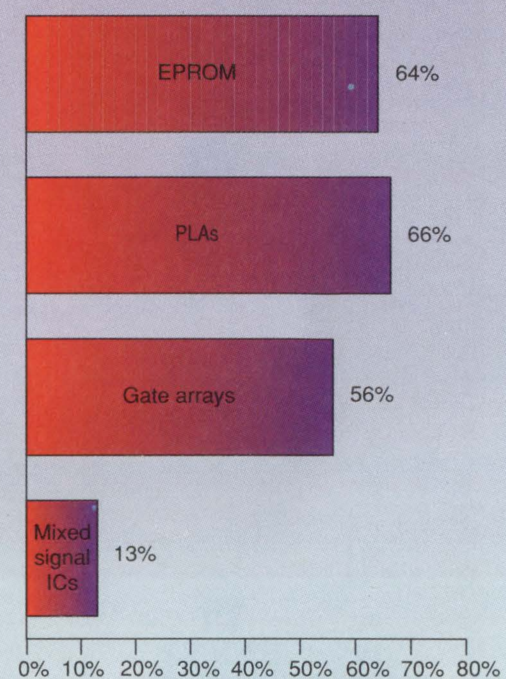
QUICK NEWS: PCs

For now at least, UK personal computer buyers are showing a preference for Unix-based multiuser systems, according to London market watchers Wharton Information Services Ltd. "June was a spectacular month for Unix in the UK when it outperformed the single user DOS market by 50%," said managing director Keith Wharton. Revenues generated from DOS systems that month amounted to £106.3 million ($63.78 million US), but buyers spent £152.7 million ($91.62 million US) on Unix systems.

Among makers of computers and workstations, the most spectacular performers were Sun Microsystems Inc. and ICL Ltd., according to Wharton. "Workstations represented 67% of the market, which is a Sun benefit." He added that Unix System 5 is the dominant operating system and Sparc the preferred processor.

DRAM SURVEY

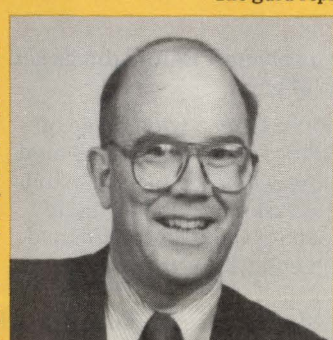
WHICH SEMICUSTOM OR ASIC DEVICES DO YOU USE?



Source: a survey of Electronic Design readers by Penton Publishing Inc. Total exceeds 100% because readers gave multiple answers.

TALES FROM THE SKUNK WORKS

John D. Trudel, founder and director of The Trudel Group, a high-technology business development consulting firm, will write a series of columns on skunk works. Trudel is the author of High Tech with Low Risk. *He has been a principal in four successful high-tech ventures and enjoyed a long career at Tektronix where he played key roles in business venturing and new product development for several divisions.*



In times of high uncertainty and rapid change, the most effective organizational form is a small, quick, multidisciplined team—the skunk works of yore. The U. S. invented such teams, but historically we have used them only in times of war or great stress. Our trading partners, like the Japanese, have studied the skunk works and turned it into a process.

The skunk works, or core team, is a small, close-knit, separate group of talented people tasked with doing difficult things on a tight schedule. Because the team contains all the resources and empowerment it needs to function, it can move quickly. It needs no approval from higher authority once its objectives and budgets are set. Schedules can be compressed because functional barriers and organizational friction are low. Team members make decisions and act in real time without outside interference. Higher management serves almost as a board of directors. Their job becomes review and approval, but *only* at key milestones.

The team has several key roles. The team leader has full operational responsibility. He ensures a common vision, adequate funding, and is accountable for results. The technologist's job is to twist raw technology into working and practical devices. His customer is the guru. We'll define a guru as the marketing equivalent of a chief engineer—seasoned, senior, technically competent, knowledgeable about the business, and a world-class expert.

The guru represents the market need and ensures that it is met competitively and profitably. He tells the technologist what is important to work on and when to stop. The production leader sees that a quality product can be produced quickly and economically. The actual composition of the team varies and changes depending on the type of product, the industry, and many other factors. Many important things are situational and experiential. As a result, consultants and those that have been there before can provide valuable guidance. You seek to create magic. You want your team to make the correct decisions and implement the right products quickly. You want synergy, and for one plus one to equal five, 50, or 500. This can and does happen. The phenomenal results achieved by skunk works are well documented.

The key attributes of an effective skunk works are instability, self-organization, overlapping development phases, multilearning, subtle control, and organizational transfer of knowledge. A discussion of team attributes will appear in the next column.

The Trudel Group, 52001 Columbia River Hwy., Scappoose, OR 97056; (503) 690-3300; fax (503) 543-6361.

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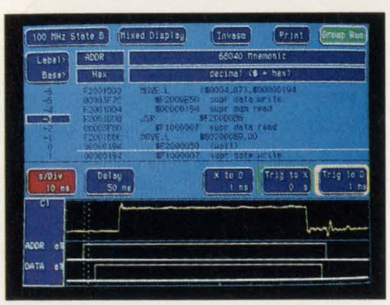

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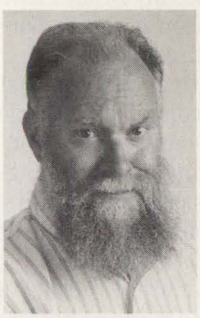
PEASE PORRIDGE

WHAT'S ALL THIS COPPER-CLAD STUFF, ANYHOW?

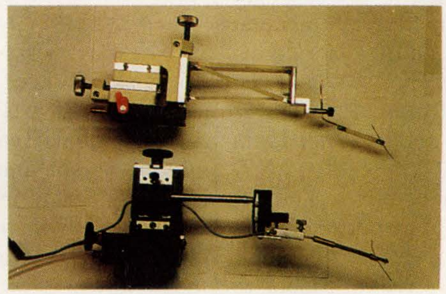
The other day, one of our junior engineers told me enthusiastically, "I solved that oscillation problem on the new circuit. I just put down the probe on that sensitive node I suspected, and the oscillation went away." I said that's great, but how many picofarads do you think that is? He replied, "I don't know, how many?" I told him to measure it on the Impedance Bridge.

He came back in a few minutes, kind of glum, because the probe had 3.2 pF, and he knew he didn't have room to fit in that much capacitance on the chip, which was already rather crowded. I said, "Oh, don't feel bad, maybe it only needs less than 3 puffs. Try a probe with less capacitance." He went out and measured every kind of probe that we had ever bought, and they were all kind of gross, 2 or 3 or 4 puffs. I said, "No problem, try this prober with a new arm that we just made up." We fabricated the lever arm out of small strips of copper-clad, with insulation provided by peeling the copper off the glass-epoxy material. He went over and measured 0.22 pF. Then he dropped this probe tip on his circuit and it turned out that even 0.22 pF was enough to stop the oscillation. Because he had room to fit in that much capacitance, he was in pretty good shape.



BOB PEASE
OBTAINED A BSEE FROM MIT IN 1961 AND IS STAFF SCIENTIST AT NATIONAL SEMICONDUCTOR CORP., SANTA CLARA, CALIF.

The moral of this story has nothing to do with oscillations, but rather about copper-clad, printed-circuit-board material—glass-epoxy board material. Now, I sort of take this stuff for granted, but I realized that this rather magical stuff is extremely useful. Without it, we'd have lots of problems. I always wanted to write a story about copper-clad for Pop 'Tronics, or one of the other popular electronics magazines for hobbyists, but now that I think of it, this is a better place to write the story. I mean, we engineers can *bluff* a lot and pretend we know more than most technicians, but if we get to Crunch Time needing to produce a miracle, it's nice to know how to solve problems that even the smart technicians can't. And if we weren't aware of all the good things you can do with copper-clad, maybe we couldn't envision the kind of little fixture we will need to pull off that miracle. I'll try to list several examples of useful, valuable things you can do with it.



These probe stages are commercially produced, but the upper probe tip has a capacitance of 0.3pF, 10x better than the store-bought one. Because it's easy to make truss structures out of copper-clad material, you can make an arm to any size and to any desired rigidity.

First, I'll mention that here around Silicon Valley, several places sell the board to hobbyists, over-the-counter, for about 1 cent per square inch. So, if you want to a make a 6-sided box about 4 in. x 4 in. x 4 in., that will cost you less than a buck—not too bad. Of course, we're talking about the conventional 1/16-in.-thick glass-epoxy material. If you shop around, though, you can get the 1/32 in. and the 1/8 in. and whatever else you need.

Next, I must admit that the tools and techniques for working with it aren't very obvious. If you try to cut up a slab of copper-clad with a saw, you'll probably dull the blade pretty fast. But heavy shears or tin-snips do quite well. Metal nibblers (I'm delighted to say they're available at every Radio Shack) are priceless. In our lab we have a big shear; it can cut precision lines across a big sheet. However, you may not need one of those.

Thermal approaches are also valuable. A good hot iron (with a little solder to help the heat transfer) can easily remove a strip of copper, leaving some pretty high-grade insulator. In the first example, a strip of epoxy board 1/2 in. wide by 4 in. long, with a stripped area just 1/2 in. square, had only 0.2 pF. If we had *tried* to get low capacitance, we could have made the unclad area 1/4 in. wide by 1 in. long and then drilled holes in it, getting the capacitance down below 0.1 pF. Of course, before you peel off an area of foil, you need to cut with a good knife or saw to define the edges.

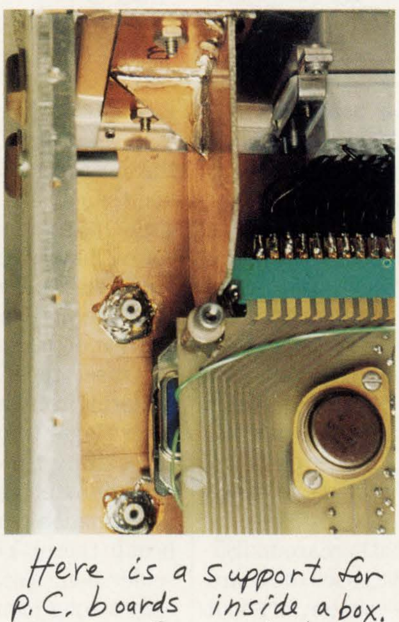
Then, of course, when you want to join two sheets together, you need a good hot soldering iron with a decent size of tip, 1/4 in. or bigger (those cute little ones with the skinny tip don't get the foil hot enough fast enough, which tends to cause delamination when you try to soak the heat in there). You can put little dabs of solder along a seam to make a mechanically strong joint. If you want to make something air-tight and water-tight, you need a good continuous bead of solder. It's possible, but a lot of work is required.

Okay—what can you make with copper-clad? You can make BOXES of just about any shape and size. Inherently, these boxes give you good electrostatic shielding, which is an added bonus. Just remember that the copper gives you no magnetic shielding: If you put one of these boxes near a transformer, such as on a soldering iron, the magnetic flux at 60 and 120 Hz comes *booming* on in and can (temporarily) ruin a quiet breadboard. If you need shielding from magnetic flux, add some iron, or push the offending transformer away.

You can make any kind of boxes—square, L-shaped, multi-shielded with cute little compartments and walls, and holes in the walls, and feedthroughs, connectors, etc., etc. These boxes can be extremely strong if you put on a cover that bolts on tight, and/or solder them with heavy seams. You can make 3-sided boxes, or 5-sided boxes. You can bolt on real hinges, or make poor-man's hinges out of copper wire.

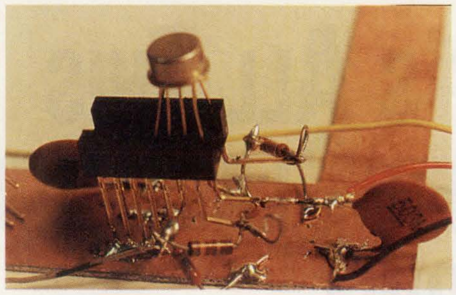
You can peel off strips of copper to make zones where a slab of copper is insulated. You can add heat sinks, fins, or any kind of connector. One of my all-time favorite discoveries was that you can use a metal nibbler to cut slots in the side of a sheet of copper-clad, and then slide 5-way binding posts into the slots. They look neat and sit secure; no drilling is required. You can use some of these techniques to get quick results, saving a huge amount of time compared to conventional metal-working techniques.

The next major thing you can do is make structural beams—brackets, levers, cantilevers, I-beams, L-brackets, spacers, shims, pushrods, flying buttresses—just about any kind of levers or beams or supports. Cut first, solder second, drill as needed—it's an awfully creative medium to work in. The technicians in our lab all look at each others' mechanical designs and say, "That's neat." Now that reminds me of some even wilder arrangements that will occasionally be useful.



Here is a support for P.C. boards inside a box. Most of us don't own a welder, but we can all build neat copper-clad structures with a soldering iron,

I was recently helping a neighbor with a serious Meccano set project, and I realized that when I was a kid playing with my Erector Set, I built all kinds of structures. It was a lot of fun, but if I could have played with an equivalent amount of copper-clad and a soldering iron, I could have invented some *marvelous* machines and structures, just before I burned the house down.



Here's a view of a wire-wrap socket, with the leads bent at various angles, for your convenience in making soldered connections.

Other things I like to build with copper-clad are breadboards and circuits. When people discard the 1/8-in.- or 1/4-in.-wide strips that they cut off the edge of a sheet with the shear, I scoop them up and save them and use them for little ground buses and power buses. When you solder them to cross-braces (which have insulating stripes peeled off), they're quite rigid and rugged, and very neat for op amps or logic designs.

I'm also compelled to state that some of the *cleanest*, *lowest-leakage* (sub-picoampere) layouts in the world use the *air* over a piece of copper-clad as the insulator. You can buy a clean polyimide board or you can get teflon pc boards or teflon stand-offs. But plain old air above a crummy piece of copper-clad is just as good an insulator, and usually better.

Another trick I like to use with copper-clad, for a quick-and-dirty applications circuit, is to use a 16-pin wire-wrap DIP socket for a 14-pin IC. I take the two pins on one end, and one of the other pins that will be grounded, and solder them to the copper-clad ground plane. All of the other pins I bend up at varying angles, for ease of soldering. I tack a couple of capacitors to the ground plane to use as power-supply bypasses. Then I tack some power-supply wires on them, and I have a breadboard in about 2 minutes, all ready for me to slap in the resistors and other components.

Now, I think you readers ought to know, I don't just sit at home on an evening and type out these ideas, then shove them into print. First I type out a good draft and make 30 copies and show them to my friends. At this point of the story, I threw copies to my Brain Trust, and invited them to show me some more things you can do with copper-clad.

Dennis Monticelli pointed out that when you peel the copper off and file down the tip, you can make a non-metallic screwdriver or a non-magnetic tool for adjusting RF circuits. Fran Hoffart explained how he uses copper-clad for shims and spacers.

And at the last minute, I recalled a little framework I had made, to hold up a 35-mm slide in front of my camera, so I could take a photograph of the slide's image and thus make my own copies of slides.

In conclusion, there are almost an infinite number of things you can do with copper-clad, pc-board materials, and I wouldn't mind hearing your neat ideas, too.

All for now. / Comments invited!
RAP / Robert A. Pease / Engineer

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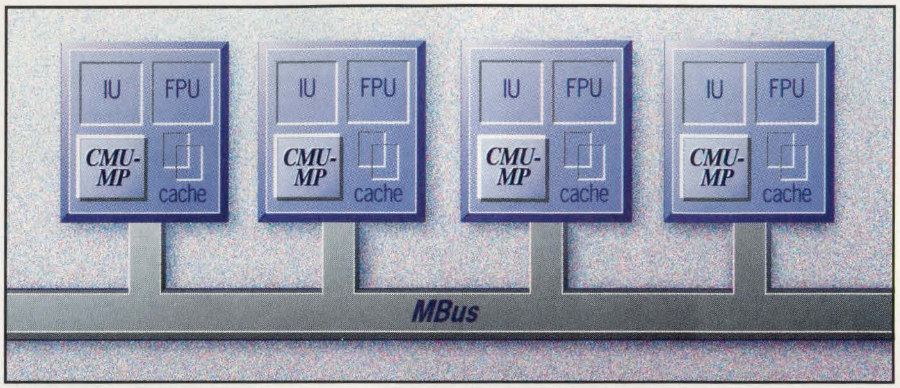

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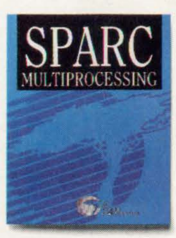

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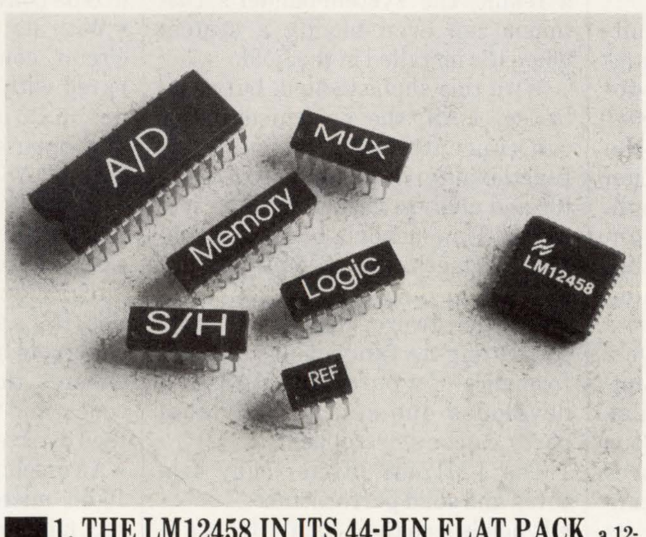
13-BIT DATA-ACQUISITION IC SPORTS 32-WORD FIFO

IC DIGITIZES EIGHT ANALOG VOLTAGES, PUTTING OUT 12-BIT + SIGN WORDS AT 90 KHZ, AND STORING THEM IN A 32-WORD FIFO MEMORY.

