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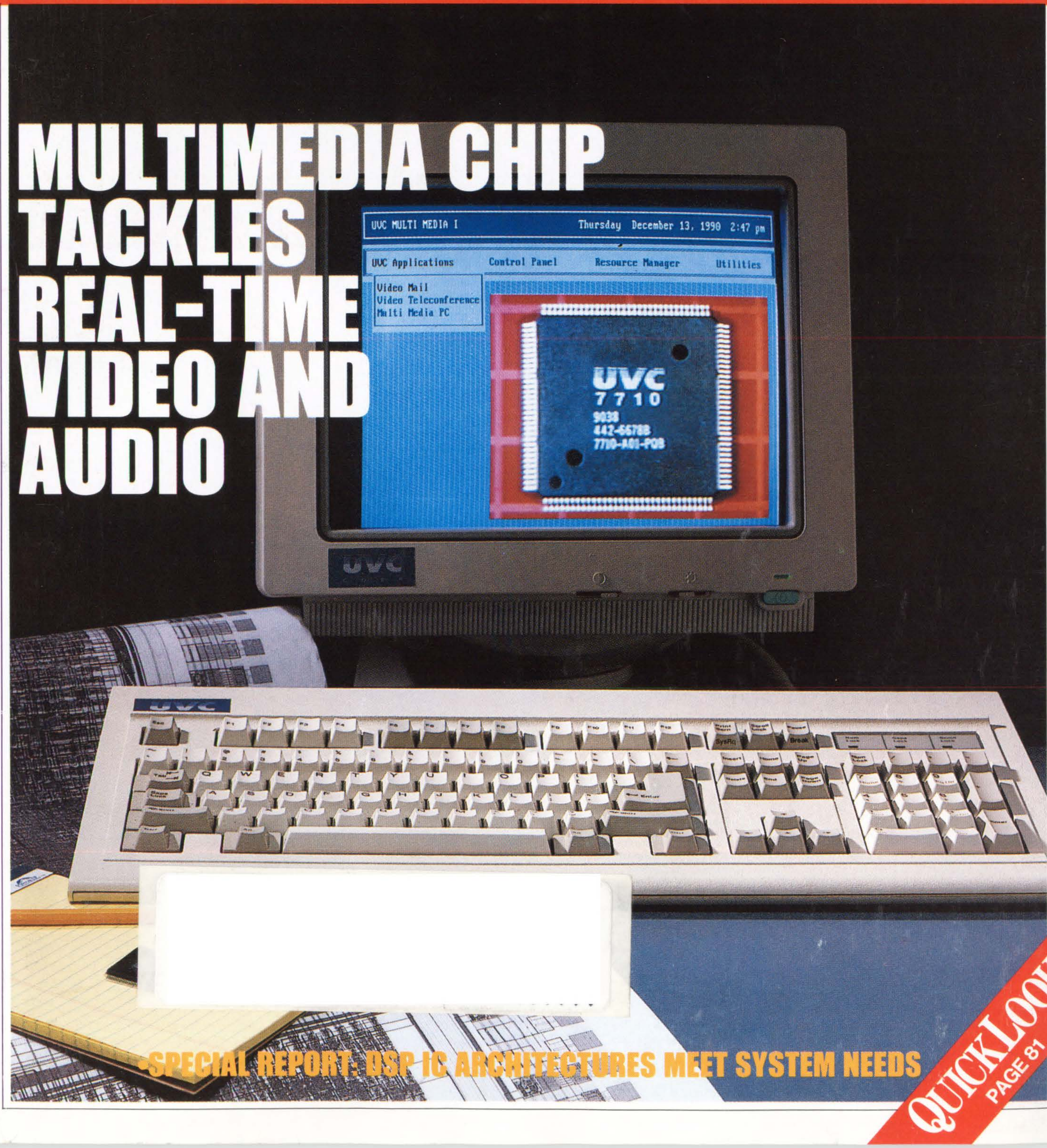
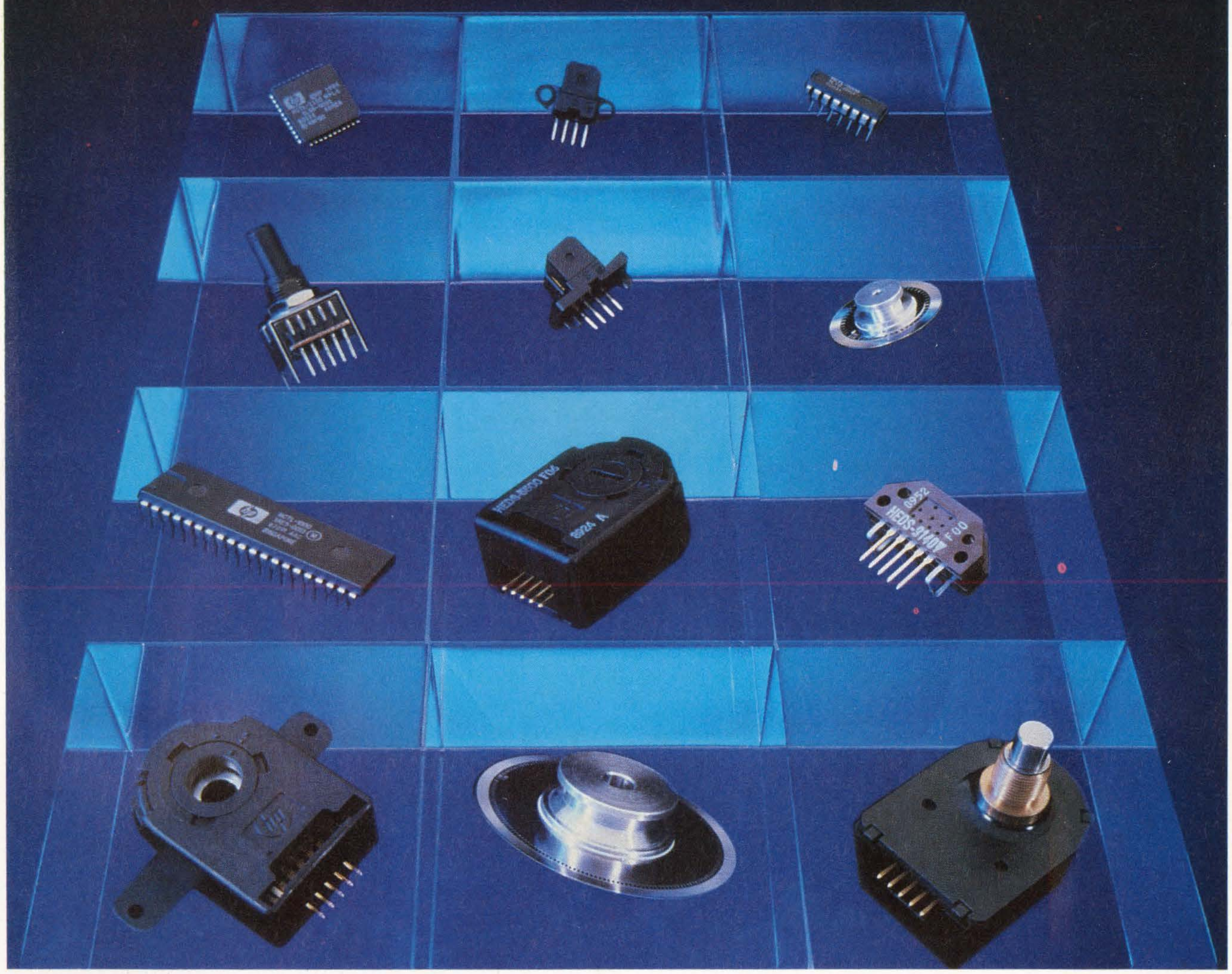


•SPECIAL REPORT: DSP IC ARCHITECTURES MEET SYSTEM NEEDS

QUICKLOOK PAGE 81

Control Tower



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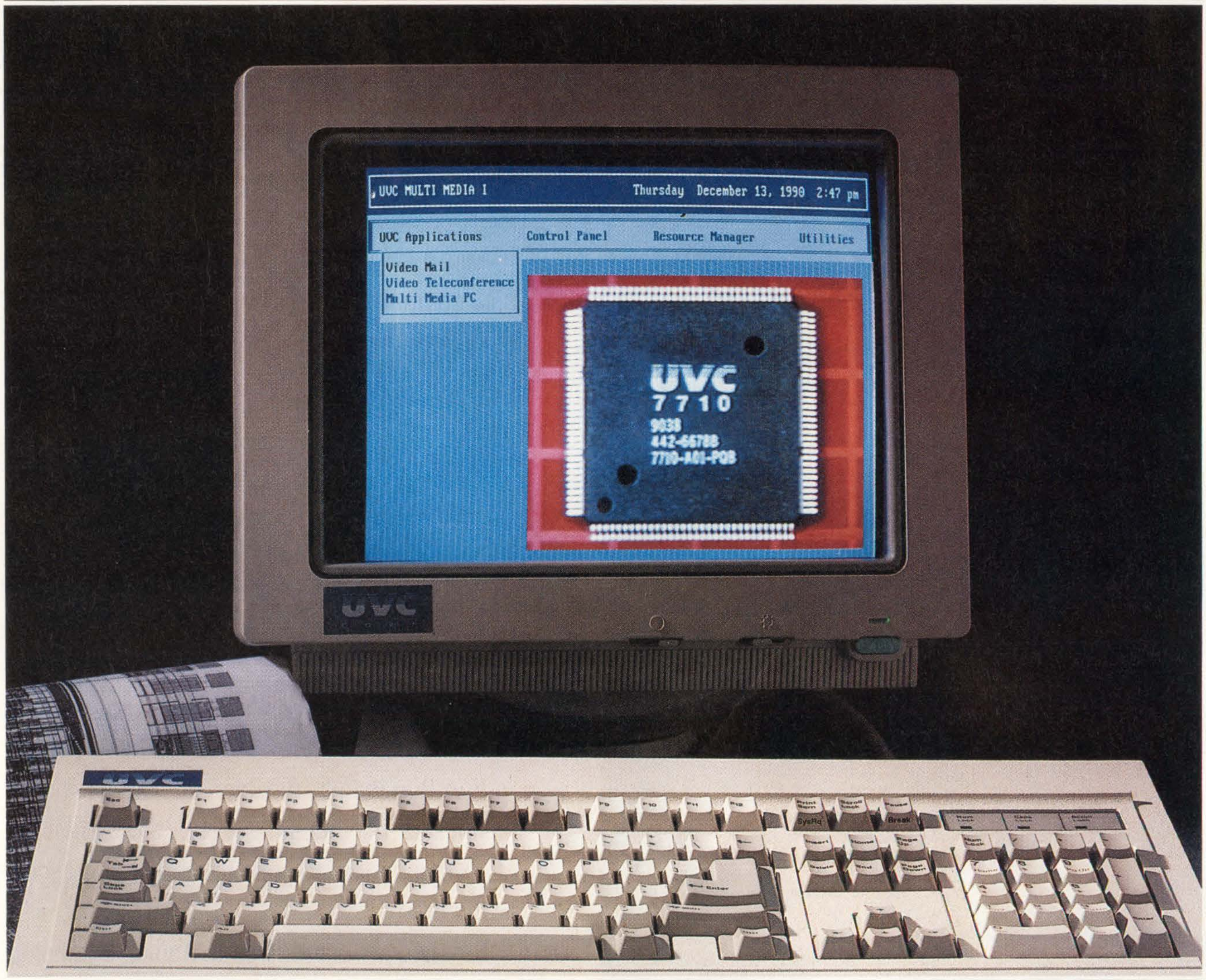

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- Electronic Design's Top 100 Products covered during 1990
- First details on a new multiprotocol communications IC
- A test engineer's insights into designing for testability
- Replacing trimmer pots with new 8-bit DACs
- Plus regular features:

Ideas for Design
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Technology Advances
...and more

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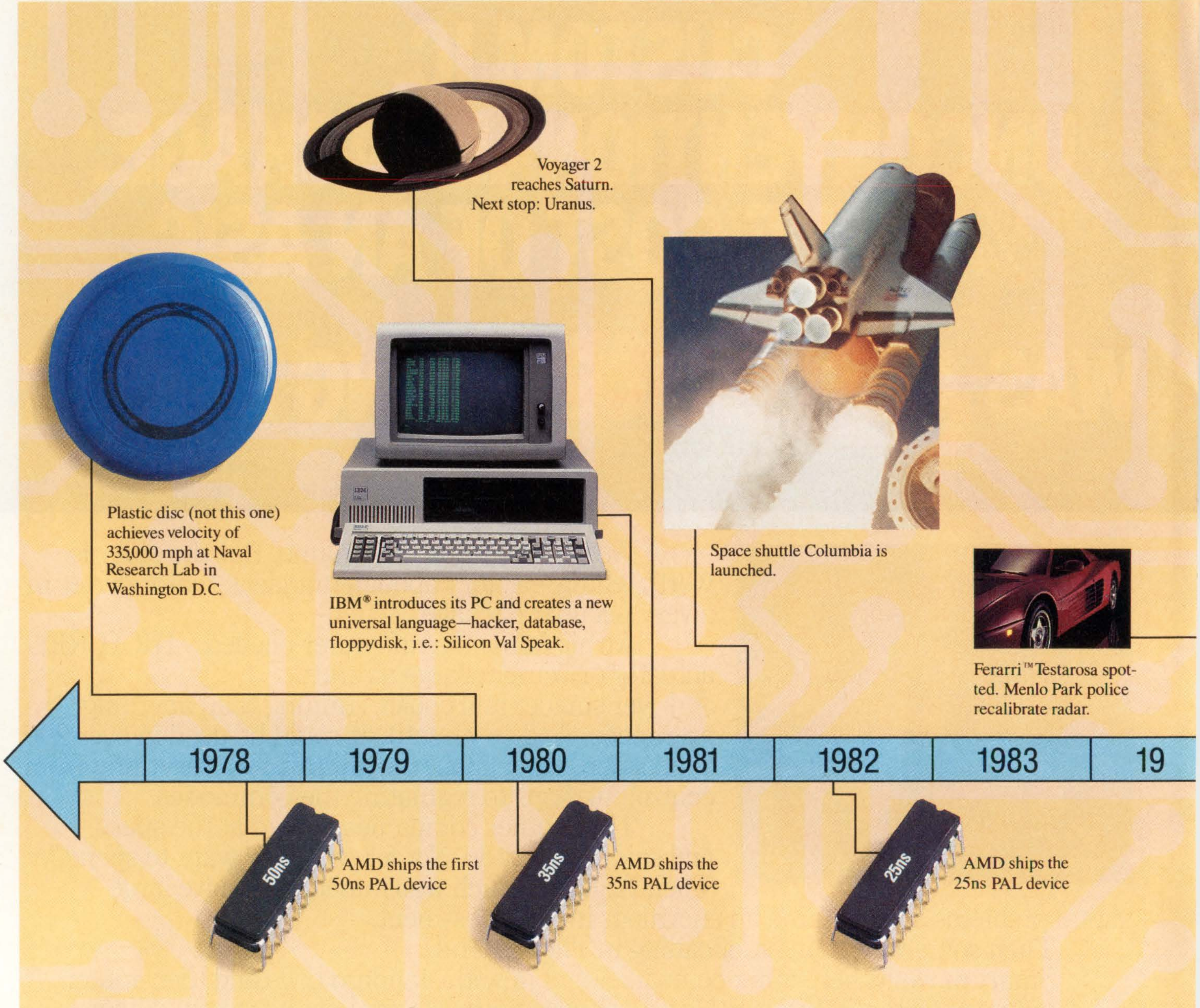

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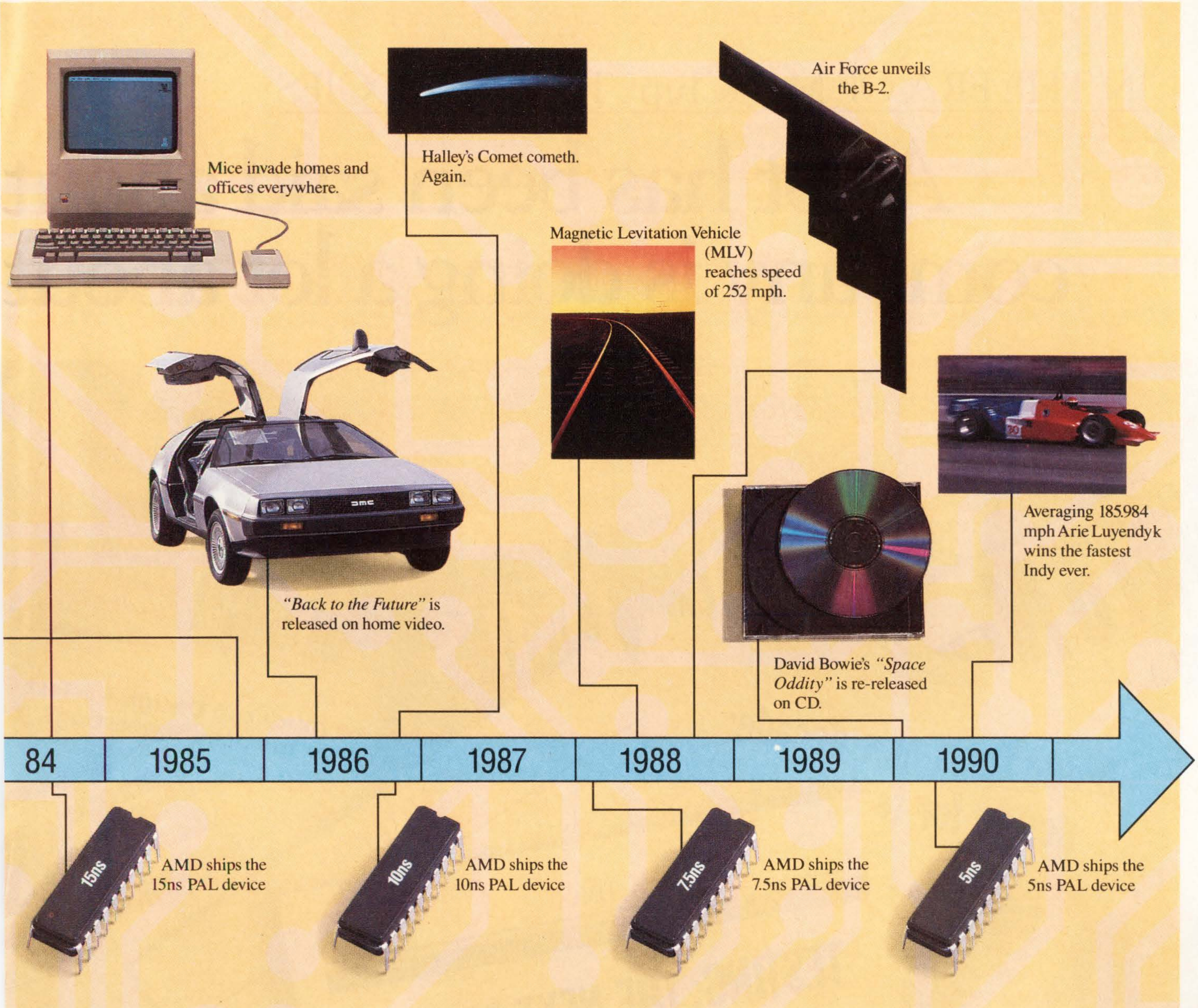

16R8-4 family that moves at a crisp 4.5 nanoseconds. And for the fastest version of the standard in field programmable logic, ask for our 10ns 22V10.

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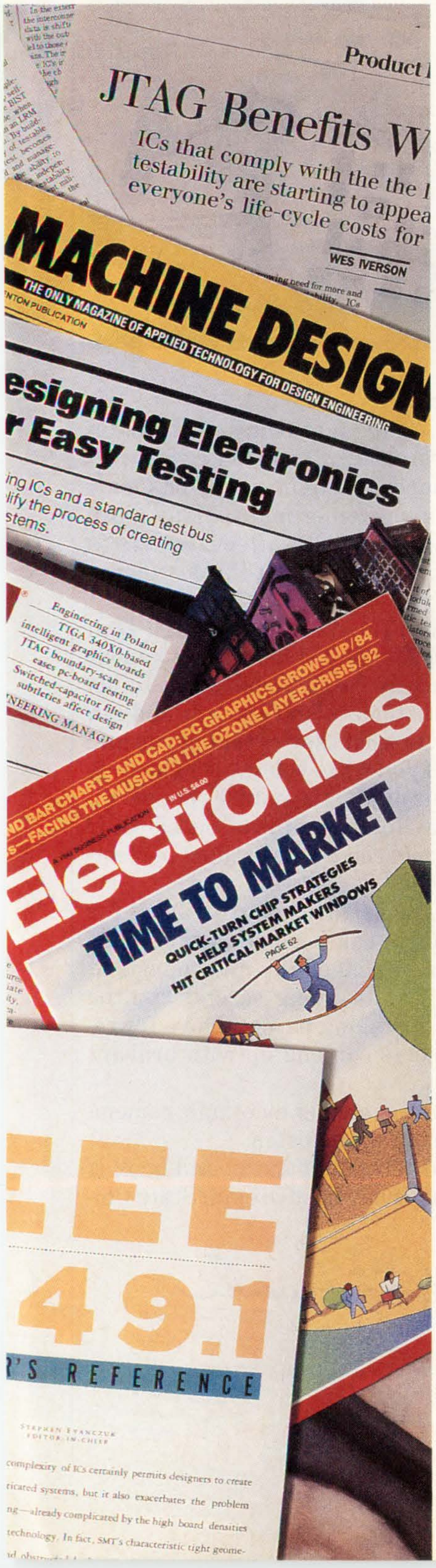
CIRCLE 178

IN THE ERA OF MegaChip™ TECHNOLOGIES

A lot has been said about
company is doing a lot about

testability, but only one it. Texas Instruments.



You've seen the headlines and read the stories. Design-for-test (DFT) is a challenge but one that's now easier to live with. The reason: Texas Instruments is the first to develop products for implementing the JTAG/IEEE 1149.1 testability standard quickly and effectively.

To market faster at lower cost

By implementing testability into your system from the outset, you can create one that uses high-performance circuits and is readily manufacturable, one that is lower in total cost and on the market faster. You can expect:

- Test integration — from silicon to system — that reduces debug and test time
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- Reduced capital investment in test equipment
- Increased system fault coverage and reliability

SCOPE, our broad-based solution

To simplify and speed your design task, TI has developed its SCOPE™ (System Controllability/Observability Partitioning Environment) family. It is a coordinated, broad-choice set of commercial and military products compatible with the IEEE 1149.1 standard.

Included are bus-interface devices, standard cells, gate arrays, and digital signal processors, as well as our ASSET™ (Advanced Support System for Emulation and Test) diagnostics software.

On the way are diary memories, a series of IEEE 1149.1 stand-alone controllers, and microprocessors with boundary-scan and built-in self-test features.

We are in for the long haul

As a member of the Joint Test Action Group (JTAG), we contributed to the formulation of the IEEE 1149.1 standard and wholeheartedly support it. We are committed to growing our SCOPE family of products so that designing to the IEEE 1149.1 standard will be like second nature.

Your future competitiveness depends upon an engineering methodology where design teams bear the burden of testability, manufacturability, and reliability. The demands of concurrent engineering will be met in part by the extended capabilities accessed via the IEEE standard — from embedded system information that allows realtime availability of data throughout the design cycle to emulation and realtime system analyses capabilities built right into the silicon.

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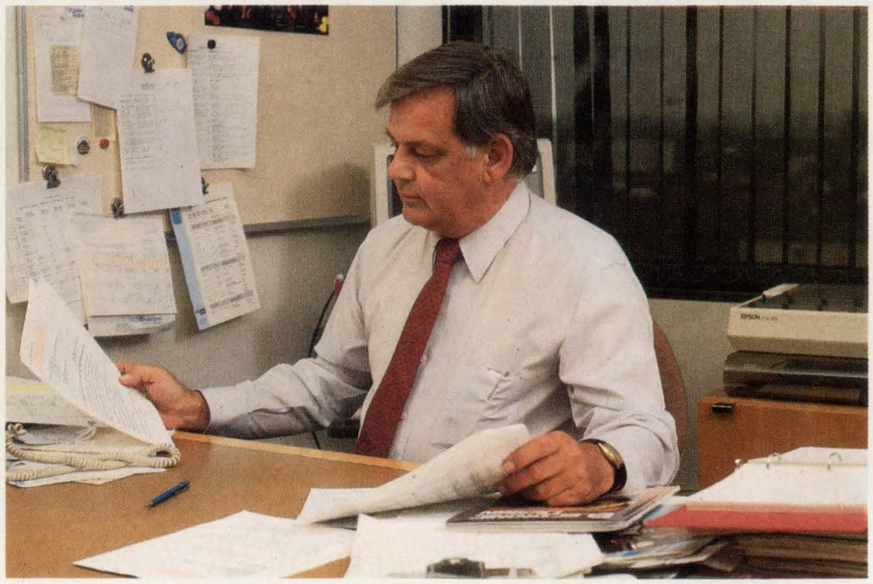
Call 1-800-336-5236, ext. 3909, and we'll send you our unique floppy disk presentation. Just pop it into any MS-DOS™-compatible PC to find out more about DFT and TI's SCOPE testability family. What's more, the disk features a formula that allows you to calculate the cost-effectiveness of implementing testability in your system.

You will continue to read headlines about DFT. We intend to make many of them.

TEXAS INSTRUMENTS

CIRCLE 118

EDITORIAL



BEING A GOOD LISTENER

As previously mentioned on this page, there's a growing emphasis on customer satisfaction throughout the electronics industry in an effort to attain total quality. For engineers designing products, new designs must concentrate heavily on customer input. Many more companies these days are sending engineers out to talk with customers to compare what's possible with today's technology with what the customers say they need.

Some interesting points on this topic are raised in a new book, "High Tech at Low Risk," by John J. Trudel, a high-technology business development consultant and former technologist and executive at Tektronix Inc. In his book, Trudel states that simply talking with customers isn't enough, and can even be misleading. You must listen carefully to what they're telling you and disregard their polite comments that only tell you what you want to hear. A good litmus test, he points out, is whether your product's features or specifications are changing in any unanticipated way following the discussions. If they're not, he says, "you either miraculously conceived the product perfectly yourselves, or, more likely, you're not listening."

Such customer-driven changes can be the most difficult to swallow for many creative design engineers. New products can become pet projects, crafted with features that exemplify the creator's ingenuity in demonstrating the possibilities of new technology. But just as doting parents run the risk of producing uncontrollable children by mistaking parental love for responsible child-rearing, doting project engineers can end up with brilliant products that solve nobody's problems.

So, as a reminder, if you find yourself in these customer meetings, remember that miracles are rather infrequent these days. And listen.

By the way, Trudel's highly recommended 196-page paperbound book is available for $9.95 from Regional Services Institute, East Oregon State College, La Grande, Ore. 97850.

Stephen E. Scrupski
Editor-in-Chief

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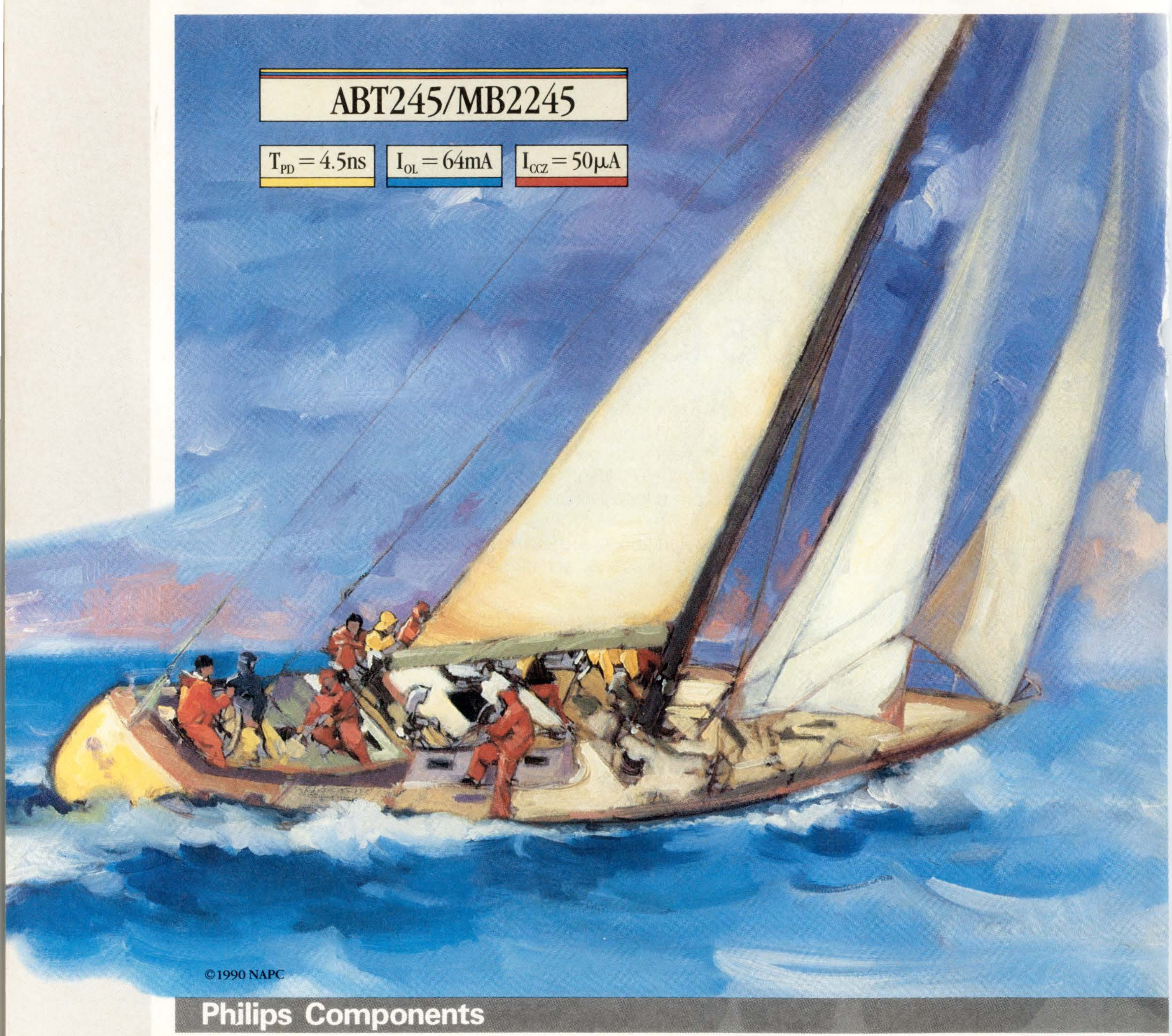
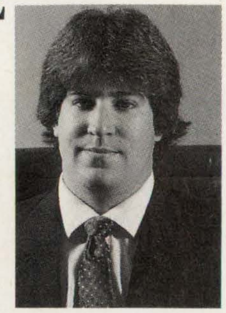


HARD DRIVE STANDARDS ARRIVE



RICHARD NASS
COMPUTER SYSTEMS

At present, standards for testing hard disk drives are just about nonexistent. Each maker, user, or repair person has some method of testing drives, and it's usually inconsistent with everyone else's approach. For this reason, it's somewhat common for as many as 40% of returned hard drives to be labeled "no problem found" by the manufacturer. In other words, the maker finds nothing wrong with the drives because they pass the manufacturer's tests, but fail the OEM's tests. And there may be nothing wrong with the drives except that they're incompatible with the OEM's testing procedures. This situation causes "drive float," a condition where usable drives float between the manufacturer and the OEM, with one claiming there's a problem and the other saying there isn't.

This problem launched the Post-HDA (Head-Disk Assembly) Testing Consortium in July of this year. The group, initiated by FlexStar Inc., San Jose, Calif., set a goal to develop a family of hard-disk-drive testing standards that can be used by all interested parties. Ultimately, two people running a test on the same drive should get the exact same results.

The members include drive, system, and test-equipment manufacturers; value-added resellers; and third-party service organizations. The impressive list of companies includes Adaptec, Apple, Areal, Conner, FlexStar, Fujitsu, HP, IBM, Maxtor, NEC, NCR, Quantum, Seagate, Sun, Toshiba, Western Digital, and Zenith. Initially, membership was free, but now there's an annual $1000 fee.

The Consortium will also try to establish interface-independent test standards that can be correlated across all drives and applications. To help ensure the consortium's success, they will first focus on the more general and broadly needed test standards. These involve PC/AT and Small Computer Systems Interface (SCSI) drives of all sizes and capacities. Once the standards are established, the organization, its committees, and its working groups will focus on more in-depth, technical, and niche-oriented issues. Initial tests include index and RPM, seek time, window margins, and media-defect map. The group also plans to branch out to cover peripheral devices.

Each test will be considered by a subcommittee that reports back to the organization as a whole. The subcommittees will make standard recommendations that will be voted on by the Consortium. Presently, about 50 tests are being looked at. The group's intentions are to have the first set of standards approved within 60 to 90 days.

To help resolve the inconsistencies in testing, FlexStar recently released a $2995 test system that will expedite the testing process. The company's portable 3000S single-port tester offers complete menu-driven parametric testing of all 5.25-in. or smaller Winchester drives using ST506, Enhanced Small Device Interface (ESDI), or AT interfaces. The device employs the same test programs that are used by the company's larger test system. This ensures that the test will produce the same results, regardless of whether they're performed at the factory or on location. The 3000S supplies a concise printout of every test result. Therefore, problems can be pinpointed and a determination can be made as to whether the drive can be repaired locally or must be returned to the manufacturer.

Peripheral Research Corp. (PRC) was recently appointed as an outside facilitator and administrator of the standards consortium. PRC will represent the group and try to increase membership and expand into international territories. The next meeting will take place Jan. 24 at the Milpitas Sheraton in Milpitas, Calif. Anyone interested in attending or joining the Consortium should contact Dennis Waid of PRC at (805) 963-8081.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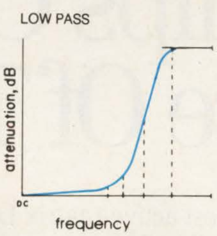
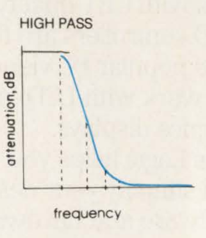


MODEL NO.	PASSBAND, MHz (loss <1dB) Min.	fco, MHz (loss 3db) Nom.	STOP BAND, MHz (loss>20dB) Max.	(loss>40dB) Max.	Min.	VSWR pass-band typ.	stop-band typ.	PRICE $ Qty. (1-9)
PLP-10.7	DC-11	14	19	24	200	1.7	18	11.45
PLP-21.4	DC-22	24.5	32	41	200	1.7	18	11.45
PLP-30	DC-32	35	47	61	200	1.7	18	11.45
PLP-50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

high pass dc to 2500MHz



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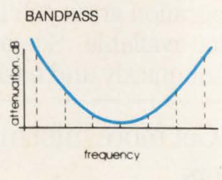
PHP-100	90	400	82	55	40	1.5	17	14.95
PHP-150	133	600	120	95	70	1.8	17	14.95
PHP-175	160	800	140	105	70	1.5	17	14.95
PHP-200	185	800	164	116	90	1.6	17	14.95
PHP-250	225	1200	205	150	100	1.3	17	14.95
PHP-300	290	1200	245	190	145	1.7	17	14.95
PHP-400	395	1600	360	290	210	1.7	17	14.95
PHP-500	500	1600	454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

bandpass 20 to 70MHz



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

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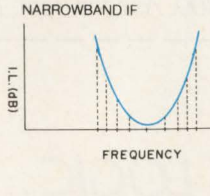

MODEL NO.	CENTER FREQ. MHz F0	PASS BAND, MHz I.L. 1.5dB max. F1-F2	STOP BAND, MHz I.L. > 20dB F5	F6	STOP BAND, MHz I.L. > 35dB F7	F8-F9	PASS-BAND VSWR Max.	PRICE $ Qty. (1-9)
PBP-10.7	10.7	9.5-11.5	7.5	15	0.6	50-1000	1.7	18.95
PBP-21.4	21.4	19.2-23.6	15.5	29	3.0	80-1000	1.7	18.95
PBP-30	30.0	27.0-33.0	22	40	3.2	99-1000	1.7	18.95
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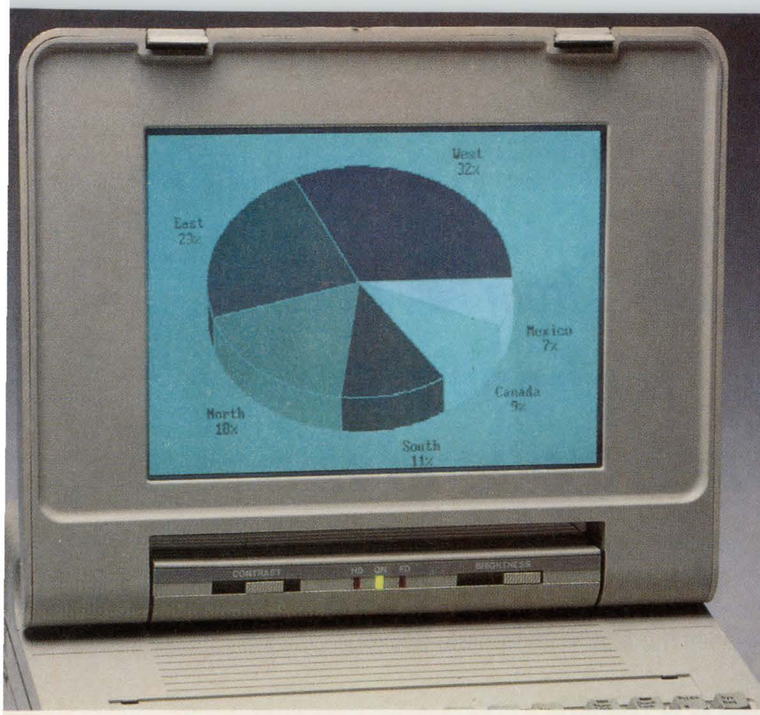

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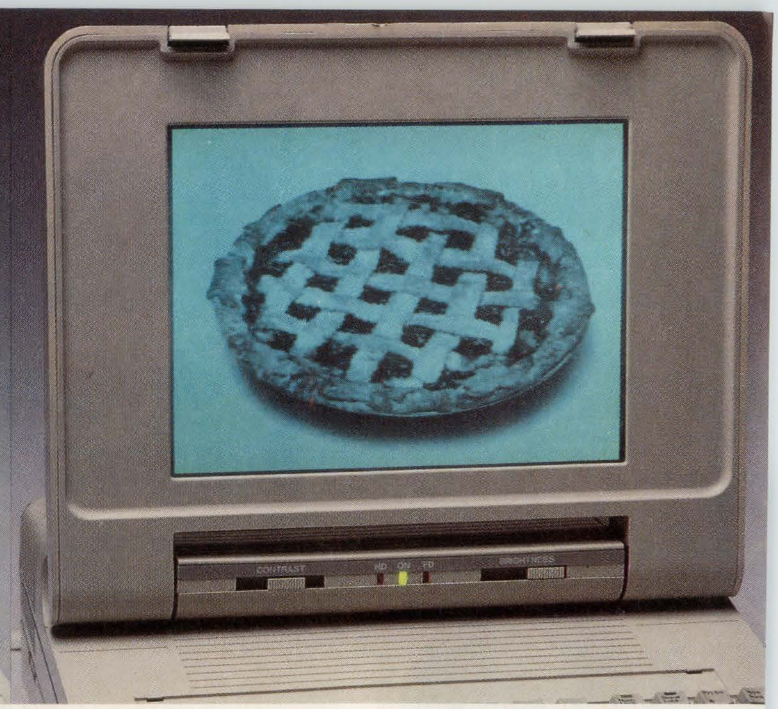

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CLOSING THE GAP

SHRINKAGE MAKES ROOM FOR MORE CMOS GATES

By universally shrinking array features and incorporating a reduced gate-oxide thickness, Motorola's ASIC Div., Chandler, Ariz., created a family of CMOS arrays that contain up to 318,000 available gates. The new H4C Series of arrays have an effective channel length of 0.7 μm and a power dissipation of 3 μW/MHz/gate. The arrays will incorporate an internal core-cell architecture identical to Motorola's 105,000-gate HDC Series. Consequently, the H4C Series will enter the market with a foundation of proven library functions. Built in a triple-layer-metal, single-polysilicon process, the H4C Series has a 180-ps typical gate delay. In addition, the arrays come with embedded boundary-scan logic. The H4C Series will be available in April, 1991. For more information, call Ruth Waterman at (602) 821-4158. *LM*

QUANTUM FET TO UP LOGIC SPEED 10 TIMES

Most experts see 0.2-μm technology as the practical limit for conventional semiconductor devices. However, a new kind of device, the quantum FET (QFET) potentially ups speed limits by a factor of ten while simultaneously dropping both power and size by similar factors. Gene Cavanaugh, an engineer at Valid Logic Systems, San Jose, Calif., recently filed for a patent for the device. The QFET takes advantage of a physical phenomenon known as quantum tunneling, which ups speed by eliminating the area of electronic conduction where carriers slow down by as much as 3000 times. This single-junction device, which appears capable of building transistors at virtually the molecular level, employs a new manufacturing process called rapid thermal processing (RTP). According to Cavanaugh, the technology, based on ultra-fine layers of material, is a superior alternative to future generations of CMOS devices now being developed. Cavanaugh recently shared his ideas with TI, IBM, and Intel, to establish a licensing agreement that will bring the technology into production. As this occurs over the next 3 to 5 years, Valid expects to have the inside track in developing design-automation tools to take advantage of the technology's speed, power, and size. For additional information, call Scott Seiden at (408) 944-8048. *FG*

1000-MIPS DEVICE IS WITHIN REACH

One seemingly unattainable plateau is 1000 MIPS of computing performance. However, a group of researchers at Rensselaer Polytechnic Institute, Troy, N.Y., has received a three-year contract from the Defense Advanced Research Projects Agency (Darpa) to surpass the 1000-MIPS barrier. The design team is developing a fast reduced instruction set computing (FRISC) device, forged from silicon, with a peak performance of 250 MIPS. The group then plans to build a similar device from a layered material of gallium arsenide and aluminum gallium arsenide. If difficulties, such as heat production, can be overcome, the new device should have a large enough speed increase to reach the 1000-MIPS level. There are also other problems that must be addressed. For instance, to achieve the high speed, a change in architecture was required. As a result, new software will have to be developed to achieve compatibility with the high-speed device. *RN*

FERRITE MATERIAL OPTIMIZED FOR 200 KHZ

A report from the German-Japanese joint venture Siemens Matsushita Components (S+M) in Munich, Germany, discloses that a new ferrite material optimized for frequencies up to 200 kHz has been developed. The material's initial typical permeability is 6500 to 7000. Called T37, it supplements S+M's T35 and T38, two ferrite substances the company is already marketing. The T35 is for frequencies up to about 400 kHz with lower permeability values; the T38 boasts a permeability of more than 10,000 but is designed for frequencies to only 100 kHz. The T37 makes it possible to fabricate much smaller ring-core chokes than previously possible for frequencies up to 200 kHz. For example, these chokes can be used in noise-suppression filters. *JG*

OSF/1 GETS INCREASED NETWORKING CAPABILITIES

By enhancing the software's networking qualities, the Open Software Foundation, Cambridge, Mass., has taken the next step toward unveiling its OSF/1 operating system. Users can now work from any workstation on a network as if that workstation was their own, regardless of the workstation's location. The OS runs on a wide range of hardware platforms, from PCs and workstations to supercomputers and multiprocessing systems. It incorporates the Motif graphical interface that's accessible on more than 120 platforms and 40 different OSs. Over 300 Motif-based applications are now available. OSF/1 is endorsed by Digital Equipment Corp., Hewlett-Packard, Hitachi, IBM, and Siemens Nixdorf Information Systems. The OSF has now grown to more than 200 members, with the recent additions of Apple Computer, Microsoft Corp., and NCR Corp. *RN*

Nine More Firms Back Independent Framework

Nine computer-aided-engineering (CAE) companies have signed up for the Best-of-Breed Program developed by InterAct Corp., New York, N.Y. InterAct is the only independent supplier of framework software for a networked environment. Companies that joined the program will participate in jointly developing and marketing encapsulations of their tools in InterAct's framework, the Integrator. Encapsulations are descriptions of the tools that make the tools plug-compatible with the framework. The encapsulations will be sold with the Integrator as part of an accompanying Tool Encapsulation Library. The current library consists of encapsulations from GenRad Inc., Valid Logic Inc., and Viewlogic Systems Inc. The new Best-of-Breed participants include Data I/O Corp., CAD Language Systems Inc., and Meta-Software Inc. Interact is expecting additional Best-of-Breed memberships by the end of the year. For more information, call (212) 696-3700. *LM*

Digital I/O Card Lowers Cost, Ups Reliability

Employing a PC/AT interface card designed around a proprietary ASIC, users can get reduced cost per I/O and improved reliability. The ZT 14CT72 from Ziatech Corp., San Luis Obispo, Calif., consolidates 192 points of bidirectional digital I/O on one card and connects AT-type systems to high-current peripheral devices. The card can drive high-current peripherals, such as industrial I/O modules, with the help of the 16C48 48-point ASIC. Most available digital I/O cards use older 24-point ICs. In addition, it supplies a current sink of 12 mA, further improving reliability. Each of the 14CT72's digital I/O lines can be programmed individually as an input or an output, adding configuration flexibility for industrial applications. The digital I/O card also features open-collector outputs that don't glitch at power-up and power-down. Therefore, external devices aren't inadvertently triggered. The board can be used in or outdoors as it can withstand harsh environments. It uses CMOS components, but is also TTL-backplane compatible. The 14CT72, which takes up only one slot in the backplane, costs $545 and comes with the device-driver software. Large-volume discounts are available. For more information, call Phil Nash at (805) 541-0488. *RN* **CIRCLE 473**

Protective IC Turns Off DMOSFETs In 15 ns

A building-block IC that protects power MOSFETs and insulated-gate bipolar transistors (IGBTs), and turns them off in under 15 ns, has been unveiled. The device, from Motorola's Discrete & Materials Technologies Group in Phoenix, Ariz., replaces the handful of discrete devices typically used in pulse-width-modulation (PWM) applications to protect current-source-driven FET gates from overdrive, and discharge the voltage stored on the FETs' gate capacitances. Built on a high-speed bipolar process, the chip is a three-terminal network with input, output, and return (ground) pins that connect to the PWM drive, FET gate, and FET source, respectively. To a drive pulse, the IC looks like a diode between it (the IC) and the FET gate, followed by a 10.4-V protective Zener between the FET gate and source. Looking back at the output, the gate sees a silicon controlled rectifier (SCR) and a Zener between the IC and the source. While the PWM signal is driving the gate, the SCR is off. When the drive is removed, the SCR turns on rapidly, discharging FET gate capacitance and turning off the FET. Motorola is putting the tiny IC, the MDC1000, in TO-92, SOT-23, and SOT-223 packages. Pricing runs between $0.35 and $0.70 each in 1000s. For additional information, call Mike Lissy at (602) 244-5504. *FG* **CIRCLE 474**

Semiconductor Laser Emits Green Light

Optimized construction and precise control of layer deposition have allowed experts at the Philips Research Laboratories in Eindhoven, the Netherlands, to develop a semiconductor laser that emits green light with a 555-nm wavelength. This, the company says, is the first green-light semiconductor laser reported to date. The laser's active zone consists of 16 layers that are extremely flat and of equal thickness. Each 1-nm-thick layer consists of an indium, gallium, and phosphor compound. The layers are separated by other thin layers that include aluminum. A key to the laser's development was precise control of the deposition and composition of extremely thin layers of specific thickness, from the gas phase, onto a suitable substrate, in an organo-metal-gas-phase epitaxial process. The green-light laser delivers a continuous optical output power of 3 mW and has a differential efficiency of 0.4 mW/mA. The device emits green light only when it's cooled to the temperature of liquid nitrogen, which presently limits the laser's usefulness for special scientific purposes. *JG*

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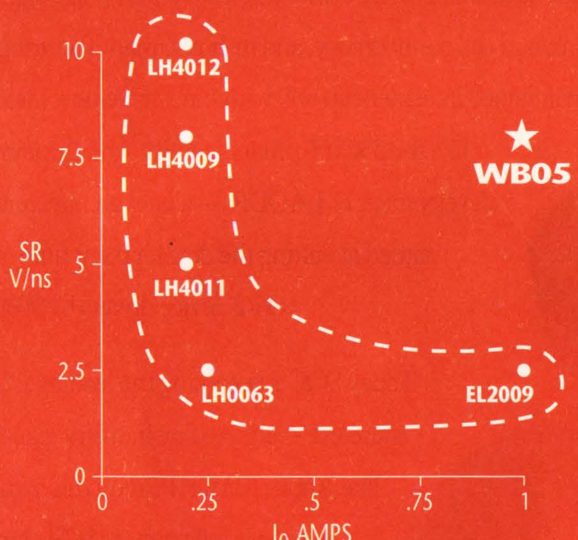

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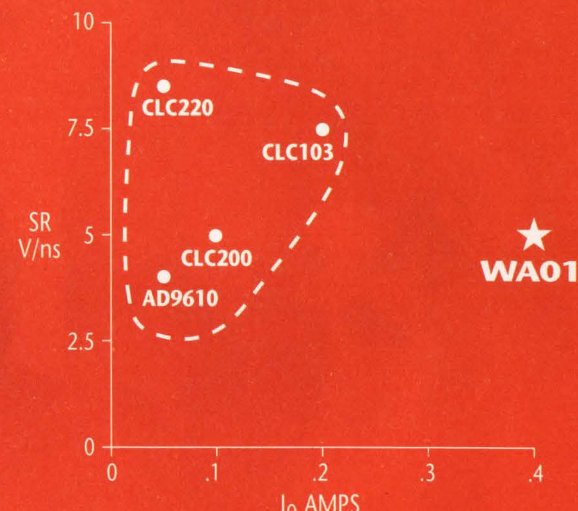

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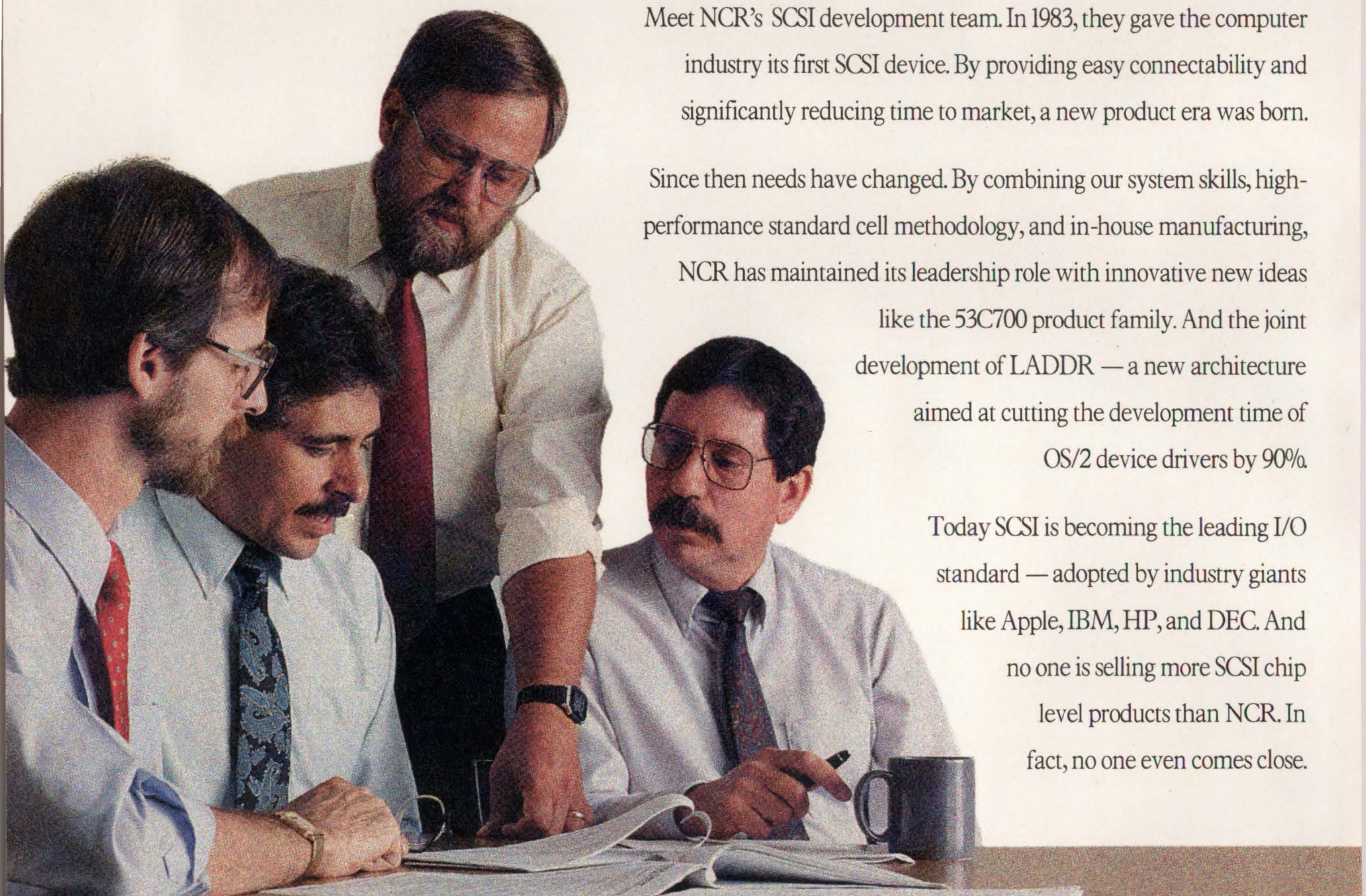
CIRCLE 176

Here's one reason that over half of all SCSI devices sold are NCR.



We created the market... and we still lead the way.

Meet NCR's SCSI development team. In 1983, they gave the computer industry its first SCSI device. By providing easy connectability and significantly reducing time to market, a new product era was born.

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Today SCSI is becoming the leading I/O standard — adopted by industry giants like Apple, IBM, HP, and DEC. And no one is selling more SCSI chip level products than NCR. In fact, no one even comes close.

Part of the NCR SCSI Development Team: (left to right) **Jerry Armstrong**, Sr.Software Engineer; **Harry Mason**, Strategic Marketing Manager; **John Lohmeyer**, NCR Sr. Consulting Engineer and Chairman of the ANSI X3T9.2 Committee and **Dave Skinner**, SCSI ProductManager.

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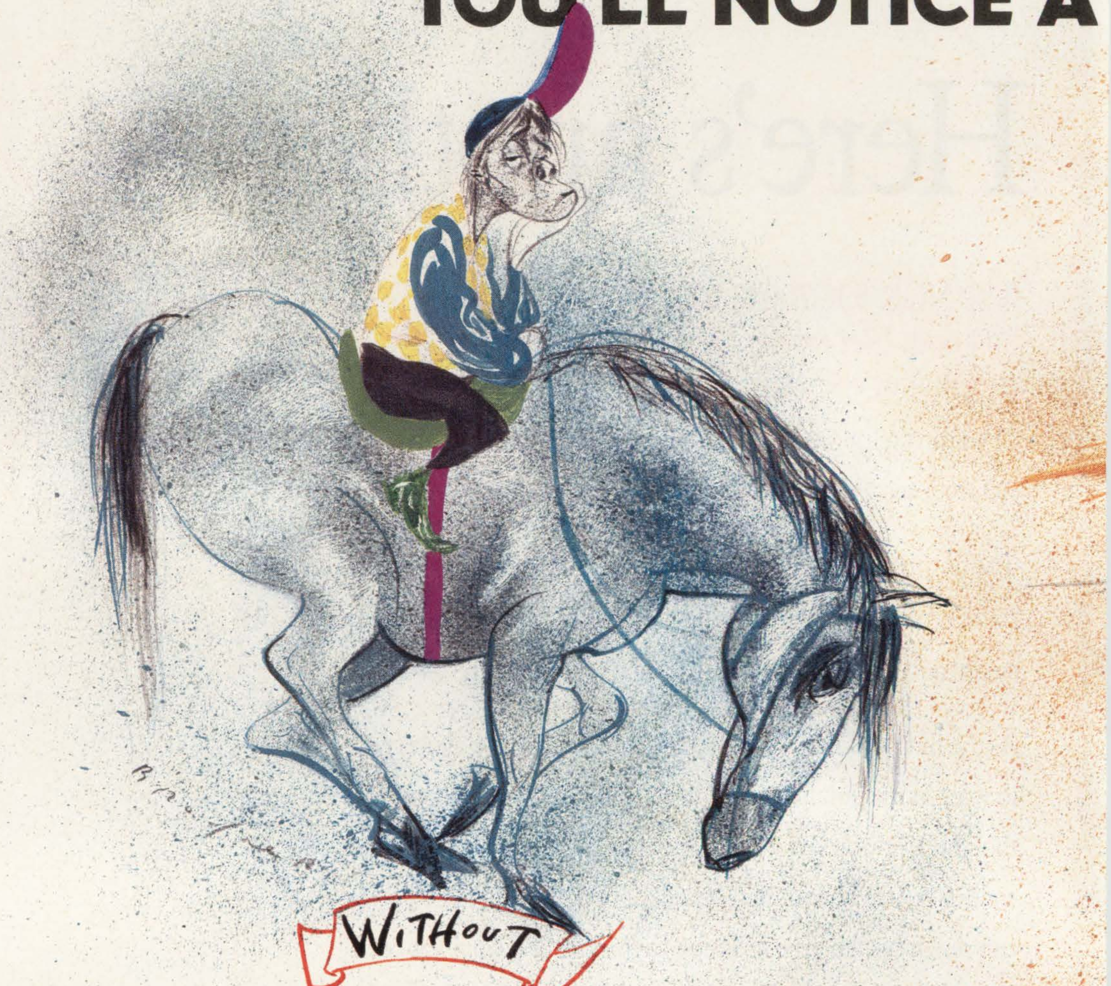

Systems utilizing the new Samsung 84C31 take off. They run like Triple Crown-winning thoroughbreds. They blaze, scorch, and leave others in their dust.

In a word, they are fast.

And they make even speedy 68040 systems that *don't* use the 84C31, look like they're not in motion.

The 84C31 was designed with the close cooperation of Motorola. It is the *only* DRAM controller designed specifically for Motorola's powerful 68040 and 68030 microprocessors.

SAMSUNG'S DRAM CONTROLLER FOR THE 68040 AND 68030

Part Number	*RAMs Supported*	*Package*
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KS84C32-33CL	256K, 1Mb, 4Mb	84-pin PLCC

Samples and production available now.

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The 84C31 supports both the burst and non-burst modes of the 68040. It also provides a direct interface

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to the microprocessor. Which saves you dollars, board real estate, and

68030 PERFORMANCE SUMMARY		
Access Clocks	*DRAM Speed*	*Frequency (Mhz)*
4-2-2-2	70 ns	20
5-2-2-2	120 ns	20
5-2-2-2	80 ns	25
6-2-2-2	120 ns	25
6-2-2-2	80 ns	33
7-2-2-2	100 ns	33

68040 PERFORMANCE SUMMARY		
Access Clocks	*DRAM Speed*	*Frequency (Mhz)*
3-2-2-2	80 ns	25
5-2-2-2	100 ns	25
6-2-2-2	120 ns	25
5-2-2-2	80 ns	33
6-2-2-2	100 ns	33

design time, since it means you don't need additional glue logic.

Ease of design is another advantage. As a glance at our System Design Guides will show, it's an unusually simple chip to design in.

All in all, we believe the 84C31 is the best memory controller solution available today.

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SAMSUNG
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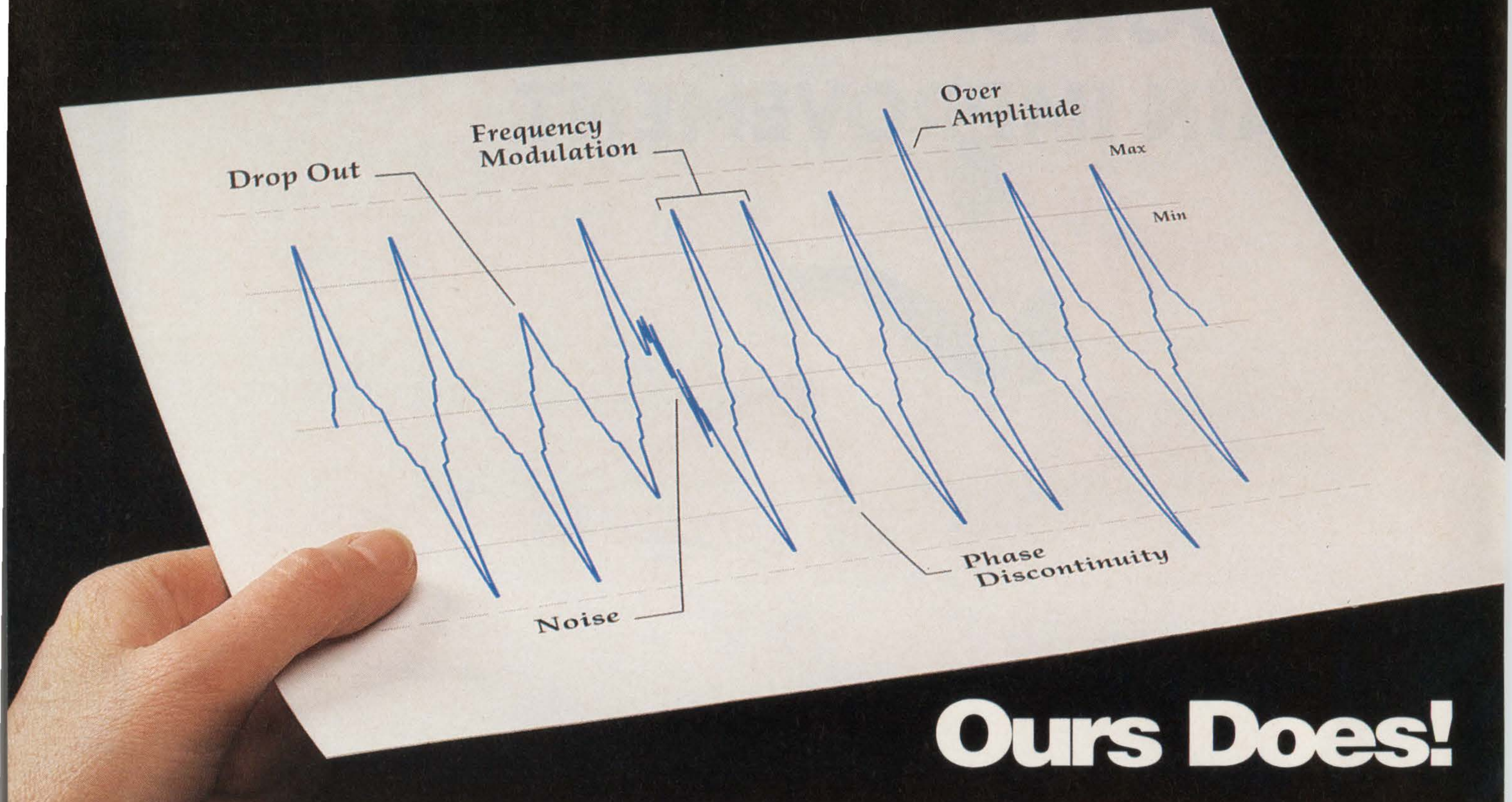
CIRCLE 205

Does Your Signal Generator Simulate The Real World?



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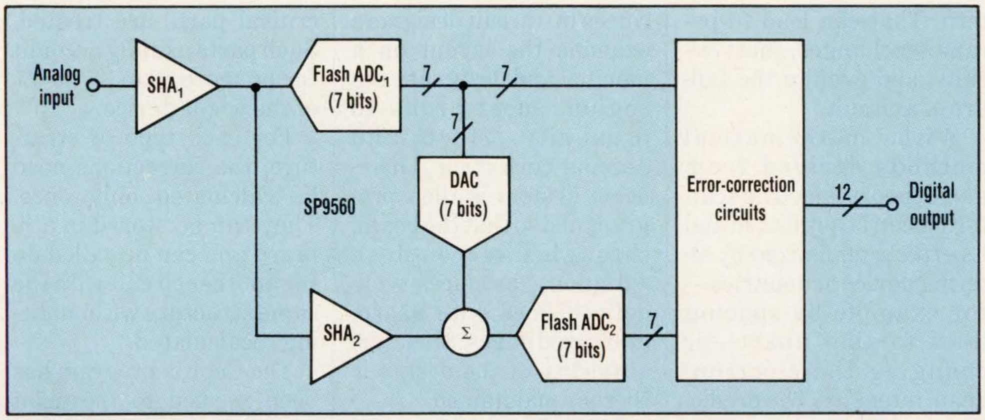


Brigade Of Buckets Cuts Supply Voltages And Power Needs Of 10-MHz, 12-Bit ADCs

Today's 12-bit, 10-MHz, two-step or subranging analog-to-digital converters (ADCs) require 5 to 10 W of power from ±15- and +5-V supplies. There is one exception that doesn't require a –5-V supply (ELECTRONIC DESIGN, *Sept. 13, p. 54)*. However, by moving to a new architecture, Joseph Sousa, a designer at Sipex Corp., Billerica, Mass., has done the job without the ±15-V rails. As a result, power was cut to a maximum of 3.5 W using one +5- and one –5-V supply. This new two-step architecture employs a "bucket brigade" sample-and-hold amplifier design with feed-forward that performs several pipelined conversion steps in parallel *(see the figure)*.

The circuit uses two identical sample-and-hold amplifiers (SHAs). SHA_1, connected to the input, acquires the signal. The second, SHA_2, lies in the error path. Once SHA_1 acquires a signal to 12-bit accuracy, it's put into hold. A few nanoseconds later, when it settles to 7-bit accuracy, the first flash ADC, ADC_1, starts its conversion. At the same time, SHA_2 starts to acquire the held signal from SHA_1. When the held signal from the first SHA settles to 12-bit accuracy, the second SHA acquires the signal from it—also to 12-bit accuracy—and the second SHA is switched to a hold mode.

The digital output of the first flash ADC, the 7 most-significant bits (MSBs), are applied to a 12-bit-accurate, 7-bit DAC and to the error-correction circuitry. SHA_1 is now free to acquire the next sample.

The second SHA, now holding the original input signal, continues to hold it for the conversion's duration so the error signal can settle to 12-bit accuracy. The error signal is the difference between the input signal and the output of the DAC. After the error signal settles to 12-bit accuracy, ADC_2 starts its conversion, just as ADC_1 starts converting its next input sample. The 7-bit output of ADC_2 is combined with the MSBs in the correction circuits to form the final 12-bit-accurate output.

The architecture doesn't require any critical timing. Time is available for both SHAs to settle to full, 12-bit accuracy. Using two SHAs also enables both flash conversions to occur at noncritical times in the conversion process, reducing the risk of digital switching voltages getting into the analog signals. The extra time available for signal acquisition by the SHAs allows for discrete JFET switches that have low pinch-off voltages. The switches, in turn, make it posssible to use lower full-scale input voltages. In fact, the input voltage, nominally ±1.25 V, is reduced to ±0.5 V at the input, increasing head room in the SHAs and making it easier for them to grab fast-changing large signals—essentially increasing full-power input bandwidth.

The architecture has been used to build the Sipex SP9560 ADC. At 10 MHz, the device has a –72-dB spurious-free dynamic range and a –66-dB signal-to-(noise + distortion) ratio. Its full-power bandwidth is 30 MHz. Differential and integral linearity are within 0.75 and 1 LSB, respectively. The SP9560 comes in a 46-pin hermetically sealed metal can. Commercial-temperature-range units, in lots of 100, go for $700 each. Military devices, expected early 1991, will run $975 each in similar lots. For more information, call Bill Lundgren at (508) 671-1944.

FRANK GOODENOUGH

Computer-Aided Program Advances E-Beam Lithography

With an intelligent computer program, Germany's Siemens AG has advanced electron-beam lithography far beyond its present limits. Called Caprox for computer-aided proximation, the software program corrects the blurs and rough edges in line structures that electron scattering causes when an e-beam is used to produce submicron features.

Caprox, which Munich-based Siemens developed jointly with the software house Sigma-C GmbH, also of Munich, should have a big impact on submicron device design. With the new program, the design grid—the distance between lines—can be narrowed five-fold, from the typical 0.5 to 0.1 μm. That translates into higher circuit density.

The correction process that Caprox performs takes little computing power, Siemens says. So instead of a large number-crunching machine, a workstation can be used to run the program.

In general, e-beam lithography for producing masks and reticles for

VLSI circuits with submicron structures is the technology of choice because of its high overlay accuracy and resolution. And because of its high flexibility, e-beam lithography is an excellent technique for writing patterns directly on the wafer.

In practice, the high resolution is limited by the proximity effect, which is caused by electron scattering in the resist and substrate. This can make closely spaced e-beam-exposed regions diffuse into each other, much as ink blots do on paper. The result is blurred edges and merged regions of the pattern. That can lead to parameter changes, short circuits, and even to the failure of a circuit.

With mathematical methods derived from game theory, electron scattering can be predicted and its effects minimized by altering device geometries—for example by spacing lines farther apart—or changing the electron-beam intensity. The prediction methods, however, call for an enormous amount of computing power, and the number-crunching process involved can take days, if not weeks, for a complex VLSI device.

This is where Caprox comes in. Circuit designers examine the layout on a monitor and designate the regions most prone to proximity effects and needing correction. The e-beam system is then programmed so that the beam, through electron-dose variations, produces well-defined lines with sharp, unblurred edges. Structural fidelity of the design is thereby maintained.

With Caprox, it takes only four hours to correct a VLSI circuit that has state-of-the-art complexity. This big time savings compared to the number-crunching scheme results from the fact that only a circuit's critical parts are treated. Such parts usually account for no more than 3% to 5% of the whole device.

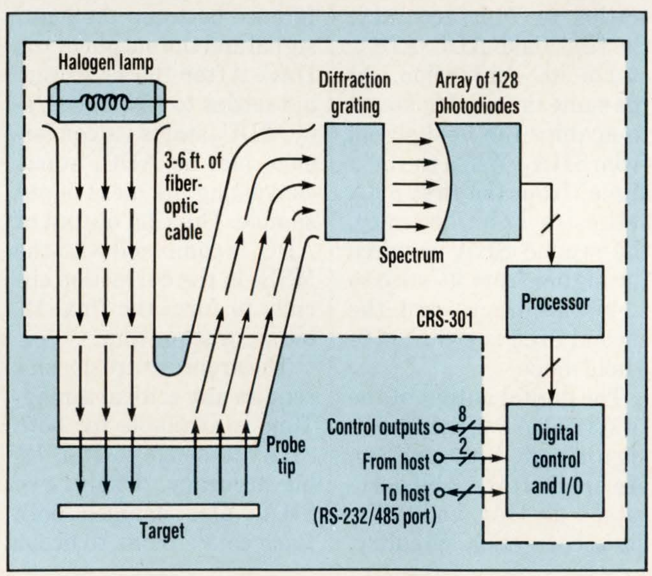
For each type of structure, the corrections need be calculated only once. They can be stored in a library and can be called up for another circuit with the same structure without being recalculated.

The Caprox program has been readied to the point where Siemens is employing it in developing circuits that call for direct-write e-beam techniques. Siemens says that the Caprox program will be used in production in about three years.

JOHN GOSCH

FIBER CABLE, DIFFRACTION GRATING, PHOTODIODES, AND PROCESSOR MEASURE COLOR

By implementing readily available technology, designers at the Micro Switch Div. of Honeywell, Freeport Ill., created a rugged, on-line system that moves color recognition from a spectrophotometer in a laboratory to the factory floor. Until now, so-called on-line color sensors consisted of one photodiode examining the reflected or transmitted light passing through one color filter. However, the Micro Switch Color Recognition Sensor—the CRS-301—employs the complete visible spectrum, from wavelengths of 400 to 800 nm.



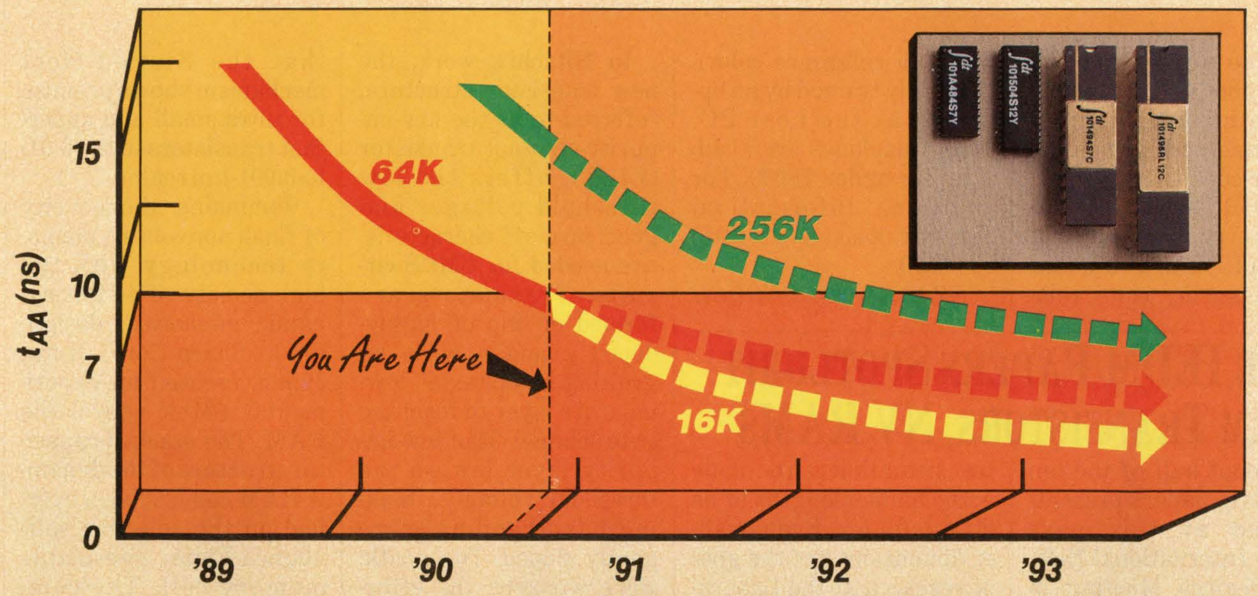
At the heart of the CRS-301 lies a diffraction grating and an array of 128 photo diodes *(see the figure)*. Light from a high-intensity halogen lamp passes down a fiber-optic cable (a bundle of fibers) to a probe tip. The radiation impinges on its target, which is located between 0.1 and 2 in. from the probe tip. The light reflects back to the probe tip and passes down additional fibers in the cable to a diffraction grating. It creates the spectrum of the impinging light and directs it to a linear array of 128 photodiodes. The diodes sense the light's intensity from the grating over the full range of colors in the visible spectrum, converting the pattern of light intensity into a unique set of data representing the color signature of the target.