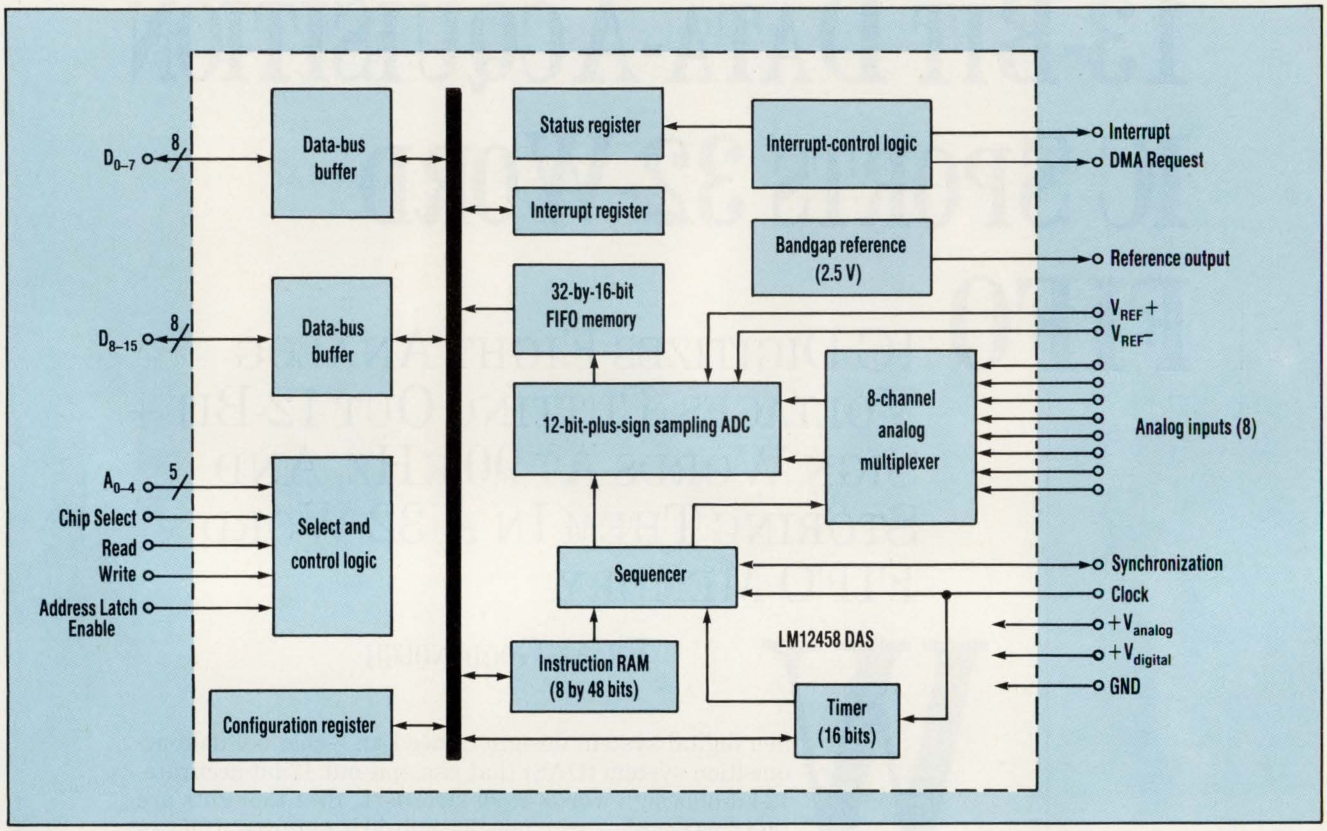
FRANK GOODENOUGH

When digital system designers need an 8-channel data-acquisition system (DAS) that can spit out 12-bit-accurate, 12-bit-plus-sign words at 90 kwords/s, first thoughts are that a pc board or an expensive hybrid is required. If it can also dump each sequential word into a 32-word FIFO memory for future acquisition by a host via a DMA channel, they see a good-sized, expensive pc board. If time-to-market is critical, they don't even consider rolling their own design, even if they have a good support team of experienced analog designers. A designer rolling his own design will be okay if he's working with any one of the standard buses available (e.g. AT, VME, Multibus) and/or has plenty of space and money. If not, then digital designers must turn to the analog experts to put together a customized DAS, while they themselves concentrate on providing the digital interface with the DAS output. The time has come to change those images.



1. THE LM12458 IN ITS 44-PIN FLAT PACK, a 12-bit-plus-sign data-acquisition-system on a chip, replaces a large handful of analog and digital ICs and discrete parts.

National Semiconductor's new LM12458, the "smartest" and most complete IC DAS, does that and more, in one chip. The first of a family, it helps a digital designer get complex systems needing 12-bit-accurate voltage measurements to market quicker and cheaper, with additional features, and in a smaller box. Alternatively, because the LM12458 comes with ready-to-use menu-driven software, it



2. FOLLOWING UP TO 32 CONVERSIONS by its 12-bit-plus-sign ADC, the LM12458 data-acquisition system on a chip stores the results in a 32-by-16-bit FIFO for future retrieval by a host processor.

simplifies the job of an analog designer learning to "talk digital," while similarly cutting time-to-market, as well as system size and cost. Regardless of the application, the DAS will typically save a good-sized handful of expensive ICs and discrete parts *(Fig. 1)*.

National's ADC1241, a 12-bit-plus-sign (13-bit resolution), sampling, self-calibrating analog-to-digital converter, lies at the heart of the LM12458. Surrounding the ADC with FIFO and instruction memories on the same chip simplifies the job of linking digital to analog circuitry and vice versa within a DAS, for both digital and analog designers *(Fig. 2)*.

By permitting the ADC to convert up to 32 voltages without interrupting the host (for example sequentially digitizing all eight inputs four times), the LM12458's FIFO reduces the time the host spends servicing the DAS, significantly upping its number-crunching time. Moreover, when such digital peripherals as the memories are added to a pc-board DAS, their configuration usually must be modified for each new system (different analog and digital ICs, board layout, and software). Using the LM12458, software alone can perform major system redesign. As a result, the system-builder's customer can even modify a system when it's installed in the field.

With this sophisticated, but easy-to-use, DAS, the system designer can concentrate on the system's functionality, deciding how to monitor and analyze variables in the real world. Time needn't be squandered with the mechanics of implementing the system. Such processes as prototyping hardware, debugging code, and testing the functionality and performance of a purchased DAS, or a developed one and its individual parts, can be sidestepped.

The LM12458 offers many features and solid performance:

- It needs less than 30 mW from a 5-V rail (less than many op amps).
- The host programs its operation, yet the DAS runs standalone.
- It has three conversion modes (at a 5-MHz clock rate).
- It offers 8-bit-plus-sign performance without self-calibration (4-μs conversion time). Or 12-bit-plus-sign performance with self-calibration (8.6-μs conversion time).
- With its 8-bit-plus-sign watchdog circuit, conversion results are compared with stored high and low values, in 1.6 μs maximum for each pair of comparisons.
- The DAS has a 13-bit throughput rate of 90 kHz (with a 5-MHz clock).
- The input-signal range is 0 to 5 V.
- Self-calibration keeps the DAS's integral and differential nonlinearities (INLs and DNLs), as well as offset errors, to less than 1 LSB. It also ensures that there are no missing codes, and that all codes are guaranteed over temperature.
- An on-chip 32-word FIFO links 8- or 16-bit microprocessor buses via direct memory access.
- Free, menu-driven "how to" software is provided.

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13-BIT-PLUS-SIGN DAS IC

The LM12458 is designed for control by a host processor. However, its relationship with the host could easily be described as symbiotic. That is, the host downloads the operating details over the 8- or 16-bit-wide bidirectional data bus (D_0 through D_{15}). But once its storage registers are loaded, it runs standalone. It may interrupt the host or vice versa. Chip selection and random control are provided via additional address-and-control lines.

At power-up or anytime thereafter, the host downloads a set of operational instructions to the chip's instruction RAM. These include indicating which of the three operating modes to use, which of the input channels should be single-ended and which connected to form differential input pairs, how often and in what order each channel should be sampled, and in which of two self-calibration modes to operate. In addition, the number of conversion results to be loaded in the FIFO (up to and including 32) prior to host interruption is downloaded and stored in the interrupt register.

In both the 8-bit-plus-sign and the 12-bit-plus-sign modes, the ADC performs continuous conversions as directed by the instruction RAM, loading the results into the 16-bit-wide, 32-word FIFO memory. When the FIFO is full or after a programmed number of words (up to and including 32), the FIFO sends an interrupt to the host from the interrupt-control logic circuits. At that time, the host has three options: ignore the interrupt and direct the DAS to continue operation; direct its DMA controller to take over the bus (while it performs some other task) and put the data directly into memory; or take the data from the bus. Alternatively, rather than waiting for an interrupt from the DAS, the host can interrogate the DAS and retrieve the FIFO's contents from the bus or via direct memory access, at any time.

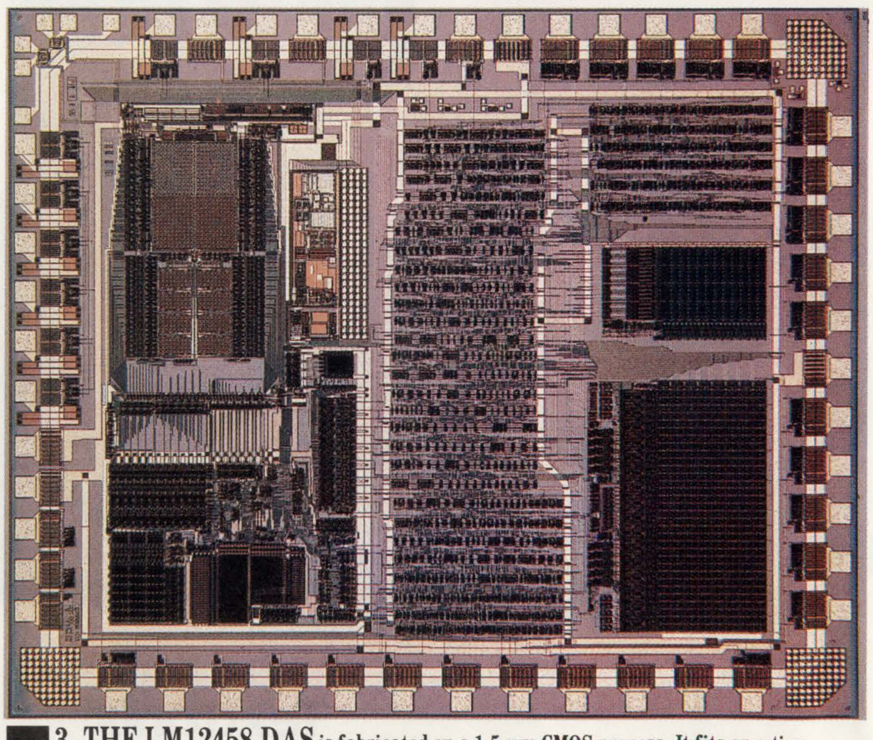
The DAS is fast enough to keep up with virtually all common available processors (such as the 386) and has a bus access time of just 30 ns. After receiving the data (or at any other time), the host can put the DAS into a sleep mode, dropping its quiescent current from a low 4 mA (20 mW of power) to just 40 μA if the clock is left running, and 10 μA if the clock is turned off.

The "watchdog mode" truly brings a new dimension to 12-bit DASs. When in that mode, the converter continuously samples the programmed channels and compares the results with a high and low value (including checking the sign bit) stored in the instruction RAM. If the sampled voltage is outside the "window" defined by the stored data, a host interrupt is generated. The host can then request that an 8- or 12-bit successive-approximation conversion be performed by the ADC on the errant input, and the results put on the bus for the host to examine. Each "watchdog" conversion takes just 1.6 μs, which is less time than a conventional conversion because just two comparisons need to be made. The two values stored in the instruction RAM are used as the input words for the ADC's charge-redistribution (switch-capacitor) DAC. The comparator's output indicates if the input is above the high limit or below the low limit.

The chip's 16-bit timer circuit, with inputs from the instruction RAM and the clock, programs the conversion rate. The sequencer, with inputs from the timer, the external clock, and the RAM, controls the ADC, its sampling circuitry, and the analog multiplexer.

Three versions of the DAS will ultimately be available: the extended-industrial-temperature range CIV (available now) and BIV (available within 90 days), and a military-temperature-range device CME (available next year). The three differ in guaranteed maximum INL error over temperature (after self-calibration), which runs ± 1, $\pm 1/2$, and ± 1 LSB, respectively. Over temperature and after self-calibration, all three versions feature a maximum DNL error of $\pm 1/2$ LSB, maximum zero error of ± 1 LSB, and maximum positive and negative full-scale error of ± 2 LSB. It should be noted that these LSB errors are relative to 13 bits for the 12-bit-plus-sign conversion mode, and relative to 9 bits for the 8-bit-plus-sign and "watchdog" conversion modes.

Because the DAS's ADC samples voltages quickly before quantizing



3. THE LM12458 DAS is fabricated on a 1.5-μm CMOS process. It fits on a tiny 38,000-mil^2 die.

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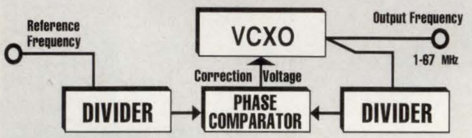

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M2005	1.0 to 4V	± 75-300 ppm
M2006	0 to 5V	±150 ppm
M2007	0.5 to 4.5V	±250 ppm

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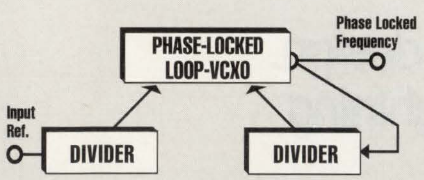

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13-BIT-PLUS-SIGN DAS IC

them, National is providing the dynamic (ac) specifications (albeit typical ones) needed for signal-processing applications. While sampling a 20-kHz sine wave, the DAS's signal-to-noise ratio (SNR) runs 72.5 dB maximum, its total harmonic distortion is –70 dB maximum, and the spurious-free dynamic range is 78 dB minimum. An ideal 12-bit ADC would have an SNR of 74 dB.

All specifications are called out for clock frequencies of 5 MHz, resulting in a minimum 13-bit throughput rate of 90 kHz and a typical 9-bit rate of 130 kHz. Typically, the chip easily runs at twice that frequency, while providing a 13-bit throughput rate of 180 kHz. However, codes may be missed and other specifications may not be met when the device is operating at that frequency.

The charge-redistribution techniques used by the ADC, coupled with its ability to run off a single 5-V rail, add subtle characteristics to its operation and performance. For instance, the full-scale input voltage can equal the supply voltage (which can drop to as low as 4.5 V and have the DAS still typically meet all its specifications). However, the minimum input voltage is 0 V (the inputs must not be allowed to go negative). Most applications will probably operate with input signals running from 0 to 5 V. If chosen, the 5-V analog supply rail can become the $V_{REF}+$ input, and $V_{REF}-$ can be connected to ground *(Fig. 2, again)*.

The LM12458 DAS is basically designed for high-level signals. If low-level signals must be handled, an amplifier-per-channel must be used, an unappealing thought when the goal is to cut size and cost. However, as noted earlier, this is the first of a family of analog ICs to which peripheral digital functions have been added. Its first sibling, the LM12454, will arrive early next year. It brings the multiplexer's outputs and the ADC's inputs to the outside world, that is, to pins on the package. However, this requires four additional pins, though all 44 on the PLCC package are in use. To get the four additional pins, National borrowed four input pins, reducing the total number of inputs from eight to four. Using the LM12454, the system designer can add a programmable-gain instrumentation amplifier between the multiplexer and the ADC, and/or a filter to cut noise or aliasing.