The color signature feeds a processor that compares the data with the signatures of up to eight colors (in memory), which the processor is trained to recognize. Where color matches occur, the processor provides digital outputs for direct control of actuators, alarms, and/or inputs to programmable-logic controllers. Alternatively, or in addition, the data can be sent through an RS-232 or RS-485 link to a host computer for storage and detailed or statistical analysis.

The CRS, which can quickly make a decision in under 50 ms, can be used in assembly-line, quality-control applications ranging from the inspection of coated or plated metal strips moving at over 1,000 ft./min. to checking the color of processed food. When inspecting metal strips, the sensor picks up variations in the shade of the coating caused by improper curing, bends in the metal, or the wrong coating. Nicks, scratches, streaks, or glossy patches also show up.

Food quality control not only includes processed food in clear containers,

Break Through 7ns



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IDT10048[illegible]	16K (4K × 4) 100K ECL	7	500
IDT101484	16K (4K × 4) 101K ECL	7	700
IDT10490	64K (64K × 1) 10K ECL	8	420
IDT100490	64K (64K × 1) 100K ECL	8	320
IDT101490	64K (64K × 1) 101K ECL	8	420
IDT10494	64K (16K × 4) 10K ECL	7	700
IDT100494	64K (16K × 4) 100K ECL	7	500
IDT101494	64K (16K × 4) 101K ECL	7	700
IDT10496RL	64K (16K × 4) 10K STRAM	12	1000
IDT100496RL	64K (16K × 4) 100K STRAM	12	800
IDT101496RL	64K (16K × 4) 101K STRAM	12	1000
IDT10504	256K (64K × 4) 10K ECL	12	800
IDT100504	256K (64K × 4) 100K ECL	12	600
IDT101504	256K (64K × 4) 101K ECL	12	800

BiCEMOS is a trademark of Integrated Device Technology, Inc.

CIRCLE 187

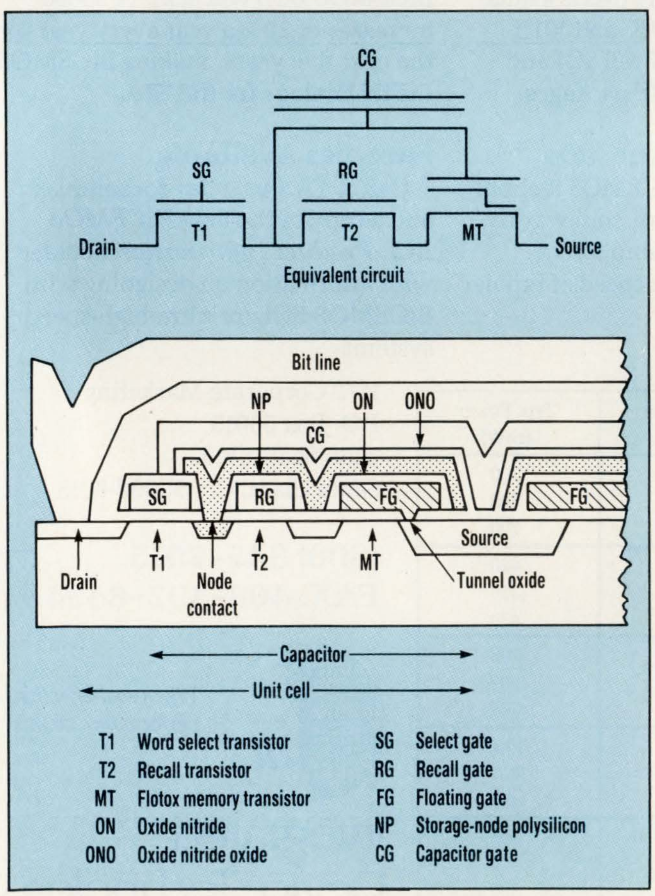
but also such items as baked goods. Other applications include checking labels and sorting colored or color-coded parts.

The CRS has a color-difference resolution of 1 CDU (a CDU is a standard for measuring color relative to a reference color). It's easily trained by an operator at the host PC. These machines are available for under $8000. For additional information, call Pat Keister at (815) 235-6600.

FRANK GOODENOUGH

LATE IEDM PAPERS SPOTLIGHT 0.1-μM TRANSISTORS, NV RAMS

About half of the ten late papers presented at this past week's International Electron Devices Meeting in San Francisco, Calif., described some of the smallest and most unique devices that have ever been fabricated. Researchers at Hitachi Ltd.'s Central Research Laboratory, Kokubunji, Japan, have proposed a new type of MOS transistor that can be made with channel lengths of as little as 0.1 μm. Even smaller dimensions are the goal of research at the Laboratory of Applied Physics of the California Institute of Technology, Pasadena, Calif. An improved tunneling transistor that employs the Stark Effect is being examined for use when dimensions drop to 0.01 to 0.001 μm.



In Hitachi's work, the new transistor structure, referred to as the low-impurity-channel transistor (LICT), offers the low threshold voltages and good turn-off characteristics needed for CMOS circuits. Transistors are formed on top of highly-doped p and n wells by growing an epitaxial, low-impurity layer to form the gate channel. That low-impurity layer lowers the threshold voltages, making band-bending more gently sloped. The gentle slope weakens the effective field for conduction carriers, which in turn reduces scattering due to surface roughness. The highly-doped wells prevent punchthrough and make it possible for sharp turn-offs. CMOS structures fabricated with 0.1-μm gates showed normal transistor operation: saturation currents of 1.75 mA and 1.45 mA were attained for the n- and p-channel devices, respectively.

Experimenting with Stark-Effect tunneling transistors implemented in a gallium antimony/indium arsenide/aluminum antimony/gallium antimony (GaSb/InAs/AlSb/GaSb) heterostructure, researchers at the California Institute of Technology have increased the transistors' beta to values as high as 40. Such levels are up to four times higher than those previously obtained for tunneling structures. The improvement was accomplished by rearranging the base structure so that the emitter-collector current is controlled by a base that's positioned in such a way where only a small base current is needed. The results suggest that the Stark-Effect mechanism shows promise for ultra-small and super-fast transistors in the 0.01-to-0.001-μm realm.

Combining the novelty of flash nonvolatile memory technology with the high-density of 4-Mbit dynamic memories, designers at Sharp Corp., Nara, Japan, created an experimental 4-Mbit nonvolatile RAM. The stacked-capacitor structure of the dynamic-RAM cell has been overlaid on the selective self-aligned Flotox nonvolatile memory cell. The combined structure permits a non-destructive store/recall (DRAM to EEPROM or EEPROM to DRAM) operation that doesn't disturb the original data in the DRAM or EEPROM *(see the figure)*.

The new cell structure employs three layers of polysilicon and contains three transistors and one storage capacitor (formed over the transistors). In the EEPROM portion of the cell, the tunnel region, which is formed with a selectively self-aligned procedure, lies outside of the cell's implant region. Furthermore, a new self-aligned technology for creating the DRAM storage-node contact to the source diffusion of the word-select transistor was also implemented. By combining the new fabrication steps and 0.5-μm design rules, the entire nonvolatile DRAM cell can be squeezed into 11 μm^2. The DRAM storage capacitance is 40 fF and the EEPROM has a coupling ratio of 0.75.

In other component areas, research at AT&T Bell Laboratories, Murray Hill, N.J., has yielded the first bipolar laser driver that op-

+ 5V TO ± 15V DC-DC CONVERTERS POWER UP TO 30W LOADS

No Design Required — Just Drop In

Maxim's MAX742 and MAX743 dual-output DC-DC converters provide the simplest solutions for generating ±15V or ±12V analog supplies from low input voltages, such as +5V digital supplies. To make designing with the parts as simple and reliable as plugging in modules, we not only specify all critical components, we also provide them.*

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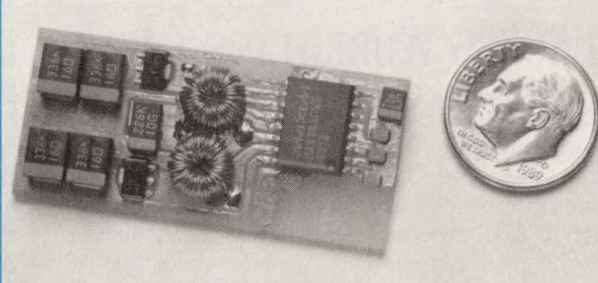

Using surface mount components, the MAX743 DC-DC converter delivers 3W in less than half the board space of the smallest modules. Power density is a healthy 18W per cubic inch.

	MAX742	MAX743
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Output Voltage	±12V or ±15V ±4%	±12V or ±15V ±4%
Output Power	30W	3W
Power Switch	External	Internal
Price	\$5.82**	\$5.82**

** MAX742 and MAX743, 1000-up, FOB USA

Evaluation Board Simplifies Prototyping

A MAX743 (through-hole) evaluation board containing a MAX743 and all the components required to build a 3 Watt DC-DC converter is available from Maxim for only \$20. To order your evaluation board, send check or money order to Maxim Integrated Products, 120 San Gabriel Drive, Sunnyvale, CA 94086. For applications assistance or information on other Maxim products call (408) 737-7600, ext. 4000 or FAX (408) 737-7194.

* MAXL001 - 100μH Low-Loss Toroid Inductors (\$1.47, 1000-up) and MAXC001 - 150μF Low-ESR Capacitors (\$0.29, 1000-up)
MAX743CPE Production Kit (\$8.18, 1000-up) includes:
1 - MAX743CPE
2 - 100μH Low-Loss Toroid Inductors
3 - 150μF Low-ESR Capacitors
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CIRCLE 150

erates at 10 Gbits/s. Useful for high-speed optical networks, the driver is implemented with indium phosphide/indium gallium arsenide heterojunction bipolar transistors to achieve a 100-mA pk-pk modulation current.

AT&T's laser can drive 100 mA at up to 10 Gbits/s when powered from a 4-V supply. It employs a differential current switch, an input buffer, and current-mirror circuits to set the dc (I_{dc}) and modulation-current (I_{MD}) levels. A total of 25 heterojunction bipolar transistors (HBTs) were used by the driver chip. Both I_{dc} and I_{MD} are precisely double-mirrored from external current references and could be varied in magnitude accordingly. To obtain a modulation current of 100 mA, four HBTs are used in the current switch. Each HBT has an emitter size of 2.5×11 μm, which results in an input capacitance of 0.5 pF per device. The input buffer that drives these transistors consists of emitter-followers biased with cascoded current sources.

DAVE BURSKY

FIRST 80386 WORKALIKE TRIMS POWER WITH STATIC LOGIC

By reengineering the logic and using the same microcode as on Intel's 80386DX processor, the first software-compatible single-chip replacement for the 32-bit 80386 microprocessor has been developed. Demonstrated by Advanced Micro Devices Inc., Sunnyvale, Calif., the chip threatens to break Intel's sole-source stranglehold on the personal computer industry. And it may bring price relief to system manufacturers sooner than Intel would have done if no alternate source was available.

Although the Am386DX or 386DXL can execute the same software when inserted into the same socket that holds the Intel 80386DX, AMD designers added something extra. Rather then implement the CPU registers with dynamic CMOS logic as Intel did, the designers used fully static logic. The static design added about 5000 transistors to the processor, upping chip area by about 10% over that of Intel's chip.

However, the AMD chip consumes much less power than Intel's. At the full 33-MHz clock rate, Intel claims its 386DX draws about 550 mA. In comparison, AMD's design consumes less than 400 mA at 33 MHz. And the fully static design of the AM386DXL version enables the clock frequency to be stopped when the chip goes into a standby mode, dropping current drain to less than 1 mA. In contrast, because Intel's 386DX uses dynamic logic, the clock can't be stopped, but it can be slowed to a minimum of 8 MHz. At that slower clock rate, Intel's chip draws over 130 mA, placing a heavier load on the power source compared with AMD's chip.

The Am386DX and 386DXL are actually the same chip. However, the Am386DX isn't tested at the very low clock frequencies or with the clock stopped to verify that data is maintained in the registers. With the commonality of design, AMD can reduce manufacturing overheads. Reduced overheads will translate into price parity between the two versions—there won't be a price premium for the DXL low-power version. Also being developed are 16-bit bus-interface versions of the processor that operate as if they were Intel 80386SX or SXL processors. Actual OEM prices for the chips, however, will not be set until 1991.

To fabricate the chip, AMD employs a 0.8-μm CMOS process equivalent to the process Intel uses for its processor. The AMD process is the same that the company is applying to build its recently released second-generation, Am29050 RISC processor. The lower power consumption of the static logic allows the AMD chip to be housed in a 132-lead pin-grid array similar to Intel's, or in a 132-lead plastic quad-sided flat package that saves about 40% of the board area over that occupied by the PGA—a significant savings for space-limited portable and notebook computers.

The most critical testing has already started—over 20 desktop system manufacturers are evaluating the chip and have put it through extensive compatibility testing versus the Intel processor. No incompatibilities have been found. So far, tests have been done with various operating systems, such as DOS 3.3, 3.31, 4.01, OS/2 1.1, 1.2, 2.0, and Xenix. Over two-dozen additional application packages were also tested, including Microsoft Windows 3.0 and Word, Lotus 1-2-3, Aldus Pagemaker, Dbase III+, among others. The chips have been tested at 20, 25, and 33 MHz. AMD is also setting up relationships with chip-set vendors to ensure that the Am386DXL will have support in place for portable system designs. Therefore, system makers will have options available to differentiate their portable products.

Probably the biggest hurdle that AMD faces, however, is the legal issue of its right to use the microcode. Although AMD expects the courts to decide in its favor, based on the wording of the contracts it signed with Intel, there's the possibility that AMD may lose. In that case, the most likely alternative would be to create a "clean room" version of the microcode that doesn't infringe on the copyrights that Intel has on its microcode. Such a revision to the microcode is possible, as proven in the recent case settled between NEC Corp. for its V-series microprocessors and Intel.

AMD has already overcome the first legal hurdle. In a ruling last month, U.S. District Judge William Ingram sided with AMD that it had the right to call the chip the Am386. Intel tried to stop AMD from using the 386 part-number designation, claiming it was a trademark. However, past precedent in the semiconductor industry dating back to the first discrete devices overwhelmingly backs AMD's case for using the part number with the company name.

DAVE BURSKY

1 μA OP AMP EXTENDS BATTERY LIFE 15X

3.6μW Power Consumption — Lowest Ever

Maxim's new MAX406 op amp is the lowest power op amp on the market today, requiring a maximum supply current of only 1.2μA — leakage current in most battery-powered applications. And, it consumes less than 3.6μW* of power enabling lithium or alkaline batteries to last years longer. A review of the specs below will show you that the new MAX406 is the ideal op amp for solar powered products, hearing aids, barcode readers, and many other micropower applications.

- **1.2μA max Supply Current**
- **< 0.1pA Input Bias Current**
- **0.5mV max Input Offset Voltage**
- **Input Voltage Range Includes Neg Supply Rail**
- **40kHz Gain Bandwidth**

MAX406 VS. ALTERNATIVES

Device (T_A = 25°C)	I_Q μA max	V_{OS} mV max	I_B pA typ	Rail-to-Rail Output
MAX406	**1.2**	**0.5**	**<0.1**	**YES**
ICL7611	20	2	1	YES
TLC271	23	2	0.1	NO
OP90	20	0.15	4000	NO

- **Wide Supply Voltage Range: +2.4V to +10V or ±1.2V to ±5V**

Rail-to-Rail Output Sources 2,000X Supply Current

The MAX406 maintains linearity under heavy load conditions and is capable of sourcing as much as 2mA from a 9V battery. The output swings rail-to-rail while the input voltage range extends to the negative supply rail. The new device operates from voltages as low as 2.4V while maintaining widest input and output voltage ranges.

Lowest Bias Current, Highest Stability

Input bias current of the MAX406 is less than 0.1pA — a 10X improvement over other low-power op amps. Input offset voltage is 0.5mV maximum, eliminating the need for offset nulling in most applications. As a buffer, the MAX406 is extremely stable without any external compensation, even when driving capacitive loads as high as 1μF.

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CIRCLE 169

IN THE ERA OF MegaChip™ TECHNOLOGIES

YOUR DSP: ALL THERE

There is a big difference. Only Texas Instruments brings it all together for you in DSPs, from software to silicon... and we have 10,000 users to prove our point.

OR JUST ALMOST?

Designers are applying TI's single-chip TMS320 DSPs (digital signal processors) in more systems around the world than any other. In fact, leading manufacturers in most market segments — including telecommunications, computers and computer peripherals, automotive, industrial controls, consumer products, and military systems — use TMS320 DSPs.

These designers choose our DSPs because they know there is a big difference between all there and almost. With TI, they know they are getting the most complete DSP solution in the business — (1) performance, (2) support, and (3) broad choice. These important factors are worth careful consideration as you evaluate DSPs:

☐ Yes ☐ No **1. Am I assured of access to the top-performance devices in the field?**

Naturally, performance is a high priority for any DSP-based system. The TMS320 family consistently sets the performance standards for the industry. Among the newest additions are the highest performance fixed- and floating-point single-chip DSPs, both with clearly defined road maps for future performance upgrades. Multiprocessing DSPs offer even higher performance.

☐ Yes ☐ No **2. Is world-class support in place to help speed my design to market?**

Few if any DSP vendors equal the level of support that TI offers.

Industry-standard high-level language optimizing compilers (ANSI C and Ada), HLL debuggers, the SPOX™ multitasking DSP operating system, and scan-based emulators provide you with a development environment similar to that traditionally enjoyed in general-purpose microprocessor design.

Low-cost evaluation modules allow you to accurately evaluate and benchmark a TMS320 processor for your application.

Such leading-edge tools are only the beginning of our comprehensive support. Other TMS320 support includes:

- A hot line staffed with DSP personnel ready to answer your technical questions
- An on-line bulletin board service
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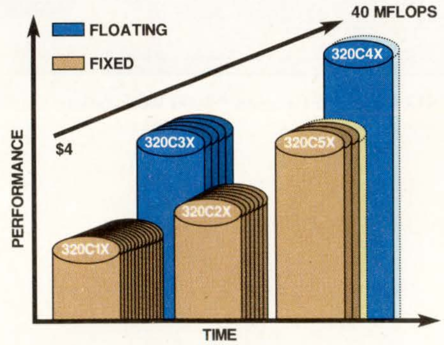
- More than 100 third parties and consultants
- Hands-on workshops
- University program with more than 100 universities participating

WHAT'S AHEAD FOR TI's TMS320 FAMILY



☐ Yes ☐ No **3. Is the choice of devices broad enough that I can closely match a DSP to my price/performance needs?**

Our TMS320 family spans five generations — more than 20 members offering a price/performance range from $4.00 to 40 MFLOPS. Your choice includes:

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- DSPs optimized for specific applications
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- Multiprocessing DSPs
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- Compatibility to protect your software investment

At TI, we have it all, and we are ready to help you put it all together.

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We will send you our three-volume TMS320 DSP Applications Library. If you prefer, we'll send you our TMS320 product overview and support brochure. We feel sure you will soon be one of the thousands around the world achieving design success with the leadership TMS320 family.

TEXAS INSTRUMENTS

A true leader

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leads by example.

Example #1: Performance

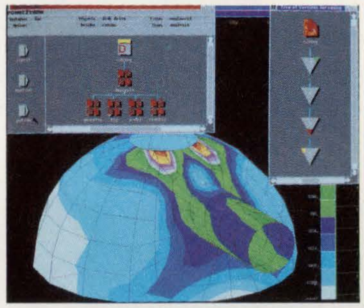
No matter how you measure it, Digital's DECstation 5000 workstation leads all others in performance. Whether it's raw CPU performance, 2D or 3D graphics speed, or price/performance, the DECstation 5000 workstation comes out ahead. In fact, for overall performance, nothing else is close. And we've got the numbers to prove it.

PERFORMANCE COMPARISON CHART (1)	SUN SPARCstation 1+	IBM 320/520	DECstation 5000 cx
Graphics & Windowing (2)	0.24	0.71	1.59
Integer	1.04 (3)	1.34	1.61
Floating Point	1.10 (3)	2.6	1.7
Overall Performance	0.65	1.35	1.63

(1) All data normalized to DECstation 3100. Comparable configurations tested. Geometric mean used to combine results. Performance will vary depending on applications and environment. (2) Graphics and windowing data measured using X11perf benchmark. CPU Integer and Floating Point performance measured from running SPEC V1.0 workload. (3) SPEC performance estimate based on SUN 4/330 results published by Sun Microsystems, Inc.

Example #2: UNIX based Applications

When you run with the leader, you know you're in good company. The DECstation 5000 workstation runs more than 1,500



UNIX based applications, including the industry's most popular MCAD and EDA applications.

Example #3: PowerFrame™ for Design Integration.

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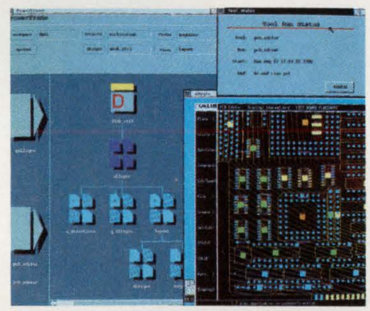

ogy, while keeping your options open for the future.

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374, 377, 534, 273	Registers	Std, A, C
821, 823, 825	Registers	A, B, C
373, 533	Latches	Std, A, C
841, 843, 845	Latches	A, B, C
646, 648, 651, 652	Register/Transceivers	Std., A
29FCT52, 29FCT53	Register/Transceivers	A, B
543, 544	Latch/Transceivers	Std., A
827, 828	Buffers	A, B, C
861, 862, 863, 864, 865	9/10-bit Transceivers	Std, A
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2241…2864	25-Ohm Resistor outputs (All parts)	Std, A
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QS8886	16Kx4, Fast OE	12 ns
QS8885	16Kx4, 2 CE, OE	12 ns
QS8882/1	16Kx4, Separate I/O	12 ns
QS8883	16Kx4, Cache Tag	12 ns
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CIRCLE 108

LOW-COST COMPRESSION SOLUTION EXPANDS SPHERE OF MULTIMEDIA TECHNOLOGY INTO CONSUMER DOMAIN.

COMPRESSION CHIP HANDLES REAL-TIME VIDEO AND AUDIO

MILT LEONARD

A year-long effort to pack the essential functions of a multi-board video-compression system onto one piece of silicon has produced the industry's first single-chip processor. The UVC7710 multimedia processor, from UVC Corp., compresses video and audio signals with compression ratios up to 500:1. It also performs control functions for memory, the system bus, and VGA displays, as well as control and sync functions for special video and windowing operations.

But that's not all: The processor includes all of the circuitry needed for connecting to IBM PC/AT interfaces, as well as National Television Standards Committee (NTSC), phase-alternating line (PAL), and RGB-encoded signals. The processor acts as a multimedia engine on a PC motherboard for applications with limited storage and bandwidth.

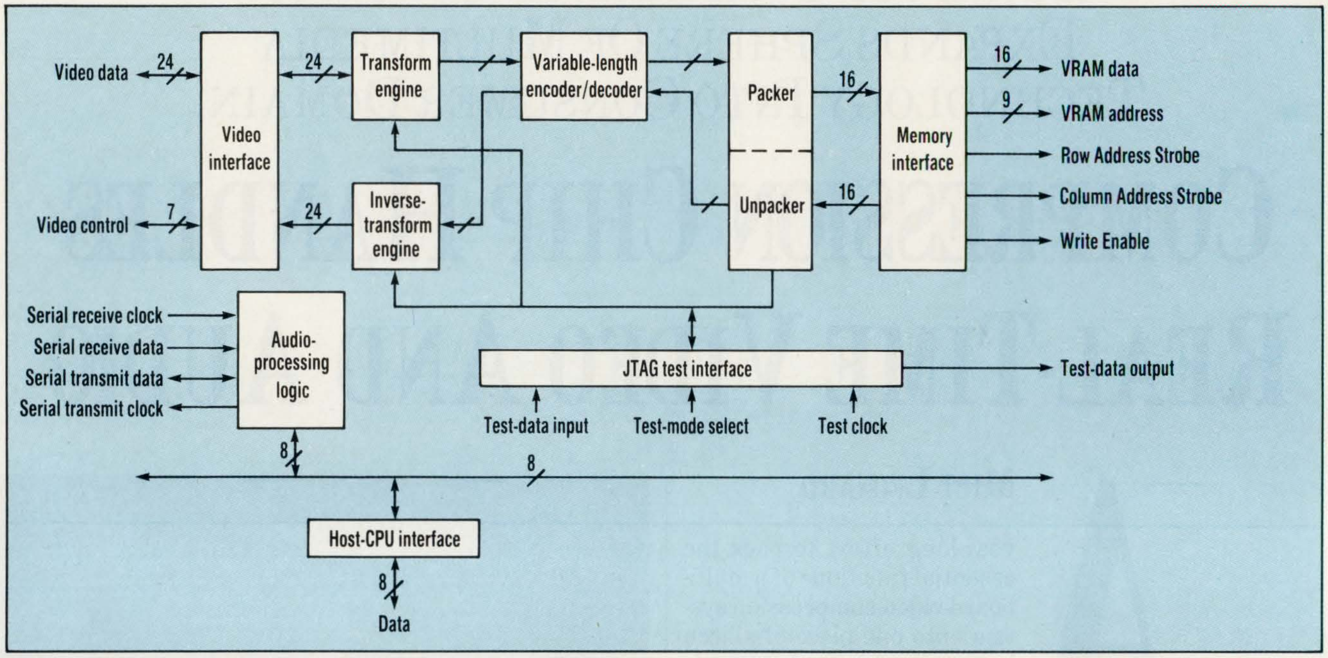
Equally impressive, the 7710 enables the design of circuit cards that sell for one-tenth the price of other board-level multimedia solutions with equivalent functionality.

For the business world, this means an economical way to treat color motion video as ordinary digital information that can be stored, indexed, manipulated, and moved across digital communication lines as any other file. Video teleconferencing, color facsimile, and video mail can be linked to T1, Integrated Services Digital Network, and local-area network circuits over corresponding communications lines.

In the consumer market, target applications can vary over a wide range. These applications can range from low-cost video telephones to high-end electronic products with built-in video instructions.

Unlike other compression ICs that consume silicon area with direct and inverse cosine-transform circuits for intraframe or interframe processing and motion prediction, the 7710 performs frame-based compression. Each line within a frame is stored and compressed on a line-by-line basis. Moreover, the chip architecture uses minimal pipelining *(Fig. 1)*.

As a result, the processor requires just 128



1. ARCHITECTURAL SIMPLICITY is a significant factor in the performance of the UVC7710 multimedia processor. Video data flowing from the video and memory interfaces passes through just three function blocks: a transform engine that compresses the image, the entropy encoder that further compresses video data, and the packer that converts encoded data into 16-bit words for storage in the external VRAM image buffer. Data travelling from the memory interface to the video interface pass through inverse processing functions.

kbytes or more of video RAM (VRAM). Its I/O latency time in less than 100 μs. A patented on-chip compression algorithm, contained in compression-code tables, is simpler than the proposed Joint Photography Experts Group (JPEG) standard. With fewer calculations required, the video processing rate is 12.5 million pixels/s for real-time full-motion video. Although the maximum frame rate is arbitrarily set at 30 frames/s by system software, the company says it can be higher.

Silicon area, which would otherwise be used for complex intraframe or interframe processing, has been devoted to features that reduce system chip count. For example, the processor has a half-duplex 24-bit bidirectional video I/O bus to transfer digital video data between the chip and external video devices. These devices are usually standard digital-to-analog and analog-to-digital converters that supply analog video signals between the 7710 and external devices. The video source can be a scanner, a digital camera, a VCR, a laser disk, or a graphic-image file. The bus is composed of 8 bits of red, 8 bits of green, and 8 bits of blue data. Dataflow direction is controlled by the 7710.

The video interface also produces the timing necessary to generate standard video streams, including vertical sync, composite sync, and blanking functions. This circuitry also controls external video output logic to generate NTSC, PAL, and/or RGB video formats for a display monitor. With a video input, the processor is typically used in the "genlock" mode, which synchronizes the chip to the incoming video stream from one or more sources.

COMBINING IMAGES

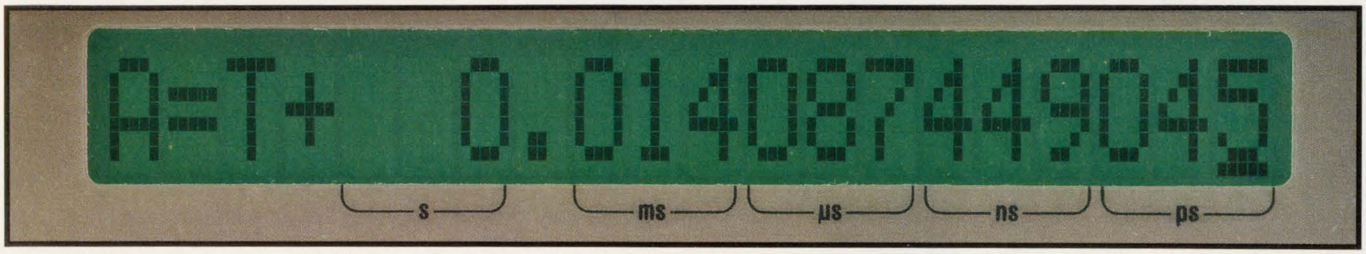
The genlock mode is useful for combining two or more video images on one screen. In this case, the processor is programmed to act as a video-timing slave. The vertical sync and horizontal sync lines become inputs to the chip, providing timing signals extracted from the incoming video signal by the external video logic.

An external video quantizer controlled by a sample clock from the chip samples the analog video input and transfers the sample to the 7710. At the video output, a pixel clock strobes the compressed output data into the external video interface for conversion back to an analog signal.

Supporting 64-kword-by-4-bit and 256-kword-by-4-bit VRAMs, the memory interface is also designed for system simplicity. A multiplexed address bus connects directly to the VRAM, and compressed video is sent to memory through serial read and write channels. The processor relieves host overhead by performing the refresh function. It also arbitrates host access to its VRAM parallel channel.

In the input mode, the 7710's audio-processing logic accepts digitized serial audio signals and performs data compression for storage. In the output mode, the processing logic accepts stored and compressed audio data and delivers a reconstructed serial digital data stream for external conversion into analog audio. The serial interface to the external analog circuitry supports the Texas Instruments serial transfer protocol. Although the 7710 is designed to link with the TLC32045 (or

Go ahead ... add 5 psec



Picoseconds are no problem for the DG535 Precision Pulse & Delay Generator.

The DG535 provides 4 edge (delay) and 2 pulse (delay and width) outputs, all with 5 ps resolution, 1000 sec range, 50 ps rms jitter, and adjustable output levels. The outputs drive 50 Ohms or high impedances to 4 Volts with a slew rate of 1 V/ns - just right for driving TTL or ECL or even high speed analog circuits. Throw in the 35 Volt output option and you can trigger almost anything. For even greater accuracy and stability, add the 1 ppm optional timebase .

Top it off with the intelligent menu-based front panel and standard GPIB interface, and the DG535 is probably the most versatile timing generator you can find.

On the bench or in a test environment, the DG535 has the accuracy, stability, precision, and reliability you need to solve your tough timing problems - all at a price you can afford. Call SRS for more information on the DG535, even if you don't need picosecond resolution.

DG535	**$3500**

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- 5 ps delay resolution
- 50 ps rms jitter from trigger
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- Internal/external trigger to 1 MHz
- Internal/external timebase
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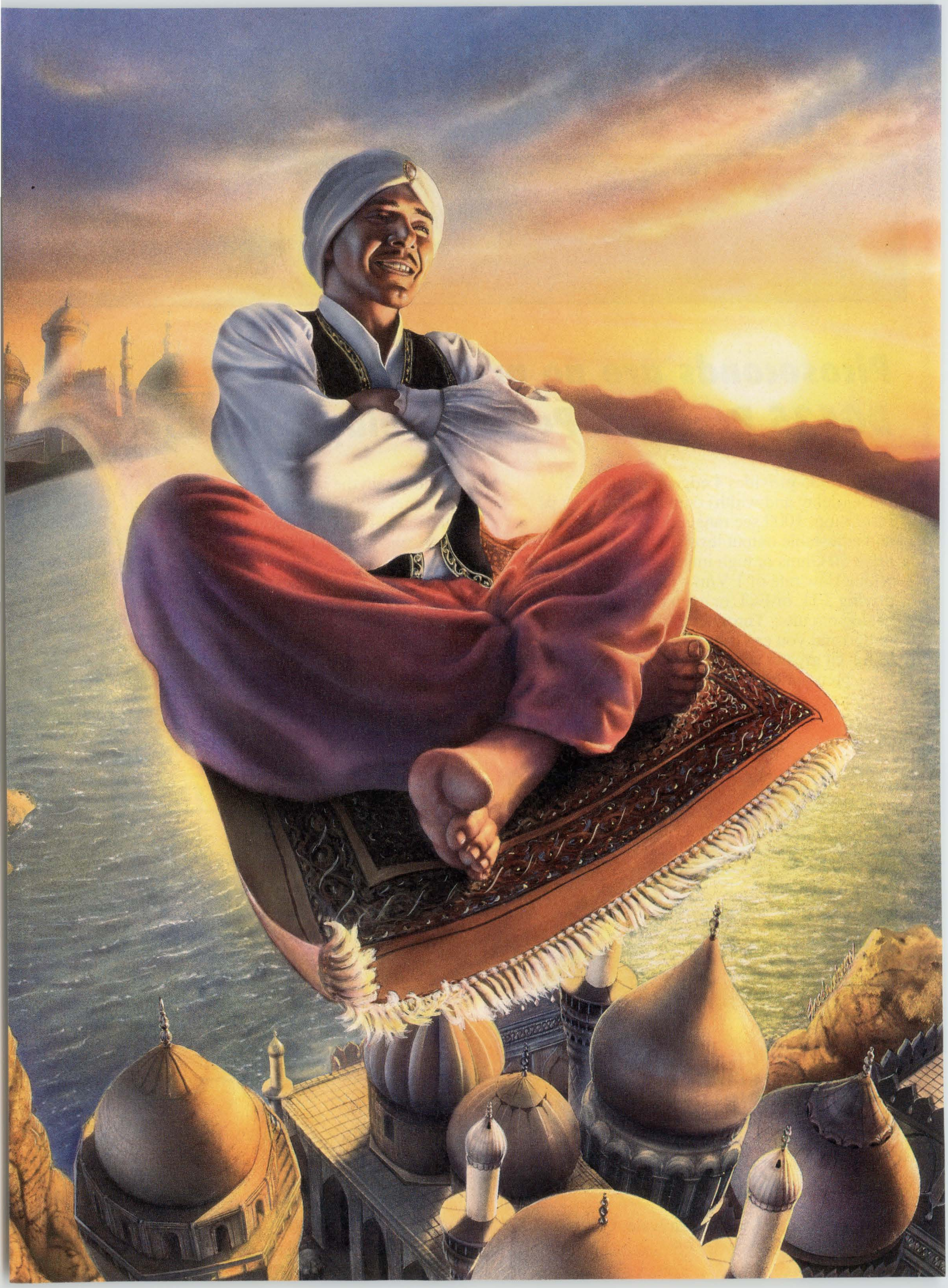

Fly non-stop in 150 picoseconds.

Bipolar gate arrays with mixed TTL-ECL interface capability–express, luxury service between logic levels.

If you thought it would take a magic lamp to find a simple way of mixing interfaces, Motorola's semi-custom arrays are about to make your wish come true. Our third-generation ETL Series offers 150 picosecond performance, up to 1200 MHz operating frequencies and mixed ECL, PECL (pseudo ECL) and TTL compatible interfaces.

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The ETL Series offers unique packaging features to simplify your system design. The MCA750ETL package incorporates an integrated heat slug with direct air exposure. Used without a heat sink in a still air environment, this package dissipates up to 1.5 watts at an ambient of 55° C. Additionally, the pin placement simplifies board layout by permitting the I/Os to run in one side and out the other, leaving the ends of the chip for power pins.

Motorola's ETL Series is perfect for telecommunications and computer applications such as CPU translators, bus interface drivers, RAM drivers and memory controllers. Three different arrays offer I/O counts designed to match 18, 32 and 64-bit bus interfaces and memory driver widths. Plus, you can program any signal pin for input, output or bidirectional signals for use in full ECL, full TTL, TTL/ECL and TTL/PECL systems.

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Array	equivalent gates	minimum addressable units	universal I/O cells	package
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*Plastic Quad Flat Pack with exposed heat slug (optional molded carrier ring is available).

A well-traveled development path.

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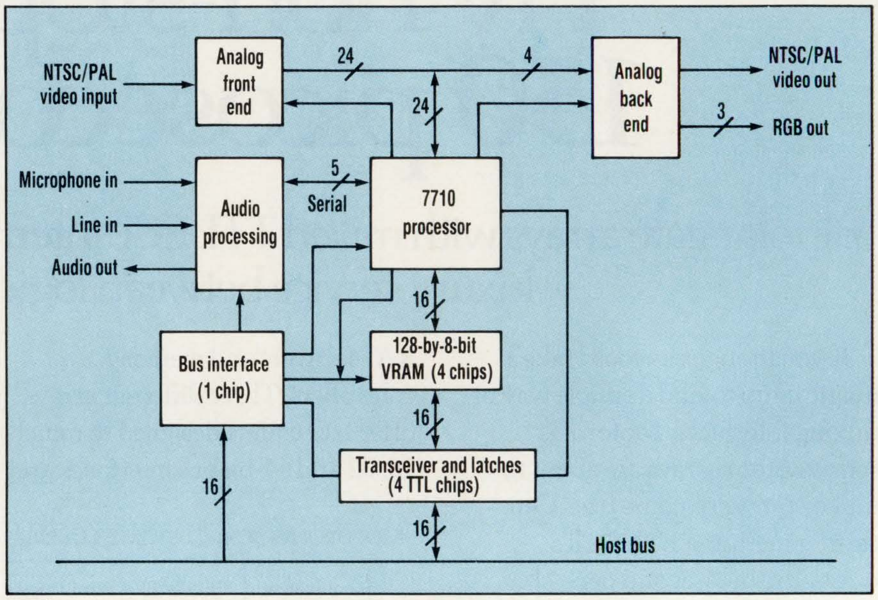
equivalent) voice-band analog interface chip from TI, connection to other serial protocols and support chips is possible by using simple external logic, the processor's companding technique, or its bypass mode.

To synchronize stored audio and video data, the audio interface can generate and remove audio time-markers, which are adjustable in 16.6- and 33.3-ms increments. The chip inserts a unique marker code into the compressed audio and video data so that the separately stored audio and video data can be time-tracked. The marker is removed by the chip automatically when audio or video is uncompressed. Buffering between the audio-processing logic and host interface includes DMA capability for data transfer between the processor and host CPU.

The host interface is CPU-independent, operating equally well with 8-, 16-, or 32-bit microprocessors. The interface consists of a 16-bit bidirectional data bus, a 4-bit address bus, five control lines, and one line for an external clock.



2. A 7710-BASED MULTIMEDIA subsystem can be implemented with a maximum of 18 chips. In addition to the 7710, the system includes 125 kbytes of VRAM, standard TTL ICs for the analog front and back ends, audio-processing circuits, a host-bus interface, and transceivers and latches.

Software Support

Working in concert with UVC's software package, the 7710 has several programmable features that further contribute to implementing a multimedia system with a minimum number of chips *(Fig. 2)*. These include programmable display-window size and offset, variable audio-sampling rate, and selectable compression ratio to optimize image quality for any desired communication bandwidth. Other features include chroma-keying and selectable zoom factors of X1, X1.5, and X2. Chroma-keying treats parts of an image as being transparent, based on the image's color values. As used in the 7710, the technique makes it possible for users to specify background color. The technique also contributes to frame-processing speed by eliminating the need to compress the same solid background in a series of frames.

Another useful feature is a software-controlled, single-step mode to code and decode non-standard video data formats, such as the 640-by-480-pixel video format employed in IBM's video-graphics-array (VGA) display systems. Other modes provide chip and system testability.

The 7710 can be used for data compression or expansion at both ends of a communications link. Alternatively, data expansion at a receive-only terminal, such as a video monitor, can be performed by UVC's software. Aside from supporting image-handling operations, a principal role of the system software is file management.

The software package has a standardized file format to ensure that compatibility exists among applications, and to allow for conversion between standard video file formats and UVC's format. For example, the software can convert tagged image file format (TIFF) or JPEG files to the UVC format for file transfer. TIFF is a standard file format that stores graphic images in a bit-mapped (raster-graphics) format. A communications spooler manages file transfer between local and remote stations.

Other software tools include high-level function libraries and sample source code to minimize application-development efforts, and low-level function libraries for complex application development. The menu-driven software also has a disk driver that supports data capture and playback using magnetic media. Suites of multimedia applications software provide video and audio capture, editing, video fax, and real-time video conferencing using standard telephone lines. Also available is a video-mail system that manages video and audio messages exchanged between workstations, and optional file-password security and descriptors, which are words that identify files in an indexed storage system for fast data retrieval.□

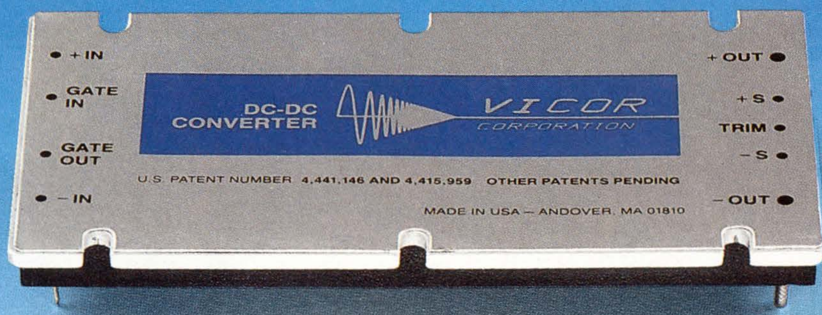
Price And Availabilty

The single-chip UVC7710 multimedia processor is being sampled and will be available in the first quarter of next year for $175 each in lots of 10,000. This price is expected to drop below $100 within a year. A development kit and supporting software will be available in the first quarter of next year.

UVC Corp., 16800 Aston St., Irvine, CA 92714; (714) 261-5336. **CIRCLE 511**

How Valuable?	Circle
Highly	524
Moderately	525
Slightly	526

1985 : smallest



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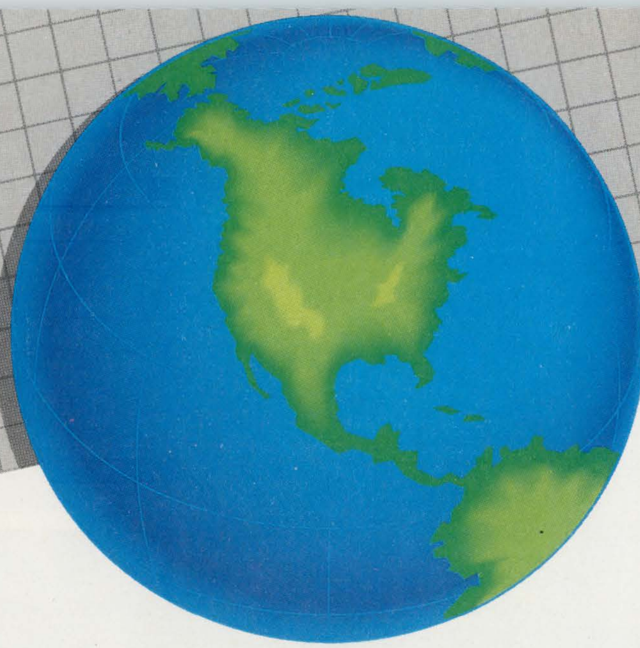
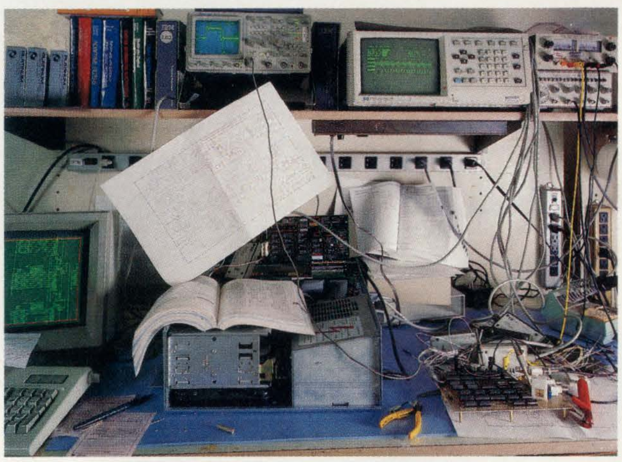
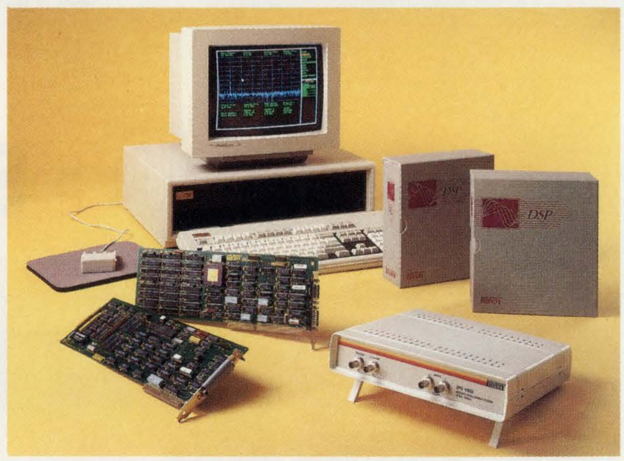


There Are Two Ways to Do DSP!



The Hard Way

- Time consuming
- Incompatibilities due to multiple vendors
- Unclear path from prototype to production
- Steep learning curve for software and hardware
- Uncertain results—room for doubt?



The Easy Way

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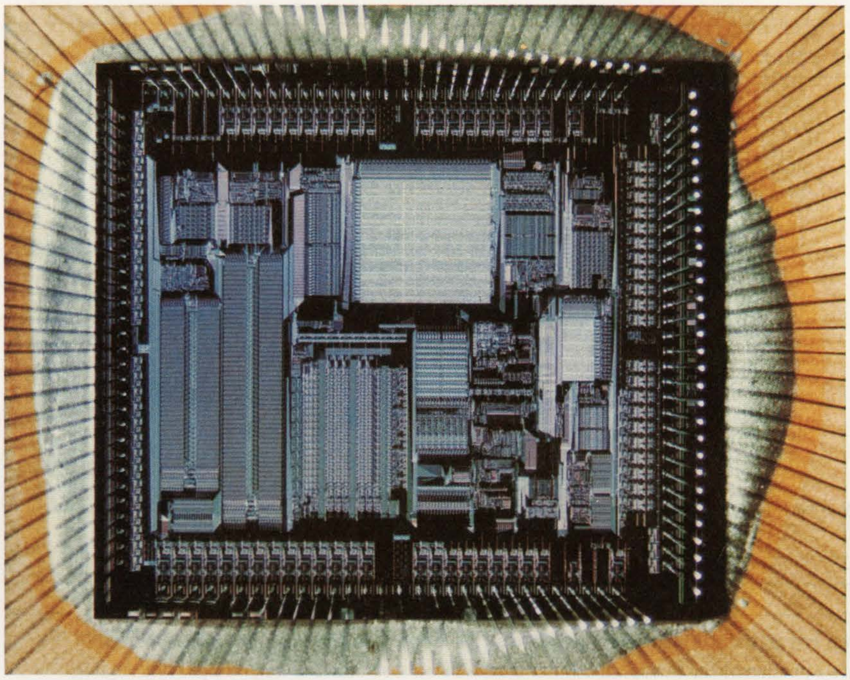


DAVE BURSKY

HIGHER INTEGRATION AND MERGED ANALOG AND DIGITAL BLOCKS LET DSPS DO THE HARD JOBS.

EVOLVING DSP CHIPS DO MORE

Over the past decade, digital signal-processing chips have evolved from hard-to-use building-block circuits to relatively simple-to-program, general-purpose all-in-one chips. Advances in chip integration, architecture, and design tools promise to accelerate that trend. Ultimately, designers will be able to create application-specific DSP chips with just the right mix of features for their intended applications.

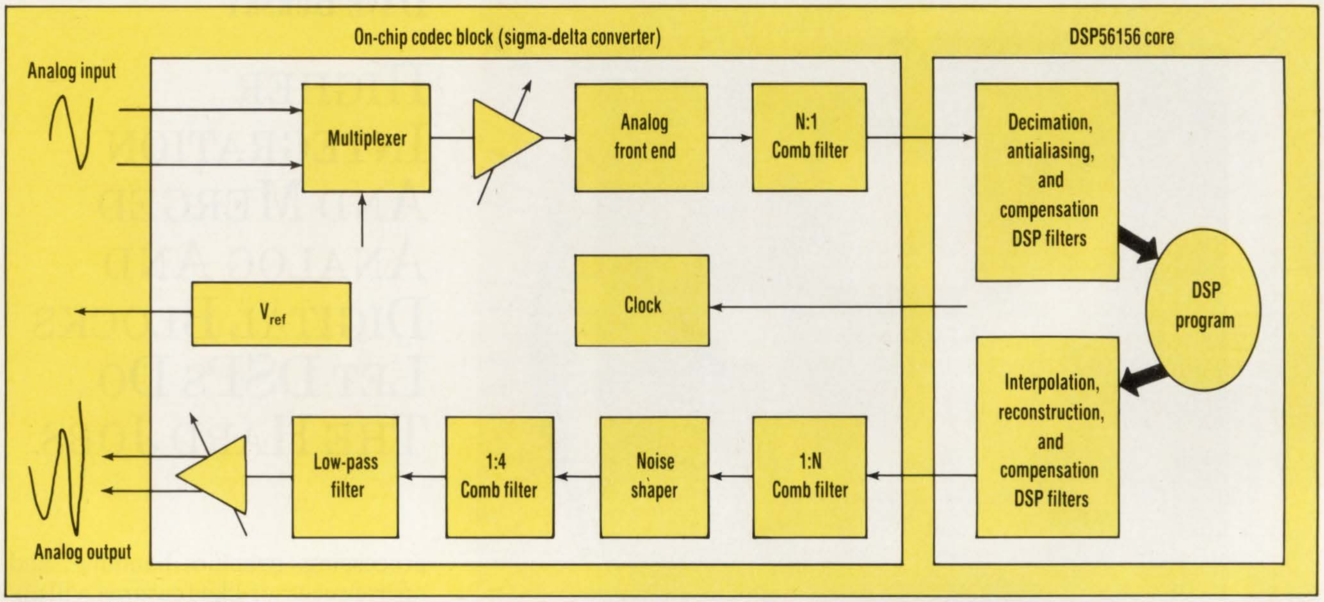
Already, DSP chips come in a wide variety of resolutions, ranging from 16-bit integer processors to full 32-bit IEEE-compatible floating-point units, all with on-chip blocks of RAM and ROM. Furthermore, in addition to the high-speed computational blocks, the DSP-chip architects have begun including microcontroller-like features, such as serial and parallel ports, counter-timers, and most recently, analog-to-digital and digital-to-analog converters (ADCs and DACs). More analog front-end processing, graphics handling, and microprocessor-like features will appear on future-generation DSP chips.

The wide range of resolutions and features of DSP chips suits them as solutions to many types of signal-processing, control, image-processing, and pure computational problems. As prices drop to less than $10 for some 16-bit DSP ICs, such chips are finding their way into consumer products.

Higher-resolution, and thus more-expensive devices with wider-dynamic ranges, tackle still tougher applications, such as CD audio, industrial controls, digital servo control loops, and so on. The full, 32-bit floating-point processors offer the widest dynamic range of the lot, finding homes in demanding applications, like radar and sonar signal processing, image processing, and even as graphics accelerators and math coprocessors. This is due to their computational speeds in the 15 to 30 MFLOPS range, and in most cases, IEEE-754 compatible floating-point math.

One of the latest applications that serves as a driver for new DSP offerings is the GSM (Groupe Special Mobile), a standard for mobile cellular telephones that's supported by 17 countries. Issued by the European Telecommunications Standards Institute, it defines the most advanced mobile telephone system. The system will employ sophisticated speech processing to reduce the data rate to 13 kbits/s. Data reduction will come from several circuit techniques. They include rectangular pulse excitation with long-term prediction (RPE-LTP), linear predictive voice coding, channel half-rate convolutional coding, and diagonal interleaving. Other system features include frequency hopping in the 900-MHz range, automatic adaptive-channel equalization, and Viterbi decoding for error correction.

Many telephone functions can be performed by DSP chips. But trimming system size and weight and to reduce system power and chip count for better battery life requires integrating analog front- and back-end circuitry



1. FULL 16-BIT sigma-delta analog-to-digital and digital-to-analog converters are included on the Motorola 56156 16-bit integer DSP IC. The chip is the third entrant in the race to capture a portion of the European cellular communications market. Similar chips from Analog Devices and AT&T were released earlier this year.

on the DSP chips. DSP chips have already surfaced in many digital telephones and line cards, such as Dallas Semiconductor's DS2130 voice messaging processor. They compress the standard 64-kbit/s pulse-code-modulated data streams from codecs into 32- or 16-kbit/s, or lower-speed data streams to increase the number of voice channels on one 64-kbit/s Integrated Services Digital Network telephone line.

The market for GSM phones is in its infancy, witnessed by the fact that deliveries will start in 1991. However, Analog Devices and AT&T have developed DSP chips aimed squarely at the mobile-telephone market, and Motorola has also just released a chip. The world market of an estimated 350 million units is certainly a tempting target, justifying the development of focused DSP chips. The markets in the U.S. and Asia are less developed than elsewhere. But the U.S. will adopt an 8-kHz voice-coding scheme as Japan and the rest of the Pacific Basin still try to settle on a standard.

Designers at SGS-Thomson estimate that each mobile telephone may require two or three DSP chips initially. Each chip will deliver about 40 MIPS of computational throughput to handle all of the signal-processing needs. Analog-signal handling to go with the digital processing will entail 10-bit a-d conversion at 1 MHz for the rf interface, and 14-bit conversion at 8 kHz for the voice processing.

16-Bit Workhorses

Most designers agree that for most voice-processing applications, 16-bit integer processors can handle almost all applications. As it turns out, 16-bit DSP ICs are today's industry workhorses. Such chips can be had from at least a half-dozen sources: the TMS320 family from Texas Instruments and Microchip, the ADSP2100 series from Analog Devices, the DSP16 series from AT&T, the just-released M56100 family from Motorola, the 32FX16 from National Semiconductor, the mPD77C2x family from NEC Electronics, and the ST189xx family from SGS-Thomson. Volume prices for such chips range from as little as $5 for the simplest 16-bit units to about $60 for the most complex integer processor.

Most DSP chips start with three basic and common features: a high-speed arithmetic unit with a hardware multiplier for either integer or floating-point operations, and RAM and ROM for data and program storage. Each company, though, has taken slightly different approaches to accelerate the computations and the execution of each chip's instructions.

The divergence in DSP chip architectures is caused by several reasons. These include differences in host-interface support, I/O ports, special features to aid in program execution, and links to real-world signals, such as those of ADCs and DACs.

Multiple address generators that address data and program memories in parallel, and a 16-word instruction cache enable the ADSP-2100 family to quickly run through its algorithms. A 15-word instruction cache aids AT&T's DSP-16 series to quickly execute short code loops, and zero-overhead looping can be repeated as many as 127 times to simplify repetitive algorithms. One of the more unusual integer DSPs, the ST189xx series from SGS-Thomson, can perform complex-number (real + imaginary components) calculations—a key operation for modem and data-communication subsystems.

Taking a totally different approach to DSP, National started with its general purpose 32000-family CPU core. It then added a flexible

DSP block onto the chip so that control and DSP functions could be developed using a unified instruction set on the 32FX16. TI and Microchip did just the opposite—each company started with a DSP core and then added control and microcontroller-like functions to the chip.

As costs come down, 32-bit floating-point DSP chips continue to gain momentum. These chips are the rage as computation accelerators in 3D graphics applications, and as math accelerators on coprocessor cards in PCs. Most companies offering integer processors also supply 32-bit floating-point DSP chips. Prices for such devices range from well below $20 to several hundred dollars for the top-performing 32-bit floating-point chips. In between the 16- and 32-bit chips lie a number of offerings with 18-, 22-, and 24-bit resolution. Motorola, NEC, and Oki are probably the most notable contenders in this middle area.

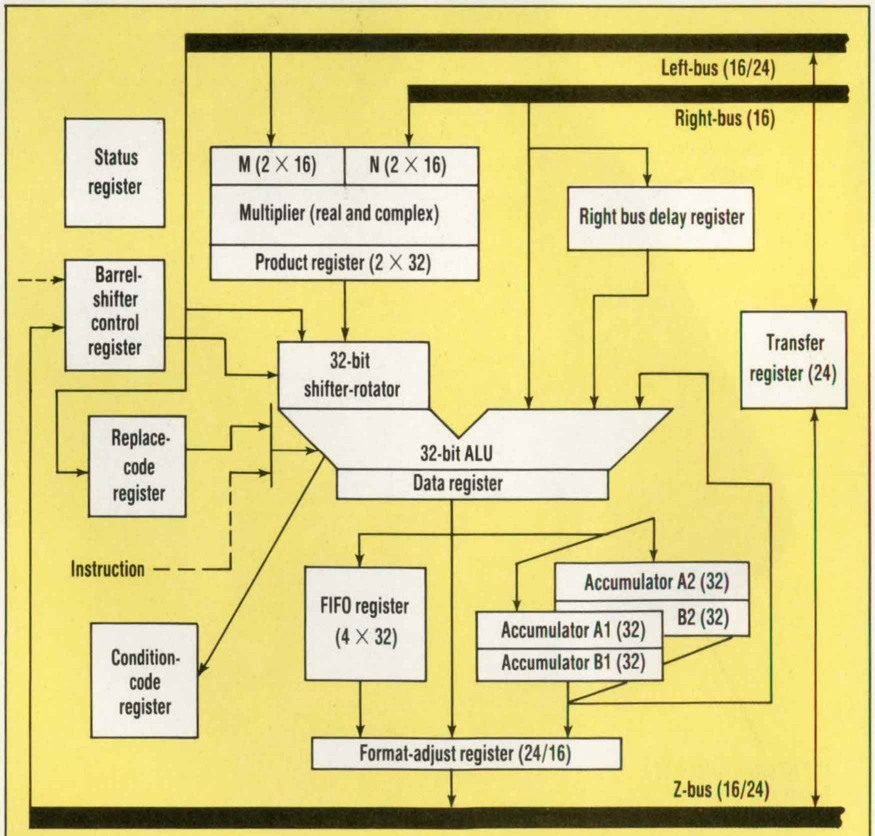
In addition to the generic DSP chips, many application-specific DSPs have appeared over the last few years. These chips typically pack arrays of math elements to better handle large data arrays. Such functions as finite-impulse-response filters, fast Fourier transforms, convolutions, and other signal-processing operations are some of the hard-wired functions that can usually be integrated into silicon. Harris Semiconductor and Plessey Semiconductors recently released some application-focused chips aimed at communications applications, while LSI Logic and SGS-Thomson unveiled chips targeted for image processing. Other vertically focused chips aimed at speech processing come from the DSP Group; image-processing chips from the Inmos Div. of SGS; video signal-processing chips from ITT Intermetall; and other communication-applications chips from Sharp; Silicon and Software Systems; Stanford Telecommunications; newcomer Zilog, who will offer the CD2400 DSP chip licensed from Clarkspur Design of San Jose, Calif.; and Zoran.

In the integer world, DSP chips are gaining 14-bit ADCs and DACs, communication codecs, phase-locked loops, timers, I/O ports, and other features targeted for communications and control subsystems. Earlier this year, both Analog Devices and AT&T released details of their 16-bit integer DSPs—the ADSP21msp50 and DSP16C, respectively—that include 16- and 14-bit sigma-delta converters. And, just last month, Motorola released details of its 56156, a 16-bit version of its 24-bit 56000 DSP family with on-chip 16-bit sigma-delta converters.

In AT&T's chip developed for battery-powered systems, low power was of utmost importance. To decrease power consumption over the previously released DSP16A, AT&T designers came up with a clever way of clocking selective portions of the chip to minimize power during operation. Unused portions of the chip aren't clocked, so the static logic consumes little power.

The processor also includes a special reduced-power sleep mode, which wakes up the chip when an interrupt occurs. That sleep mode suits the battery-powered communication systems well because such systems are often in a standby mode, either waiting for an incoming call or for someone to start an outgoing call. Either situation would generate the interrupt signal to wake up the chip and have it respond.

Motorola's M56100 series is based on a 16-bit DSP core macrocell—the 5616—which will permit designers to create their own customized DSP chips just as easily as macrocell-based ASICs have been pulled together in past years. The core has been optimized for voice and data applications. As many as six operations can be done simultaneously to achieve a cumulative throughput of 240 millions of operations per second (MOPS). The processor needs just two instruction cycles (100 ns) to



2. HANDLING COMPLEX NUMBERS in its unique multiplier-accumulator stage, the ST18932 DSP core macrocell from SGS-Thomson also has a four-word FIFO register, four accumulators, and a temporary register, all waiting to catch the results coming from the ALU.

start handling an interrupt when the processor runs at 40 MHz. Such a fast response enables the processor to readily tackle the real-time communication systems as well as industrial and embedded control systems. The core also has a fast return from an interrupt.

Math operations, such as multiply-and-accumulate (MAC), are common in DSP algorithms. To simplify these tasks, a single-cycle 16-by-16-bit multiplier and dual 40-bit accumulators enable the chip to perform 40 million MACs/s with minimal overflow because the wide accumulators accommodate word growth. In comparison, most of the other integer chips have 36-bit accumulators and could thus be more subject to round-off error. The reduced round-off error translates into a cleaner signal and less background noise.

Based on the core approach, designers at Motorola created both the previously mentioned 56156 and the DSP56116, a general-purpose 16-bit DSP chip. The DSP56156 is basically a 56116 that has an on-chip sigma-delta codec and a frequency synthesizer *(Fig. 1)*. The sigma-delta converter, intended for voice processing, has 14-bit resolution, an 80-dB dynamic range, and a 60-dB peak signal-to-noise ratio. The sampling clock frequency can range from 100 kHz up to 3 MHz, depending on the voice quality and power consumption desired. An internal voltage reference generates the necessary reference value for the converter. A phase-locked loop forms the heart of the on-chip synthesizer, enabling the internal timing circuits to boost the external 40-MHz clock up to 80 MHz.

Although it doesn't have on-chip codecs, the ST1893x family from SGS-Thomson offers other architectural features for communication applications, such as modems and speech processing, that set it apart from most other integer DSP chips. All family members can perform two data reads and one data write in one cycle, as well as multiplication and ALU or shift operations, up to three address pointer updates, and such I/O operations as mailbox exchanges or serial I/O transfers. That combination of operations permits the processor to multiply two complex 16-bit numbers in just two cycles—most other DSP chips would require four or more cycles for the same complex-math operation.

Parallel Fetches

The processor core implements a full Harvard-style architecture that simultaneously performs instruction and data-memory fetches. At present, SGS-Thomson has developed separate analog front-end/back-end chips to handle the analog signals for voice and data-modem signals. However, because the chip's processor core—the ST18932—is part of the company's 1.2-μm standard-cell library, customized versions with analog functions or yet additional digital features aren't that far away.

The ST18940 and 941 are more recently released CMOS family members, with 32-bit integer arithmetic units. They're upwardly source-code compatible with the original 16-bit NMOS (TS68930) and upgraded CMOS members (ST18930/931) of the ST18 family. The two chips are similar except that the 940 has an on-chip 3-kword-by-32-bit program ROM and a 512-word-by-16-bit coefficient ROM. The ROMless 941 addresses 64 kwords of external memory and contains a 128-word-by-16-bit coefficient RAM. Each chip also has a pair of 256-word-by-16-bit data RAMs that act as small caches for coefficient or repetitive data values.

Furthermore, the ability to split the calculations so that direct operations on complex numbers can be performed suits the chips for applications that require convolution,

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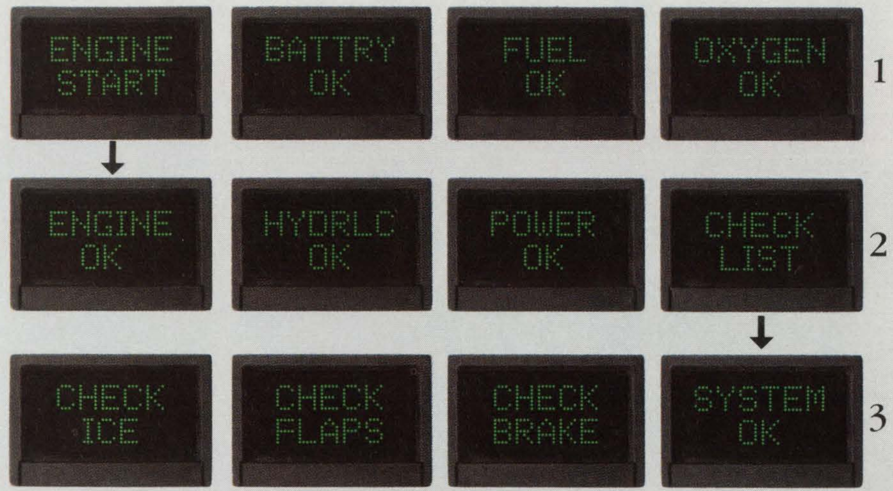

AN APPLICATIONS EXAMPLE.
While the following example is for aircraft, it could apply to any air, land, sea or space system.

SEQUENCE ONE: The four-pushbutton display reads "ENGINE START," "BATTERY OK," "FUEL OK," OXYGEN OK." The operator selects "ENGINE START."

SEQUENCE TWO: The four-pushbutton display now changes to read "ENGINE OK," "HYDRLC OK," "POWER OK," "CHECK LIST." The operator selects "CHECK LIST."

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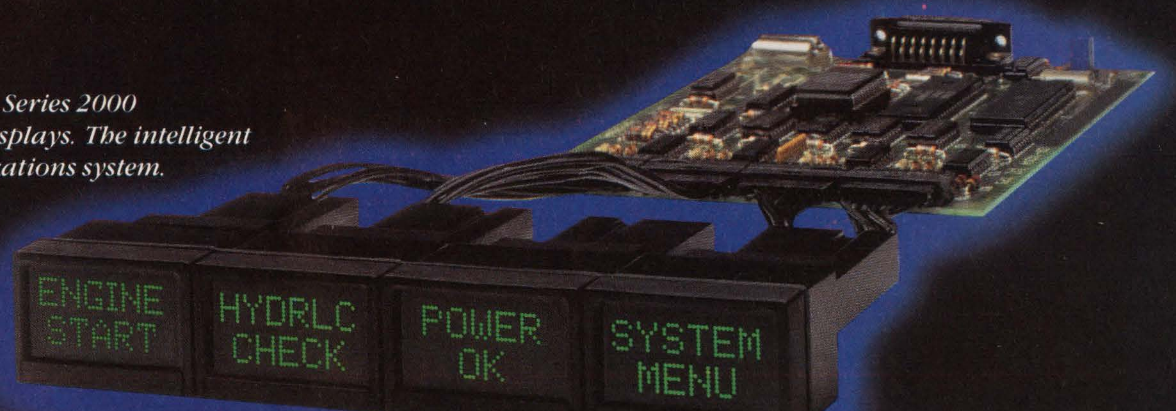

SERIES
VIVISUN 2000™

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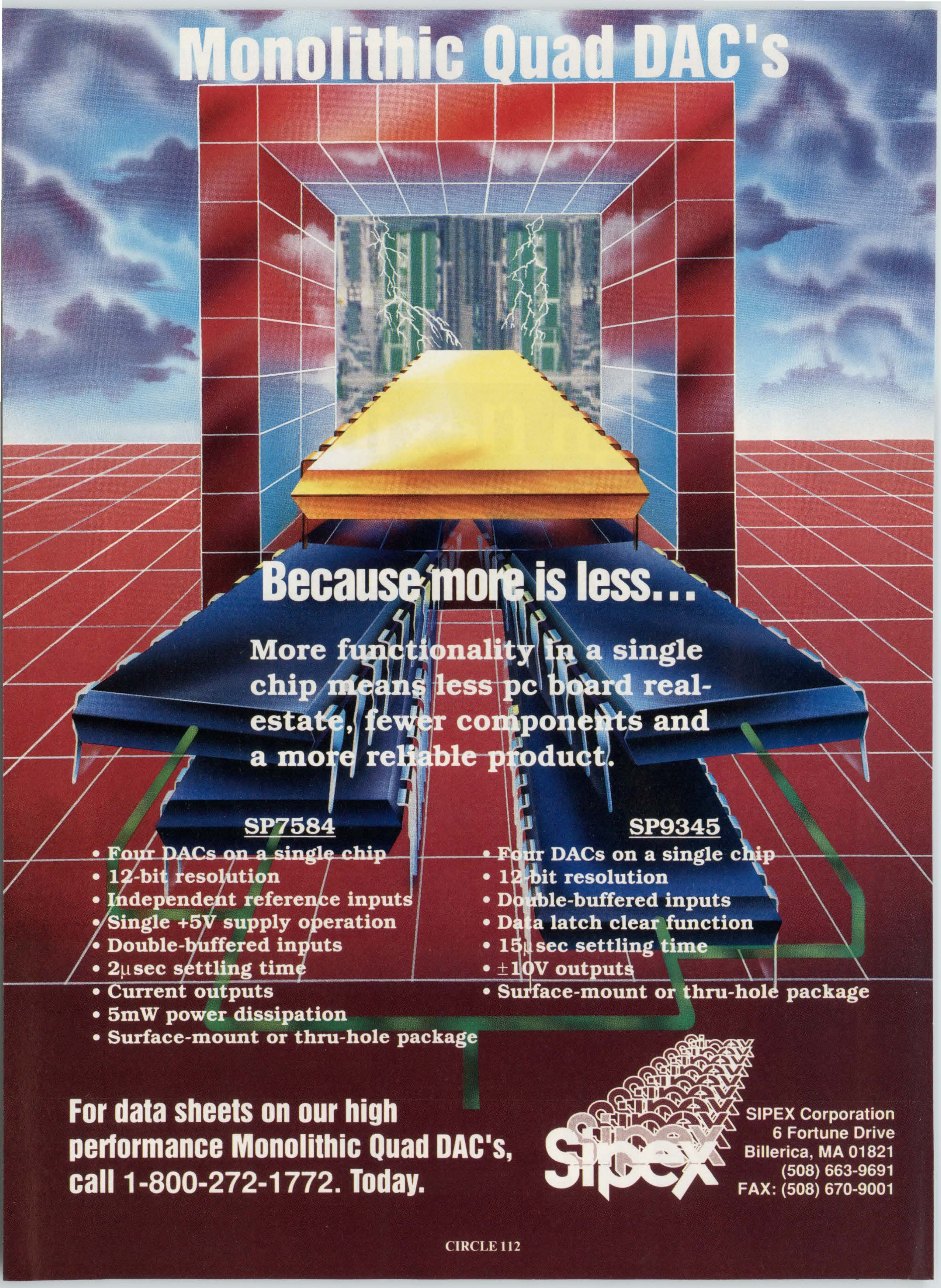
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CIRCLE 112

echo cancellation, and fast Fourier transforms (FFTs).

Another enhancement over the 18930/31 processors was the addition of a second serial port. This, for example, permits direct connection to codecs and other devices that tie into ISDN. A parallel port, dual 16-byte FIFO buffers, and a DMA controller were also added so that the chip can provide more local control and data movement. The FIFO memories improve the chip's ability to handle asynchronous exchanges on the system bus, improving multiprocessor communications.

The actual core is similar to the main processor block in the 18940, dissipating about 350 mW when operating at full speed with instruction cycle times of 77 ns. During standby, the core power consumption drops to less than 0.5 mW. In the core is a complex multiplier, a 32-bit ALU, and a pair of register files (one is 192 words by 16 bits, while the other is 128 words by 16 bits) that hold the real and complex values. Also included is boundary scan logic to simplify testing and a loop counter and sequencer for address counting.

On the ALU's output are a four-word-deep FIFO buffer, as well as four accumulators and a temporary register *(Fig. 2)*. The abundant number of accumulators and the FIFO register lets the core handle multiple operations without storing data in its main memory array, thus accelerating simple operations. Furthermore, the FIFO buffer allows the ALU to deliver results at a different rate faster than the output bus can transfer the data. That permits the ALU to achieve a higher effective throughput.

High-Speed Ports

In addition to high-speed cores that perform many operations in parallel, one major problem is getting the data from the real world into the DSP chip so that it can be processed. Looking at that problem, designers at Burr-Brown, Tucson, Ariz., are searching for ways to take advantage of such features as high-speed serial ports, which are now on chips from AT&T and other companies.

Dedicated I/O buses or ports are also important for multiprocessing applications, where data must be moved from DSP to DSP IC, or from board to board. At the board level, many companies have created their own local data-transfer bus. At the chip level, most DSP chip suppliers haven't really addressed this issue at 16 bits. However at the 32-bit level, there have been developments. The most recent 32-bit floating-point DSP entries from AT&T, Motorola, and Texas Instruments include multiple I/O ports that greatly reduce the data bottleneck problem when moving large amounts of data.

To confront the data movement hurdle, designers at AT&T, Motorola, and TI have all taken different approaches on their respective 32-bit floating-point DSP chips, coming up with interesting architectural solutions. The first chip to offer a solution, the DSP32C from AT&T, included a pair of high-speed 10-Mbit/s serial ports that can shuttle data into and out of the chip. Such serial ports help keep the pin-count of the chip down to a reasonable level—as few as 64 pins for a non-expandable single-chip version, or as many as 164 leads in a PQFP if maximum system expansion is desired.

The dual high-speed serial ports not only allow simple data transfers, but also permit multiple DSP chips to be interconnected into an array that can process large amounts of data in parallel. A 16-bit parallel I/O bus plus the 32-bit data bus gives system designers plenty of architectural freedom to set up various data-transfer paths.

A newer device, the DSP3210, adds a high-performance 32-bit microprocessor bus interface that lets the chip easily tie into the host system bus on workstations and high-performance PCs. The new bus interface has all of the hooks for any company's CPU and can perform byte swapping when working in mixed-processor systems. Furthermore, the chip can handle either multiplexed and asynchronous buses. With all single-cycle instructions and up to four memory accesses per instruction cycle, the 3210 can deliver a math throughput of 25 MFLOPS. The DSP32C core was upgraded so that the chip could handle multimedia-type applications that mix video, audio, and text. That requires a large address space—much larger than that of the 32C which has a 24-bit address bus. Consequently, a full 32-bit address bus was included on the 3210 to provide a 4-Gbyte range.

Also added was byte addressability and some new instructions that improve context switching, add more looping options, and enhance process flow. To improve internal operations, a 32-bit barrel shifter was added to accelerate algorithms that require either shifting by an immediate value, or logic or arithmetic shifts. The block can also shift an amount controlled by a register value rather than an immediate value. Those operations come in handy when streamlining scaling algorithms, such as those that might be used in audio and image-processing applications.