The DAS's weak spot is its inability to take on additional channels. While a second rank of multiplexing can be added, the chip isn't truly prepared to handle it, and significantly more host overhead would be required. But all isn't lost. Just add a second or third LM12458 or as many as needed. At $29.60 each in hundreds, it's the easiest and least-expensive way to go. That works out to a per-channel cost of $3.70 to $7.40 each, depending on the number of differential-input channels.

Even without a look at the data sheet, becoming familiar enough with the DAS to design it into a system may be a formidable task. To simplify the job, National has taken two tacks. By the end of October, an evaluation board and a floppy-disk-full of menu-driven software will be available. The software is divided into two parts. One section teaches the user how to set up the DAS, and the other section explains how to operate the evaluation board while it's connected to a PC.

Because many of today's 12-bit sampling ADCs can still run $20 each in 100-unit quantities, how can National offer this complete DAS for under $30? The reason is simple: The chip, built on an advanced 1.5-μm CMOS process, is tiny and less than 200 mils on a side *(Fig. 3)*. That's significantly smaller than most 12-bit, sampling ADCs.□

PRICE AND AVAILABILTY

The LM12458CIV DAS goes for $29.60 each in quantities of 100 in a 44-pin PLCC. Pricing for the evaluation and regular boards will be available within 30 to 60 days. The "how to" software is free.

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GAAS CHIPS STREAK PAST MAXIMUM X3T9.3 SERIAL-DATA RATE TO REMOVE BANDWIDTH BOTTLENECKS.

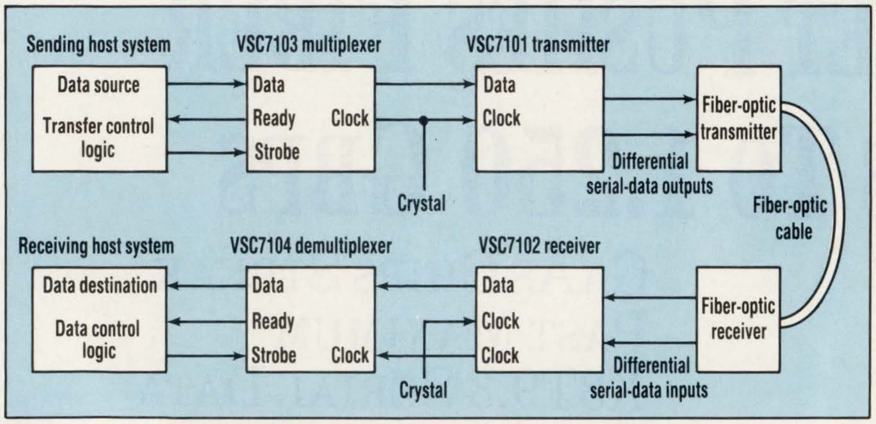
MILT LEONARD

Available bandwidth is a precious commodity in the connectivity schemes of the high-speed, data-communications world. Throughput performance is no longer constrained by the speed of the communicating devices, but rather by the bandwidth limitations of network backbones, copper cabling, and CPU buses. In an assault on such bottlenecks, a joint development effort by Vitesse Semiconductor Corp. and Advanced Micro Devices Inc. has resulted in the industry's fastest chip set capable of implementing the ANSI X3T9.3 Fibre Channel Standard for fiber-optic, point-to-point communications. An upgraded version of AMD's 175-MHz TAXIchip set—the 1.25-GHz G-TAXIchip set—supports the Fiber Distributed Data Interface (FDDI) and the high-performance parallel interface (HIPPI) standards.

Implemented in Vitesse's 0.8-μm gallium-arsenide technology, the G-TAXIchip set consists of four ICs: the 32-to-8-bit (for Fibre Channel) or 40-to-8-bit (for HIPPI) VSC7103 multiplexer and VSC7104 demultiplexer, both operating at up to 150-MHz; and the 1.25-GHz VSC7101 transmitter and VSC7102 receiver *(Fig. 1)*. AMD's chip set, called GAAF TAXI, consists of the Am79G358 multiplexer, Am79G359 demultiplexer, Am79G368 transmitter, and Am79G369 receiver. At the data source, the multiplexer and transmitter combine to convert 32 or 40 lines of parallel data into serial data at rates of up to 1.250 Gbits/s. This serial data can be transmitted through a coaxial cable or converted to light pulses for transmission through an optical fiber.

At the receiving end, the receiver recovers the electrical clock and data signals and sends them to the demultiplexer, which restores them to the original 32- or 40-line parallel-data format. The transmitter and receiver chips contain a phase-locked loop (PLL) for clock multiplication and recovery, respectively. The self-contained PLL doesn't require external components. These chips also provide pinouts for diagnostic loopback testing.

Aside from the high data rates afforded by GaAs processing, the G-TAXIchips differ from their silicon predecessors with respect to the additional control logic in the multiplexer. This added control is required in order to conform with the Fibre Channel standard and to implement the transmission code. Unlike AMD's original TAXIchip set, which uses 4B5B block coding,



1. GaAs PROCESSING enables the G-TAXIchip set to handle serial data at rates of up to 1.25 Gbps, which translates to parallel data rates of up to 125 Mbytes/s. The multiplexer and transmitter convert parallel data from the source to serial data for transmission over short coax or fiber-optic cable. The receiver and demultiplexer decode serial data into parallel format at the receiving end. The transmitter output and receiver input interface directly to optical links.

the G-TAXIchip set uses IBM's patented 8B10B coding to ensure reliable recovery of dc-balanced data at gigabit rates.

The multiplexer and demultiplexer chips interface to the host-system bus. These devices have two types of electrical interfaces, TTL- and ECL-compatible. Handshake signals and bus parallel data are TTL-compatible. Data and strobe interfaces to the transmitter and receiver are single-ended, 100K-ECL-compatible, referenced to +5 V.

Transmitting The Data

As determined by a select pin, either 32- or 40-bit-wide parallel TTL data from the data-source host enters the transmission circuitry through a standard external FIFO buffer. The 7103 multiplexer disassembles the data into 4 or 5 bytes (8 bits each), and encodes the data into a 10-bit-wide parallel data transfer to the transmitter *(Fig. 2)*. The multiplexer bus interface can be asynchronous, but the highest throughput is possible only when it operates synchronously with the system clock.

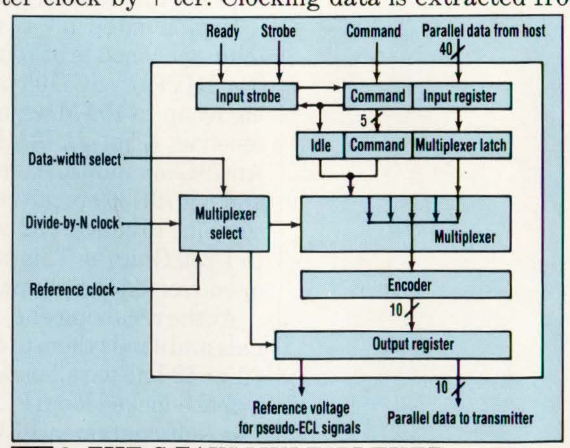
Serial-link speed is derived from an external master-frequency source. This signal is used for synchronous data-byte transfer between the 7103 multiplexer and the transmitter. The master clock frequency is one-tenth the serial-link speed, and 4 or 5 times the frequency of the input data bus. Thus, a 25-MHz, 32-bit bus needs a 100-MHz clock source to run, say, the G-TAXI multiplexer and transmitter. An on-chip PLL is part of the clock-multiplying scheme in the transmitter.

In a typical synchronous setup, a crystal-controlled oscillator with ECL output drives the clock-input pins of the multiplexer and transmitter. In designs where the G-TAXI-chip set is synchronous with the host, the multiplexer can reduce this byte-clock frequency by a factor of four or five for use as the master clock by the rest of the system. Alternatively, in sending the host, synchronous logic can generate the strobe signal. In systems where G-TAXI multiplexer inputs are asynchronous to the clock frequency, data can be entered at a rate less than maximum without regard to actual word boundaries.

The transmitter serializes data from the multiplexer chip, and shifts it out to the serial data link through an external fiber-optic transmitter *(Fig. 3)*. Differential-output pins carry the serial bit stream. The transmitter's PLL multiplies the system clock frequency by a factor of 10 (8-bit mode) or 12 (10-bit mode), depending on the state of its Data Mode Select pin. Another pair of output pins connect to the receiver chip for loopback diagnostic testing. In this mode, the system is configured to allow an automatic tester to clock test patterns at any convenient rate or sequence. If the system uses a nonreturn to zero, inverted (NRZI) transmission code, an NRZ-to-NRZI conversion circuit is included.

At The Receiving End

The 7102 receiver and 7104 demultiplexer architectures are essentially the same as their counterparts at the sending end, except for small variations that perform the reverse functions of receiving and decoding. For example, the 7102 receiver has the added functions of a sync detector and a second input multiplexer with buffered inputs. The sync detector reestablishes byte boundaries upon loss of byte-symbol sync or at power-up. The buffered-data multiplexer decodes the serial-data input for subsequent conversion to a 10-bit-wide parallel output to the 7104 demultiplexer. The receiver's second multiplexer function is also applied to the loopback inputs from the transmitter. Clocking data is extracted from



2. THE G-TAXI MULTIPLEXER reconstitutes 32- or 40-bit-wide input data into 4 or 5 bytes, which are encoded into 10-bit words for transfer to the transmitter. Operating parameters, such as data width and the byte sequence to be loaded into the 8B10B encoder, are controlled by the multiplexer-select logic block.

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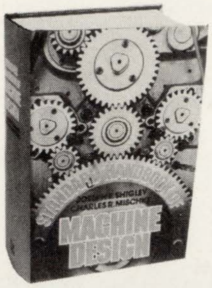

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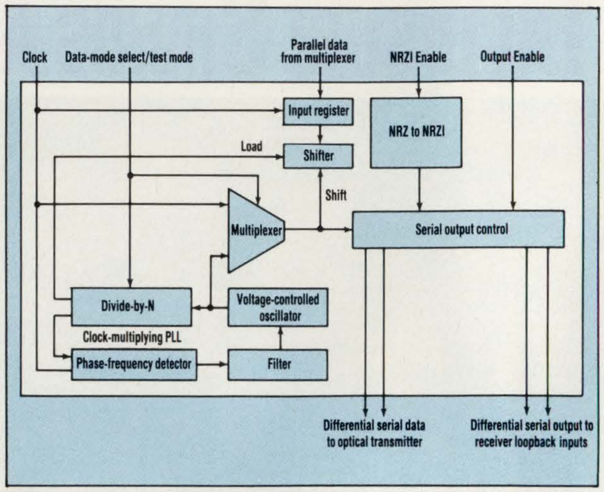
COMMUNICATIONS CHIP SET



3. ALL DATA, CONTROL, and clock lines for the G-TAXI transmitter operate at pseudo-ECL levels. The receiver architecture is similar to the transmitter's except for an additional on-chip PLL at the transmission-media interface.

the incoming serial datastream by the clock-recovery PLL.

The 7104 demultiplexer decodes and reassembles the 10-bit-wide parallel data from the receiver back into its original 32- or 40-bit-wide parallel format. All operations are user-transparent, with data words seemingly being written into one end of a FIFO buffer and read from the other, remotely located at the other end.

Although serial-link speed is determined by the voltage-controlled oscillator (VCO) in the transmitter, the receiver must know what data rate to expect. It must also follow data rates that are faster or slower than the local reference clock. These requirements are handled by the 7102's PLL and clock circuits, which enable encoded clock and data signals to be decoded into separate clock and data patterns. The center frequency established at the clock-input pin can track data with frequency offsets of 0.1% and jitter of 40% bit-time.

To implement high-speed communication links between PCs, workstations, and minicomputers, the G-TAXIchip set is intended to overcome the bandwidth inadequacies of common LAN standards, such as FDDI token-ring, Appletalk, and Ethernet. As microprocessor clock rates exceed 50 MHz, access to main memory is constrained by bus bandwidth. This problem is addressed by the emerging Scalable Coherent Interface (SCI) standard, which increases effective bandwidth by packetizing serial bus data for simultaneous packetized-data transfer between entities. Using fiber interconnects or controlled-impedance signal traces, the G-TAXIchip set enables a multiprocessor system to reach its full performance potential with the bus-emulation protocol.

Another target application is video-signal distribution. The chip set offers similar benefits to such applications as radar, in which digitized data from sensors must be transported to remotely located instruments for collection and analysis. Other prime applications are the military, which requires radiation tolerance and secure data transfer, and consumer products like non-compressed high-definition TV.

Operating a 5-V power supply, the transmitter and receiver are packaged in 28-pin leaded ceramic chip carriers. The multiplexer and demultiplexer require 5- and 2-V supplies and come in 132-pin aluminum quad flat packs with extra ground pins to combat ground bounce. AMD and Vitesse share the marketing and sales rights for the G-TAXIchip set.☐

PRICE AND AVAILABILTY

Samples of the G-TAXI and GAAF TAXI chip sets are available now from Vitesse Semiconductor and AMD for $995 each. Volume quantities of 1000 or more sets will be available in October for $603 each.

Vitesse Semiconductor Corp., 741 Calle Plano, Camarillo, CA 93012; Tom Dugan, (805) 388-7582.

Advanced Micro Devices, P.O. Box 3453, Sunnyvale, CA 94088-3000; Chris Ciufo, (408) 749-4809. **CIRCLE 513**

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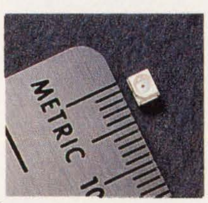

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SOFTWARE-PROGRAMMABLE DSP CHIP TAKES ON COMMUNICATION JOBS

DEVICE EXTENDS CUSTOMIZED DSP DESIGNS TO LOW-BIT-RATE DIGITIZED VOICE COMMUNICATIONS.

JOHN GOSCH

With digital cellular mobile-radio communications soon to invade Europe and the U.S., equipment suppliers and designers are already clamoring for chips dedicated to this application. At the same time, they're pushing semiconductor producers to develop circuits for mobile telephone sets that fulfill a number of exacting demands: a high level of integration to help bring set volume down to pocket-size dimensions; low power consumption, a requirement for hand-portable, battery-operated equipment; and low cost, a prerequisite for mass markets consuming such equipment.

Meeting these demands is the application-specific ST18932 digital-signal-processor core from SGS-Thomson Microelectronics. It allows designers to customize the complete chip from megacell and standard-cell libraries on commercially available workstations like those from Mentor Graphics. The 18932 is the first software-programmable DSP megacell for a customer-designed ASIC device, the company claims.

Furthermore, while DSP techniques have been extensively used in high-speed telephone modulator-demodulators, such as 9600-bit/s full-duplex V.32 modems, the 18932 for the first time extends customer-designed DSP chips to applications in low-bit-rate, digitized voice communications. Consequently, it can handle functions that include high-quality speech encoding, multipath channel equalization, and decoding.

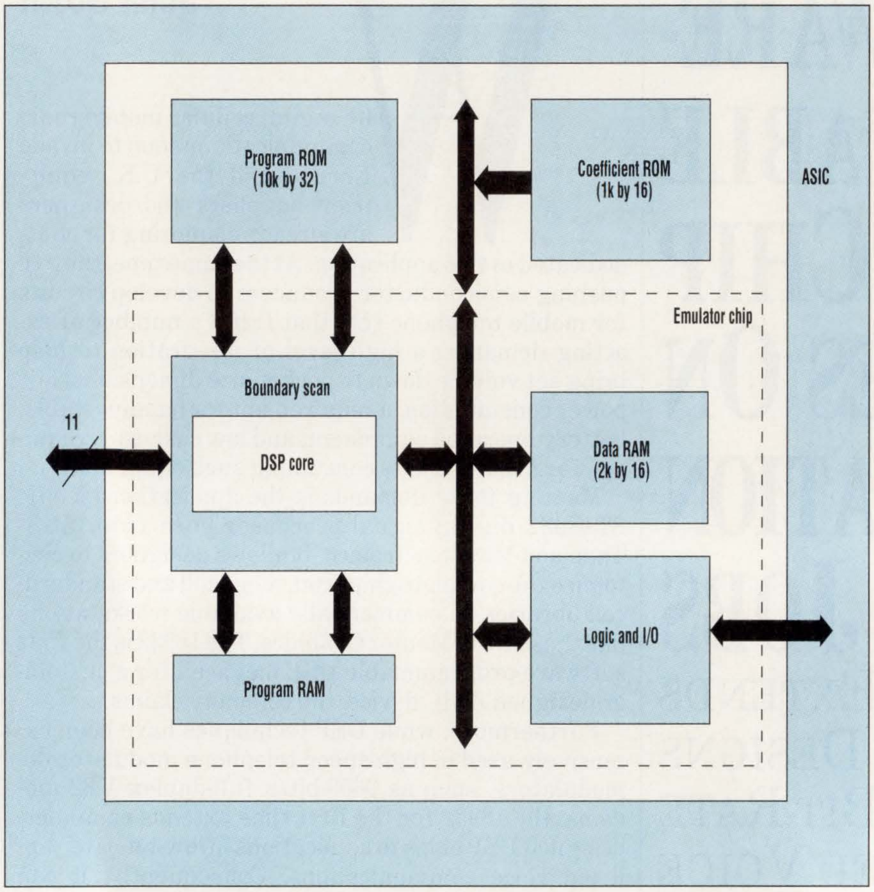
Economically, technically, and for industrial applications, SGS-Thomson considers its true ASIC semicustom DSP approach the best solution to a low-cost, low-power, and high-integration IC for use in portable, battery-operated mobile telephone sets. The ASIC uses digital-technology-compatible delta-sigma analog-to-digital and digital-to-analog converters.