The improved chip also includes one hardware timer for event control (32 bits) and a bit-programmable I/O port containing 8 lines, each of which is software-programmable as an input or output. These lines can be used for sensing, output status, and so on, and are handy for board-level testing applications or for a small amount of control.

In fact, the lines and timer may often eliminate the need for a small microcontroller that often provides the I/O for DSP systems. A low-power Wait For Interrupt instruction enables the chip to reduce its power drain to just a few milliwatts.

One major architectural change to the DSP ICs was including a task scheduler that enables the chip to store data and instructions in low-speed memory, and pull the data and instructions, as needed, into the chip. This is so the chip can continue to operate at top speed, unaware that inexpensive low-speed memory is actually feeding it.

Part of the scheduler includes control for page-mode DRAMs and quad-word transfers, among other control aspects. One other change versus the DSP32C is that the 3210 doesn't have the 16-bit I/O port. Because the new chip was designed as a bus master, all transfers will take place over the host bus, bypassing the need for a separate I/O bus.

Aiming at multiprocessor systems, dual 32-bit-wide bidirectional data buses—each with its own 32-bit address bus—on Motorola's 96002 DSP chip lets multiple processors easily cascade to multiply the processing power.

Large amounts of RAM and multiple 32-bit buses were included on the chip so that reasonably complex algorithms and their data points can be executed without the processor referencing off-chip memory. And, when off-chip memory must be accessed, the dual 32-bit address buses allow the chip to control two 4-Gbyte data memory spaces plus a third 4-Gbyte space for program storage. The large address spaces are an ideal fit for complex graphics and multimedia applications that demand gobs of memory for storing image and voice data.

Employing as many as six bidirectional byte-wide ports, designers at Texas Instruments are proposing a major I/O change for its forthcoming TMS320C40, which the company expects to sample in the second quarter of 1991. Targeted specifically at parallel-processing applications, such as found in image and seismic data analysis requiring computations with 2D and 3D arrays of processors, the C40 allows simultaneous multiple data transfers over its ports at individual rates of up to 13 Mbytes/s.

The six bidirectional byte-wide I/O channels can be used separately or cascaded for 16, 32, or some other word width. An intelligent DMA processor on the chip can perform task

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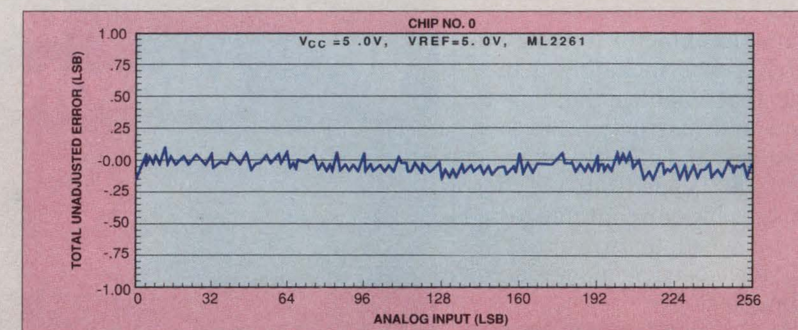

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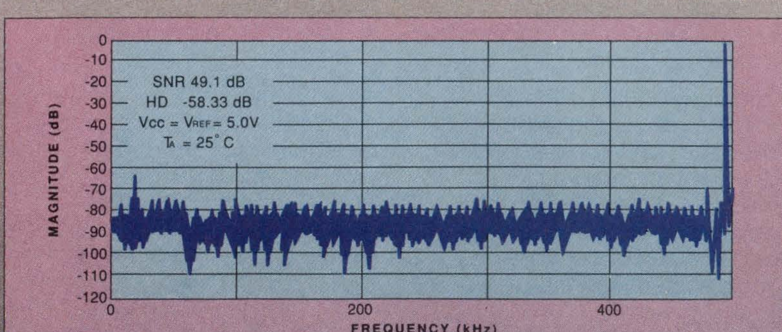
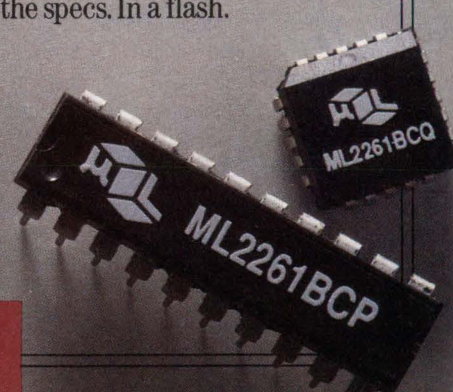


The ML2261 maintains ideal signal-to-noise ratios independent of increasing analog input frequencies to 500kHz.



Micro Linear

CIRCLE 134

scheduling for the I/O ports, permitting the chip's main processor to just queue up such tasks as data transfers or DMA operations and then go off and start another operation. Dual 32-bit data buses, each with their own address bus, gives the chip a 4-Gword address space to handle data-intensive applications. When running at 25 MHz, the chip executes most of its integer or floating-point instructions in just 40 ns, delivering one of the top floating-point throughputs—50 MFLOPS—of any DSP chip.

The multiple ports make it possible for many 320C40s to be interconnected in various schemes—rings, stars, hypercubes, and so on—and have the data move exactly where it's needed. With a total throughput of 275 MOPS and the ability to transfer data at an aggregate rate of 320 Mbytes/s, the C40 offers much-coveted system flexibility.

A FAST PROCESSOR

One of the ultimate chips for parallel processing is the Datawave, a CMOS array processor that delivers a peak performance of 4 billion operations/s. The chip targets image processing and the computations required in image data compression, television, and other video systems. The Datawave chip delivers a sustained throughput of 750 Mbytes/s through the use of a 125-MHz clock and 16 pipelined superscalar 12-bit RISC processors on the chip, all working in parallel. Most other array processors have hardwired data paths (ELECTRONIC DESIGN, *July 12, p. 133*).

With a throughput of 1.4 GOPS and the ability to transfer 3.2 Gbits/s, a chip coming from Silicon and Software Systems also plans to tackle real-time video processing. On the chip are 10 programmable 10-bit processors and a unique configurable architecture (ELECTRONIC DESIGN, *Nov. 22, p. 34*).

Specific and well-defined algorithms are often used in signal-processing applications. When that happens, specifically optimized chips, such as finite-impulse-response filters, fast-Fourier-transform processors, convolvers, and so on, can be designed and implemented to accelerate those algorithms many-fold over what can be done with a general-purpose chip. These optimized chips have been created and released by Array Microsystems (formerly Signal Processing Technology), Harris, Plessey, Zoran, and many other companies.☐

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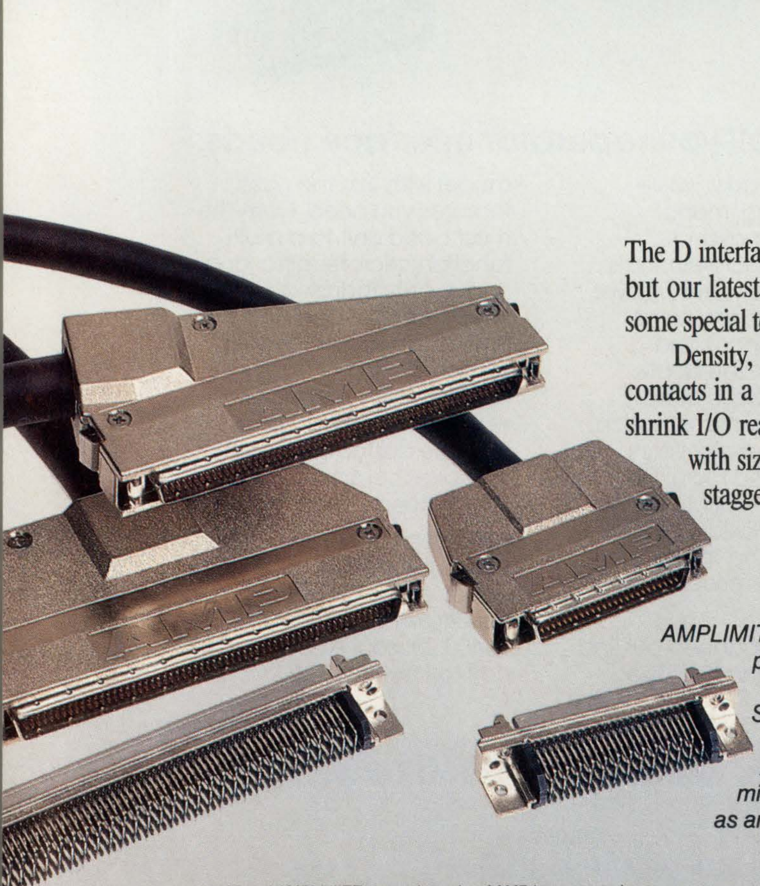

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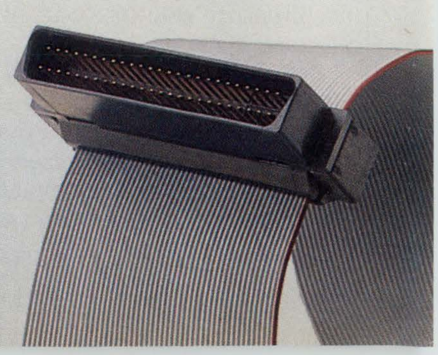

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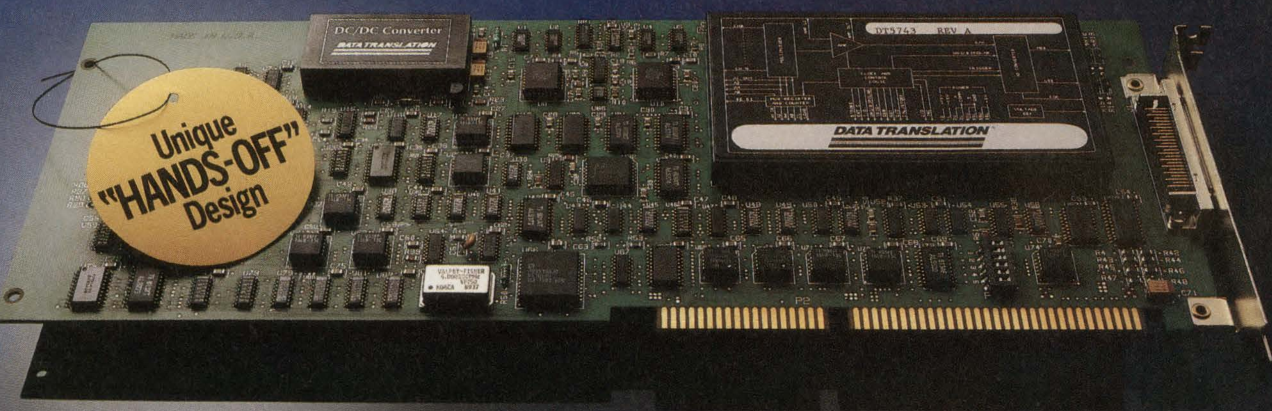

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PROPER FILTERING BALANCES SAMPLE RATE, RESOLUTION, AND SETTLING TIME.

UNDERSTANDING ANTIALIASING FILTERS

To achieve optimum results from digitized data-acquisition systems, engineers must keep in mind that they are dealing with the analog world through a sampled-data process. That sampling process imposes restrictions on the input signal spectrum that can be applied to the system's analog-to-digital converter (ADC). Consequently, an engineer must pay very careful attention to the front-end analog (antialiasing) filtering that precedes any data conversion.

Whether an engineer designs the filters himself or buys filter modules, he must understand the role a presampling filter plays in a digital signal-acquisition system. When digitally sampling a dc system, a good filter eliminates noise but allows a change in signal to settle out in a reasonable time.

To digitally acquire ac signals, presampling filtering is even more critical. Without antialiasing filters, an engineer can't distinguish useful information from mathematical aberrations.

SIGNAL ALIASING

When a continuous signal is sampled, the frequency spectrum is duplicated, or aliased. The center-to-center separation between aliases is equal to the sampling frequency. If the sampling function is fast compared to the sampling period, the duplication repeats into infinity. A continuous signal containing frequencies between $-f_h$ and $+f_h$, when sampled at f_s, contains the frequencies $nf_s - f_h$ to $nf_s + f_h$, where n goes from –infinity to +infinity *(Fig. 1)*.

To reconstruct the continuous time signal, or to reliably analyze the frequency components of the signal, the aliases can't overlap. The gap between edges of

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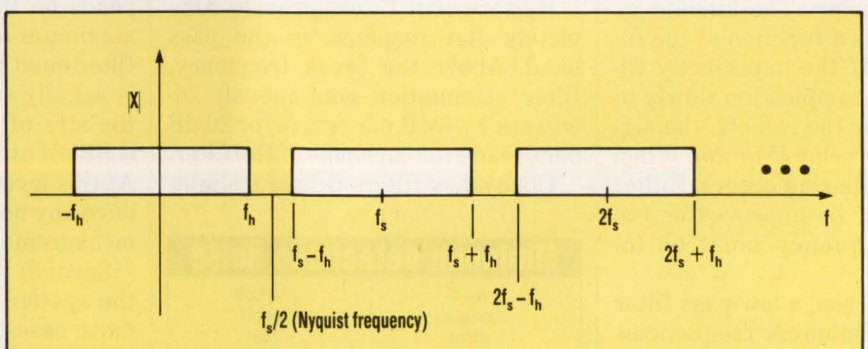


1. WHEN SAMPLED AT A FREQUENCY OF f_s, a continuous signal spectrum containing frequencies between $-f_h$ and $+f_h$ is duplicated (aliased) at multiples of the sampling frequency.

the aliases depends on the bandwidth of the continuous time signal and the sampling frequency. The highest frequency of the continuous signal is f_h, and the lowest frequency of the first alias is $f_s - f_h$. The gap is the difference between these two frequencies, or $f_s - 2f_h$.

The limit for signal analysis occurs when the gap between aliases reaches zero, but the aliases don't yet overlap. This happens when $f_h = f_s/2$, otherwise known as the Nyquist frequency. The aliases will overlap if the sampling frequency is lower or the signal bandwidth is higher, making it impossible to draw meaningful conclusions from the sampled signal.

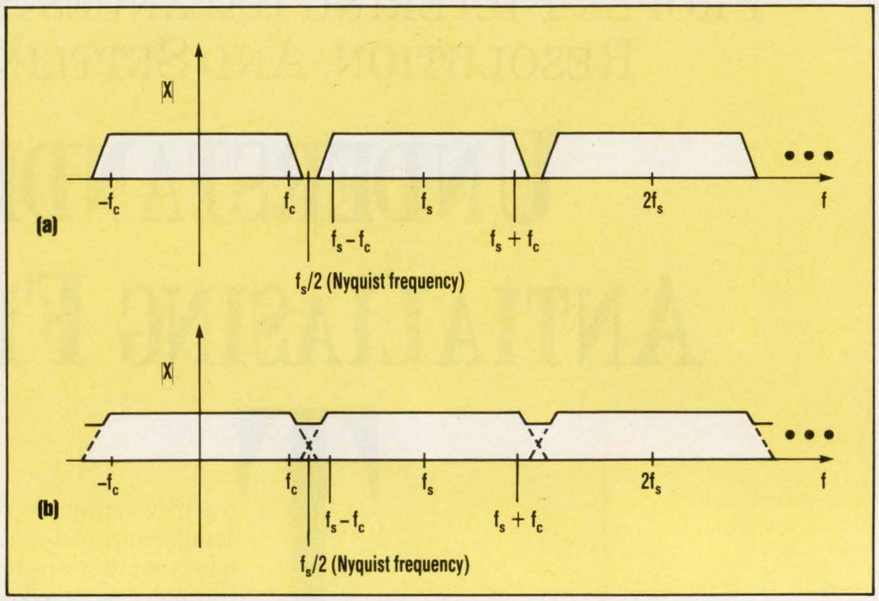
The signal profile under consideration results from a white-noise source filtered by a perfect low-pass filter. Such a filter passes all frequencies up to the cutoff ($f_c = f_h$), and completely blocks all others. Every practical filter, however, has a noticeable roll-off between the pass band and stop band. These filters will pass each frequency, virtually without distortion, up to some corner frequency f_c.

The filter then attenuates increasing frequencies at a faster rate *(Fig. 2a)*. Some filters have a limit in the maximum attenuation, which will be discussed later. The effect of the roll-off must be considered when relying on such a filter to eliminate aliasing errors.

Filter Type

It can be seen that the gap between aliases shrank because of the imperfect filtering. The amount of the shrinking is a function of the filter's roll-off. If the imperfectly filtered signal is sampled too slowly to compensate for the roll-off, the signals begin to overlap *(Fig. 2b)*. When this happens, aliasing occurs. Either the filter must be improved or the sampling frequency must be increased.

In the ideal case, a low-pass filter completely eliminates frequencies above the cutoff and perfectly passes frequencies below it. The range of frequencies passed is called the pass band, all others are called



2. BECAUSE PRACTICAL FILTERS **aren't ideal, they don't immediately attenuate all frequencies above the corner frequency f_c. However, as long as they supply sufficient attenuation before the Nyquist limit of $f_s/2$ is reached, aliasing will not occur (a). If the sampling frequency isn't high enough or the filter rolls off too slowly, the duplicate spectrums overlap and aliasing occurs (b).**

the stop band. All real filters, however, have a transition band where the attenuation increases but hasn't yet reached the stop band. Some filters have a ripple, or variation, in the response in the pass band. Some filters also have a limit to the amount of attenuation present in the stop band. For realizable filters, designers need to balance pass-band ripple, transition band roll-off, and stop-band attenuation. At this point, it's helpful to compare the responses of three common types of low-pass filters used in data conversion applications *(Fig. 3)*.

Butterworth filters provide completely flat response in the pass band. Above the break frequency, filter attenuation continuously increases by 6 dB per octave, or 20 dB per decade for each pole of the filter.

Chebyshev filters deliver a slightly faster roll-off overall than Butterworth filters, and the roll-off at the break frequency is sharply higher. The increased roll-off comes at the price of ripple in the pass band.

Elliptic filters offer the steepest transition band at the expense of ripple in both the pass band and stop band. The stop-band ripple imposes a finite limit on the maximum attenuation of the filter.

Minimum detectable noise

A–d resolution (bits)	1/2 LSB weight (dB)
8	−54
10	−66
12	−78
14	−90

Noise Filtering

Butterworth and Chebyshev filters are both used for noise filtering. Specifying filter characteristics depends on the application. First, the maximum allowable error from the filter must be determined. The error is usually specified as a function of the size of the least significant bit (LSB) of an ADC, typically 1/2 LSB. At this level, the filter doesn't introduce any noticeable error to an ADC measurement *(see the table)*.

Second, the worst noise source in the system should be examined. In most cases, it's either 60-Hz noise from power lines or broad-band noise from switching power supplies. Then the minimum attenuation the filter needs to supply at the noise fre-

quencies should be determined. Ideally, this specification would allow enough attenuation to remove all noise from the digitized signal, even if the noise level was as large as the signal. Thus, the attenuation is related to 1/2 LSB of the ADC.

Third, the corner frequency and the number of poles for the noise filter can be selected from the required attenuation and noise frequency. For example, a 12-bit ADC system requires a filter attenuation of 78 dB at 60 Hz. A four-pole Butterworth filter rolls off at 80 dB per decade, a four-pole Chebyshev slightly faster. If the break frequency is placed one decade below 60 Hz, the goal is achieved. As a result, our first estimate of filter parameters is a four-pole Butterworth filter with break frequency of 6 Hz.

To ensure that this filter works, the step response of the system with the filter in place should be confirmed. Even though the signal is assumed to be dc, a change in level must be responded to within a reasonable time, with the response again better than 1/2 LSB. The step response of an n-pole Butterworth filter with corner frequency of f is given in equation 1. Substituting err for $1 - [v_{out}/v_{in}]$ in equation 1 and solving for time yields equation 2, which determines the settling time for a low-pass Butterworth filter.

(1) $v_{out}/v_{in} = 1 - e^{(-ft/n)}$
(2) $t = -(n/f)[\ln(err)]$

For a 12-bit system, a 1/2 LSB error equals 1-(40955/40960), or 1.221 $\times 10^{-4}$. This yields a settling time of about 6 seconds. If the settling time is too long, either use a higher order filter (more poles) or accept less attenuation at 60 Hz.

Antialiasing Filters

Filtering out alias frequencies but passing frequencies of interest requires filters with steeper roll-offs than Butterworth or Chebyshev filters. The filter type most often used is a Cauer elliptic filter. These filters offer the steepest roll-off of any commonly available filter and have a maximum attenuation limit in the stop band. In comparison, Butterworth and Chebyshev filters have an ever-increasing attenuation until stray capacitance begins to shunt signals around the filter.

Elliptic-filter performance stems from pole placement on an oval about the origin of the s-plane, much like a Chebyshev filter. Elliptic filters also include a pole pair on the imaginary axis at a frequency greater than the corner frequency of the filter. These poles are responsible for the sharp roll-off of these filters.

Poles on the imaginary axis present a challenge to building stable elliptic-filter circuits. If component variation causes a pole to drift into the right half of the s-plane, the circuit becomes unstable.

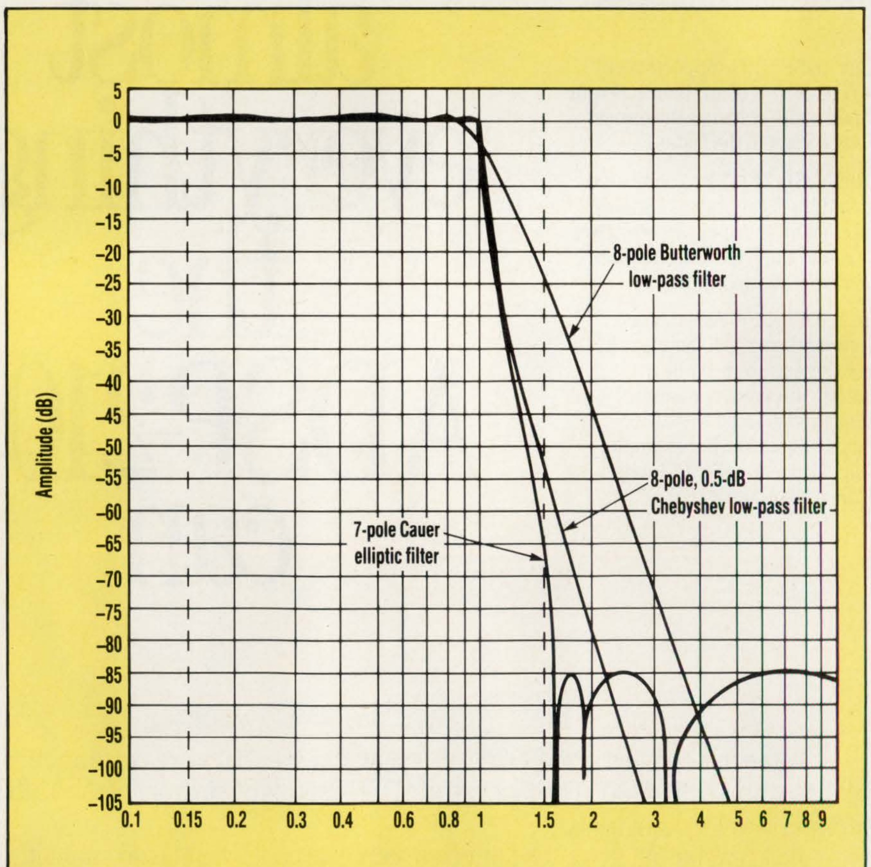
Four parameters are important when specifying an elliptic filter. First, like Chebyshev filters, elliptic filters exhibit a ripple in the pass band. The ripple is usually specified in decibels.

Then the corner frequency is specified in hertz. The corner frequency is defined as the point the filter response curve last passes through the specified pass-band ripple. The corner frequency is only –3 dB in elliptic filters.

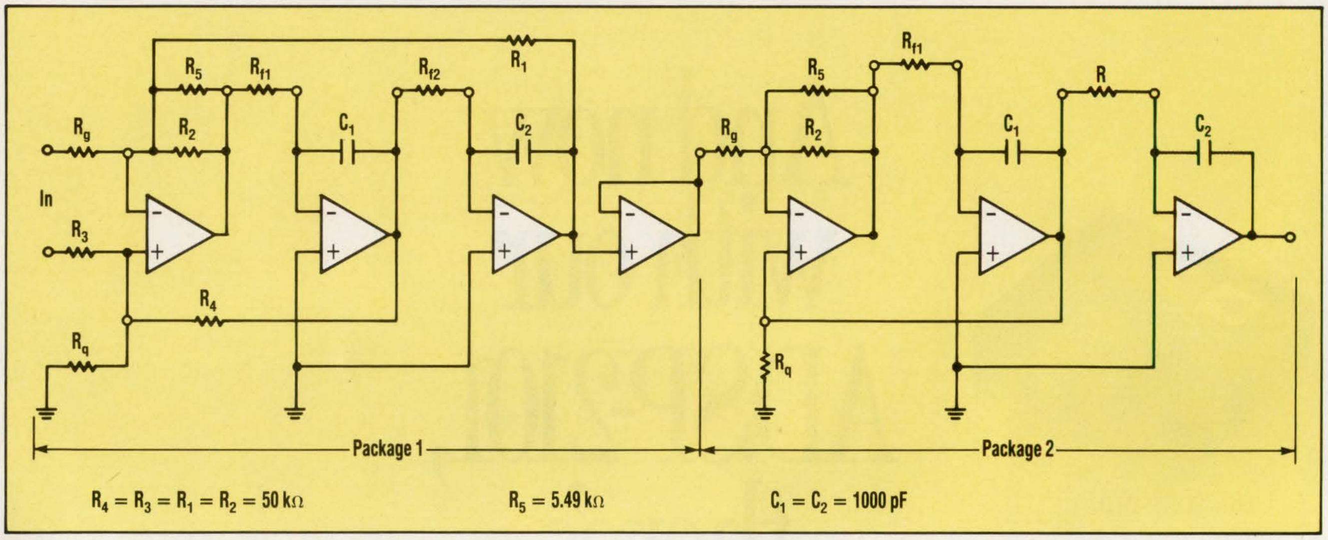
Specifying Attentuation

Next, the shape of the transition from pass band to stop band must be given. The specification may be an attenuation at a particular frequency on the slope, or it may be the frequency where the stop band should start.

Lastly, the attenuation floor must be specified. Elliptic filters have a maximum attenuation limit, and that



3. AN 8-POLE Butterworth, 8-pole Chebyshev, 7-pole Cauer elliptic filter are plotted in the frequency domain. The Butterworth filter has a maximally flat pass band and the slowest descent into the stop band. A steeper descent into the stop band is realized by the Chebyshev filter, at the expense of ripple in the pass band. The Cauer elliptic filter has ripple in the pass band and stop band but exhibits the steepest roll-off into the stop band.



4. BASED ON THE STATE-VARIABLE filter topology, this four-pole Butterworth filter consists of two cascaded second-order filter sections. The design is implemented with two Burr-Brown UAF41 universal active filters. Resistors R_{f1} and R_{f2} set the section's natural frequency, R_g sets the gain, and R_q sets the section's Q.

limit should ensure 1/2 LSB performance.

When matching an elliptic filter to an application, the frequencies being analyzed, the ADC's precision, and the sampling speed must be taken into account. For example, start by considering the highest frequency of interest, 10 kHz.

This sets the corner frequency of the elliptic filter at 10 kHz. Assuming a 12-bit ADC, a maximum stop-band ripple of –78 dB is needed. The attenuation floor should also be down at least –78 dB.

With the pass-band ripple and stop-band attenuation determined, all that remains to characterize the filter is specifying the filter's roll-off in the transition zone. This roll-off depends on the sampling speed.

Design Or Buy?

If an input signal contains frequency components that are faster than half the sampling frequency, the resulting digitized signal contains aliases. The minimum sampling frequency is therefore twice the frequency in which the filter's stop-band attenuation reaches 78 dB, not twice the frequency to be analyzed. If the speed of the ADC was already selected, a filter that satisfies this criteria must be selected or a designer must settle for a lower frequency to analyze. If the ADC system is still being selected, then sampling speed is controllable. In many cases, a faster ADC system costs less than a steeper filter.

Once the characteristics are determined for the required filter, an engineer must decide whether to design the filter himself or to buy one. Good filters are expensive because building filters to meet specifications is a specialized business. Rarely is it worth the time and effort to build filters when only a couple are needed.

If an engineer is designing a product for resale or needs many of the same type of filter, then designing his own may be worthwhile. However, a big problem in roll-your-own design is that filter response is very sensitive to component values. The component values generated from design equations must be used exactly, even if the values aren't standard.

As an example of a low-pass filter design, consider a 12-bit data-acquisition system with an input signal-to-noise ratio of 10 dB, and a noise source at 60 Hz. A filter is needed that attenuates the noise source below the ADC's resolution.

Also needed is a full-scale step change of the input to settle to within 1/2 LSB in less than 5 seconds. Because a flat response is desired in the pass band, a Butterworth filter would be the best choice.

An acceptable maximum signal-to-noise ratio after filtering is 78 dB (1/2 LSB for a 12-bit system). Because there's already a signal-to-noise ratio of 10 dB, the filter has 68 dB of attenuation at the noise frequency to meet specification.

Checking Step Response

As a starting assumption, the corner frequency of the filter is set three octaves below the noise frequency to 7.5 Hz. This sets the minimum filter roll-off at 68 dB in three octaves, or 22.67 dB per octave. With each pole of a Butterworth filter contributing 6 dB per octave, at least a four-pole Butterworth filter is required.

Once the corner frequency and the number of poles are set, the step response time can be checked for the filter using equation (2). The maximum error (err) allowed is [–1(40955/40960)], which yields a step response of 4.8 seconds.

If a faster response time was required, a six-pole filter with corner frequency at 15 Hz yields a step response of 3.6 seconds. Though the step responses sound slow, they're probably acceptable for monitoring environmental variables, such as temperature.

DATA-ACQUISITION FILTERS

The response time assumes a full change step in the input. This step is unrealistically conservative in most applications.

With the filter characterized, a circuit must be designed to synthesize the desired response. One approach is to use two second-order filter sections based on the state-variable filter topology *(Fig. 4)*.

Each second-order filter section consists of two integrators and a summing amplifier connected in a feedback loop. The stage's corner frequency is determined by the RC time constants of the integrators. A multiple-amplifier package helps realize the filter in a compact space.

REALIZING A DESIGN

A good choice is Burr-Brown's UAF41, a quad op-amp package with additional internal components to synthesize active filters. One op amp serves as an input summing amplifier, two op amps function as integrators, and the fourth op amp is uncommitted. The natural frequency and Q of the filter section are determined by user-supplied external resistors. The uncommitted fourth op amp may be used as an output buffer to eliminate the loading effects of subsequent circuitry. It's essential that the second filter stage isn't loaded by subsequent circuitry.

Synthesizing a four-pole Butterworth filter requires two UAF41s and some external resistors *(Fig. 4, again)*. Resistor values R_{f1}, F_{f2}, R_g, and R_q set the filter characteristics. The following equations govern the relationship between external resistors and filter characteristics:

$$R_{f1} = R_{f2} = 5.033 \times 10^7/f_0$$

$$R_g = 50\ k\Omega \times V_{in}/ V_{out}$$

$$R_q = 5.0 \times 10^4/ [3.48\ Q + (Q/3.16)(50\ k\Omega/R_g) - 1]$$

The first equation determines the values of R_{f1} and R_{f2}:

$$R_{f1} = R_{f2} = 5.033 \times 10^7/ 7.5 = 6.710667\ M\Omega$$

With the second equation, $R_g = 50\ k\Omega$ is selected for unity gain.

Selecting R_q requires knowing Q, a ratio of the energy stored in a circuit to the energy lost in each period of the response. The UAF41's data sheet gives two values of Q for a four-pole Butterworth filter: 0.54118 and 1.3065. The higher the filter's Q value, the less damped the circuit and the more prone to oscillation.

As a result, the low Q filter section should precede the high Q circuit to avoid possible signal clipping owing to ripple. As derived from the last equation, R_q for the first two-pole filter stage should be 47.41287 kΩ; the second stage should have an R_q equal to 12.62604. The two filter stages are isolated by one of the internal buffering amplifiers.

An important factor is the precision with which the resistor values are specified. These resistors determine pole placement in the system transfer function. If the actual resistors used are only approximations, the actual positions of the poles move, changing the filter's response. At best, this means the filter might not properly attenuate noise sources or cause an unacceptably long step response.

Sometimes, however, the actual pole location could move into the right half plane, particularly when synthesizing such complex filters as Chebyshev or elliptic filters.

For designers who wish to buy their antialiasing filters, a couple of suggested sources are:

Frequency Devices Inc.
25 Locust St.
Haverhill, MA 01832
(508) 374-0761

Precision Filters Inc.
240 Cherry St.
Ithaca, NY 14850
(607) 277-3550

Kevin R. Sharp, a design engineer with Burr-Brown, holds a BSEE from the University of Missouri at Rolla.

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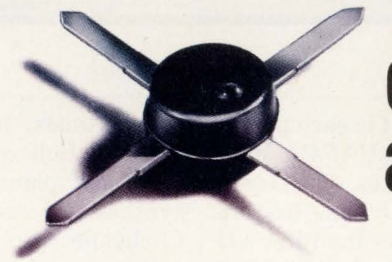

dc to 2000 MHz amplifier series

SPECIFICATIONS

MODEL	FREQ. MHz	GAIN, dB 100 MHz	1000 MHz	2000 MHz	Min. (note)	●MAX. PWR. dBm	NF dB	PRICE $ Ea.	Qty.
MAR-1	DC-1000	18.5	15.5	—	13.0	0	5.0	0.99	(100)
MAR-2	DC-2000	13	12.5	11	8.5	+3	6.5	1.50	(25)
MAR-3	DC-2000	13	12.5	10.5	8.0	+8□	6.0	1.70	(25)
MAR-4	DC-1000	8.2	8.0	—	7.0	+11	7.0	1.90	(25)
MAR-6	DC-2000	20	16	11	9	0	2.8	1.29	(25)
MAR-7	DC-2000	13.5	12.5	10.5	8.5	+3	5.0	1.90	(25)
MAR-8	DC-1000	33	23	—	19	+10	3.5	2.20	(25)

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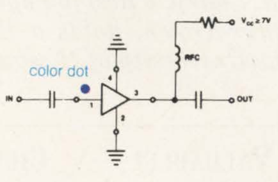

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*MAR-8, Input/Output Impedance is not 50ohms, see data sheet. Stable for source/load impedance VSWR less than 3:1

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80 × 50	10%	X7R	2200, 4700, 6800, 10,000 pf
120 × 60	10%	X7R	.022, .047. .068, .1µf

† Minimum Order 50 per Value

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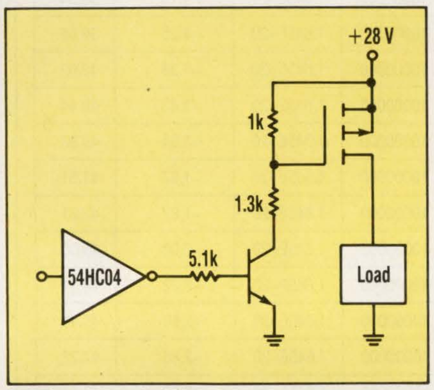
C113-Rev. D

CIRCLE 521 CURRENT SOURCE DRIVES POWER FET

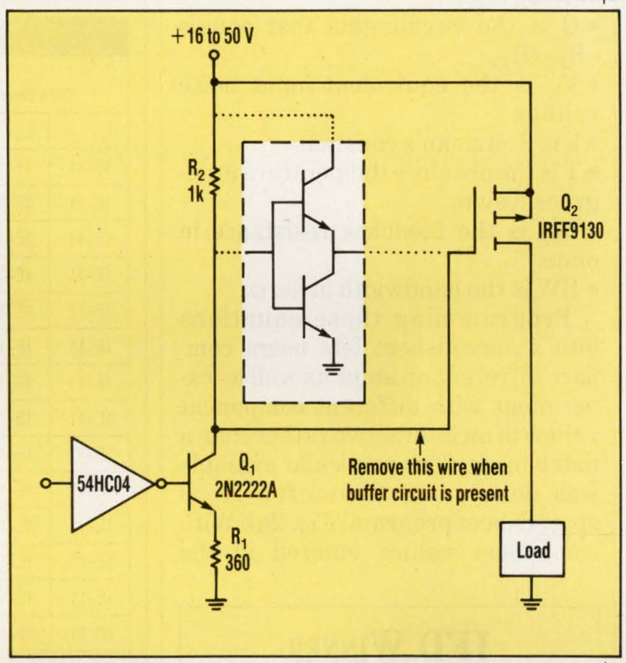
CARL SPEAROW
Sundstrand Corp., 4747 Harrison Ave., Rockford, IL 61125; (815) 394-3263.

Many applications require that a p-channel power FET drives grounded loads from a positive supply. Consider a gate-drive circuit that operates with a 28-V supply *(Fig. 1)*. It employs a resistive divider to produce a gate-source voltage of 12 V. However, the problem with this circuit is that the gate-source voltage is proportional to the supply voltage. Therefore, it can't tolerate any large variations of the supply voltage, a characteristic that's present in many applications.



1. THIS COMMON p-channel FET driver uses a 28-V supply. Because the gate-source voltage is proportional to the supply voltage, this circuit can't tolerate a large supply-voltage variation.

In an improved circuit, Q_1 and R_1 form a switched current source of about 12 mA *(Fig. 2)*. The current flows through R_2, which supplies 12 V to the FET. The circuit works well over a wide range of supply voltages. Furthermore, it switches smoothly in the presence of large ripple and noise on the supply. The switching time (about 1 μs) can be reduced considerably by lowering the values of R_1 and R_2 at the expense of higher power dissipations in the resistors and Q_1. Alternately, a buffer circuit can be added to produce switching times of 100 ns without generating a significant power dissipation.□



2. THIS IMPROVED CIRCUIT operates from a 16- to 50-V supply. Q_1 and R_1 form a 12-mA switched current source. The current flows through R_2, sending 12 V to Q_2. Adding the buffer circuit (within the dashed lines) offers 100-ns switching times. Otherwise, the circuit switches in 1 μs.

CIRCLE 522 FIND OP-AMP NOISE WITH SPREADSHEET

ROBERT M. CLARKE
Analog Devices, One Technology Way, P.O. Box 9106, Norwood, MA 02062; (617) 937-2250.

By employing a spreadsheet's built-in graphics and programming capabilities, users can easily compare the noise performance of different op amps and plot their noise versus a variety of resistance and gain values. Using a noise model for the op amp *(Fig. 1)*, the expression for the effective integrated output noise (V_{on}) equals:

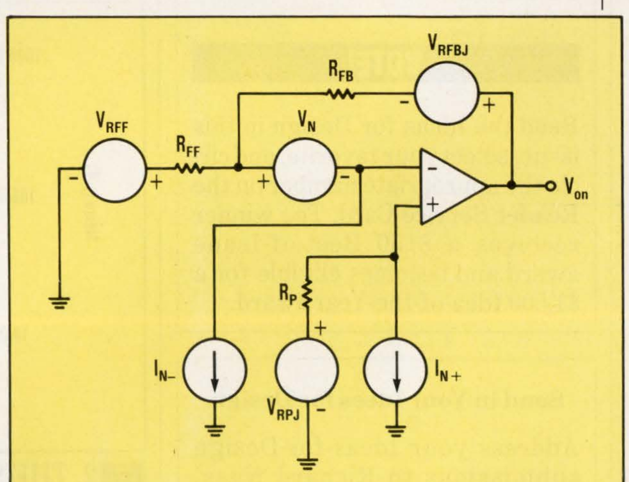
$$V_{on} = \{[I_{N-} R_{FB}]^2 + [I_{N+} R_P(1-G)]^2 + [V_N(1-G)]^2 + 4kT[R_{FB} + R_{FF}G^2 + R_P(1-G)^2]\}^{1/2} BW^{1/2}$$

and the expression for the effective integrated input noise (V_{in}) equals:

$$V_{in} = V_{on}/(1-G)$$

where

• V_{on} = the output



1. THIS OP AMP noise model accounts for noise current through the inverting (I_{N-}) and noninverting (I_{N+}) inputs and the input noise voltage (V_N). Each current induces a noise voltage in the resistors through which it flows.

noise voltage

- I_{N-} is the input noise current at the inverting input
- R_{FB} is the feedback resistance in ohms
- I_{N+} is the input noise current at the noninverting input
- R_P is the resistance at the noninverting input
- G is the circuit gain that equals $-R_{FB}/R_{FF}$
- V_N is the equivalent input noise voltage
- k is Boltzman's constant
- T is the absolute temperature in degrees Kelvin
- R_{FF} is the feedback resistance in ohms
- BW is the bandwidth in hertz.

Programming these equations into a spreadsheet lets users compare different op amps as well as experiment with different component values in an interactive rather than a batch mode. This particular example was done using Microsoft's Excel spreadsheet program *(Fig. 2a)*. With component values entered in the cells across row 9, the formula for the effective integrated output noise in μV (entered in cell J9) is:

```
=((A9*E9)^2+(A9*F9*(1-I9))^2
+(C9*(1-I9))^2+H9*(E9+D9*I9^2
+F9*(1-I9)^2))^0.5*G9^0.5*1000000
```

This noise model for an op amp accounts for noise through the inverting and noninverting inputs as well as the input noise voltage. The noise versus circuit gain can be plotted by using the values obtained from the spreadsheet *(Fig. 2b)*.□

IFD WINNER

IFD Winner for August 9

Robert Mayer, Peerless Instrument Co., 90-15 Corona Ave., Elmhurst, NY 11373; (718) 592-3300. His idea: *"Find Temp With RTD Varied Current."*

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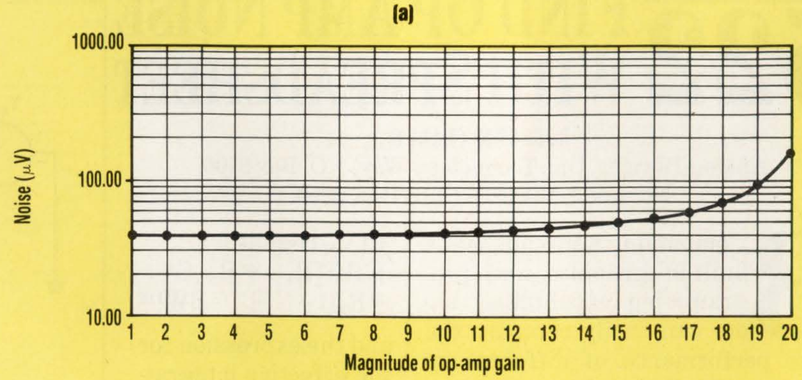
Send in Your Ideas for Design

Address your Ideas-for-Design submissions to Richard Nass, Ideas-for-Design Editor, Electronic Design, 611 Route 46 West, Hasbrouck Heights, NJ 07604.

OP AMP NOISE CALCULATIONS

Data Sheet Values			Circuit Values			Circuit Bandwidth	Thermal Contribution	Circuit Noise Gain	(μVrms)
I_{n+}	I_{n-}	V_n	R_{in}	R_f	R_p	(Hz)	4kT	$G=R_f/R_{in}$	
1E–11	1E–11	2E–09	1000	1000	0	10000000	1.645E–20	–1.00	38.59
1E–11	1E–11	2E–09	950	1000	0	10000000	1.645E–20	–1.05	38.81
1E–11	1E–11	2E–09	900	1000	0	10000000	1.645E–20	–1.11	39.06
1E–11	1E–11	2E–09	850	1000	0	10000000	1.645E–20	–1.18	39.34
1E–11	1E–11	2E–09	800	1000	0	10000000	1.645E–20	–1.25	39.66
1E–11	1E–11	2E–09	750	1000	0	10000000	1.645E–20	–1.33	40.02
1E–11	1E–11	2E–09	700	1000	0	10000000	1.645E–20	–1.43	40.44
1E–11	1E–11	2E–09	650	1000	0	10000000	1.645E–20	–1.54	40.93
1E–11	1E–11	2E–09	600	1000	0	10000000	1.645E–20	–1.67	41.51
1E–11	1E–11	2E–09	550	1000	0	10000000	1.645E–20	–1.82	42.21
1E–11	1E–11	2E–09	500	1000	0	10000000	1.645E–20	–2.00	43.05
1E–11	1E–11	2E–09	450	1000	0	10000000	1.645E–20	–2.22	44.11
1E–11	1E–11	2E–09	400	1000	0	10000000	1.645E–20	–2.50	45.45
1E–11	1E–11	2E–09	350	1000	0	10000000	1.645E–20	–2.86	47.22
1E–11	1E–11	2E–09	300	1000	0	10000000	1.645E–20	–3.33	49.64
1E–11	1E–11	2E–09	250	1000	0	10000000	1.645E–20	–4.00	53.13
1E–11	1E–11	2E–09	200	1000	0	10000000	1.645E–20	–5.00	58.54
1E–11	1E–11	2E–09	150	1000	0	10000000	1.645E–20	–6.67	67.91
1E–11	1E–11	2E–09	100	1000	0	10000000	1.645E–20	–10.0	87.46
1E–11	1E–11	2E–09	50	1000	0	10000000	1.645E–20	–20.0	148.64

(a)



(b)

2. THE SPREADSHEET CALCULATIONS MAKE IT POSSIBLE for users to compare different op amps in the same circuit configuration or vary component values and look at the effects on noise (a). The spreadsheet's results can be plotted. Here, the noise is plotted versus circuit gain for an AD844 current-feedback op amp for a 10-MHz bandwidth (b).

CIRCLE **523**

ADJUST VOLTAGE THROUGH ZERO

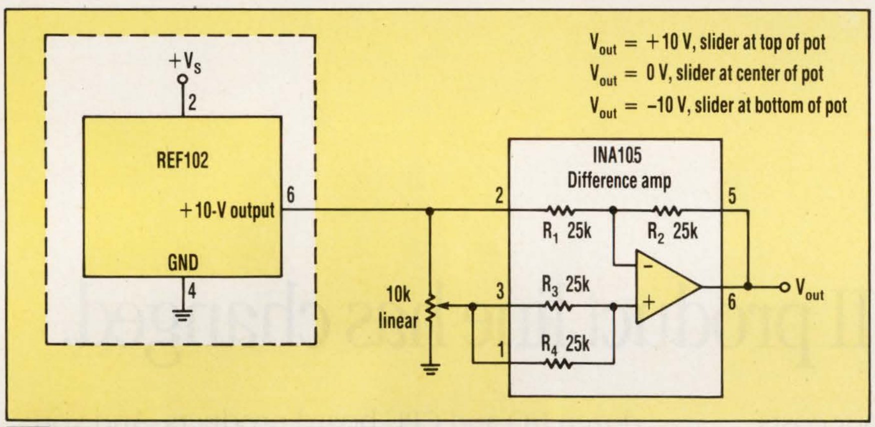
R. MARK STITT
Burr-Brown Corp., P.O. Box 11400, Tucson, AZ 85734; (602) 746-7445.

Many situations require a precision voltage source that can be adjusted through zero to both positive and negative output voltages. This type of bipolar source would eliminate the need to adjust the power supply down to 0 V. Then users would have to swap the output leads and adjust the supply back up to get a negative output voltage. Furthermore, the effects that occur when the input from the low-impedance source becomes an open circuit would be avoided. Lastly, the precision source enables users to actually adjust the output to 0 V, without letting a small voltage offset limit the range.

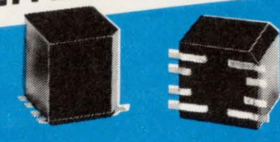
Perhaps the most obvious implementation of a bipolar voltage source would be to use a positive and negative voltage reference. However, a simpler solution is to employ one voltage reference and a precision unity-gain inverting amplifier. If a precision difference amplifier is used for the unity-gain inverting amp, the circuit requires just two chips and a potentiometer.

To understand how the circuit works, first consider the –1 V/V to +1 V/V linear gain-control amp *(see the figure)*. A Burr-Brown INA105 difference amp is used in a unity-gain inverting amp configuration. A potentiometer is connected between the input and ground. The pot's slider is connected to the noninverting input of the unity-gain amp; this input is typically connected to ground. With the slider at the bottom of the pot, the circuit is a normal-precision unity-gain inverting amp with a gain of –1.0 V/V ±0.01% maximum. With the slider at the top of the pot, the circuit is a normal-precision voltage follower with a gain of +1.0 V/V ±0.001% maximum. With the slider in the center, there's equal positive and negative gain for a net gain of 0 V/V. The accuracy between the top and the bottom will usually be limited by the accuracy of the pot. Precision ten-turn pots are available with 0.01% linearity.

A –10- to +10-V adjustable precision voltage source is one application for the –1- to +1-V/V linear gain control amplifier. Adding a precision 10.0-V voltage reference is all that's required.□



THIS AMPLIFIER CIRCUIT produces a gain that ranges from +1- to -1-V/V. The polarity is determined by the potentiometer's slider position. By adding a precision 10-V voltage reference (within the dashed line), a -10- to +10-V adjustable precision voltage source is attained.



QUICK LOOK

EDITED BY SHERRIE VAN TYLE

MARKET FACTS

Countering trends in other sectors of the electronics business, the U. S. holds the lead in advanced controller markets—for 8-, 16-, and 32-bit devices. Japanese companies dominate the 4-bit controller market, but demand is eroding in that sector, according to Electronic Trend Publications.

The Saratoga, Calif., market researcher predicts that worldwide shipments of embedded control devices—microcontrollers, microprocessors, and embedded processors—will top \$8.3 billion in 1995. Last year, shipments totaled \$3.3 billion. Revenues will grow fastest for 32-bit devices, which are expected to grow at an compound annual rate of 45% between 1989 and 1995. In contrast, revenues for 4-bit control devices will rise just 1.6% during that period. Sales of 8-bit devices will grow 13.5% from 1989 to 1995 while sales of 16-bit devices will grow 32.3% in that span.

More advanced controllers will go into cars, image-processing equipment, cellular phones and pagers, and wide- and local-area networks. Just as in microprocessors, controllers will be more highly integrated and have more functions. Indeed, microcontrollers and microprocessors will become more alike. C compilers will become the norm for 8-bit devices. Controllers will become even more specialized. Also look for real-time event control with 16- and 32-bit controllers.

Reduced-instruction-set computer chips and RISC hybrids will supplant complex-instruction-set computer architecture in 32-bit controllers. In addition, 16- and 32-bit controllers will take on more digital signal-processing tasks.

BEST SELLERS

Which technical books are the most popular in Silicon Valley?

ELECTRONICS:

1. *Art of Electronics*, 2nd ed. by Paul Horowitz and Winfield Hill. Cambridge University Press, 1989. ***\$49.50.***

2. *Noise Reduction Techniques in Electronic Systems*, 2nd ed. by Henry W. Ott. Wiley, 1988. ***\$47.95.***

3. *SPICE: A Guide to Circuit Simulation and Analysis Using PSPICE* by Paul Tuinega. Prentice-Hall, 1988. ***\$20.60***

4. *Discrete-time Signal Processing.* A. Oppenheim and R. Schafer, Prentice-Hall, 1989. ***\$52.***

5. *Logic Design Principles* by Edward J. McCluskey. Prentice-Hall, 1986. ***\$50.***

This list is compiled for *Electronic Design* by Stacey's Bookstore, 219 University Ave., Palo Alto, CA 94301: (415) 326-0681; fax (415) 326-0693.

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QUICKLOOK

TIPS FOR ENTREPRENEURS

One phrase making the rounds these days is *vulture capitalist.* But those who use this phrase probably haven't reaped the benefits of venture capital funds. Nor are they among the many entrepreneurs who, having recognized the benefits and reaped the rewards, return to venture capitalists for money, over other sources, to finance more than one start-up.

Venture capitalists do more than provide money. They use their expertise to work with company leaders to build success from the ground up. Entrepreneurs who understand the venture capital process seize the opportunity to use the VC as a valuable resource to:

- Bring in advisers and top talent
- Act as consultants and help obtain financing
- Build business skills and troubleshoot

These entrepreneurs see the VC as a partner who hangs in and helps the fledgling business take off, not as a vulture to pick its bones and fly away.

Venture capitalists can assist a budding company in building a good management team by using its network of contacts to find top-notch leaders and help persuade them to come on board. Many VC firms have industry specialties. Directories such as Western Association of Venture Capitalists, Menlo Park, Calif. or the National Venture Capital Association in Arlington, Va., list a firm's specialty, investment list, and skill level.

Some successful companies are backed by a syndicate of VCs representing a good mix of skills. The extent to which a venture capital company is involved in start-ups is generally proportional to the degree of help required to get the new company off on firm footing. The VC becomes a free consultant with heavy involvement in the early stages. As the venture builds momentum, the VC takes a back seat and comes in only as asked or needed.

An MIT study asked entrepreneurs and investors how much involvement the investor had in the company. Investors said they were heavily involved, while the entrepreneurs thought they were hardly involved at all, seeing investors only one or two days a month. By making assistance available to the board of directors and providing overall policy guidance, the venture capitalist can profoundly affect the success of a business. Ultimately, though, the entrepreneur is responsible for making it all work.

by Fred Haney, senior vice president of 3i Ventures, Newport Beach and Menlo Park, Calif., which invests in high-tech start-ups.

KMET'S KORNER

...Perspectives on Time-to-Market

BY RON KMETOVICZ
President, Time to Market Associates Inc.
Cupertino, Calif.; (408) 446-4458

Developing high-technology products usually requires design tools. Engineers working without the latest tools may complain that they are at an extreme disadvantage. Tools are appearing at a frenzied pace from suppliers around the world. Hardly a design team works without desktop publishing systems, mechanical design tools, electrical circuit simulators, materials' databases, software-development systems, IC and pc-design systems, and other tools. CAD/CAE systems not only are reshaping new product development efforts but they also have the potential to streamline the entire NPDP process. As such, product developers are constantly adding tools to the process to make improvements in productivity possible. Often, focusing on productivity and speeding up the process in isolated areas doesn't help overall development of new products—I learned this lesson the hard way in the mid-80s.

At that time, a new tool, the silicon compiler, appeared on the market. A few members of my work group saw the potential benefits of such a tool. In certain applications, we could take entire logic boards and reduce them to a few chips. Parts count would decline and manufacturing costs would drop dramatically. From a development perspective, the cost to design, fabricate, and test a chip was only about twice the cost of following the same process in conventional printed-circuit technology. The end product could be produced at a fraction of the cost of the pc board. We convinced ourselves and our management team that the silicon compiler would be a welcome addition to our stable of design systems.

All the promises the tool manufacturer made were true; the silicon compiler we purchased worked flawlessly. This fine tool, however, had no effect on our output of new products. Why? First, the compiler did nothing to reduce time to market. As it turned out, my work group was limited by definition issues, not by execution issues; of course, the tool couldn't help us decide what to do. Second, as the definition of our target product stabilized, we learned that an alternative architecture was required. It could not be produced on the silicon compiler. Third, others that initially expressed an interest in using the tool moved in the direction of working with the familiar rather than using something new. I jumped the gun in bringing this tool on line and got burned. Next, I'll show you how to adjust your new product development processes to help you avoid making a similar error.

EYECATCHER

THE VALUE OF EDTV STANDARD TO STIMULATE AND SUPPORT HDTV SERVICE

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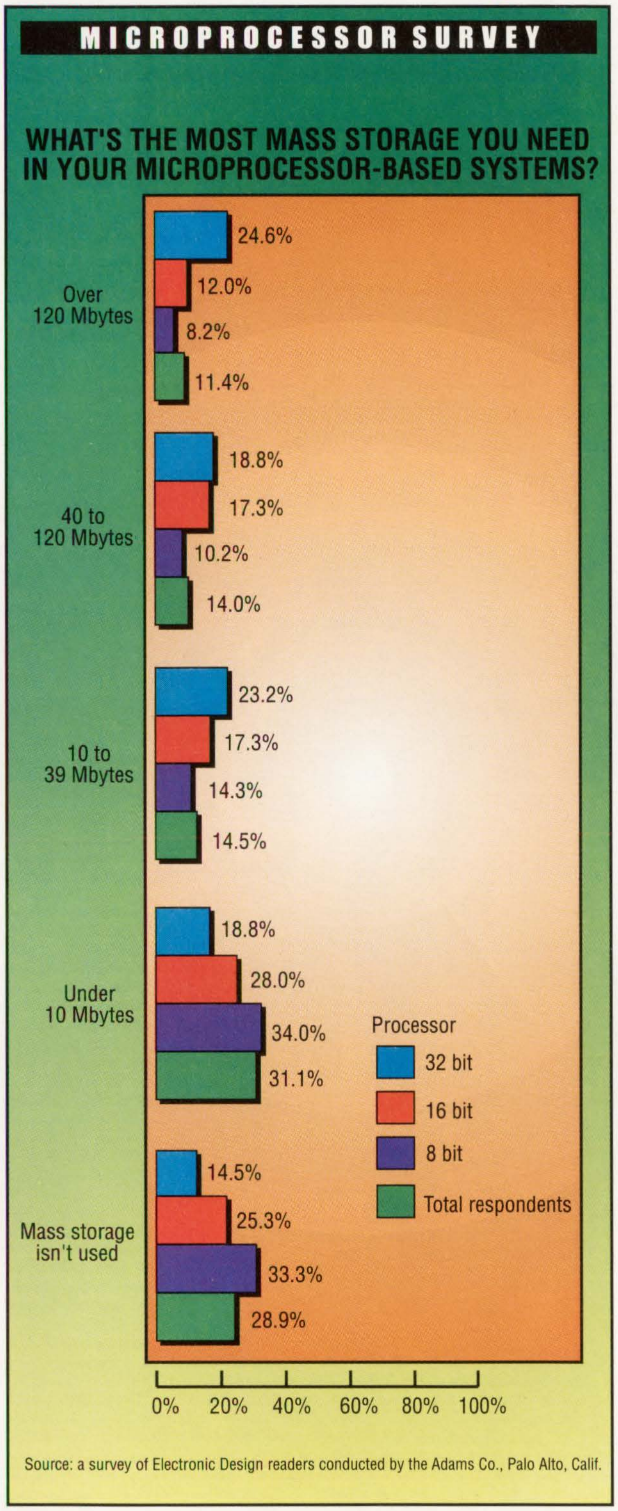
  - **Down Convert HDTV Signal to EDTV.**
- **CONSUMER RECEIVERS:**
  - **Either Equipped with Built-In HDTV & EDTV Decoders.**
  - **Or Have Standard Interface for External Decoder.**
  - **Automatic Recognition of HDTV Versus EDTV Signals by TV Set will Eliminate Any Possible Consumer Confusion.**

James E. Carnes
11/1/90

In an IEEE briefing, Sarnoff Research Center president James Carnes outlined the center's enhanced definition TV proposal. Digital EDTV, he says, offers a superior signal-to-noise ratio, easier encryption, and digital technology's rapid advances.



Corporate belt-tightening, flatter organizations, and smaller defense budgets are all affecting engineering careers. For its Careers Conference in fall 1991, the IEEE is seeking papers on engineering careers and policies and practices affecting careers. Six copies of 500-word abstracts of papers should be sent to William R. Anderson, IEEE-USA Office, 1828 L Street, NW, Suite 1202, Washington DC 20036. More information is available by calling IEEE-USA at (202) 785-0017.

TIPS ON INVESTING

For engineers, it's more important than ever to take time to do some serious retirement planning—no matter how old you are now. If you don't, as *Business Week* pointed out in a recent issue, your "glowing retirement expectations could prove a painful illusion."

The reasons aren't hard to find: less than generous pension plans for engineers that may be terminated altogether; the tendency of younger engineers to job-hop, which leaves them without substantial pension rights; curtailment of the tax deductibility of individual retirement account (IRA) contributions; and recurring financial problems in the Social Security and Medicare systems. These factors help put the main responsibility for providing a comfortable retirement squarely on an engineer's shoulders.

You can begin to do some things right now. First make sure your previous years' retirement account principal and earnings are working as hard as possible. For most, that means a self-directed IRA at a brokerage firm, because the account is totally flexible. You may divide the money in your IRA among many investment products—insured CDs, stocks, bonds, mutual funds, unit trusts, and so forth and change your portfolio mix when and as you wish.

Next, stop worrying about the loss of tax deductibility for your future IRA contributions. These contribution will *still* accumulate earnings on a tax-deferred basis, which has always been the most important feature of the IRAs from a retirement-planning perspective. Tax-deferred earnings are the cake; deductibility was just the icing.

Note that married individuals filing jointly with less than $50,000 adjusted gross income and individuals filing singly with less than $30,000 adjusted gross income, or those who do not participate in employer pension plans, can still deduct all or some of their IRA contributions. Check with your accountant or financial consultant.

Finally, work with your financial consultant to design a supplemental retirement portfolio because, in all probability, you will need it. Most engineers will need much more money to maintain their current lifestyle in retirement than they can realize from annual IRA contributions of $2,000 a year (or $4,000 a year, for working couples). Your financial consultant can help you determine how much you'll need to live comfortably and the amount of capital required to generate that income. Armed with that information, an engineer can pick from a large menu of investment products that offer IRA-like benefits. Indeed, some of these instruments are not simply *tax-deferred*, like an IRA, but are *tax-free*. The difference, of course, its that you eventually pay taxes on tax-deferred earnings (when you withdraw the money). Tax-exempt municipal bonds are the best-known tax-free product, but zero-coupon municipal bonds, tax-exempt unit trusts, and single-premium life insurance plans also offer this valuable advantage.

Once an engineer has begun to invest in these kinds of instruments, the key to success is to develop the same disciplined, systematic allocation of capital to them each year as for an IRA. With an IRA, you are forced to be disciplined by the annual contribution deadline and by the tax penalty you incur if you withdraw your money prematurely.

If you have several IRAs at different financial institutions, consider consolidating them at one location. Combining your IRA assets eases helps you monitor the performance of your assets. You also eliminate the added expense of several annual custodial fees and extra paperwork.

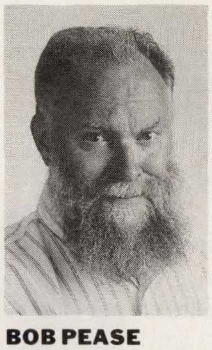
by Henry Wiesel, a financial consultant with Shearson Lehman Bros., Shrewsbury, N. J. Wiesel is also a qualified pension coordinator. He invites questions and comments, which should be addressed to the news editor, Electronic Design.

WHAT'S ALL THIS SPICEY STUFF, ANYHOW? (PART II)

The other day I was standing out in the rain, talking with a design engineer from the East Coast. He said all of the other engineers at his company ridicule him because they rely on Spice, and he depends on the breadboards he builds. There's just one hitch: his circuits work the first time and their circuits don't.

To add insult to injury, his boss forces him to help his colleagues get their circuits working, since he has so much time left over. I said that sounds pretty good to me, so long as his boss remembers who is able to get out the circuits when it comes to doing reviews for all of the guys.

This guy gave me a tip: Don't design a circuit in Spice with 50-Ω resistors. Use 50.1 Ω, it converges better. Hmmmm. That sounds kind of intriguing.



BOB PEASE OBTAINED A BSEE FROM MIT IN 1961 AND IS STAFF SCIENTIST AT NATIONAL SEMICONDUCTOR CORP., SANTA CLARA, CALIF.

Right now I'm struggling with a Spice model of a circuit. Not of a new circuit, but of an old circuit: the bandgap reference of the old LM331 that I put into production back in '77. It's a good thing I put it into production before we got Spice, because if I had first run this through Spice, I'd have been pretty discouraged. Spice says this circuit not only has a rotten tempco, but that it oscillates like a politician.

I went back and double-checked the actual silicon circuits. They soar like an angel, have very low tempco, and are dead-beat when you bang on them. They have no tendency to oscillate; they don't even ring. So why does Spice persist in lying to me? Doesn't it realize I will break its back for the impertinence of lying to the *Czar of Bandgaps*? I'm a little busy right now, but in a while I will find out why it lies to me. The Spice and CAD experts around here tell me, "Oh, you must have bad models." I've been told that before, when I was right and the experts were absolutely wrong (I mean, how can a single FET oscillate at 400 kHz?? With the help of 2 resistors...). More on this topic later.

I've already gotten several letters from readers expressing general interest and enthusiasm concerning this column about linear circuits. Already a couple writers have asked, "How about all of these new models for op amps? Won't they lead linear designers in a new direction?" My replies to them start out by covering a couple examples of old op-amp macromodels that have raised questions for over a dozen years.

A guy calls up and asks me, "What is the maximum dc voltage gain on an LM108?" I reply, "well, it's 40,000 min., but a lot of them run 300,000 or 500,000, and some of them are as high as 3 or 4 million." The customer sighs, "Oh, that's terrible...." When I ask why it's terrible, he explains that when the gain gets high, the gain-bandwidth (GBW) product will get so high that it will be impossible to make a stable loop if the GBW product gets up to dozens or hundreds of megahertz.

Sigh. I sit down and explain that there's no correlation between the dc gain and its spread when compared to the GBW product and its spread. The guy says, "Oh, I read in a book somewhere that there's good correlation, because the first pole is constant." I tell him to throw out the book, or at least X out those pages, because the first pole is *not* at a constant frequency.

These days, I read that several op-amp companies are giving away free Spice models. What do I think of these models?

Well, on a *typical* basis, I have read that some are pretty good. In several *typical* situations, they slew and settle (and ring just a little, as real op amps do) and have as good accuracy as a real *typical* op amp and its feedback resistors. Maybe in a few years, models of slow op amps will be trustworthy. But I don't think you can get very good results from modeling the fast ones. Why? Pc-board layout strays. Enough said.

And besides, how good are those models if you ask their makers? Are the models guaranteed to give such a good representation of reality that if Spice gives good results, the op amps are guaranteed to work? Well...no, not exactly. In fact, from what I've read, none of the op-amp models are guaranteed for anything. The only thing they can do "guaranteeably" is give a customer *something* when he begs for Spice models. It's guaranteed to make the customer go away happy and to keep him busy for a while. But it's not guaranteed to make him happy in the long run. This is because the performance of high-speed op amps and precision circuits depends so critically on the layout and on the resistors and capacitors, making the model itself almost irrelevant.

Now some people might say, "How does Pease dare to say that?" It's easy. I haven't got any Spice models of my op amps to give away. Not at this time. And if I did, or when I do, I won't be able to guarantee them either. At best, I may be able to say, "If you are a good engineer and use these models as a tool to pioneer some experiments that are inconvenient to test on the breadboard, you may find these models are helpful. But you had better check things out with a breadboard to confirm the circuit. For example, you can use Spice

PEASE PORRIDGE

to 'measure' some voltages or currents that are so small and delicate that you really could not measure them with a scope, a buffered probe, or current probe—not in the real world. *But,* if you try to rely solely on these models, without breadboarding, they won't tell you the whole story. Your crutches will collapse, sooner or later, and you can't say I didn't warn you."

I showed this column to Bettina Briz in amplifier marketing, and she said, "Bob, you can't say *that.*" I said, "Oh, tell me where I have said anything that is untrue, and I will fix it." She admitted that what I had said probably was...quite true. Then I said, "Well, why try to soft-pedal the truth, and pretend that you can trust computers all of the time? Wouldn't that be a disservice to our customers?" And Bettina replied, "When *we* have models, we'll have to try to educate our users. We'll point out when you can trust the models, and when you shouldn't. So, after that, are we in disagreement?" Well, maybe we did agree after all.

At present, we have a small library of op-amp models released with Analogy, Beaverton, Ore. They're only level I models, (low precision), and while we have made some progress on good-precision ones (level II), they're not released yet. These are "behavioral models" rather than Spice models, and we think they have several advantages over Spice models. There are some min/typ/max specifications that pretty much correspond to data sheet limits. If you use them wisely, they may be helpful—subject to the conditions I listed in the previous paragraph.

These models aren't free, though. They're not even cheap. But we think they're worth what you pay for them. Still, none of these models are guaranteed.

Why try to soft-pedal the truth and pretend you can trust computers all the time?

Now, seriously, where can you get a model of a transistor that's guaranteed? And to run under all conditions? I don't think you can beg or steal or borrow or buy a model of a transistor that's guaranteed. Or of a capacitor. The same holds true for a resistor.

But I can guarantee that every op amp you can buy or make has some characteristics that can't be absolutely modelled by any computer model. If you happen to depend on that feature, or the absence of that feature, it's only a matter of time before you get in trouble.

I don't think you can beg or steal or borrow a transistor model that's guaranteed.

I will also guarantee that just because you made one breadboard, and it works well, you can't put that circuit into production and get 1000 units in a row to work well. *Unless,* of course, you're a smart engineer and design the circuit "properly" and do your worst-case design studies, and plan for well-behaved frequency response, and so on. And I think that's true no matter where you buy your op amps. What's new? What color is the king's new underwear? Dirty gray, same as everybody else's.

I think there are a number of Electronic Design's readers out there who will want to comment on this topic. You may be dubious or skeptical of Spice models. You may be dubious or skeptical about my views. Your comments are invited. You may have experience with Spice or other macromodels. Good? Bad? You tell me, and I'll pass along your comments to the editors (we may have to allot a little extra space for the Letters-to-the-Editors column for a while). The guys who believe in Spice macromodels, whether they're somebody that buys or sells op amps, well, they're also invited to write in. I promise to faithfully pass all of the letters along (with appropriate comments on the side). But I think you can already tell how skeptical I am.

I was at an evening session at the IEEE Bipolar Circuits and Technology Meeting in Minneapolis recently. Several companies that sell CAD tools had done some serious work to analyze the circuit for a 12-bit a-d converter (ELECTRONIC DESIGN, *Oct. 25, p. 16).*

Even the ones that had only a little time to put in showed that macromodels were feasible and effective as a way to do good analysis while saving computing time. That was the primary objective of the study. But even the ones that put in the *most* time at analysis didn't recognize (or didn't comment about) that the noise of the reference and the comparator were rather large, and you could not achieve 12-bit resolution without slowing down the response a lot more than you would have to do otherwise (for a circuit where you didn't have to consider the effects of noise).

If a good designer of ADCs had these tools, and he knew where to look for noise, or where to insert lead inductance or extra substrate capacitances, he might use some of these CAD tools to help him design a better ADC. But if he just believed what the computer told him, he would probably be badly fooled.

Once, a customer called me up and asked me how to get my LM108s to stop oscillating in his circuit. He explained it was a simulated LM108 with some simulated feedback resistors, and simulated switches and filters. Hmmmm. I asked if he had made up a breadboard, and if it oscillated. He said he had made it and it didn't oscillate. Hmmmm. I asked him, "If you built up a breadboard and a computer model, and the real breadboard oscillated, but the computer did not, you wouldn't be calling up to complain, would you?" He stopped and thought about it. He cogitated for a while. He said "I'll call you back." And he hung up. He never did call back. I mean, what would *you* do?

All for now. / Comments invited!
(Now there's an understatement.) /
RAP / Robert A. Pease / Engineer

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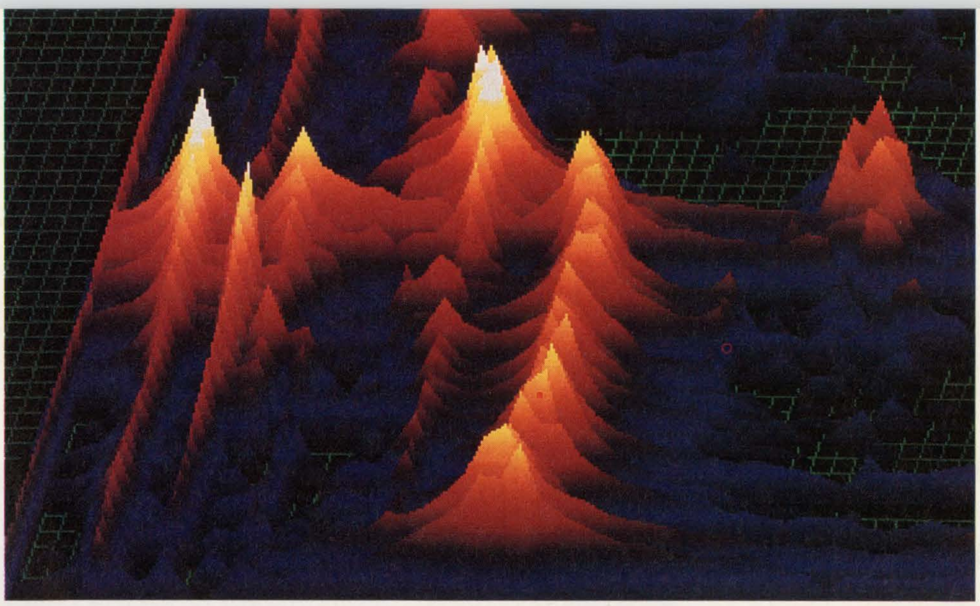

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CIRCLE 177

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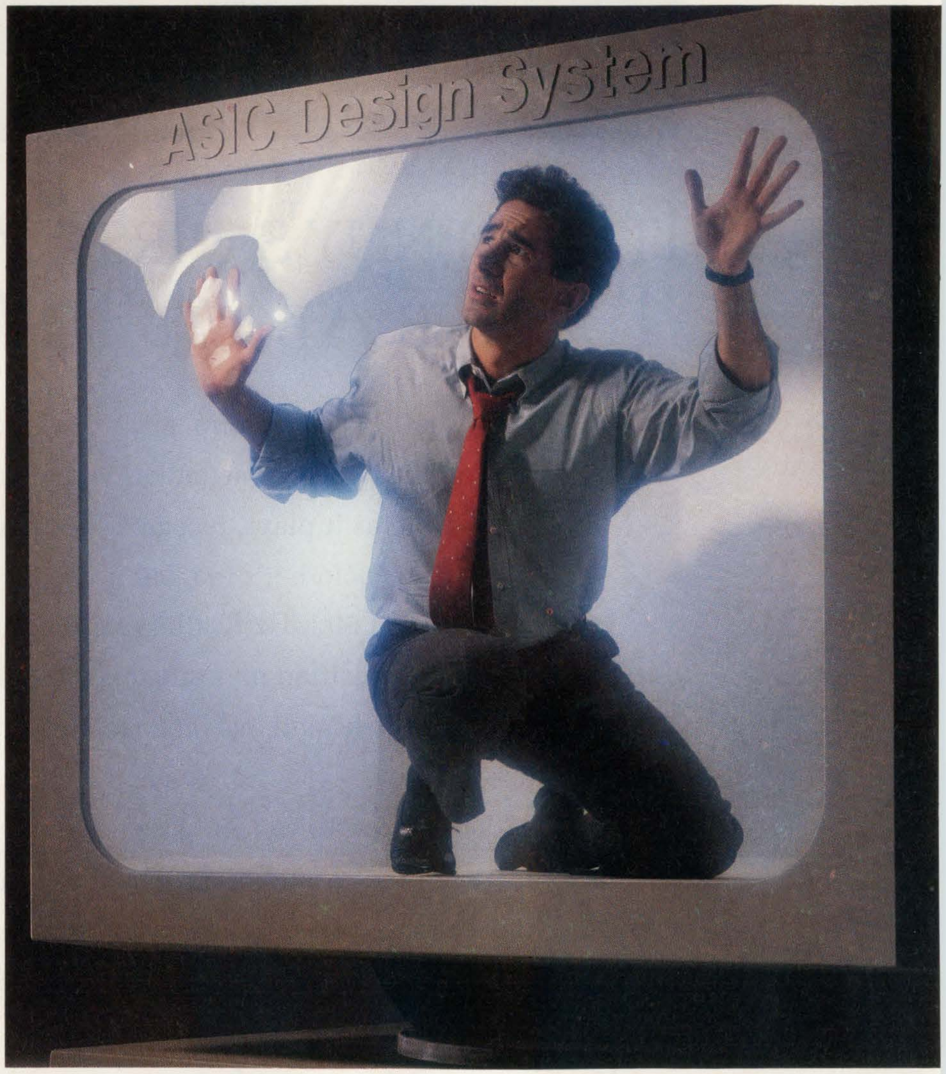

Oki ASIC Design Tool Support

Vendor	Platform	O.S. & Application
Cadence	Sun-4	Sun OS 4.0.1, Verilog 1.5C
DAZIX	LOGICIAN Sun 386i Sun-4	DNIX 5.03, Sun OS 4.0.1 Digital Application 6.1 Digital Application 6.3
Mentor Graphics	HP/Apollo DN3/4XXX	DOMAIN/OS 10.1 IDEA Series 7.0
Synopsys	Sun-4 **Interface to Mentor, Valid, Viewlogic*	Sun OS 4.03
Valid	Sun-4 Sun-3	Sun OS 4.0.1 GED, ValidSIM, RapidSIM
	DEC Station 3100	ULTRIX, ValidSIM, GED
Viewlogic	Sun-4	Sun OS 4.0.3 Workview 4.0
	PC386	DOS 3.3, Workview 4.0

Design Kits are available for 1.2μm gate arrays and standard cells and for 1.0μm and 0.8μm sea-of-gates.