The semicustom DSP approach to a design problem offers several advantages, says Luc Mary, strategic marketing director for digital-signal processors at SGS-Thomson in Paris. In addition to a high degree of integration and low-power consumption, the approach makes for a fast, inexpensive, and secure design cycle. A quick and low-cost turnaround is ensured because the company offers all necessary design tools and a complete cell library. Moreover, a VHDL (very high-level description language) model of the digital-signal-processor core provides design security.

Furthermore, the semicustom DSP technique offers high flexibility as it enables the designer to optimize hardware resources around a predefined digital-signal-processor core. Those resources include data and program memories, macro functions and peripherals, as well as small- and medium-scale integrated logic circuits, converters, and other hardware.

The approach also offers high reliability and elec-

SOFTWARE-PROGRAMMABLE DSP MEGACELL



1. THIS DSP CORE MEGACELL from SGS-Thomson simplifies the design of ASICs for communications applications. In the initial design stage, program memory can reside external to the emulator chip. It can be added on the chip in the final design stage.

tromagnetic compatibility because all resources are on-chip. There's no need for external high-speed data buses, Mary says.

Moreover, the SGS-Thomson technique enables integrated validation, test, and emulation features to be implemented with ease. In the 18932, these features are realized in the form of boundary-scan logic at the chip's periphery *(Fig. 1)*. The company offers development tools that connect directly to the boundary-scan serial interface, allowing software development and debugging on the chip. The customer connects the boundary-scan bus to the rest of the circuit so that the complete chip can be tested and evaluated.

The semicustom approach, Mary says, together with the programmable DSP core and the standard cells, also brings all of the advantages of programmable devices and dedicated logic—advantages like flexibility and high efficiency for simple functions—to the design. Finally, the approach offers good protection against infringements of property rights because all resources are on-chip. This makes it difficult to copy circuit hardware and software.

Although SGS-Thomson calls its 18932 a general-purpose device—it can be used in everything from disk-drive controls and video games to answering machines, car radios, and video phones—it's aimed primarily at telecommunications applications.

SGS-Thomson is sampling the 18932. Designers at communication houses are tailoring it to applications in mobile telephone sets. The chip can be programmed to conform to the Groupe Spécial Mobile (GSM) standard, which all European countries have agreed to adopt, and to the standard that the U.S. and others will choose.

The company offers designers all hardware and development tools needed to customize its ASIC DSP IC. Besides the 18932 DSP core megacell, the hardware includes RAM and ROM for data and program memories (size is determined by the customer); macro functions, such as serial ports; FIFO memories and timers; plus the standard-cell library with small- and medium-scale IC functions.

As for development tools, the firm offers an assembler and a linker for DSP software development. Because all cells are described in VHDL, development and simulation are possible on any workstation supporting VHDL. Hardware can be emulated in real time to develop and debug the DSP software.

Using a parallel Harvard architecture with a 32-bit instruction bus and triple 16-bit data buses, the 18932 is a fixed-point DSP IC with a 32-bit data arithmetic unit *(Fig. 2)*. The 1.2-µm CMOS core, has a 77-ns instruction cycle time. Power consumption is 350 mW at full speed and less than 0.5 mW in the low-power mode. The company is now working to shrink the core to a 0.8-µm version with a 50-ns instruction cycle. According to Mary, this version will be available toward the end of this year.

Of particular note is the core's boundary-scan logic, which enables the designer to test the core and glue logic and to emulate the core-based ASIC circuits. Eleven pins are used for various boundary-scan data inputs and outputs, and clock and control signals. The boundary-scan register has 92 cells that provide access to most of the core's I/Os.

In a typical digital mobile terminal, such as a hand-portable phone, the 18932 can take on various tasks. For example, it can link the baseband modulation signal components to the radio-frequency subsystem. And because it's programmable, the DSP IC can also implement a digital modem. Some bit-level processing is realized, with wired logic circuitry attached to the DSP chip as an on-chip peripheral. An ASIC DSP approach is best suited for such a modem, Mary says.

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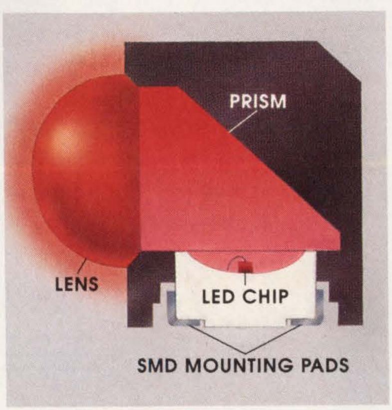

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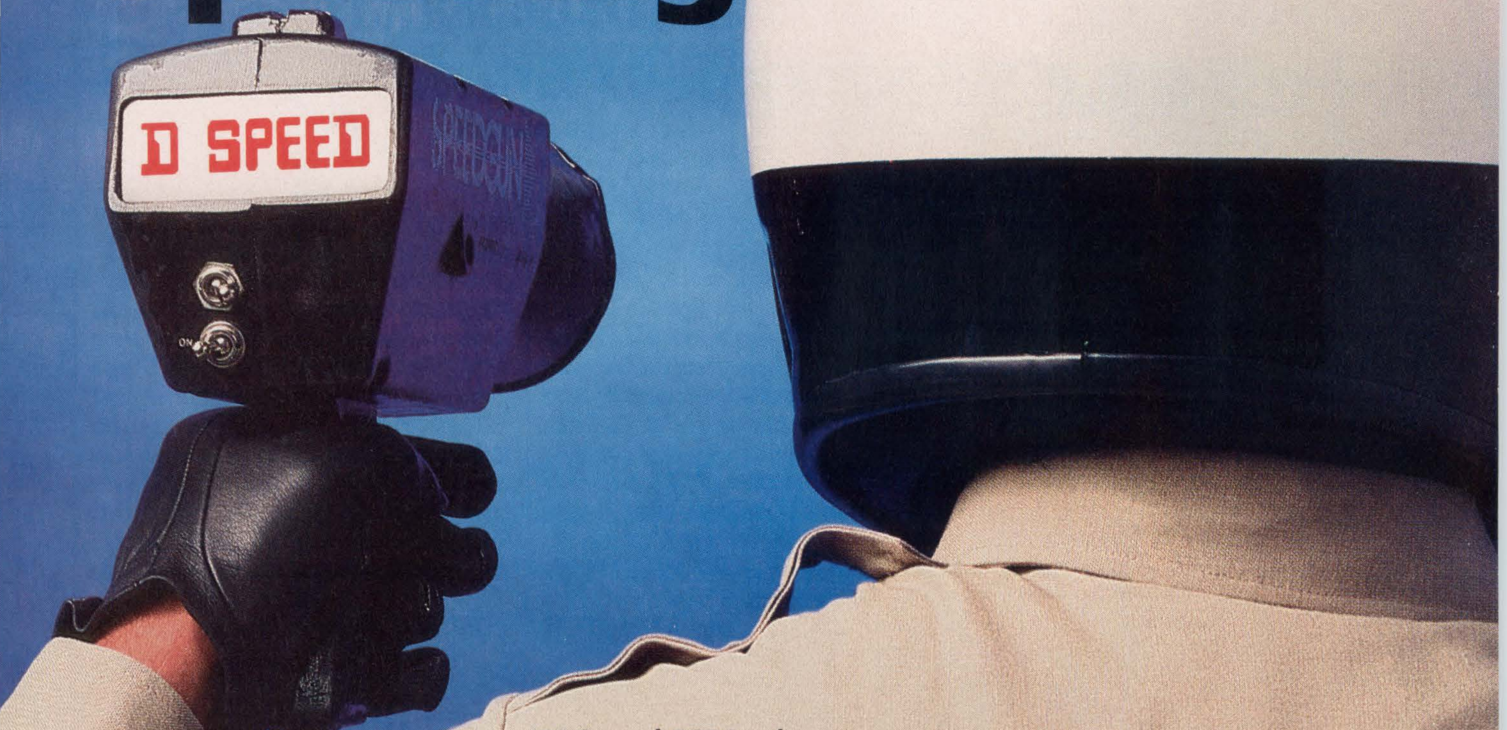

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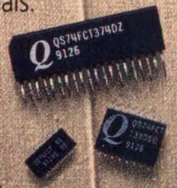

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138D (Decoder)	4.0	821D (Register)	5.3
139D (Decoder)	4.0	823D (Register)	5.3
521D (Comparator)	4.1		

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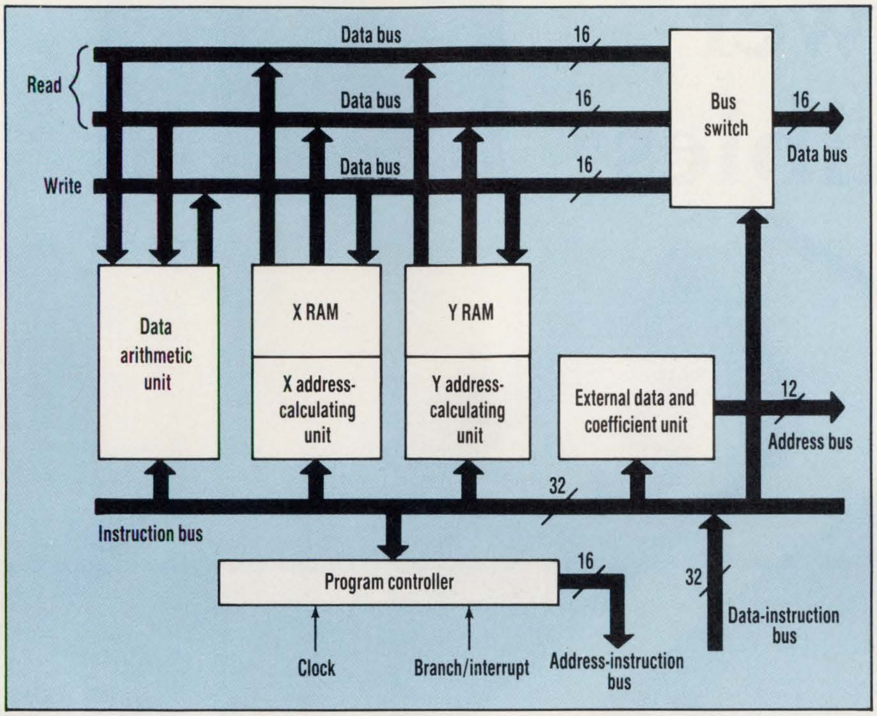

2. THREE 16-BIT DATA BUSES reside on the ST18932 DSP megacell core from SGS-Thomson. Two of these buses feed the operant to the data arithmetic unit. The third feeds the results of previous operations into memories internal or external to the core.

In fact, SGS-Thomson will use its DSP core in a new generation of high-speed modem chips.

What's more, delta-sigma converters used in the vocoder analog front-end are feasible with a standard digital CMOS process. This enables the DSP core and analog front-end to be integrated on the same chip. The entire vocoder can then be packaged in one device. As a result, a simple interface can be produced at low cost.

If the telephone set is to connect with the subscriber via a keyboard and visual display, DSP may also be added to the basic function of the human interface. Here, DSP techniques could cancel repetitive noise, like that in a moving car, thus enhancing listening comfort. Also, by using DSP methods in an interface, the signal-to-ambient-noise ratio can be maintained at a constant value. This contends with occasional noise increases, such as car acceleration or passing through a tunnel.

These considerations, Mary says, point to an ASIC DSP approach rather than to a microcontroller. The ASIC design makes it possible to incorporate any microcontroller features, including timers, general-purpose I/Os, liquid-crystal display drivers, or analog front-end converters, into the DSP chip.□

Price And Availabilty

Samples of the ST18932 are available now. The customer can house them in a variety of packages generally available for ASIC designs. The number of pins depends on the customer's design. The packages are: a plastic leaded chip carrier (PLCC) with up to 84 pins; a plastic quad flat pack (PQFP) with up to 208 pins; a ceramic quad flat pack (CQFP), also with up to 208 pins; and a ceramic leaded chip carrier (CLCC) with up to 84 pins. These four packages are for surface mounting. Others are ceramic and plastic pin-grid array packages with up to 300 and 223 pins, respectively. These two packages are for through-hole mounting. Typical price for the ST18932 ASIC DSP IC is around $20 each in quantities of 10,000 units.

SGS-Thomson Microelectronics, Via C. Olivetti 2, I-20041 Agrate Brianza, Italy; Contact: Maria Grazia Prestini; phone: (0039)-39-603-5597. **CIRCLE 514**

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Slightly	552

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FAX MODEM CHIP HANDLES TEXT, PHOTOS, AND VOICE

MODEM CHIP TEAMS WITH CONTROLLER IC TO FORM MULTIMEDIA LINK BETWEEN PCs AND PORTABLES OVER PHONE LINES.

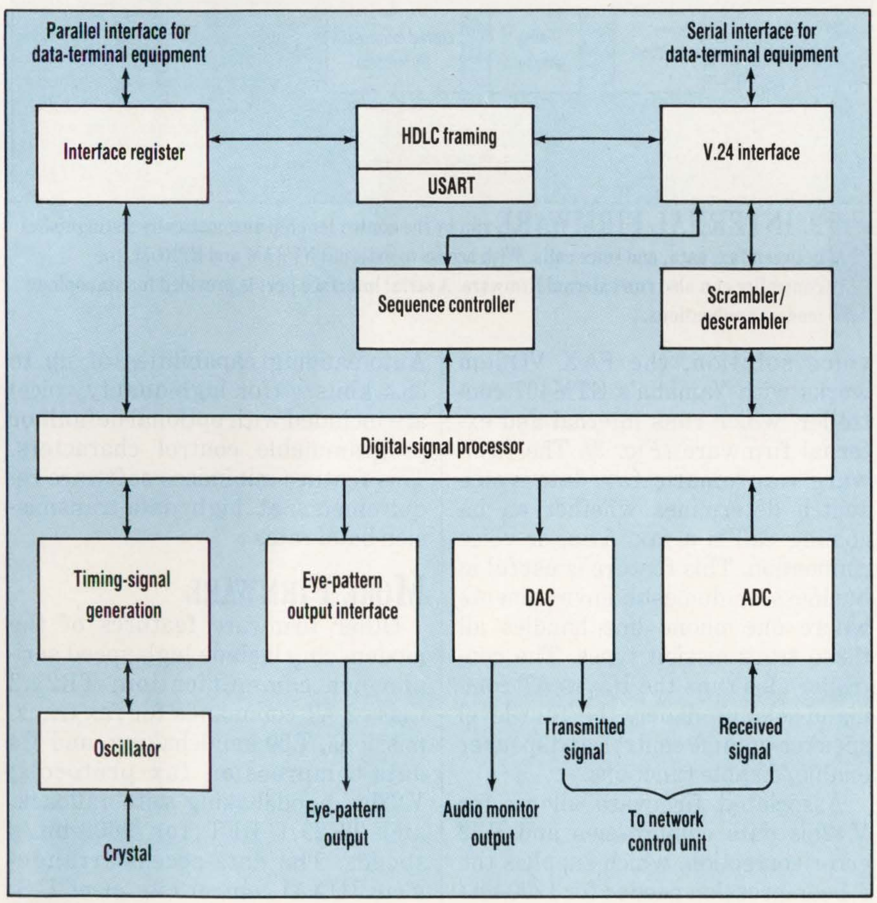
MILT LEONARD

Imagine a business professional, with just a few keystrokes at a PC, sending a spreadsheet with voice instructions and photographic backup over one telephone line to another location. The recipient then calls up the spreadsheet on a PC screen, plays back the voice message over the computer speaker, and views the photographic image. Such a scenario is now possible with the introduciton of the YTM403 FAX VOdem single-chip modem from Yamaha Corp. of America.

The YTM403 is a single-chip modem that combines facsimile, data, voice, and caller-identification functions for multimedia communications applications *(Fig. 1)*. Its built-in voice-recording and playback operations include adaptive-differential, pulse-code modulation (ADPCM) for 12-to-4-bit, 3:1 data compression and decompression. The chip's internal analog-to-digital and digital-to-analog data conversion, coupled with the increased bandwidth afforded by ADPCM compression, make the chip ideal for use in voice-mail applications.

The modem has built-in HDLC (High-Level Data-Link Control) framing, including bit stripping and cyclic redundancy checking required for Group 3 fax transmission and reception in the error-correcting mode. Fax transfers are supported by the 9600-bit/s binary-file-transfer (BFT) protocol.

The chip also supports data-pump functions with synchronous, half-duplex operation at 7200, 4800, 2400, 1200, and 300 bits/s. For modem-to-PC or modem-to-database communi-



1. THE FAX VOdem CHIP is built around a powerful digital- signal processor that performs complex mathematical operations associated with data, image, and voice processing. These include modulation and demodulation, filtering, compression and decompression, caller identification, and FM sound generation.

cations, the data pump operates asynchronously in the full-duplex mode, at 2400, 1200, 600, and 300 bits/s. Furthermore, the YTM403 FAX VOdem chip is compatible with CCITT communication standards, supporting CCITT V.29, V.27ter, V.26bis, V.22bis, and V.21, as well as Bell 212A and 103 standards.

Because all of the chip's communication modes are separate from each other, the modem can implement various mode combinations to meet specific application requirements. "For example, the V.26bis standard can be combined with the V.23 backward-channel standard to meet transmission requirements of many banks," explains Robert Starr, Yamaha Corp. national sales and marketing manager.

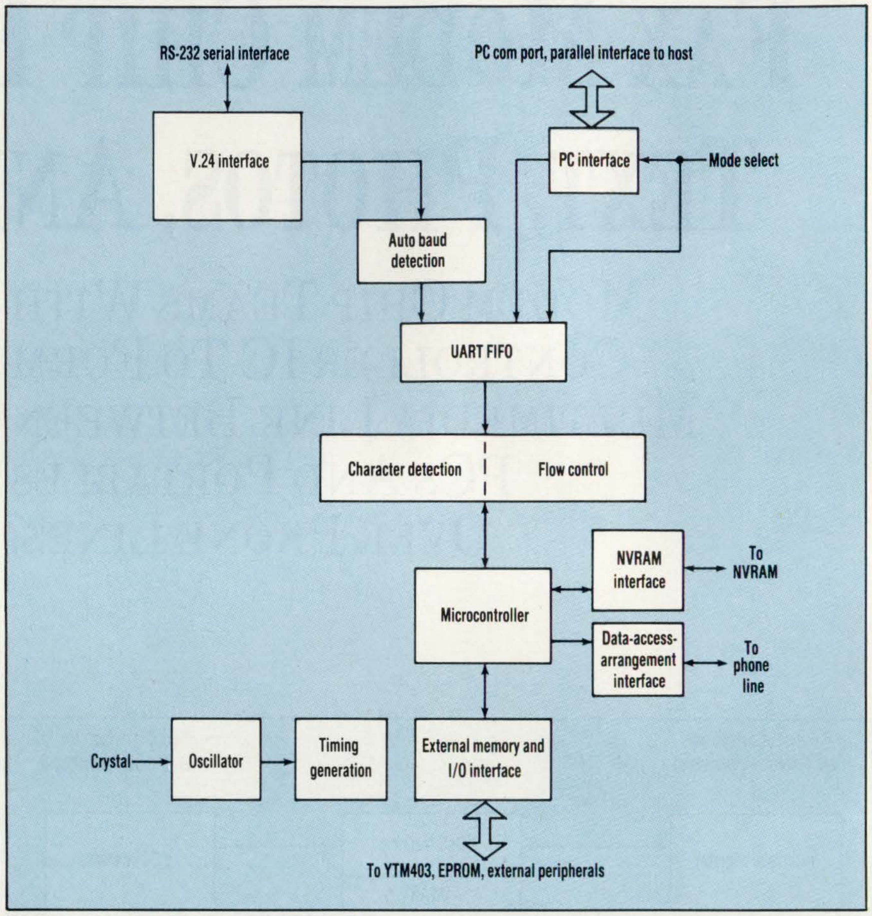
Many Features

Other modem features include a scrambler/descrambler, training and handshake sequencers, an equalizer, a programmable-tone generator, and tone detectors. To interrupt messages in a voice-messaging system, an on-chip DTMF (dual-tone, multiple-frequency) detector can remain active while the device is in the voice mode.

The chip also integrates a guard-tone notch filter circuit, S1 signal send/detection, transmit-clock selection, and programmable levels for carrier detection, transmission, and audio output. Band-split filters for full-duplex modem operation, eye-pattern output, loopback support, and general-purpose I/O ports are also provided within the modem chip. An external microprocessor can be used to control every function.

Available in a 64-pin shrink DIP or a 64-pin quad flat pack, the 0.8-μm CMOS modem uses 300 mW in the active mode and less than 1 mW in standby. Low power consumption and 5-V operation qualify the device for use in portable computer applications, local-area network faxes, and for wireless communications like cellular and radio fax. The YTM403 FAX VOdem chip also supports Group 3 fax transmissions over X.25 communications networks.

For a complete two-chip fax-data-voice solution, the FAX VOdem works with Yamaha's GTM407 controller, which runs internal and external firmware *(Fig. 2)*. The firmware's automatic fax/data/voice switch determines whether an incoming call is a fax, data, or voice connection. This feature is useful in business or domestic environments where one phone line handles all three transmission types. The controller also runs the Hayes AT command-set autodialer, the four-level speaker-volume control, and speaker enable/disable functions.



2. INTERNAL FIRMWARE run by the controller chip automatically distinguishes between fax, data, and voice calls. With access to external NVRAM and EPROM, the controller can also run external firmware. A serial interface port is provided for standalone modem applications.

Associated firmware allows for V.42bis data compression and V.42 error correction, which supplies the 4:1 compression needed for 1200-bit/s or higher modem speeds. The firmware also meets the MNP 5 data-compression and MNP 1 to MNP 4 error-correction protocol standards. Auto-bauding capabilities of up to 38.4 kbits/s (for high-quality voice) are included with optional default or programmable control characters. This feature minimizes software requirements at high data-transmission baud rates.

More Firmware

Other firmware features of the modem chip include high-speed serial voice communication; TR29.2 Class 2 AT commands for fax transmissions, T.30 handshaking, and T.4 data-compression fax protocols; V.22bis handshaking with fallback, and TR29.1 BFT for 9600-bit/s speeds. The data-access-arrangement (DAA) control bits meet U.S. and international requirements for linking the modem to analog telephone lines. The embedded operating system and hooks enable users to

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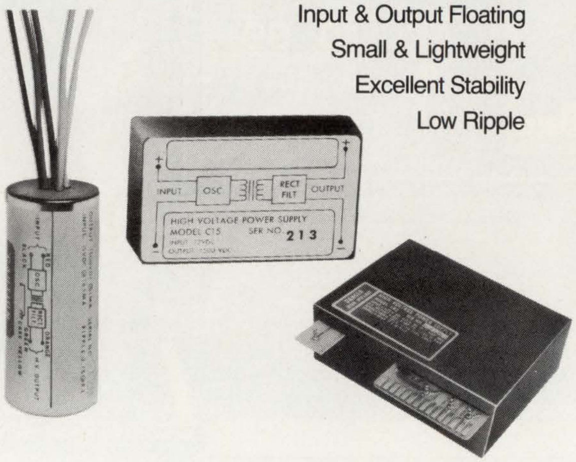

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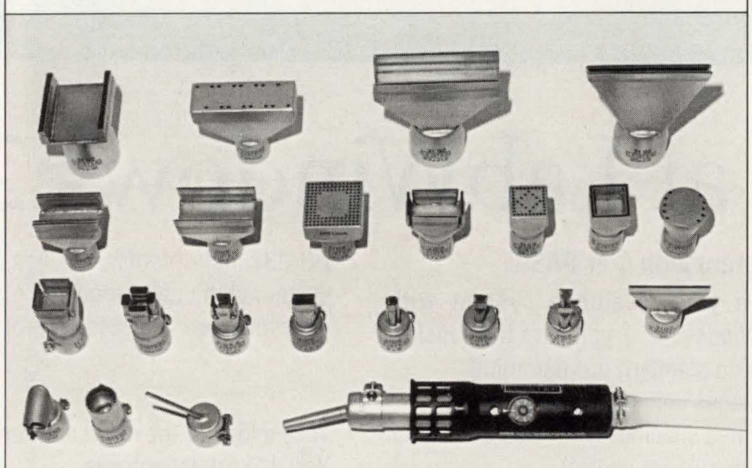

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customize Yamaha firmware with nonstandard facilities.

To meet the space requirements of smaller machines, the controller chip can address external EPROM and static RAM, each with up to 128-k-word-by 8-bit capacity. The controller can also accommodate external nonvolatile RAM for storing user-configuration information.

Two interface options are offered. A serial RS-232 interface for TTL signal levels handles standalone applications. PC-based applications can use a parallel-interface 16550 universal asynchronous receiver/transmitter (UART). This interface is also compatible with DOS-, OS/2-, and Unix-based com1, com2, com3, and com4 software. The UART has a bidirectional 32-byte FIFO buffer (16-byte transmit, 16-byte receive) that decreases bottlenecks during data transfers.

Other controller features include optional chip select for external peripherals, glue logic for the PC bus, and an option for software-based addressing to com1, com2, com3, and com4, eliminating the need for external chip-select logic. A programmable shutdown mode removes power from the controller chip, the FAX VOdem, and other chips if they aren't accessed within a user-defined time period or a maximum of 30 seconds. Automatic power-up applies operating power without losing Hayes AT command-set standards when activity occurs on the serial or parallel interface during shutdown. The controller chip is available in an 80-pin quad flat pack.□

PRICE AND AVAILABILTY

Samples of the YTM403 modem and GTM407 controller are available now. The YTM403 modem will be available in the fourth quarter for $40 each in quantities of 1000. Individual chip prices are available upon request.

Yamaha Corp. of America, 981 Ridder Park Dr., San Jose, CA 95131; Robert Starr, (408) 437-3133 or 1-800-543-7457.

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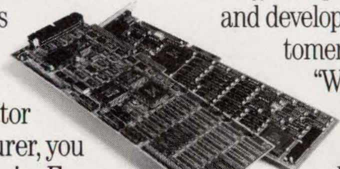

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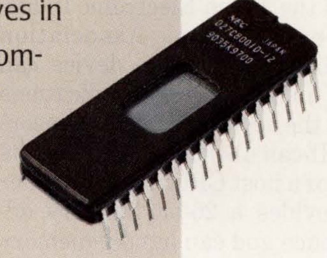

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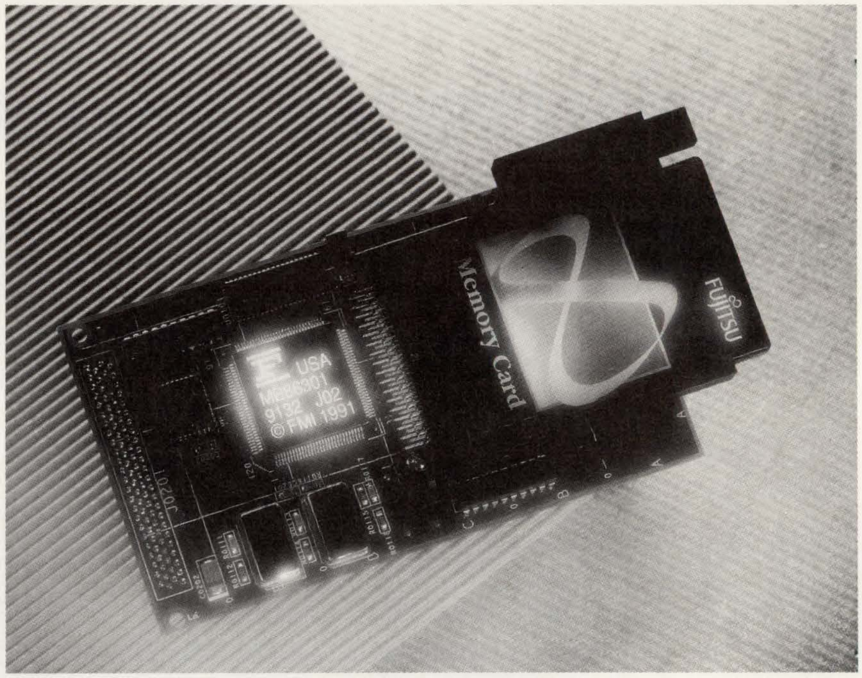
NEC

Controller Chip Ties Memory Cards Into Computer Systems

Dave Bursky



The popularity of memory cards in both personal and industrial computing applications may quickly balloon thanks to the release of the first commercial controller chip from Fujitsu Microelectronics that ties memory cards into a host computer. The chip, the MB86301, greatly reduces the amount of logic needed to connect a memory card to a host system on the system motherboard or in an adapter card.

The IC was jointly defined by Databook Inc., Ithaca, N.Y., and Fujitsu Microelectronics. The new controller chip supports a variety of semiconductor memory-card types, including SRAM, flash, UV EPROM, EEPROM, and one-time programmable ROM cards, as well as read-only mask-ROM-based cards.

The controller is fully compatible with the 68-pin memory card standards from the Personal Computer Memory Card International Association and the Japan Electronic Industry Development Association (PCMCIA/JEIDA). The device can operate in standalone applications without the need for a host microcontroller. It can also operate under the control of a host CPU. The controller chip provides a 26-bit memory address space and can handle memory cards with data-path widths ranging from 8 to 16 bits.

With a flexible register-based interface, all aspects of chip operation can be configured by an off-chip memory or host controller. There are two groupings of registers. One grouping contains 16 registers, referred to as the primary register set. The other group, called the auxiliary register set, contains eight registers. The primary registers control the basic operation of the memory-card interface while the auxiliary registers contain configuration data that tune the interface to a specific memory-card type.

Three universal timer circuits are included on the MB86301 chip to facilitate the creation of programming pulses required by the various nonvolatile memories—flash, EPROM, EEPROM, and so on. Data integrity is assured thanks to built-in 16-bit cyclic-redundancy-check and 8-bit checksum generation logic that offloads the host computer from performance-degrading overhead operations.

To ensure that the memory cards don't get damaged during the process of live insertion and removal, automatic power sequencing controls all power that reaches the card socket. Furthermore, because one main application of the memory cards is in portable systems, the card includes a low-power sleep mode that minimizes the idle-state power consumption. The chip also supplies a Host Interrupt signal that lets the host computer know when a card is being removed or when a card is being inserted.

Because memory cards come in a wide range of access times, the controller chip includes a programmable wait-state generator that can synchronize faster host systems to slow memory cards. And to write data into flash memories, a word-hold addressing mode speeds the parallel programming of 16-bit flash-based cards.

The high-voltage levels typically needed by the nonvolatile memories for programming must be generated by off-chip logic circuitry. On-chip circuits will control external pass transistors that will route the voltage to the programming pin.

The controller chip ties into host-computer processors with 8- to 16-bit data buses, and includes byte-swap logic to ensure that both Intel- or Motorola-style buses can be used. Operating from a 5-V power supply, the chip includes fully buffered interface lines to directly drive the memory cards.

The MB86301 controller chip is available in a 120-lead plastic quad-sided flat package that's 1.1 in.^{2}. In quantities of 1000, it will sell for between \$25 and \$30 each. Samples of the chip are available now from stock.

Fujitsu Microelectronics Inc., IC Div., 3545 North First St., San Jose, CA 95134; Larry Gagliani, (408) 922-9405. **CIRCLE 457**

4K EEPROM HAS 1 MILLION E/W CYCLES

The ST24C04 and ST25C04 4-kbit serial-I/O EEPROMs are organized internally as two pages of 256-by-8 bits and are compatible with the Inter-IC bus. The devices guarantee a minimum endurance of one million erase/write cycles, claimed by SGS-Thomson claims as the world's highest to date. This is made possible by a memory-cell design in which the conventional arrangement of vertically stacked gates is replaced by a lateral structure that minimizes the thermal stress on the critical tunnel oxide during subsequent processing. Also, every cell has a built-in redundancy that prevents random weak cells from compromising device integrity. Another useful feature is the write-protect mode that enables the upper page to be completely or partially protected against spurious write operations. The last byte in the upper page acts as a protect register. By writing to this byte, the user can define all or part of the page as write-protected. Once set, the protection configuration can be changed only by grounding a specific pin and writing new data to the protect register. Typical applications include TV and telephone sets, cordless phones, computer peripherals, and industrial instrumentation (for storing reference curves, calibration data, and maximum/minimum values). The ST24C04 and ST25C04 are available in 8-pin DIP or surface-mounting plastic SO14 packages. They sell for $2.30 each in quantities of more than 100 units.