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CIRCLE 156

A SPECIAL EDITORIAL FEATURE

PIPS

POWER • INTERCONNECTIONS • PASSIVES • SWITCHES • RELAYS

ELECTRONIC DESIGN

- DESIGNING PHONE-INTERFACE CIRCUITS WITH SOLID-STATE RELAYS
- A LOOK AT PHOTOVOLTAIC RELAYS IN MULTIPLEXING APPLICATIONS
- MANUFACTURER'S LISTINGS
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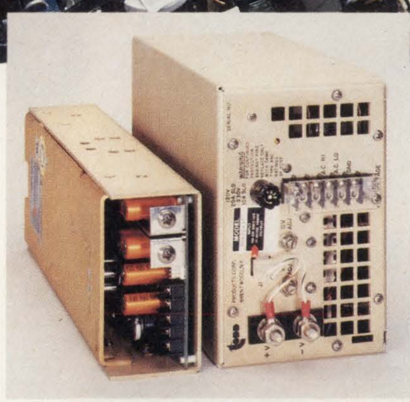


Designed for high-end computer products, TODD's MAX-750 combines a compact size, 13.5" x 5" x 2.6" compared to the typical 5" x 8" x 11" shoebox switcher (see photo insert), and very competitive pricing. OEM product designers can reduce product size with a MAX-750 or build in power supply redundancy, replacing one "shoebox" switcher with two MAX-750's in the same space.

The small package size, high power density of 4 watts/in., high peak current for motor starting, and cooling options, make the MAX-750 the power supply of choice for VMEbus systems, workstations, file servers and mini-computer systems. The switcher provides 120 amps of +5 volts for logic and memory, and features up to three auxiliary outputs providing high efficiency, tightly regulated 12 volts or −5.2 volts at up to 20 amps. Designed for world wide use, the series offers AC power fail, AC autoline select, and meets International Safety standards and Class A RFI requirements of FCC and VDE 0871.

Call 1-800-223-TODD, or Circle #171

High Efficiency DC Converters Fit AC To DC Footprint

TODD's DC to DC converters provide up to 350 watts from 48 volts DC input. Designed as companion units to TODD's standard line of AC input power supplies, they are fit, form, and function compatible with the MAX-350, MTC-250, MTC-350, and certain single output SC series products.

Available in a 250 watt "DC" single output series and a 350 watt multi output "DCX" series these power supplies have up to 50 amp main output of tightly regulated 5V power, two fully regulated, high-efficiency, post-regulated mag-amp outputs and one low-power three-terminal regulated output.

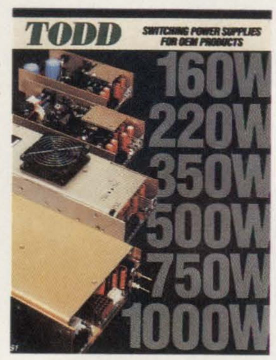
Call 1-800-223-TODD, or Circle #172

New Technology Shrinks 500 Watt Power Supply

TODD's MAX-500 switchers pack 25% more power into TODD's 400 watt package size (11.5" x 5" x 2.5"). The series incorporates a new SMT circuit, newly-available components, improvements to TODD's VERI-DRIVE current-fed inverter topology, monocoque construction, and a high efficiency FLUX-GATE switching mag-amp auxiliary post regulation. Result: higher performance, higher reliability (approaching 100,000 hours MTBF) and lower cost.

Call 1-800-223-TODD, or Circle #173

New Products Featured In 1991 TODD Catalog



TODD has just released its 1991 switching power supply catalog of over 100 standard switching power supplies ranging from 150 to 1000 watts, including several new products. Available in single and multiple outputs, ac to dc and dc to dc, these switchers meet a broad range of requirements for telecom, computers, industrial controls and medical electronics applications.

The catalog also provides details on TODD's approach to quality and innovative manufacturing, and capabilities for producing modified, repackaged and fully custom switching power supplies.

Call 1-800-223-TODD, or Circle #174

More information on these and the full line of TODD Switching Power Supplies can be obtained in EEM File 4000, by circling the response card numbers, or by contacting:

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Designing Telephone-Interface Circuitry With Solid-State Relays

Going solid state can be easier, but design concerns still loom as any of several parameters could trip up applications.

BY RANDY HAFER

AT&T Microelectronics, 2525 N. 12th St., Reading, PA 19612; (215) 939-3345.

As modems, facsimile machines, automatic telephone dialers, and answering machines inundate mainstream data-processing environments, switching and telephone-loop-test equipment become more complex. As a result, more engineers are designing electrical components and interface circuitry for use in the Public Switched Telephone Network (PSTN) environment.

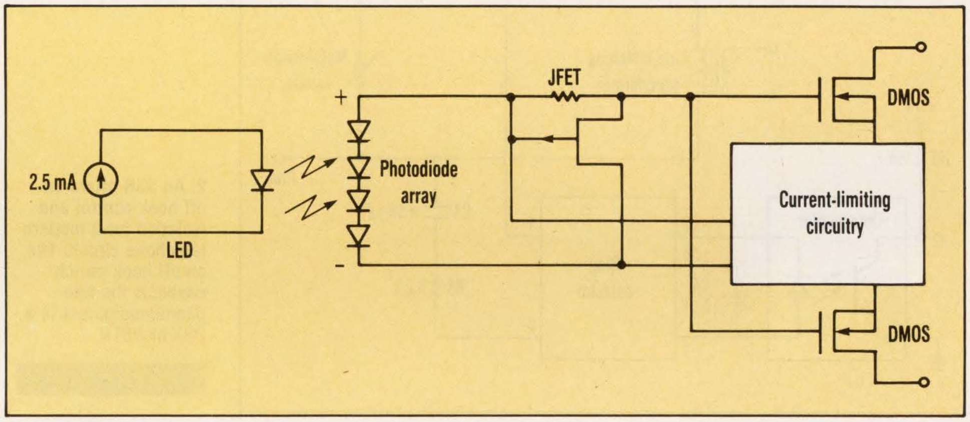
Many harsh challenges evolve from this type of environment, including a typical battery voltage of 48 V, and ac ringing signals that peak at greater than 100 V. In addition, ac inductions from power lines can be in the hundreds of volts, and voltage-induced transients from lightning may run 1000 V or more. To further complicate matters, equipment designed for this network must meet specifications drafted by a battery of regulatory agencies.

To create interface circuitry that can satisfy this environment, many designers are turning to optically coupled MOSFET solid-state relays, or SSRs *(see the table)*. Designing with SSRs is much simpler than designing with electromechanical relays. Besides requiring relay drivers and electromotive-force diodes, electromechanical relays present various problems, including contact bounce, arcing, and acoustic noise. In addition, they typically generate electromagnetic or radio-frequency interference. There also may be mounting considerations to address.

Solid-state relays, meanwhile, pose no such difficulties. The relays reduce the interface circuitry's component count and assembly costs. Their small size saves board space, and SSRs can match or exceed the performance specifications of electromechanical relays. They also last longer than electromechanical relays, increasing the number of operations that can be performed by a factor of a hundred or more.

The "solid-state" designation for an SSR refers to the fact that no mechanical poles and contacts are present, as in an electromechanical relay. In an SSR, the switching element consists of solid-state components. While SSRs are a bit more expensive than mechanical relays, their dependability suits them well for use in telephone-interface circuitry.

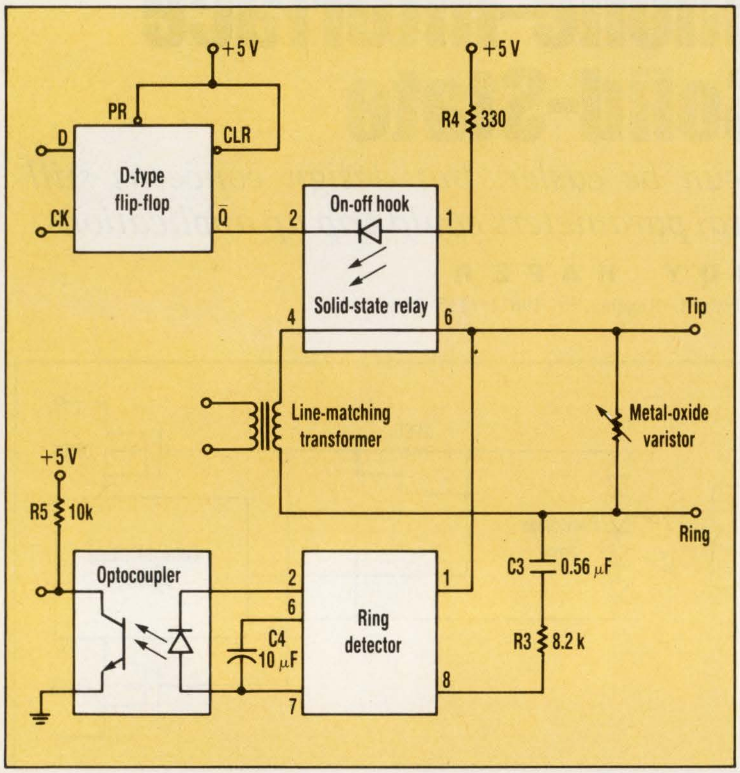
On top of these advantages, SSRs can be surface mounted, and they perform a smooth, "click-free" actuation. The SSRs' MOSFET output is extremely linear and can reliably switch both resistive and inductive loads with voltages ranging from millivolts to hundreds of volts. Furthermore, SSRs can be driven directly from logic



1. The receptor and switch circuitry for a standard, optically coupled MOSFET relay consists of a photodiode array, a JFET, and two MOSFET switches for ac-dc control.

Relay Types

Relay Type	Input	Actuation coupling	Typical isolation (V rms)	Contact type
Electromagnetic	Coil	Electromagnetic	1000 to 5000	Metallic ac/dc
Reed	Coil	Electromagnetic	500	Metallic ac/dc
Solid-state	Transformer LED	Transformer optical	1000 1500 to 4000	Solid-state ac or dc
Mosfet SSR	LED	Optical	1500 to 3750	Solid-state ac/dc
Monolithic	CMOS	Capacitive	500	Solid-state ac/dc



2. An SSR offers on-off hook control and isolation for a modern telephone circuit. The on-off hook switch connects the telephone equipment to a PBX or PSTN.

gates—virtually any logic gate can sink enough current to control the input LED of the SSR.

SSRs are also ideal for test and maintenance equipment, and for PBX and central-office switching. In these environments, longitudinal (differential) and metallic (common-mode) surges still prevail. But because the equipment is referenced to ground, the high-isolation requirements of terminal equipment don't apply.

For these ground-referenced applications, monolithic relays powered by battery or system power can be used. In telephone-interface-station applications, optically coupled MOSFET solid-state relays are the best solution.

Standard, optically coupled MOSFET SSRs consist of an LED for input control, a photodiode array for MOSFET gate drive, and a JFET for gate discharge *(Fig. 1)*. The switch element consists of two source-connected MOSFETs. If two MOSFETs are used in series, the result is a linear, bidirectional, ac-dc switch.

The gallium arsenide LED input is analogous to the coil in an electromechanical relay. When a small forward current is applied to the GaAs LED's input, it emits light that passes through an optical bubble or a translucent mold compound to a photodiode array.

The photodiode array, which is the heart of the relay, acts as a power source for the MOSFET switches. MOSFETs typically require at least 5 V of gate drive for full turn-on (4 V for a full turn-off in a depletion-mode MOSFET).

To guarantee 5 V of photodiode output under high-temperature operation (the self-heating characteristics of MOSFET operation are also a factor), photodiode arrays are typically designed to supply greater than 10 V during room-temperature operation.

Photodiodes are constructed in individual, dielectrically isolated tubs and then stacked to obtain this voltage. Typically, an array consists of 20 to 30 photodiodes.

In a Form A (normally open) relay, enhancement-mode MOSFETs are used, and the drive voltage turns the relay on. In contrast, a Form B (normally closed) relay uses depletion-mode MOSFETs, and the drive voltage turns the relay off. The JFET placed between the gate and source of the MOSFETs quickly discharges the gate capacitance, which serves to turn the relay off.

Selecting an SSR involves a number of design considerations. With regard to input, a small LED forward current is required to turn the relay on (or turn a normally closed relay off). This current typically ranges from 1 to 10 mA, depending on the relay, the load current, and the ambient temperature. Turn-on current is usually supplied by sinking a logic gate's output to the cathode of the LED and tying the LED's anode high through a pull-up resistor.

When the logic gate turns the relay off, the high-level output voltage must be enough to reduce current flow through the LED below its turn-off current or drop-out voltage specification. Most SSRs allow some amount of trickle current through the LED in their off state.

The input-to-output isolation voltage that's required in the design is mandated by the various regulatory organizations. Input-to-output SSR capacitance ranges from 1 to 3 pF. This capacitance isn't a concern in telephone-line-interface applications. Switching speeds are generally less than 2 ms, depending on the volt-amps switched. For these applications, this speed is more than adequate.

When turned on, the SSR's resistance contributes to the total telephone-loop impedance, and must be considered in the design. On-resistances from 20 to 50 Ω are acceptable and are available in MOSFET SSRs.

The load-voltage rating must

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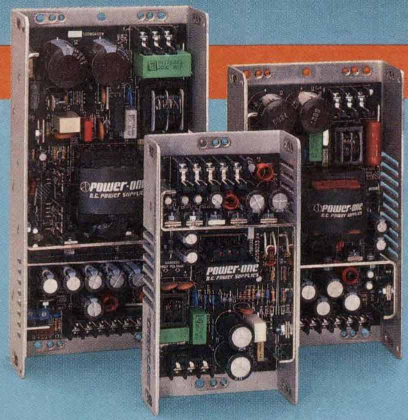

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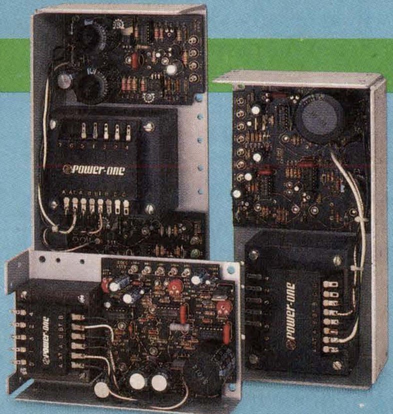

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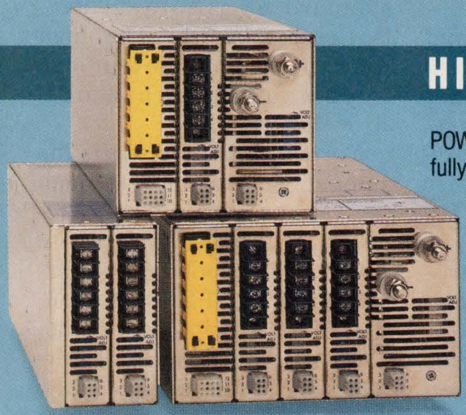

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be greater than the highest anticipated line voltage, which for design purposes is usually the worst-case lightning voltage. To properly select an SSR, the overvoltage-protection device must be considered.

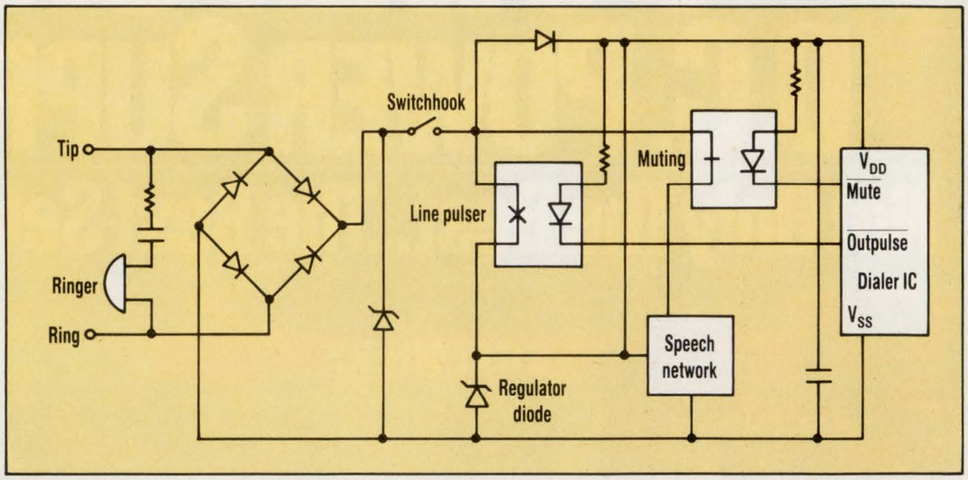
The dc bias, ring, and test voltages should be used to develop the highest anticipated line voltage. Then a protection device should be selected that exhibits a breakover voltage above this value. Once the protection device is determined, a solid-state-relay load voltage can be established from the overshoot-voltage value of the protection device.

Switch capacitance is a function of the applied voltage, and will generally vary from 5 to 60 pF. For the most part, the capacitance is of concern when the switch is turned off. However, the battery bias minimizes the switch capacitance when the switch is off. The capacitance typically isn't an issue in PSTN applications.

SSRs exhibit a knee current, which is created when the current flow through the relay is enough to forward bias the integral diode in the reverse-biased MOSFET. Remember that two source-connected MOSFETs are connected in series to supply ac-dc switch operation. The knee current identifies a lowering of the on-resistance when the diode conducts. This characteristic of MOSFET transistors reduces SSR power dissipation during high-current operation. Typical loop-operating currents usually fall below the knee-current value.

When designing with SSRs, it's also important to use an overvoltage-protection device to protect the SSR from potential lightning damage. Small, inexpensive protection devices that do the job include metal-oxide varistors, solid-state protectors, and small gas-discharge tubes.

For overshoot protection, a metal-oxide varistor is the most common solution. Metal-oxide varistors act as a Zener diode, but they dissipate considerably more energy. Under typical operating line voltage, the standby current is tolerable, but the "Zener" voltage under high-current surges can cause significant overshoot. The specifications of most metal-oxide varistors include current-voltage graphs with curves that show maximum clamping voltage versus surge current for the operating-temperature range.



3. SSRs can be used in telephones or answering machines for dial pulsing and speech muting. A Form A relay performs outpulsing; a Form B performs muting.

Metal-oxide varistors and gas-discharge tubes typically exhibit over 100 V of overshoot for a specific lightning surge. Though they're more expensive, solid-state protectors produce far less overshoot, usually between 5 and 30 V.

Unlike the metal-oxide varistor, the solid-state protectors and gas-discharge tubes also exhibit a crowbar characteristic that will shunt all transient energy around the device. These devices are used in switching systems where high reliability is a major concern within a design.

The SSR's load voltage must be higher than that of the protection device's overshoot for a worst-case surge current. Most SSRs used in telephone-line interfaces are rated for 350 to 400 V, which is enough for most applications. When metal-oxide varistors are used for Class A ringing, which occurs at a maximum of 130 V rms, an SSR load voltage rating of 350 V is adequate. Although rare, Class B ringing, which occurs at a maximum of 150 V rms, requires a solid-state relay with a load voltage of 400 V.

SSRs are also susceptible to damage from overcurrent stresses. One possible solution to this problem is current limiting. Without current limiting, as when metal-oxide varistors are used, a lightning strike will force standard SSRs into an avalanche breakdown. The high transient current from lightning may generate enough heat to destroy the switch.

Current limiting restricts the amount of current flow through the relay. Current flow is reduced using either emitter-base resistors and bipolar transistors or a small MOSFET sense transistor. The circuitry provides an alternate path that bleeds current from the photodiode array. That lowers the MOSFET gate voltage, which puts the MOSFET into saturation to increase its resistance during turn-on. The relay circuitry will clamp high-current transients and minimize power dissipation, enabling it to survive more severe transients and pass more stringent regulatory-agency requirements.

The relay's current-limiting circuitry is designed with a negative temperature coefficient,

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which minimizes the relay's power dissipation by decreasing the current through the relay when the voltage across it rises as a result of increased resistance.

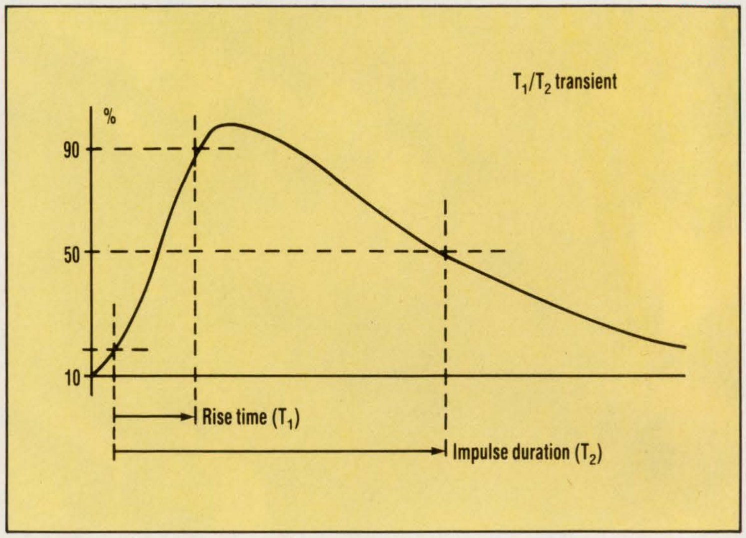
The current-limit value will decrease as temperature increases, or as electrical self-heating occurs, creating a current-foldback condition. Current limiting is set at a value that's high enough relative to the relay's maximum operating current so that it won't interfere with circuit operation at room temperature.

A number of concerns must be addressed when designing with solid-state relays on telephone loops. These include designing the interface circuit itself, and the behavior of solid-state relays under the fault considerations specified by the various regulatory agencies.

The interface circuit consists of a ring detector, an on-off hook control, isolation, and surge protection. Because they offer isolation and can easily and inexpensively protect against surges, optically coupled MOSFET relays are ideal as an on-off hook switch.

A typical line interface for a modem or fax machine includes a Form A SSR for the on-off hook control *(Fig. 2)*. The on-off hook switch connects the telephone equipment to a PBX or to the PSTN. The switch is driven by a simple logic gate and by 5 V. The SSR supplies high-voltage isolation between the telephone loop and the internal modem circuitry. The metal-oxide varistor limits the tip-to-ring voltage to a value below the load voltage of the SSR.

In a typical line interface for a telephone, SSRs are used for dial pulsing and speech-network muting *(Fig. 3)*. A Form A SSR handles the outpulsing capability. Form B (normally closed) solid-state relay provides the muting function. Because a normally closed relay is used for muting, power is only required when outpulsing occurs.



4. A double exponential, unipolar impulse wave is used to execute metallic and longitudinal surge tests on telephone equipment.

There are many specifications concerning transient voltages on a telephone loop, and a number of organizations that specify requirements for telephone-line interfaces. The specifications revolve around longitudinal and metallic stresses. The organizations include FCC, CSA, CCITT, REA, Bellcore, Underwriters' Laboratories, BABT, and VDE, among others.

Longitudinal voltages exercise the input-to-output isolation of the relay. Metallic voltages, on the other hand, stress the relay's switch when the relay is on, as in the case of an off-hook condition.

The Federal Communications Commission and Canadian (CSA) requirements are standards for telephone equipment connected to the PSTN. The CCITT, REA, and Bellcore requirements are standards for telephone-switching equipment. Underwriters' Laboratories, BABT, and VDE are organizations specifying safety requirements for telephone-interface equipment. In the U.S., the specification that's most commonly referred to for telephone equipment is known to designers as FCC 68.302.

FCC 68.302 requires that metallic and longitudinal surges, vibration and shock, and temperature and humidity tests be performed on telephone equipment. The metallic surges applied to the telephone-line interface are 800-V, 10×560-μs pulses; the longitudinal surges are 1500-V, 10×160-μs pulses. A 10×560 μs pulse refers to a double-exponential unipolar impulse wave that rises to full rated voltage in 10 μs and decays to half of the rated voltage in 560 μs *(Fig. 4)*.

SSRs can handle this testing. They're oblivious to the shock and vibration requirements, and like any IC, are resilient when it comes to temperature and humidity stresses.

The longitudinal requirements are essentially a stress test of the relay's I/O-isolation voltage. Most SSRs are 100% tested for isolation voltage. Isolation-voltage protection ratings are available at several levels, depending on the package. The most common rating figures are 1500 V rms, 2500 V rms, and 3750 V rms.

The metallic tests measure the effectiveness of the metal-oxide varistor, solid-state protector, or gas-discharge tube used to protect the telephone-line-interface circuitry. The overvoltage protector also serves as a shunt during the metallic-testing application.

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the metallic tests differs from manufacturer to manufacturer. During an off-hook metallic surge, SSRs can be subjected to huge surge currents that are well beyond the value of the continuously rated current, or even the peak-pulse current, depending on the value of load and stress impedance. Most relays rely on their avalanche-breakdown characteristics to survive these stresses.

The AT&T current-limiting feature for Form A devices responds to a metallic-test impulse wave by shutting off the relay because too much current is flowing. About 1 to 2 ms after the wave decays below half power, the relay will turn back on.

The relay continues to supply current limiting until the wave decays. With current limiting, the relay stays within its rated-current specification, and can survive the most stringent specification regardless of load or series impedance.

UL 1459 50A specifies the voltages that can be present on telephone lines from power-line cross inductions. It spells out both longitudinal and metallic power-line inductions, requiring that 600 V rms be applied to telephone lines with various source impedances for different periods of time. Typically, this specification requires designers to add a fuse to open the circuit during a power-line induction.

The Underwriters' Laboratories specification goes further, however, stating that if voltage-limiting devices are used, a voltage just below their rated value can be applied to the equipment. If current-interrupting devices are used, a current can be applied just below the current value at which the current-interrupting device trips. These conditions can be applied for better than 30 minutes.

Once again, the longitudinal requirement is essentially a test of the relay's isolation voltage. To pass the metallic requirement, a fuse must be used to open the circuit under high-current stress conditions. As long as there's no risk of fire or electrical shock, the relay is allowed to fail.

To satisfy the "slow-cook" lower-current requirement, the SSR and protector must handle a current just below the fuse's interrupt current. The fuse and protector can be used separately, or a UL-approved module containing the two functions can be employed.

The module's advantage is an interaction feature between the fuse and the protector. As the protector heats up from the slow-cook applications, it's close enough to the fuse to open it thermally.

When designing with SSRs, it's important to use an overvoltage-protection device to protect the relay from potential lightning damage.

To satisfy the lower-voltage requirement, the SSR must withstand the voltage just below the protector's breakover voltage. A standard SSR should handle the resultant current pulse generated by this voltage until the fuse reacts.

When a current-limited SSR is subjected to this condition, it begins to prohibit current flow, which in turn prevents fuse operation. Current-limited relays exhibit a negative temperature coefficient for the LED light output, the photodiode-array current output, and on the current-limit circuitry itself. Typically, the relay will stabilize at a current below 10 mA, reducing power dissipation to reasonable levels for a fault condition.

Randy Hafer, applications engineer for solid-state-relay products at AT&T, spent six years at IBM in electrical engineering and eight years at AT&T Bell Laboratories in device design.

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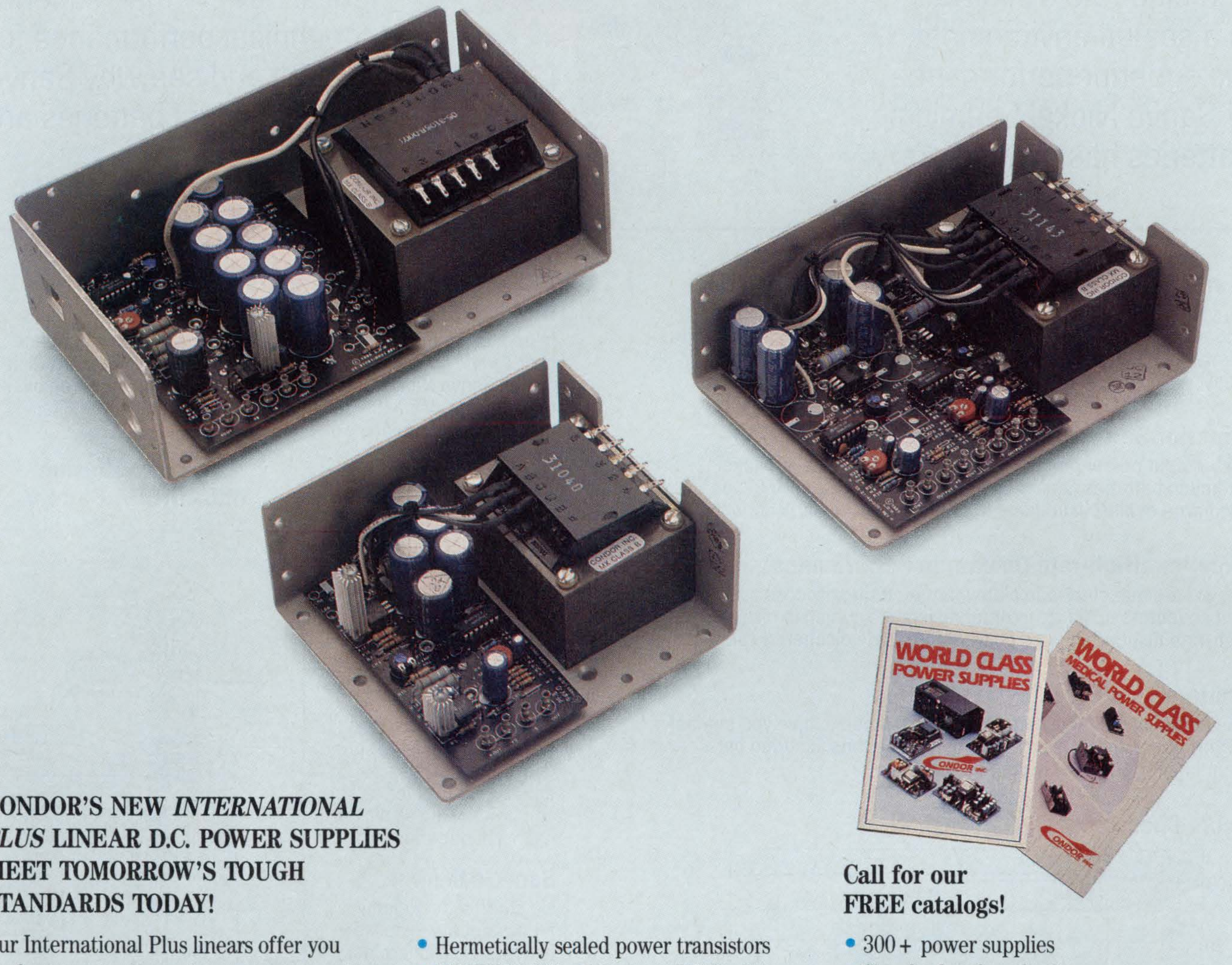

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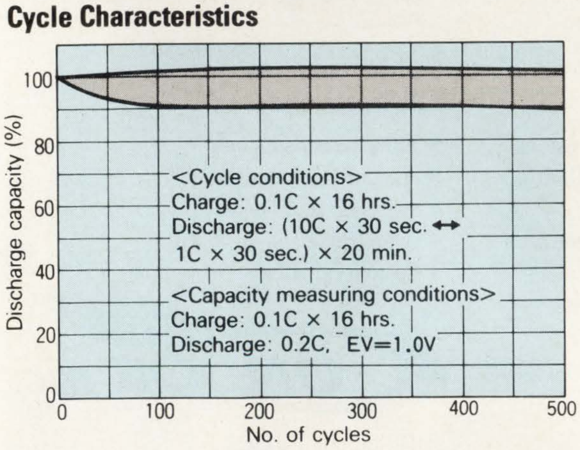

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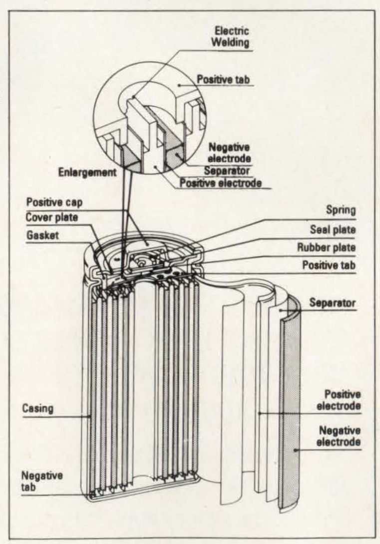

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POWERING THE WORLD

For Multiplexing Applications, Photovoltaic Relays Fill The Bill Handily

A look at relay characteristics can help with design decisions.

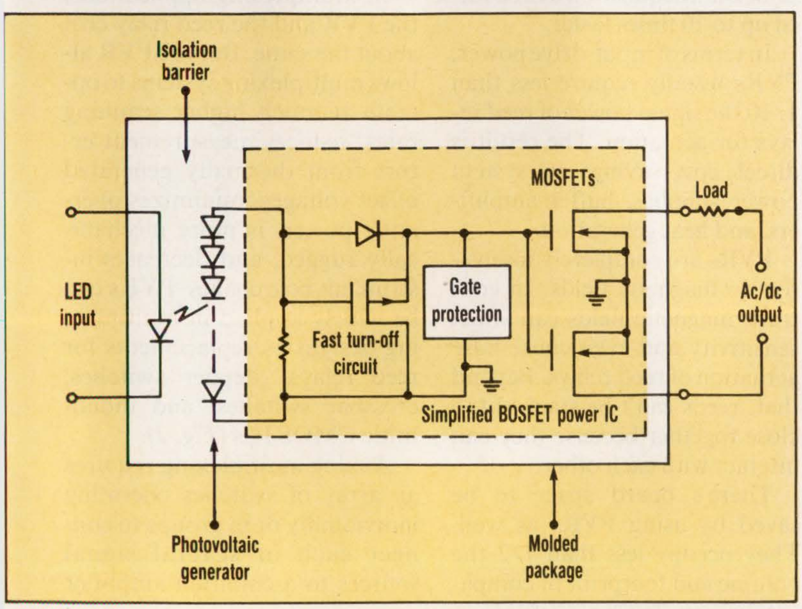
BY SHAWN FOGARTY JR.
International Rectifier Corp., Electronic Products Div., 247 Kansas St., El Segundo, CA 90245; (213) 607-8877.

The photovoltaic relay (PVR) boasts a combination of circuit elements resulting in operational characteristics not found in either electromechanical relays or thyristor-based, solid-state relays. The multivolt photovoltaic generator contained in the relay flaunts a very low output current. It's naturally compatible with the voltage-controlled input requirements of a modern power MOSFET.

Within the PVR, which is a class of solid-state relays (SSRs), there's a power-MOSFET output stage, a photovoltaic generator to drive the MOSFET gate, and an LED to achieve input optical isolation *(Fig. 1)*. The PVR brings the advantages of solid state to applications that were served only by signal-level electromechanical relays.

Versatile in its scope, the PVR switches direct current of either polarity and alternating current from power frequencies through the radio-frequency range. It accepts voltage levels from under a millivolt to ±300 V; switching rates up to several kilohertz are possible. Control requires only a few milliwatts and input-to-output isolation is in thousands of volts.

The historic design challenge in making a practical PVR was implementing it in a compact and economical manner. A discrete-component approach can't achieve either the miniaturization or cost that allow the PVR to be directly competitive with electromechanical relays. Hybrid circuit techniques, which place MOSFETs and other chips on a leadframe, are an intermediate step. But realizing a truly competitive PVR has meant innovative semiconductor processing, packaging, and advanced power-IC techniques.