SGS-Thomson Microelectronics, I-20041 Agrate Brianza, Via C. Olivetti 2, Italy. Phone: (0039) 39-6035-597. CIRCLE 458

ASYNCHRONOUS FIFOS OPERATE ABOVE 28 MHZ

SGS-Thomson has expanded its family of high-speed dual-port FIFOs with the MK45H03 2-k-by-9-bit FIFO and two new package options for the MK45H01/02/03. The FIFOs offer fully asynchronous reads and writes with maximum access times of 25 ns and minimum read cycle times of 35 ns, allowing them to be used in systems at up to 28.5 MHz. The devices offer high flexibility and ease of use via their full, half-full, and empty status flags, and allow simple width and depth expansion by using the expansion I/O pins. The MK45H03 is pin-compatible with the popular MK4503, but has a 62% faster access and 56% faster cycle time. The high speed and ease of use suit it to interprocessor communications in multiprocessor systems, printer buffers, LANs, telecommunications links, and applications involving data transfer between unsynchronized systems. The MK45H03, along with the 512-by-9-bit MK45H01 and 1-k-by-9-bit MK45H02, are available in 28-pin, 300-mil plastic DIPs; 28-pin, 600-mil plastic DIPs; and 32-pin, plastic leaded chip carriers, respectively. The MK45H01, MK45H02, and MK45H03 cost $8.93, $13.22, and $14.90 each, respectively, in quantities of 1000 or more. All devices are available now.

SGS-Thomson Microelectronics, I-20041 Agrate Brianza, Via C. Olivetti 2, Italy. Phone: (0039) 39-6035-597. CIRCLE 459

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Company-wide, the recycling spirit has spread from Cleveland headquarters to offices throughout the country. Penton employees are enthusiastic participants in expanding programs to reuse paper, aluminum cans, and other waste materials.

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By employing one or two RISC CPUs on Mbus-compatible modules, Ross Technology, a subsidiary of Cypress Semiconductor, has made it easier to implement high-performance RISC-based systems. There are three CPU subsystem modules in the first release of the family—CYM6001, 6002, and 6003. They deliver throughputs of 24, 43, and 24 Specmarks, respectively, when clocked at 40 MHz. The 6001 is designed for uniprocessor applications, while the other two are intended for multiprocessor systems.

All three modules employ the CY7C601 Sparc integer CPU, the CY7C602 floating-point coprocessor, a pair of 16-kword-by-16-bit cache memory chips to form a 64 kbyte cache, and either the CY7C604 memory-management unit for uniprocessor systems or the 7C605 MMU for multiprocessor implementations. The modules are implemented on SBus-format pc boards (3.3 by 5.78 in.) that have dual ground and power planes to minimize system noise. All components are surface mounted to minimize interconnection delays, and clock skew is controlled thanks to the compact layout.

Although the cards use the Sun SBus format, they employ Sun's MBus interface, which allows synchronous 64-bit-wide data transfers at rates of up to 40 MHz. The SparcCore modules also come with RossBoot, a bootstrap loader with internal diagnostics that help the designer get the modules running. All three modules are available from stock. In lots of 1000, they sell for \$1400, \$3200, and \$1675 apiece, respectively.

Cypress Semiconductor Corp., 3901 N. First St., San Jose, CA 95134; (408) 943-2600. **CIRCLE 460**

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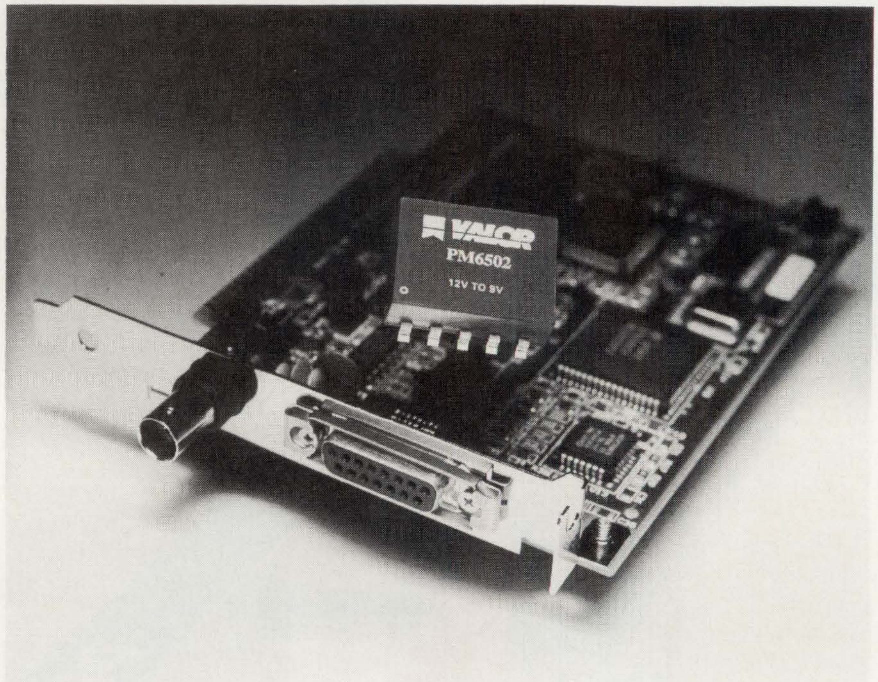
David Maliniak



The increasing demand for smaller, surface-mountable parts that lend themselves to automatic insertion escapes no segment of the OEM market. In the network-board area, it's of paramount importance. Often, the dc-dc converter on such boards is the largest component in terms of footprint.

To that end, the industry's first surface-mounted 2-W dc-dc converter, the PM6501/02, measures just 0.337 in. high by 1.100 in. long by 0.850 in. wide. The device, from Valor Electronics Inc., replaces a through-hole part that measures 0.475 in. high by 1.3 in. long by 0.8 in. wide. The SMT part is a full-featured converter for the local-area-network market. It's 9-V output powers the coaxial-transceiver interface IC in Ethernet and Cheapernet applications.

Significant hurdles had to be cleared in the converter's development. Chief among these was the problem of creating a device that could survive the 220°C temperatures of infrared-reflow processing. Most 2-W converters use electrolytic and tantalum capacitors, but they wouldn't be able to withstand SMT processing. Monolithic ceramic capacitors can handle the higher temperatures, but they're expensive in values that would match those of the electrolytic and tantalum capacitors. The company got around this problem by raising the converter's switching frequency to 1.2 MHz. That made headroom for monolithic ceramic capacitors valued at just 0.1 μF, which decreased overall costs. In addition, the 1.2-MHz switching frequency is several times higher than existing 2-W converters.

The converters have undergone extensive monitoring of internal and external temperatures during IR-reflow soldering. Four tests at high temperatures (230°C at a 3.5-minute heating cycle) and for extended oven times (208°C for 5.5 minutes) were completed successfully.

The company also drew from its experience as a supplier of magnetic components for the LAN industry to create a new magnetic assembly for the PM6501/02 converter. The assembly was required to keep magnetic-flux densities and core losses down at the device's high switching frequency. The assembly, which is being applied for a patent, has one core that serves multiple independent magnetic functions. The core is electrically divided into a transformer and a choke that don't interact with each other.

Converters are available with inputs of either 5 V dc ±10% (PM6501), or 12 V dc covering the full Ethernet range of 10.2 to 15.8 V dc (PM6502). The output is regulated to within ±5% over the operating-load range of 50 to 225 mA, with conversion efficiencies of more than 65%. A CMOS-compatible remote on-off function makes these converters well-suited to Micro Channel applications where a "jumperless" hardware configuration is required.

There are 10 leads on the devices' body, each of which is 0.075 in. wide on 0.200-in. centers. The leads serve to conduct heat out of the body and keep temperature rises as low as 14°C when installed on a pc board. These low operating temperatures and the elimination of electrolytic capacitors results in a calculated MTBF of 1.5 million hours, according to MIL-HDBK-217E.

Other pertinent specifications for the converters include a typical reflected-ripple current on the input of 20 mA pk-pk for the 5-V model and 7 mA pk-pk for the 12-V version. Ripple and noise at the output is rated at 100 mV pk-pk. Worst-case output-voltage tolerance is 8.45 to 9.55 V dc. The input-to-output isolation voltage is 2000 V ac.

Samples of the converters are available immediately, and production is scheduled to begin in October. In lots of 10,000, pricing is set at $6.65 for the 5-V model and $6.35 for the 12-V model.

Valor Electronics Inc., 6275 Nancy Ridge Dr., San Diego, CA 92121-2245; Ken Lauchner, (619) 458-1471. **CIRCLE 462**

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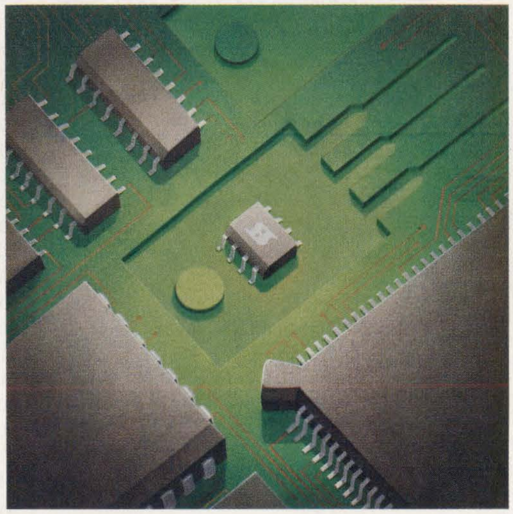
LITTLE FOOT

A GIANT STEP IN A LITTLE FOOTPRINT.



Now you can get power devices in compact digital packaging. Siliconix's LITTLE FOOT™ devices give you better use of board space ... and much more. These tiny 8-pin SOIC packages reduce part count, improve reliability, and make assembly easier than ever.

Each LITTLE FOOT device contains your choice of one or two powerful MOSFETs produced with Siliconix's SiMOS 2.5 technology (2.5M cells/sq. in.). They occupy far less space than single-transistor DPAKs, 4-pin DIPs, and TO-220s, and they offer the industry's highest power density and lowest on-resistance.

LITTLE FOOT products come in different versions that are ideal for motor control, load switching, and DC-to-DC conversion.

Si9400DY	Single P-Ch	20 V	0.25 Ω	2.3 A
Si9405DY	Single P-Ch	20 V	0.125 Ω	3.7 A
Si9942DY	Dual N- & P-Ch	20 V	0.125 & 0.20 Ω	2.5 A
Si9953DY	Dual P-Ch	20 V	0.25 Ω	2.3 A
Si9955DY	Dual N-Ch	50 V	0.13 Ω	3.0 A
Si9956DY	Dual N-Ch	20 V	0.1 Ω	3.5 A
Si9959DY	Dual N-Ch	50 V	0.3 Ω	2.0 A

With this standard surface-mount packaging, LITTLE FOOT can reduce manufacturing costs. Unlike other power devices, there's no special setup required. With LITTLE FOOT you use the same process flows and soldering profiles as other SMDs.

There's less setup time, no tube jamming, just one insertion for two MOSFETs, no solder voids, no lead trimming, and quicker visual inspection. So you can reduce the number of steps in your production cycle and get to market quicker.

You can count on Future Electronics' delivery performance to match the superior performance of LITTLE FOOT. Call Future Electronics for your LITTLE FOOT order and profit from immediate, off-the-shelf delivery — and unmatched product expertise. Or call **1-800-554-5566, ext. 562** for your LITTLE FOOT Design Kit or more information about other analog or power products from Siliconix.

Siliconix

LITTLE FOOT is a trademark of Siliconix

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Low-Cost Unit Analyzes Networks To 1.3 GHz

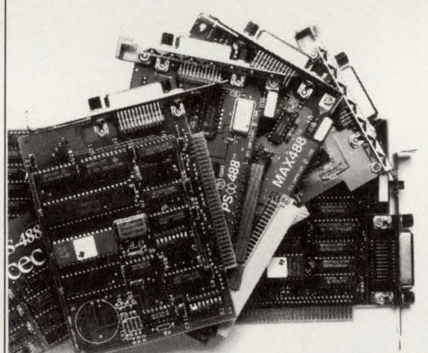
The HP 8711A RF network analyzer measures transmission, reflection, and absolute power over a 300-kHz-to-1.3-GHz bandwidth. The unit's range, automated features, and low price make it ideal for applications in cellular and mobile communication, CATV, and consumer electronics. The internal swept-synthesized source completes a full-band sweep in only 50 ms. Frequency resolution is 1 Hz and dynamic range is 90 dB. A 3.5-in. floppy drive and optional Instrument Basic package allow automated testing without an external computer. Test programs can be written by automatic recording of keystroke entry, directly on the instrument, through an optional PC-compatible keyboard, or by an external computer. The HP 8711A network analyzer costs $13,500. The Instrument Basic option costs $1350 and the keyboard is $210. Delivery is estimated at 16 weeks.

Hewlett-Packard Co., 19310 Pruneridge Ave., Cupertino, CA 95014; (800) 752-0900. **CIRCLE 463**

VXI System Performs Functional Test

The enhanced VXI 2000 Functional Test System is a complete package, consisting of a VXI chassis, core instrumentation, embedded PC controller, and program development and execution software. Two VXI modules—the Digital Pin Electronics (DPE) card and the Universal Pin Electronics (UPE) card—supply the core instrumentation. Each DPE card has 192 pins with 5-MHz TTL capability. Each UPE card is a virtual instrument with 8 pins, each of which performs seven basic instrument functions. The card has been upgraded to extend the normal operating mode of 20 MHz to allow a high-frequency mode at 50 MHz. The controller is a standard RadiSys EPC-2, an 80386-based embedded PC. The controller has 4 Mbytes of RAM, a 40-Mbyte hard disk, a 3.5-in. floppy-disk drive, two RS-232 ports, a parallel port, an IEEE-488 port, a VGA display, and an AT-style keyboard. Prices depend on the cards ordered. A 400-pin system with software costs $97,000 and is available with a four-month delivery schedule.

Giordano Associates Inc., 5 Century Dr., Parsippany, NJ 07054; (201) 292-0079. **CIRCLE 464**



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Acquisition Software Runs Under Windows 3.0

The LabDriver for Windows software runs under the real, standard, and 386-enhanced modes of the Windows 3.0 operating system. The software, a dynamic link library, controls National Instruments' plug-in data-acquisition boards for the PC/XT/AT/EISA and IBM PS/2 computers. The package includes high-performance, low-level functions for analog, digital, and timing input/output, as well as easy-to-use high-level functions for stream-to-disk acquisition and waveform generation. A resource manager lets users take advantage of multiple functions and boards simultaneously. LabDriver for Windows is available immediately for $295.

National Instruments, 6504 Bridge Point Pkwy., Austin, TX 78730-5039; (800) 433-3488 or (512) 794-0100. **CIRCLE 465**

Function Generator Features Versatility

The PM 5135 function generator for general-purpose applications in training and education, service, production testing, and development labs, has standard pushbutton-selectable sine, triangle, and square waveforms and a frequency range from 1 mHz to 2 MHz. Other features include a versatile sweep mode and easily adjustable dc offset and attenuation settings. Sweeps can be single or continuous, with a logarithmic characteristic. The sweep ratio is continuously variable from 1 to 2000, and the sweep start frequency is programmable. The sweep function covers more than 3-1/2 decades, which is ideal for such tests as audio sweeps in the 20-Hz-to-20-kHz frequency range. The sweep period is continuously adjustable from less than 10 seconds up to 150 seconds. Sweeps can be triggered manually by pushbutton control, or from an external trigger source. A facility for an external sweep mode is also provided. A choice of pushbutton-selectable attenuation settings cover the range of 0 to 60 dB in 10-dB steps. The instrument also has a continuously variable adjustment over 0 to 20 dB. The PM 5135 function generator is available now. Price will be given on request.

Philips Test and Measurement, P.O. Box 218, NL-5600 MD, Eindhoven, The Netherlands; Phone: (0031) 40-788620. **CIRCLE 466**

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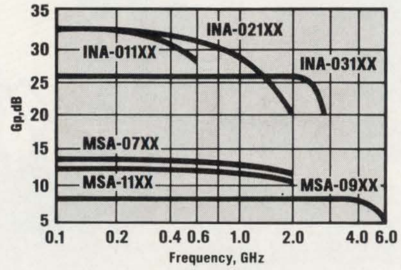

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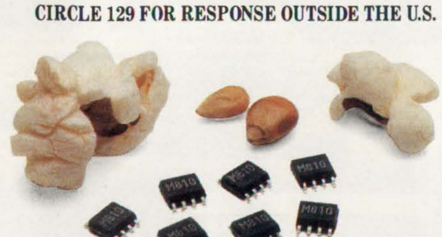


Putting Microwave Technology to Work for You

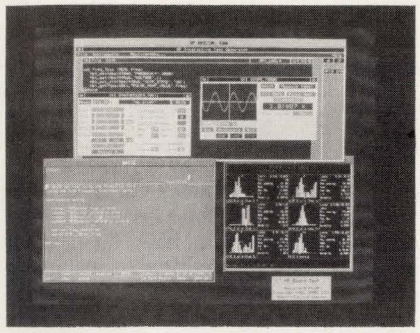
AVANTEK

VXI-Based Board Tester Cuts Development Time

The HP 307X VXI board-test system uses high-performance pin cards, system cabling, and closely integrated HP ITG software to speed up development of combinatorial test setups. By combining VXIbus technology with the HP 307X board tester, the system eliminates the need for time-consuming customized hookups and programming.

The HP AccessPlus pin card and associated cabling cut hardware-development time by creating an engineered, through-the-system connection from the instrument source to the device under test. With an external VXIbus connection, the card offers 100-MHz performance. Users control HP AccessPlus resources with high-level system commands that automatically set up measurement paths and then automatically reconfigure those paths for either differential or coaxial measurements.

With the basic HP 307X family's architecture, the VXIbus mainframe can be mounted in the testhead or externally. As a result, users can place C-size modules directly in the testhead. Because some instrument types aren't available in VXIbus format, the HP



307X VXI also works with IEEE-488 instruments. The integrated HP ITG software reduces software development time by providing graphical front panels that allow interactive control of the instruments. Menu pull-downs permit fast access to system commands and instrument controls. Users can adjust control settings and make measurements with a mouse.

HP 307X VXI board test systems start at $221,500, with availability scheduled for November.

Hewlett-Packard Co. *19310 Pruneridge Ave., Cupertino, CA 95014; (800) 752-0900.* **CIRCLE 467**

■ *JOHN NOVELLINO*

Low-Cost DSO Features 200-Msample/s Rate

With a 100-MHz bandwidth and 200-Msample/s digitizing rate, the model 465 digital storage oscilloscope offers an exceptional price-performance ratio. The full digitizing rate is available on both channels, and comprehensive trigger capabilities allow the scope to capture glitches as short as 5 ns with a 0.4% (8-bit) vertical resolution on all vertical sensitivity settings. Advanced features include a 4-color plotter, automatic on-screen measurements, automatic setup, and a variable-persistence mode. The unit permits trace manipulation and testing of limits. Nonvolatile memories store the current setup parameters and up to three traces. The scope is compatible with the new IEEE-488.2 Standard Commands for Programmable Instruments (SCPI). Base price of the 465 is $3490; delivery is within 30 days.

Gould Inc., Test and Measurement Group, 8333 Rockside Rd., Valley View, OH 44125; (216) 328-7263. **CIRCLE 468**

Pulse Generator Runs At 630 MHz

The HFS 9009 stimulus system supplies up to 18 pulse-generator channels with repetition rates to 630 MHz. The increased speed, which is available on all HFS 9000 series units, allows characterization of high-speed devices to Sonet OC-12 or STM-14 standard bit rates. Edges on the 18 synchronized channels can be placed with 10-ps resolution. Another new feature is the ability to divide the chosen repetition rate by 2, 4, or 8, which provides simple logic, and the control of timing relationships, without the need for a data generator. Two 2-channel plug-in cards are available. The HFS 9PG1 supplies a 630-MHz repetition rate with a fixed transition time of less than 200 ps. The HFS 9PG2 offers programmable transition times from 800 ps to 5 ns. The HFS 9009 costs $19,995, with 12-week delivery. The HFS 9PG1 and HFS 9PG2 cost $11,000 and $7900, respectively.

Tektronix Inc., P.O. Box 19638, Beaverton, OR 97219-0638; (800) 426-2200. **CIRCLE 469**

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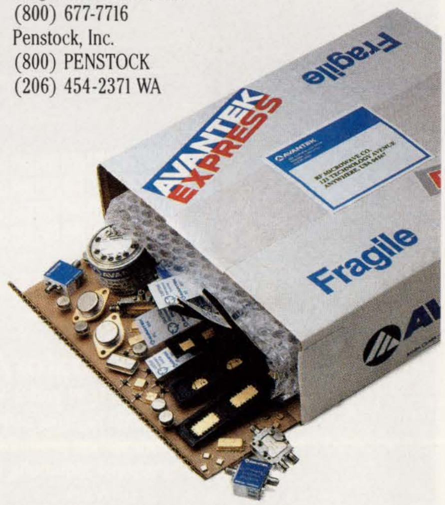

Putting Microwave Technology to Work for You

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BUILD SCREEN LAYOUTS GRAPHICALLY

Building hypertext and multimedia systems, prototypes, and front-ends becomes a simple task with HyperCASE, a visual programming tool. The software allows users to define the appearance of all information graphically, including the links between fields. This results in a program that's easy to organize and manage. HyperCASE works at the individual-component's level, allowing users to zoom out to build or define the structure of the entire application graphically, as a flowchart. Direct manipulation of fields and cards allows easy and rapid design and implementation of an application. In addition, modifications done at a later date are simpler because of the graphical representation. The software sells for $395.

Interactive Image Technologies Ltd., 49 Bathurst St., Suite 401, Toronto, Ontario, Canada M5V 2P2; (416) 361-0333. CIRCLE 470

SOFTWARE ANALYZES, BENCHMARKS PCs

Intel 80X86-based platforms can be analyzed and benchmarked with the XXBench automated tool. The software enables PC developers to accurately evaluate their systems with "real-world" applications, such as Lotus 1-2-3, Microsoft Word, and other popular packages.

Using the tool, systems can be gauged against other PCs. The software controls keyboard entries at the operating-system and BIOS level, guiding multiple applications through a standardized series of operations while capturing timing results in hundredths of a second. The reports are returned in an ASCII format. All this happens with minimal intervention from the user. Version 1.1 of XXBench is available for $2500.

XXCal Inc., Testing and Systems Div., 11500 W. Olympic Blvd., Suite 325, Los Angeles, CA 90064; (213) 477-2902. CIRCLE 471

COMPRESSION SOFTWARE DOUBLES SPACE, DOES MORE

The Stacker 2.0 software, which reduces the file compression or decompression time by about 30% over the original Stacker 1.1 software release, can be used with removable-media hard-disk drives, floppy disk drives, and RAM disks, in addition to its use on standard hard-disk drives. The software utility can more than double the storage space available on most disk drives with minimal compromise in system performance.

The improved software from Stac Electronics can compress data files by an average of 2:1 with no data losses, and on some file types achieve lossless compression ratios as high as 18:1. Stacker 2.0 is compatible with DOS 3.x, 4.x, and 5.x, as well as with Dr. Dos and Compaq's DOS 3.31 operating systems. Utility software, such as Norton Utilities and PC Tools, as well as disk-caching programs and memory managers, can also be used. The software can consume as little as 9 kbytes of resident memory or it can be loaded into high memory using a memory manager. Included with the software is a file defragmentor that works on the compressed files, password protection to prevent unauthorized file access, improved diagnostics (including Speed Disk, a utility from Symantec/Norton), and an improved user interface. For power users, the software also enables users to adjust the size of the Stacker disk volume so that the maximum compression ratio can be used. For example, if CAD files are to be stored in a Stacker volume, such files could be compressed by about 4:1. In the previous release, the compression ratio was limited to only 2:1.

Besides the software, which sells for $149 in single units, stac has developed a trio of cards that speed the algorithm's execution: an 8-bit XT-compatible board for $199, a 16-bit PC/AT card for $249, and a 32-bit adapter for IBM Micro Channel systems that costs $299. Current Stacker owners can upgrade their software for $49.

***Stac Electronics,** 5993 Avenida Encinas, Carlsbad, CA 92008; Steve Koschmann, (619) 431-7474.* CIRCLE 472

■ *DAVE BURSKY*

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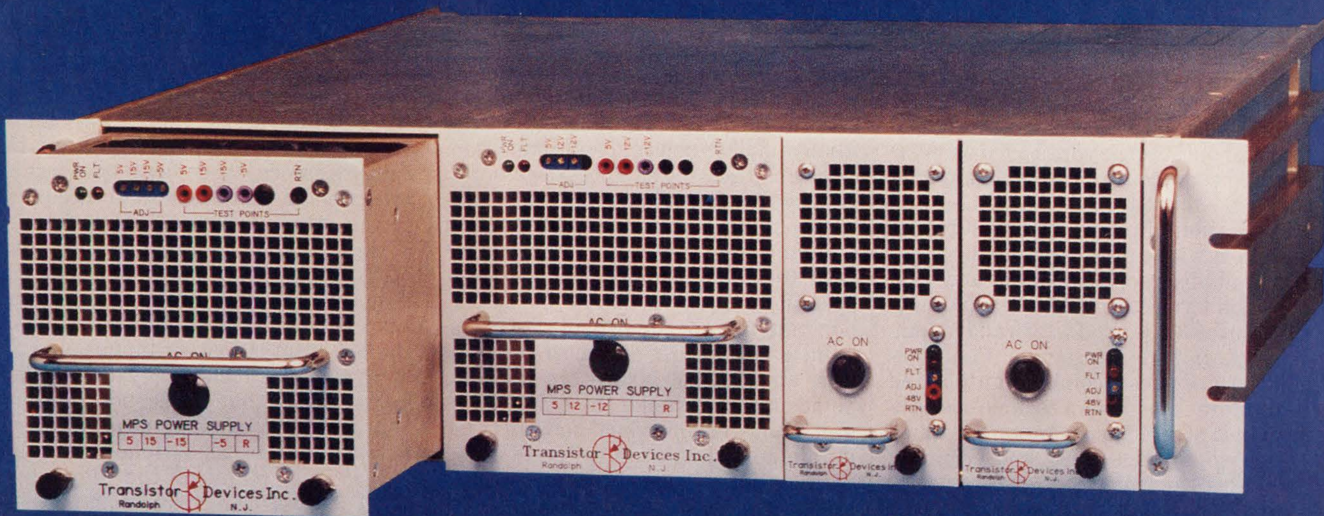
POWER FACTOR CORRECTED MODULAR POWER SUPPLIES



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FLOORPLANNER MIXES IC BLOCKS AND CELLS

AutoPlan is an automatic floorplanner that mixes custom-block and standard-cell IC designs. A pushbutton feature performs what-if analysis on placement and interconnect of a design to find the optimum layout based on user-defined constraints. The program handles placement for ICs containing any combination of predefined hard blocks and cells with underlying physical layout, and abstract soft blocks and cells that don't yet have the underlying layout. AutoPlan is used with Valid's Compose Architect interactive floorplanner, so users can combine automated and interactive design techniques. AutoPlan is offered as an option to Valid's Compose chip-assembly and Compose Architect floorplanning environments. It's shipping now, starting at $15,000. The software can be set up as a network resource on DEC, IBM, and Sun workstations.

Valid Logic Systems Inc., 2820 Orchard Pkwy., San Jose, CA 95134; (408) 432-9400. **CIRCLE 473**

SPICE OPTION DOES SYMBOLIC ANALYSIS

Symbolic Spice (Sspice) is a symbolic ac-analysis option for Spice users. The standalone package accepts Spice-file inputs and outputs symbolic transfer functions with optional numeric evaluation and user-selected approximation. Sspice can be used as a pre-processor to find design formulas, or as a post-processor using biasing-point information of transistor parameters to approximate formulas. It also has several user-specific application options. Second-order biquads are identifiable for pass-band gains, cutoff or center frequencies, and quality factors. In addition, Sspice can determine the effect finite gain-bandwidth-product has on these parameters. Sspice runs on PCs and workstations. It costs $500, and is available with multiple-copy discounts. A PC-based demo version is available with a users manual for $25.

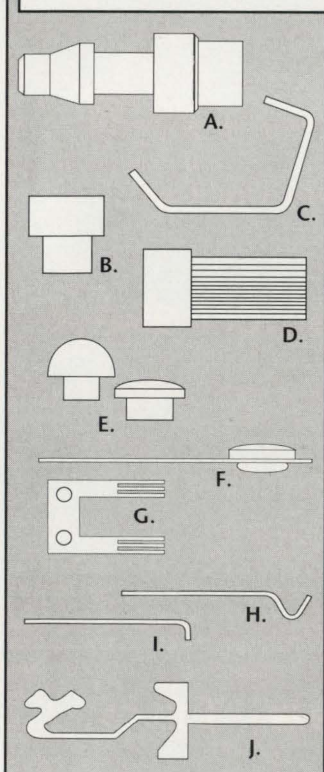
Michigan State University, Instructional Media Center, Marketing Div., P.O. Box 710, East Lansing, MI 48826-0710; (517) 353-9229. **CIRCLE 474**

PC PROGRAM ANALYZES DIGITAL BOARDS

DDA is a pc-board analysis program that runs on DOS-based computers. The interactive software performs 65 tests on each net of a design. These tests include ac, dc, and power-supply analysis. DDA will also flag schematic-capture errors like device model errors, misnamed net nodes, and multiple use of the same reference designator. All of the active devices are tested for operation within their guaranteed specifications. DDA's analysis will achieve more than 98% fault isolation. In addition, the program is fast—running on a 33-MHz machine, it can analyze a 100-chip design in less than 10 seconds. Context-sensitive help explains design anomalies and suggests possible causes and corrections. Many of the algorithms DDA uses were developed and proven through its work in past years as a service bureau. DDA is available now. Call the company about pricing.

Digital Design Analysis, 150 El Camino Real, Suite 200, Tustin, CA 92680; (714) 573-8730. **CIRCLE 475**

Precious Metal Contacts and Stampings



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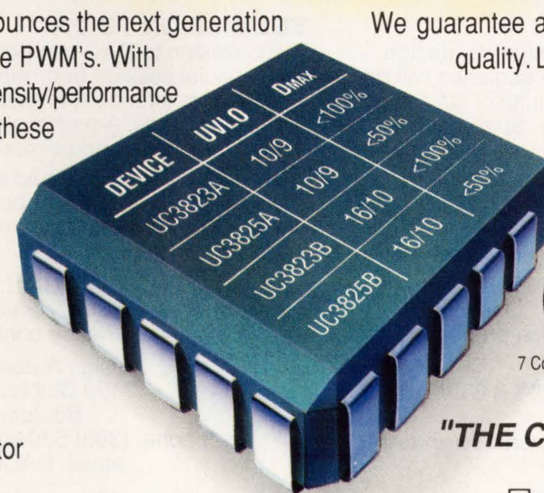

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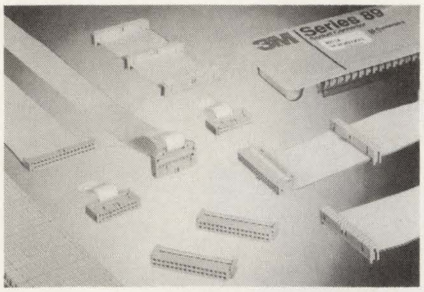

Lower assembly costs are a primary benefit of the Series 89 insulation-displacement socket line. The connectors feature a preassembled, one-piece body that can increase assembly speed by three times. Blister packaging speeds loading of automated-assembly equipment. The connectors come in 0.100-by-0.100-in. wire-mount styles and feature 30-μin. gold plating in the socket-wiping area. Call for pricing and delivery.

3M Electronic Products Div., P.O. Box 2963, Austin, TX 78769-2963; (800) 225-5373. **CIRCLE 476**

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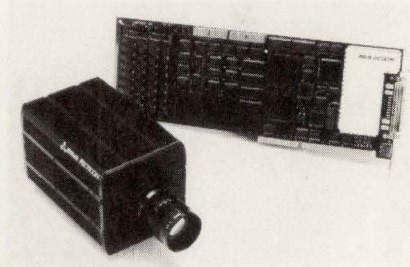

SB4256 controller-processor for the IBM PC AT and compatibles. Blurred images are made crisp and clear by video that's 16 times faster than conventional systems. The camera can be positioned in a production environment up to 100 ft. from the computer. The processor board handles frame rates from 30 to 480 frames/s. The camera and board's list prices are $14,780 and $7500, respectively. Delivery is in six weeks from receipt of order.

EG&G Reticon, 345 Potrero Ave., Sunnyvale, CA 94086-4197; (408) 738-4266. **CIRCLE 477**

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Redpoint Ltd., Cheney Manor Swindon Wiltshire, SN2 2QN, United Kingdom; Phone: +44 (0)793 537861. **CIRCLE 478**

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- Requirements of a DA environment which minimizes the challenges in using the tools.
- Strategies for evaluating DA vendors when preparing for a purchase.
- Strategies for choosing the best DA tool for a particular class of design problems.
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DEADLINE: Authors should submit their papers no later than October 25, 1991. Each submission should include 8 copies of the complete manuscript. Notice of acceptance will be mailed by February 7, 1992.

FOR MORE INFORMATION: To encourage those who have never submitted to DAC, special assistance and consideration is available. Please contact:

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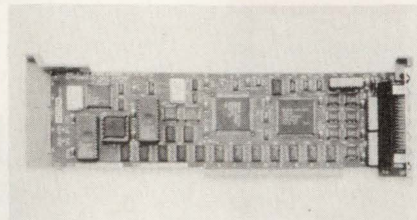
SCSI Controllers Aim At Raid And MCA Cards

Allowing designers to quickly implement their own Raid (redundant array of inexpensive disks) subsystems, the ADP92 disk-array controller gives designers a choice of Raid levels 0, 1, 3, or 5. The board, which measures just under 10 by 14 in., manages up to seven ranks of five drives each. On the host side, it provides a differential 8- or 16-bit fast SCSI port that runs at up to 20 Mbytes/s. On the array end are five 8-bit single-ended SCSI ports, each able to transfer 5 Mbytes/s. The board can perform on-line data regeneration for up to one failed disk per rank, and can automatically reconstruct lost data, perform automatic data recovery and concurrent reconstruction, and support partial ranks (3+1 or 2+1).

Data paths on the board include end-to-end error detection to ensure data integrity. Striping size is programmable for Raid-0 and Raid-5 levels. Throughput for the card peaks with Raid 0 at 475 I/O operations/s, and decreases to 450, 195, and 425 operations/s for levels 1, 3, and 5, respectively. The controller card sells for $3295.

For designers that need a complete Raid subsystem, the NCR6292 desktop subsystem provides Raid 0 or 5 modes and holds one rank of five drives of either 236 or 426 Mbytes each (1.2 or 2.1 Gbytes of total storage without parity, and 0.944 or 1.7 Gbytes with parity). With the 236-Mbyte drives, the 6292 sells for $15,790.



And for designers using IBM PS/2 systems with Micro Channel buses, the ADP-37 host adapter provides an 8- or 16-bit SCSI-2 differential interface that transfers data at up to 20 Mbytes/s. The MCA card is a bus master and includes a 32-word-by-32-bit FIFO buffer to maximize transfer efficiency. The card can be used in 8-, 16-, or 32-bit slots and supports command queuing and multithreaded I/O operations. In singles, the card goes for $845.

NCR Microelectronics Corp., 1635 *Aeroplaza Dr., Colorado Springs, CO 80916; (719) 596-5795* **CIRCLE 479**

■ *DAVE BURSKY*

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Users gain a new approach to time- and cost-efficient automated factory development and programming by using the VMEbus Intelligent Universal Controller (VIUC) System from PEP Modular Computers. The VIUC consists of a high-performance 3U VME board and graphically oriented code-development software that runs on an IBM PC-compatible system. The VME board functions as a programmable logic controller (PLC) running under Microware's OS-9 real-time operating system.

After standard relay-ladder-logic (RLL) code is developed, it runs on the VME board. PEP claims that the system offers performance and architectural capabilities that exceed proprietary PLCs. Control code is developed, simulated, and debugged using sequential-function charts (SFCs) and RLL standards on a software tool called ISaGRAF. ISaGRAF is a DOS-based graphical windowing tool developed by CJ International as part of an agreement with PEP. The CASE tool can be used with any VME hardware.

The VIUC System offers a line of VMEbus-compatible 32-bit intelligent universal controllers that act as expandable PLCs. It also supplies a fast compilation of ISaGRAF-developed SFC and RLL code into a compact, downloadable module. The code runs as tasks under OS-9. PEP is also developing ISaGRAF ports for real-time operating systems from Ready Systems and Wind River Systems. Available now, the VIUC System sells for $500 in large quantities. ISaGRAF costs $3995.

PEP Modular Computers, 600 North *Bell Ave., Carnegie, PA 15106; (800) 379-8024.* **CIRCLE 480**

■ *RICHARD NASS*

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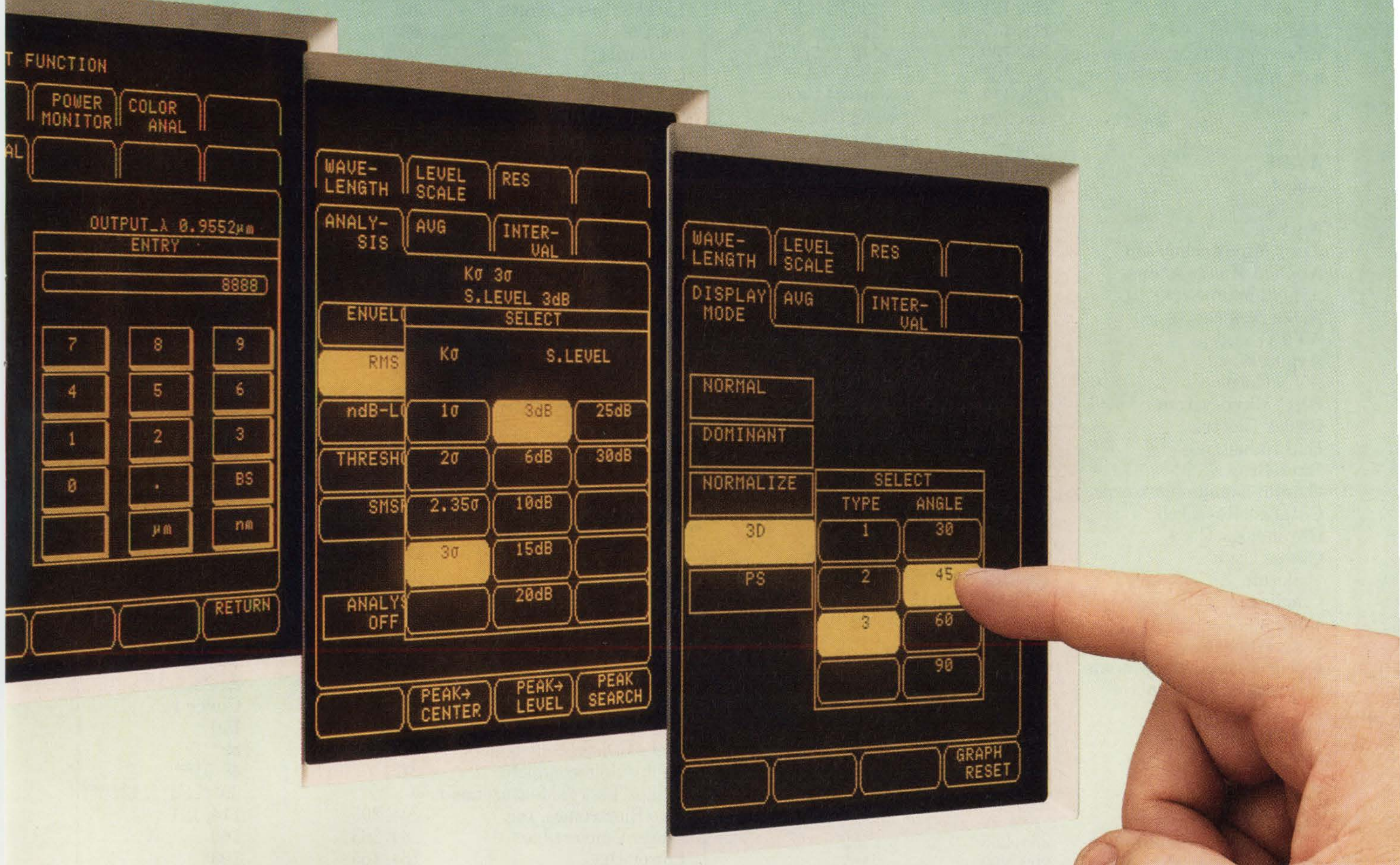

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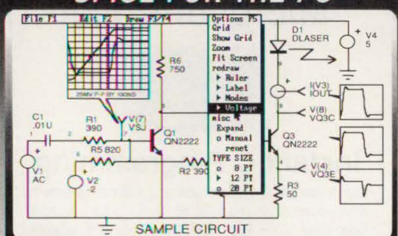

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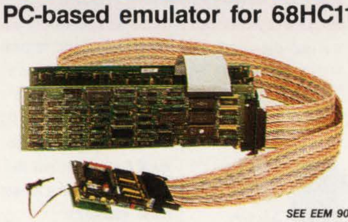

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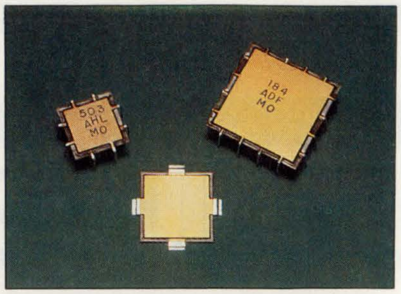

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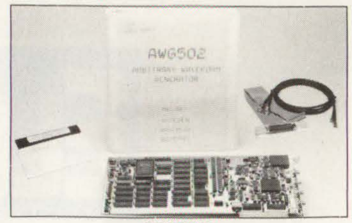

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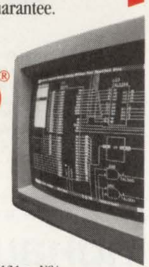

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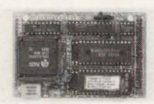

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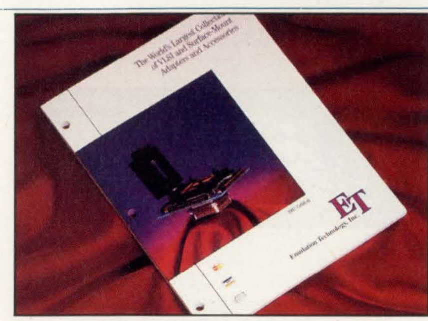

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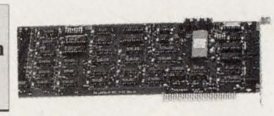

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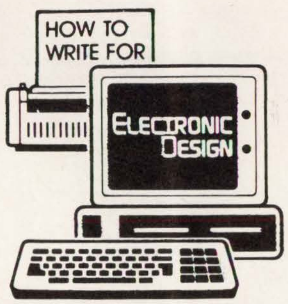

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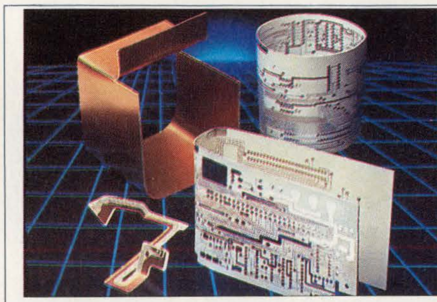

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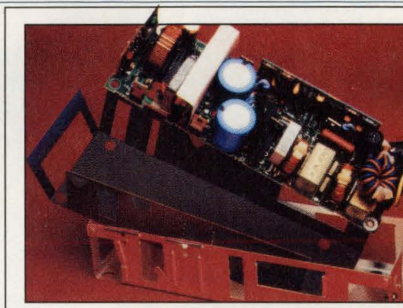

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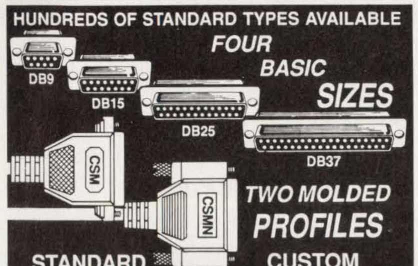

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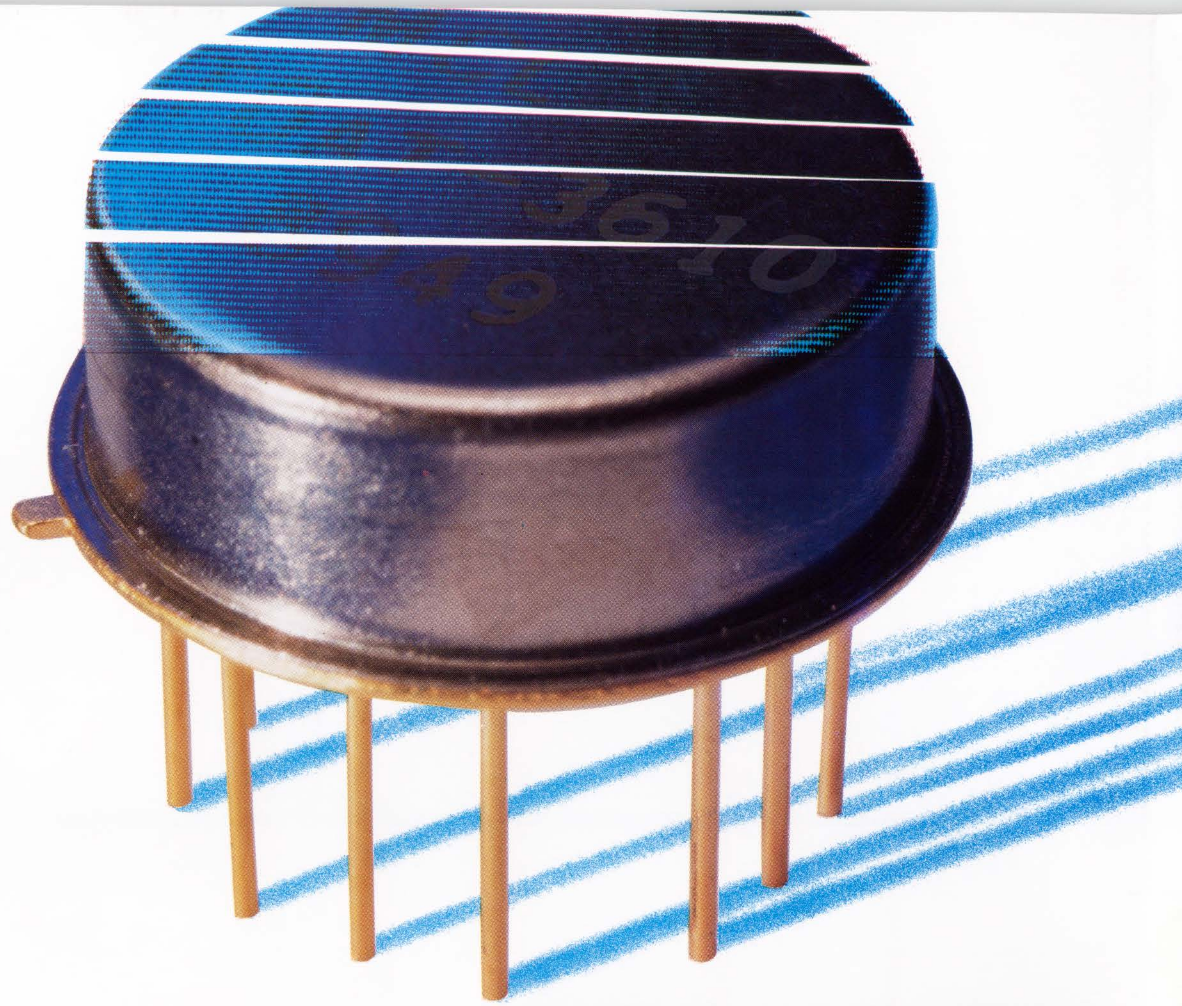

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1.0	**0.2**	**2.0**	**0.2**	**6.0**	**0.3**	**10.0**	**0.3**
1.5	0.32	3.0	0.4	9.0	0.6	15.0	0.6
2.0	**0.2**	**4.0**	**0.3**	**10.0**	**0.3**	**20.0**	**0.4**
2.5	0.32	5.0	0.5	13.0	0.6	25.0	0.7
3.0	0.4	6.0	0.5	16.0	0.6	30.0	0.7
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Parameter		1220	1224	1191	1223	1122	Units
S.R.	Slew Rate (Typ)	250	400	450	1000	80	V/μsec
G.B.W.	Gain Bandwidth (Typ)	45	45	90	100	14	MHz
t_s	Settling Time (to 0.1%) (Typ)	90	90	100	75	340*	nsec
A_{VOL}	Open Loop Gain (Typ)	50	7	45	28	450	V/mV
V_{OS}	Offset Voltage (Max)	1	2	6	3	0.9	mV
I_{OS}	Offset Current (Max)	0.3	0.4	1	—	.00005	μA
I_B	Bias Current (Max)	0.3	8	1.7	3	.0001	μA
e_n	Voltage Noise (f = 10KHz)	17	22	25	3.3	15	nV/$\sqrt{Hz}$
i_n	Current Noise (f = 10KHz)	3	1.5	4	2.1	.002	pA/$\sqrt{Hz}$
	Min Gain Stable	1	1	1	1	1	
I_S	Supply Current (Max)	10.5	9	40	10	11	mA
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