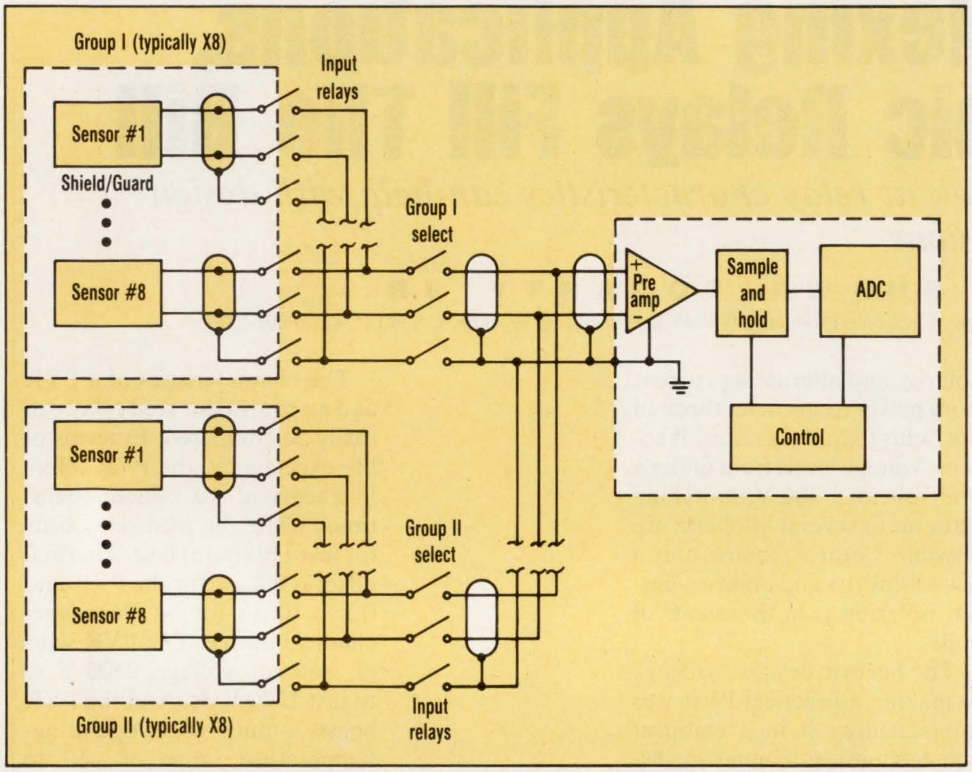
1. The photovoltaic relay contains an LED input, optical isolation barrier, photovoltaic generator to drive the MOSFET gate, and a power-MOSFET output stage.

The characteristics of a PVR and an equivalent reed relay can easily be compared. In terms of life expectancy, the PVR offers in excess of 10 billion operations, while the reed relay lasts for just 1 billion at best. Thermal offset is 0.2 μV for the PVR and 0.5 to 10 μV for the electromechanical device. The PVR wins on isolation voltage, 2500 V ac to just 1500 V dc. And the PVR boasts a much wider operating-temperature range of –40 to +85°C, compared with –20 to +70°C for the reed relay.

Typical turn-on current for a PVR with a 20-mA load is 2 mA. This value increases when switching a larger load. Note that the higher the load current, the more current is needed to operate the PVR. But for low-level usage, the PVR is considerably more sensitive than the typical reed relay. In addition, the operating power for the PVR is only a few milliwatts in contrast with the 50 to 100 mW for a reed relay.

Response time for a PVR (for example, International Rectifier's PVA3054) is 25 μs maximum when energized with 8 mA and switching a 50-mA, 100-V dc load. Special speed-up circuits can decrease this operating time dramatically. The PVR will turn off in less than 50 μs. For a reed relay, typical response time at nominal operating power is 1 ms maximum, and corresponding release times are in the 100-to-200-μs range.

A PVR's operating-voltage range is from –300 to +300 V. Typical miniature reed relays, on the other hand, can stand-off



250 V from contact to contact. The maximum switching voltage, however, is considerably below the rated peak stand-off voltage. Most reed relays live longest when switching 12 V and less.

The PVR's on-state resistance is considerably higher, however, than that of the reed relay. But in many applications, it's of little consequence. Most process-control, multiplexing, and ATE applications involve high input impedance. The PVR's on-state resistance stays constant over the device's extremely long life. In contrast, the contact resistance of many types of reed relays varies considerably over the relay's life because of contact deterioration. Typically, the contact resistance of a reed relay rises by an order of magnitude over its lifetime.

More reliable circuits are possible because of the PVR's many solid-state advantages. In addition, by capitalizing on the relay's features, innovative designers can create smaller systems.

As shown in the above comparison, a PVR lasts more than 10 times the number of operations of reed relays. Also, in the closed state, PVRs generate thermal voltages that are typically 1/5 the level of specifically designed, expensive "low-thermal" reed relays. This directly improves the accuracy of thermocouple and similar low-level measuring systems. On top of that, PVRs can operate in less than 1/10 the time of reed relays. Data acquisition can be rated up to 10 times faster.

2. Photovoltaic relays find many applications in multiplexing circuits. In this schematic of a low-level differential multiplexer, three switch poles per channel link the signal and shield or guard to the measurement system.

In terms of input-drive power, PVRs usually require less than 1/10 the signal power of reed relays for actuation. The result is direct cost savings in system power supplies, buffer amplifiers, and heat generation.

PVRs are completely insensitive to magnetic fields. In contrast, magnetic fields can affect sensitivity and even cause false actuation of reed relays. Beyond that, reeds can't be stacked too close together because they can interact with each other.

There's board space to be saved by using PVRs as well. They occupy less than 1/2 the volume and footprint of comparable reed relays, which can save lots of space when large relay arrays are required.

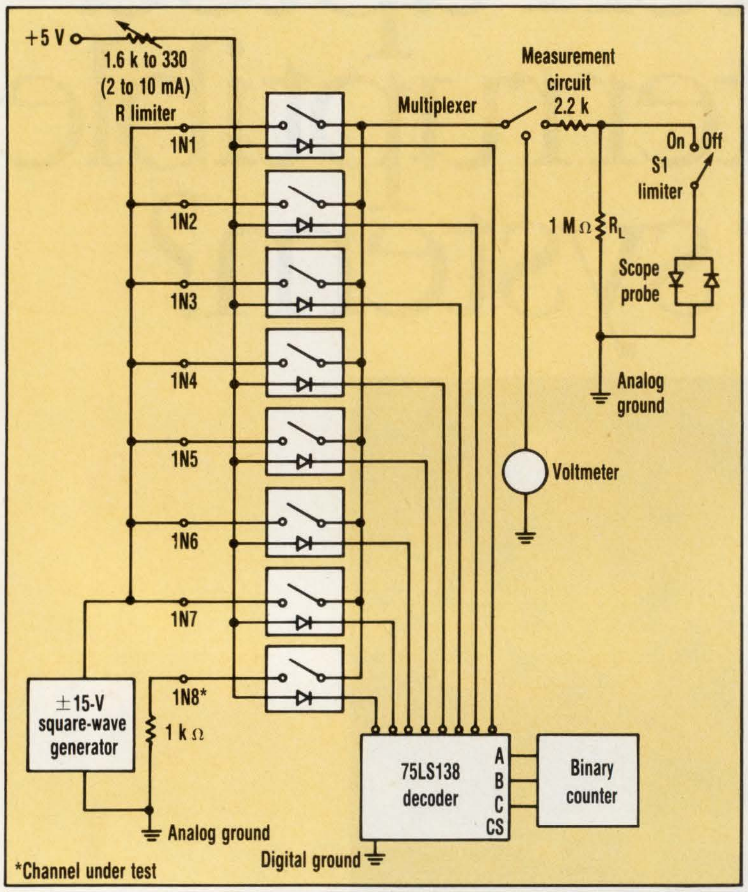
Another advantage is that PVRs require no coil diode. Because the LED input is non-inductive, a diode is never needed to suppress the inductive "kick" that can destroy a transistor driving a reed coil. Also, PVRs close fast and clean and don't bounce or arc, a problem that would induce system noise.

Finally, a PVR withstands a direct short of its load under many load conditions. Regardless of whether the short circuit occurs while the PVR is on, or if the PVR is turned on into a short circuit, the result is the same. The PVR limits the current to about 20 mA in spite of being directly connected across a 60-V line. Chance misconnections or load failures won't damage the circuit, nor will a fuse need replacing. Shortly after relieving the fault, the circuit will once again function properly.

Though modern instrumentation systems have been designed almost entirely with solid-state components, analog multiplexer inputs have opposed this trend. Until recently, the critical performance characteristics of these switches could be met only by traditional electromechanical relays.

In multiplexing applications, the PVR and the reed relay cost about the same. But the PVR allows multiplexing systems to operate at much higher scanning rates, reduces measurement errors from thermally generated offset voltages, minimizes operating power, is more mechanically rugged, and decreases instrument board sizes. PVRs can be widely applied in multiplexing designs as replacements for reed relays, stepper switches, crossbar switches, and monolithic CMOS ICs *(Fig. 2)*.

Analog multiplexing requires an array of switches operating individually or in groups to connect each of several signal sources to a common amplifier

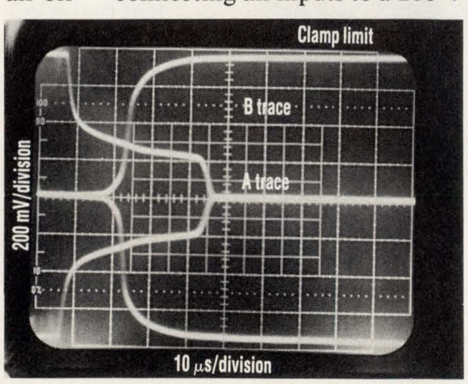


3. In an eight-channel multiplexer test circuit, leakage current is shown to be an important PVR characteristic. A voltmeter placed between an input and analog ground displays the leakage current as the voltage drop across the meter's 10-MΩ input impedance.

or measurement system. If the system's channels are selected in sequential order, the device is called a scanner. A system that can select in random order is called a multiplexer.

Many important performance characteristics can be shown in the example of an eight-channel, single-ended multiplexer that uses the PVA3354 from International Rectifier as the switching element *(Fig. 3)*. Major characteristics of the PVA3354 include an input current of 5 mA, an off-state leakage of 0.024 μA at 240 V, turn-on time of 0.1 ms, and isolation voltage of 2500 V ac. Other specifications include blocking voltage of 300 V and an output-current rating at a 10-mA input of 130 mA at 40°C.

Leakage current, the current that flows across a PVR in the off state, is an important PVR parameter. The ideal relay is an open circuit under these conditions. In a multiplexing system, the leakage through individual switches can be observed by turning off the logic-drive power and connecting a 200-V supply to the multiplexer common. A voltmeter with a 10-MΩ input impedance connected between an input and analog ground will show the leakage current as the voltage drop across the 10-MΩ input impedance. Inversely, connecting all inputs to a 200-V signal and measuring the output on the multiplexer common yields the leakage through all eight switches. Typical measurement with this method shows about 2 nA, or an average off-resistance of 10^{11} Ω per channel.

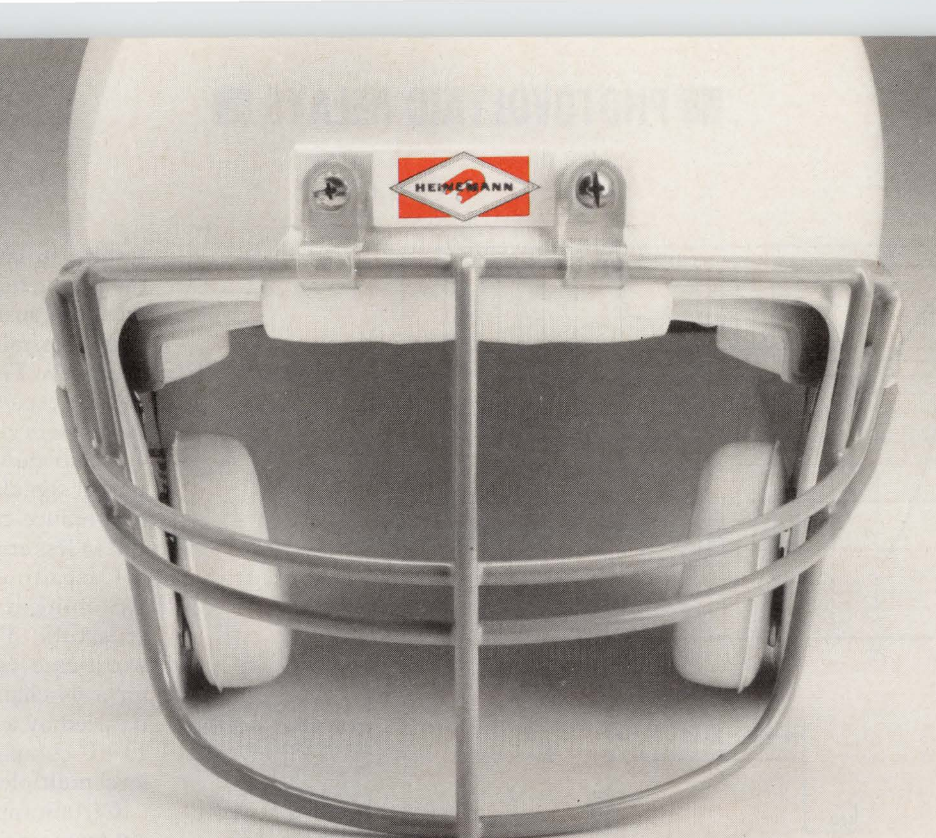


4. In oscilloscope photos of turn-on and turn-off for the channel under test, the "A" traces show settling to zero volts. The "B" traces show turn-off with the next channel's selection.

With logic power applied, a binary counter and decoder sequentially scan all eight channels. A delay isn't needed between successive addresses because of the break-before-make operation of the PVR. The channel under test is connected to a 1-kΩ, zero-volt source. The seven remaining inputs are tied to the output of a 30-V pk-pk square-wave generator to demonstrate the effects of crosstalk and settling after extreme preconditions on the first channel. By adjusting the control current-limiting resistor, the effect of the varying control current on the switching speed is apparent. Using a square wave also shows the effects of crosstalk as a disturbance of the settled zero-voltage signal.

In superimposed oscilloscope photos of the channel under test's turn-on and turn-off, the pair of "A" traces display the settling of the channel under test to zero volts *(Fig. 4)*. The "B" traces show the turn-off with the selection of the next channel. At turn-on, a short delay occurs before the last channel used is disconnected from the multiplexer common. The multiplexer slowly drifts toward zero until the channel under test begins to turn on, when rapid settling occurs. At turn-off, a short delay is experienced but the multiplexer common doesn't appear to move until the next channel begins to turn on. Full transition occurs in less than 50 μs. The traces are taken with the diode clamp circuit connected to prevent overloading of the oscilloscope input *(Fig. 4, again)*.

Switching speed depends heavily on control currents *(Figs. 5a and 5b)*. Speeds that are an order of magnitude higher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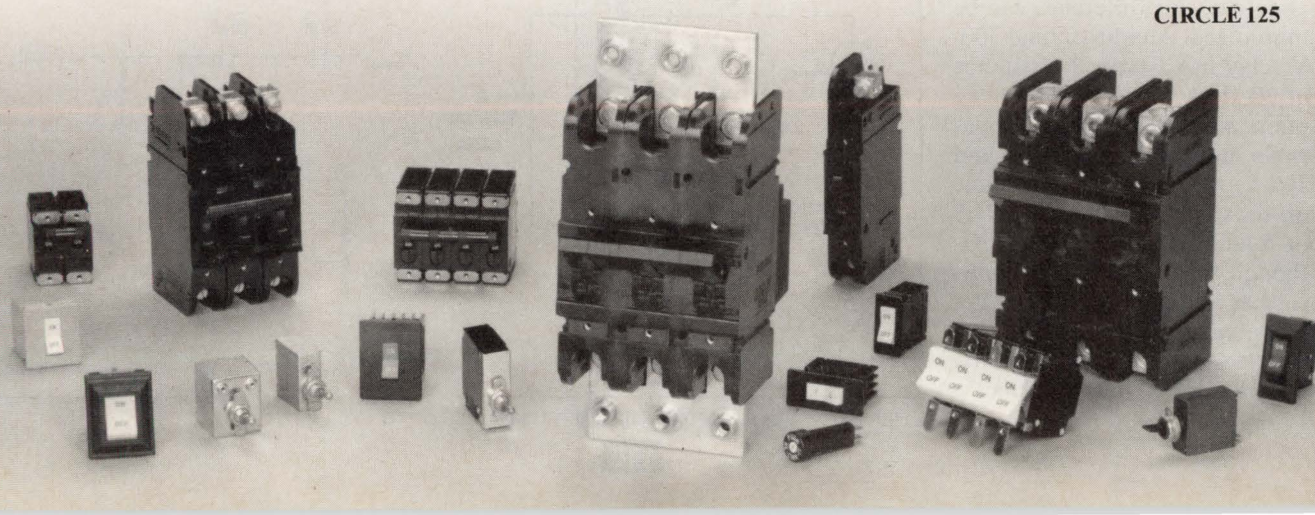
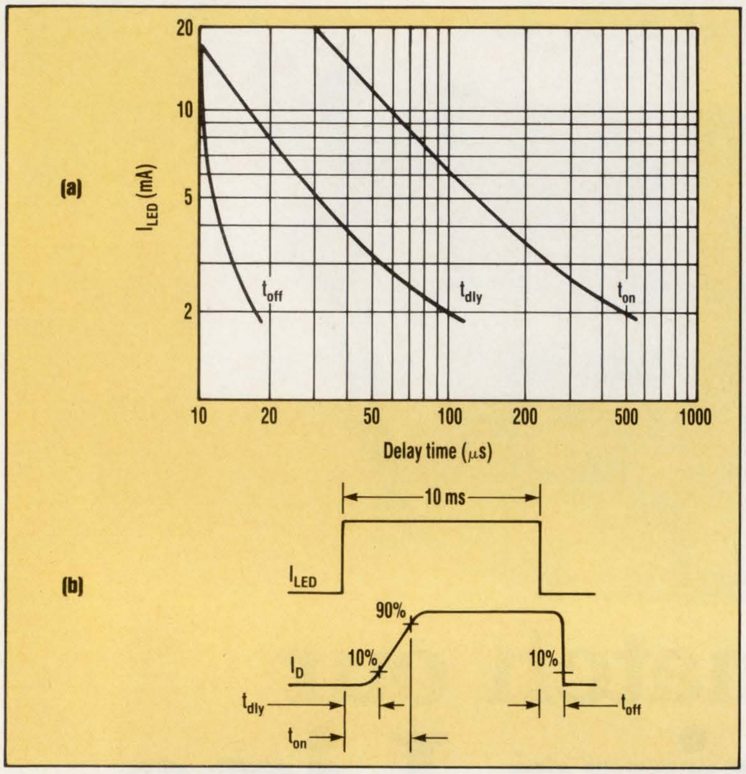




5. Control currents directly affect switching speed. Charging can be quickened by applying more control current, or by adding an R-C circuit to speed charging while keeping steady-state current nominal (a). Delay-time definitions are given (b).

than a good reed switch are readily obtained with a series 74LS driver. The turn-off delay remains nearly constant until the drive-pulse width is too narrow to allow complete charging of the fast turn-off circuit, which extends the delay before turn-off occurs. Charging may be quickened with greater control current or by using an R-C circuit to speed charging while limiting the steady-state current to a nominal value.

The closed-circuit resistance of a typical photovoltaic relay is greater than that of a metallic contact. But by choosing the relay that's best suited for an application, this difference can be minimized. A bidirectional 300-V relay has a typical resistance of 20 Ω. A typical 100-V relay offers a 5-Ω resistance. Comparable unidirectional 300- and 100-V blocking relays reduce on-resistance by a factor of 4:1 or 5 and 1 Ω, respectively. Although the resistance is significant, it is stable and doesn't degrade with switching. That allows for compensation in the system's design or calibration.

The maximum voltage across an open switch must be limited to less than the maximum blocking voltage or avalanche voltage. For example, if it's necessary to monitor signals on separate phases of the 120-V ac line, a multilevel multiplexing scheme can be used to double the number of open switches between phases. This increases the maximum blocking voltage between groups to 600 V.

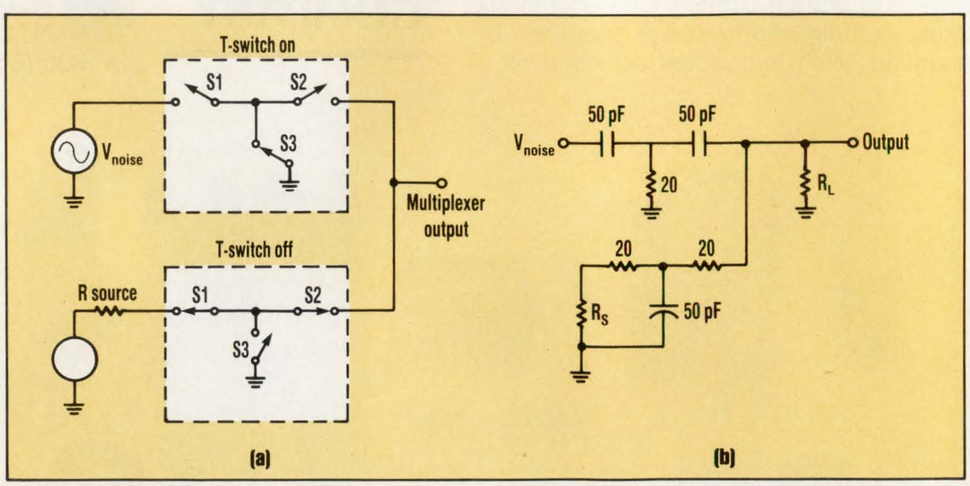
To achieve a low on-resistance, a solid-state switch requires a larger-area chip, which results in greater capacitance than a metallic contact. This must be considered when evaluating crosstalk for high-frequency signals. The non-linear open-circuit capacitance of a PVR varies with drain-to-drain voltage, and can be as low as 2 pF. Larger signals or signals with dc bias reduce capacitance and result in less crosstalk.

Cascading through two switching levels also reduces crosstalk. For example, the worst-case capacitive coupling for a 64-channel multiplexer is reduced by a ratio of 14:63 or –13 dB compared with a single-level multiplexer.

Certain applications may benefit from improved crosstalk rejection supplied by a T-switch arrangement *(Fig. 6a)*. By attenuating the capacitively coupled switch that shorts noise (S3), a much smaller error signal can pass through the multiplexer output. The T switch should be considered where the pulse or high frequencies are to be multiplexed. The equivalent circuit can be used to calculate the worst-case crosstalk for the PVA3354 device *(Fig. 6b)*. A model PVA3054 has about 1/4 of the output capacitance.

A flying-capacitor multiplexer utilizes two pairs of switches per channel to isolate both signal and return from the measurement system *(Fig. 7)*. This type of multiplexer is usually applied to low-level, low-frequency in-

6. A capacitively coupled T-switch arrangement can be used to short noise so that a smaller error signal passes through the multiplexer output (a). The equivalent circuit can calculate the worst-case crosstalk (b).



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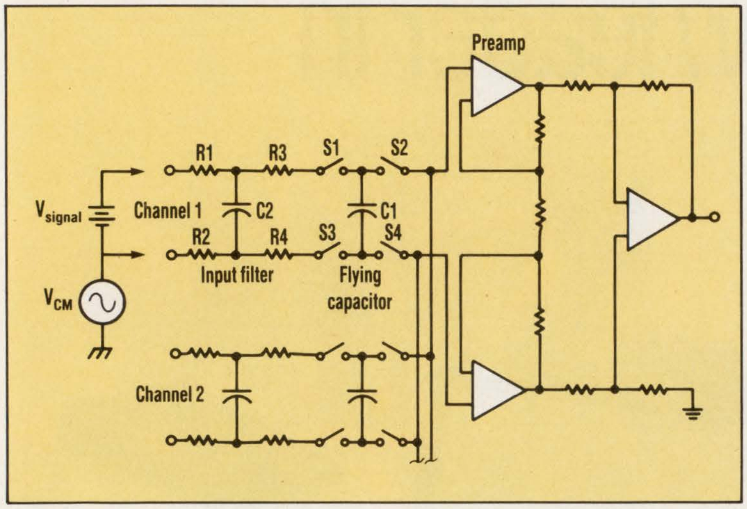

7. In a flying-capacitor multiplexer, two pairs of switches per channel isolate both signal and return from the measurement system. This type of multiplexer is usually applied to low-level, low-frequency inputs.

puts, such as thermocouples with their high common-mode voltages. The technique offers excellent common-mode rejection and isolation of the common-mode source from the measurement system. A low-pass filter (R1, R2, and C1) is often used on the input. The flying capacitor (C2) is initially charged to the signal voltage through S1 and S2.

With metallic contacts, the rapid charge transfer between capacitors results in contact pitting as the switches make initial contact. Resistors R3 and R4 limit the peak current to extend the contacts' life. But a semiconductor switch doesn't suffer from pitting and can easily handle the transient current on switch closure. That eliminates the need for resistors R3 and R4 and their resultant scaling error. The life of the PVR is therefore extended compared with reeds.

Shawn P. Fogarty Jr., product marketing manager in the Advanced Products Group at International Rectifier, received a BSEE from the University of Vermont.

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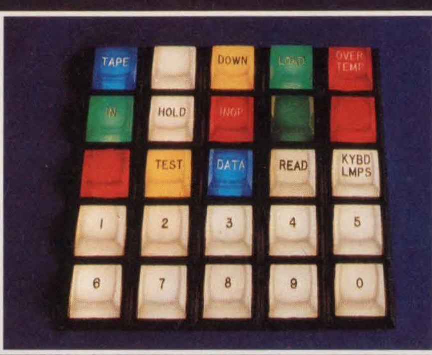

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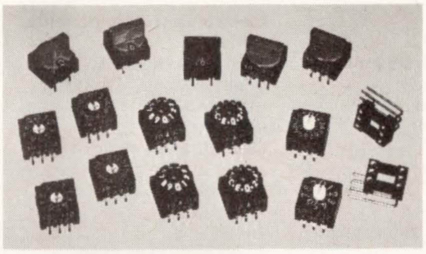

Other features include machine-loadable extruded packaging, a 125-mA-at-30-V dc contact rating, and a maximum contact resistance of 100 MΩ. Life expectancy is 20,000 cycles. All versions are from stock.

Interswitch
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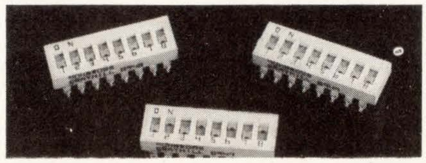
Burlingame, CA 94010
(415) 347-7727
▶ CIRCLE 654

▼ DIP SWITCH TAKES 260°C REFLOW HEAT



The materials chosen for Grayhill's surface-mounted DIP switch housing, cover, and actuators withstand 260°C. This means the switch won't suffer damage during solder-reflow portions of board assembly. The Series 90H switch uses the company's spring and ball contact system, which ensures reliability in applications of infrequent use. Two- through 10-position versions are available, and all are sealed with tape. An eight-station switch goes for $2.20 in lots of 100.

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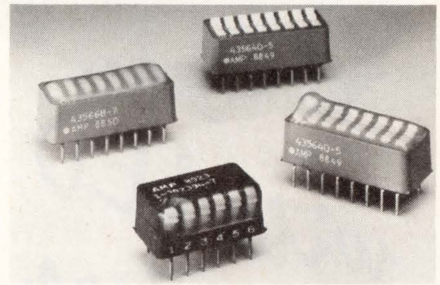

vent at 104°F without compromising the seal's integrity. The switches are offered in single-pole, single-throw versions and top or side actuation.

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(800) 522-6752
▶ CIRCLE 656

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CIRCLE 348

(continued on p. 116)

KEY

Switches

(AC)	Acceleration
(AP)	Air-pressure
(CO)	Coaxial
(DP)	DIP
(IL)	Illuminated
(KB)	Keyboard
(KL)	Keylock
(MB)	Membrane
(PC)	Pc-mounted
(PH)	Photoelectric
(PX)	Proximity
(PU)	Pushbutton
(RK)	Rocker
(RO)	Rotary
(SL)	Slide
(SA)	Snap-action
(ST)	Stepping
(SM)	Surface-mounted
(TH)	Thumbwheel
(TG)	Toggle

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(SL) (SA) (SM)
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(KL) (RO)
CIRCLE 376

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(DP) (PC) (KL) (RO)
CIRCLE 378

(continued on p. 118)

KEY

Switches
(AC) Acceleration
(AP) Air-pressure
(CO) Coaxial
(DP) DIP
(IL) Illuminated
(KB) Keyboard
(KL) Keylock
(MB) Membrane
(PC) Pc-mounted
(PH) Photoelectric
(PX) Proximity
(PU) Pushbutton
(RK) Rocker
(RO) Rotary
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(ST) Stepping
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CIRCLE 117

SWITCH MANUFACTURERS

Erni Components
Div. of Odin
520 Southlake Blvd.
Richmond, VA 23236
(804) 794-6367
(PC) (PU) (TH)
CIRCLE 379

Feme Electronics Inc.
Feme SPA
661 W. Germantown
Plymouth Meeting, PA 19462
(215) 828-5711
(PC) (IL) (PU) (RO) (TH) (TG)
CIRCLE 380

Fifth Dimension Inc.
801 New York Ave.
Trenton, NJ 08638
(609) 393-8350
(AC) (PX)
CIRCLE 381

GM Nameplate Inc.
Intaq Electrotouch
Systems
2040 15th Ave. West
Seattle, WA 98119-2783
(206) 284-5475
(KB) (MB) (PU) (SA)
CIRCLE 382

GTE Corp
Control Devices
Route 35
Standish, ME 04084
(207) 642-4535
(ST)
CIRCLE 383

George Risk Industries
802 S. Elm St.
Kimball, NE 69145
(308) 235-4645
(PC) (IL) (KL) (PU)
CIRCLE 384

Gordon Products Inc.
67 Del Mar Dr.
Brookfield, CT 06804
(203) 775-4501
(PC) (PX)
CIRCLE 385

Gordos Corp.
1000 N. Second St.
Rogers, AR 72756
(800) 643-3500
CIRCLE 386

Grayhill Co.
561 Hillgrove Ave.
La Grange, IL 60525
(708) 354-1040
(DP) (KB) (KL) (PC) (PU)
(RO) (SA) (SM)
CIRCLE 387

Grimes Co.
115 S. Arovista Cir.
Brea, CA 92621
(714) 671-3931
(PU)
CIRCLE 388

Hall Co.
420 E. Water St.
Urbana, OH 43078
(513) 652-1376
(MB)
CIRCLE 389

Hallmark Nameplate Inc.
1717 E. Lincoln Ave.
Mt. Dora, FL 32757
(904) 383-8142
CIRCLE 390

Hamlin Inc.
612 E. Lake St.
Lake Mills, WI 53551
(414) 648-3000
(AC) (KB) (PC) (PX)
(PU) (SA) (SM)
CIRCLE 391

Hasco Components Inc.
247-40 Jericho Tpke.
Bellerose Village, NY 11001
(516) 328-9292
(PX) (MR)
CIRCLE 392

Haydon Switch
and Instrument Inc.
1500 Meriden Rd.
Waterbury, CT 06705
(203) 756-7441
(SA)
CIRCLE 393

Heinemann Electric Co.
Brunswick Pike
Lawrenceville, NJ 08648
(609) 882-4800
(PC) (PU) (TG)
CIRCLE 394

Hermetic Switch Inc.
P.O. Box 1325
Chickasha, OK 73018
(405) 224-4046
(PX) (MR)
CIRCLE 395

Hettinga Inc.
2123 N.W. 111th St.
Des Moines, IA 50322
(515) 270-6900
CIRCLE 396

Industrial Electronic
Engineers
7740 Lemona Ave.
Van Nuys, CA 91405
(818) 787-0311
(IL) (KB) (MB) (PU)
CIRCLE 397

ITT Schadow Inc.
8081 Wallace Rd.
Eden Prairie, MN 55344
(612) 934-4400
(DP) (IL) (KB) (PC) (PU)
(RK) (RO) (SM)
CIRCLE 398

ITW Switches
6615 W. Irving Park Rd.
Chicago, IL 60634
(312) 282-4040
(IL) (KL) (PC) (PU)
(RK) (RO) (SL) (SA) (SM)
CIRCLE 399

IVO Industries Inc.
201 Industrial Way W.
Eatontown, NJ 07724
(908) 542-5151
(PX) (TH)
CIRCLE 400

Illinois Lock Co., Eastern Co.
307 W. Hintz Rd.
Wheeling, IL 60090
(708) 537-1800
(IL) (KL) (RO)
CIRCLE 401

Imtronics Industries Ltd.
11930 31st Ct. N.
St. Petersburg, FL 33716
(813) 572-9010
(DP) (IL) (PC) (PU)
(RK) (RO) (SL) (TG)
CIRCLE 402

InResCo
Instrument Resistor Co.
654 Ocean Rd.
Point Pleasant, NJ 08742
(908) 223-6330
(PC)
CIRCLE 403

Inter-Market Inc.
1946 Lehigh Ave.
Glenview, IL 60025
(708) 729-5330
(SM) (IL) (PU) (TH)
CIRCLE 404

Interswitch, W.J. Purdy Co.
770 Airport Blvd.
Burlingame, CA 94010
(415) 347-8217
(DP) (RO) (TH)
CIRCLE 405

JAE Electronics Inc.
1901A E. Carnegie
Santa Ana, CA 92705
(714) 753-2600
(DP) (IL) (KL) (PU) (RO)
CIRCLE 406

Janco Corp.
3111 Winona Ave.
Burbank, CA 91504
(818) 846-1800
(PC) (PU) (RO) (ST) (TH)
CIRCLE 407

Key Tronic Corp.
P.O. Box 14687, M/S 143
Spokane, WA 99214
(509) 928-8000
(MB)
CIRCLE 408

(continued on p. 120)

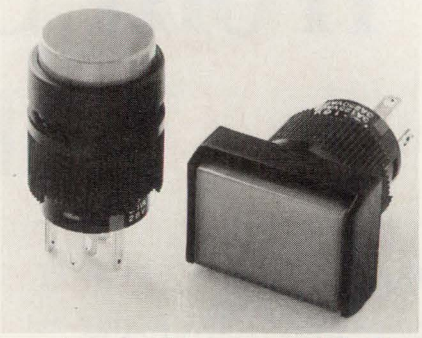
KEY

Switches

(AC)	Acceleration
(AP)	Air-pressure
(CO)	Coaxial
(DP)	DIP
(IL)	Illuminated
(KB)	Keyboard
(KL)	Keylock
(MB)	Membrane
(PC)	Pc-mounted
(PH)	Photoelectric
(PX)	Proximity
(PU)	Pushbutton
(RK)	Rocker
(RO)	Rotary
(SL)	Slide
(SA)	Snap-action
(ST)	Stepping
(SM)	Surface-mounted
(TH)	Thumbwheel
(TG)	Toggle

▼ LIGHTED PUSHBUTTONS BOAST LONG LIFE

A minimum of 1 million mechanical actuations is guaranteed for the YB line of lighted pushbutton switches. The switches may be assembled in a wide variety of combinations for maximum flexibility. For example,

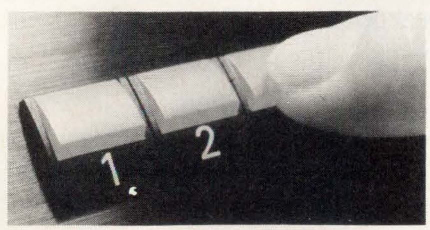


snap-in or bushing-mounted devices can be specified with momentary or alternate action circuits. Lamp selections include 5-, 12-, and 28-V incandescents as well as LEDs. The low-profile switches take up less than 1 in. of depth behind panels.

NKK Switches
7850 E. Gelding Dr.
Scottsdale, AZ 85260
(602) 991-0942
▶ **CIRCLE 657**

▼ SWITCHES AND INDICATORS PRESENT MYRIAD CHOICES

The Multimec series of switches and LED indicators offers options that can be combined in countless ways to produce an attractive panel appear-



ance. The individual switch units are based on micro-switch technology and can be joined with a variety of bezels, buttons, and indicators. The switches can be either panel-mounted or soldered directly to pc boards. A foil overlay creates a clean, modern appearance. Call for pricing and availability.

MEC A/S
P.O. Box 26
Industriparken 23
DK-2750 Ballerup, Denmark
(45) 42 97 33 66
▶ **CIRCLE 658**

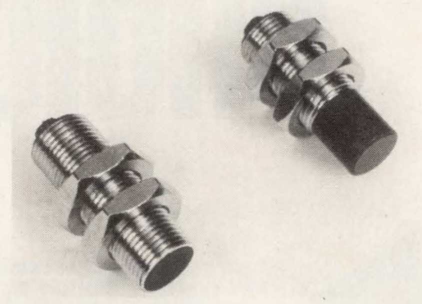
▼ MODULAR SWITCHES ADD PANEL ADAPTOR

A clean panel appearance is more easily achieved using the Series 61 flush-mount panel adaptor from EAO Switch Corp. The adaptor maintains the integrity of the Series 61 switches' sealing capability. The modular switching system is oil- and water-tight and chemical-resistant to IP 65 specifications. It also saves design time: All switches have the same back-of-panel depth, which allows pc-board mounting on the same plane regardless of the number of poles or switching action. The modular switching system, which features four international approvals, needs no special tools. The Series 61 panel adaptor costs $1.50 and delivery is from stock to six weeks.

EAO Switch Corp.
198 Pepe's Farm Rd.
Milford, CT 06460
(203) 877-4577
▶CIRCLE 659

▼ PROXIMITY SWITCHES SUIT CONTROL TASKS

Industrial-control functions are among the applications for a line of 12-mm-diameter metal-sensing proximity switches. The switch is 1.3-in long and is epoxy-cast in a threaded,



chrome-plated brass housing. It operates from 5 to 24 V dc. Sinking output, normally open or normally closed, is 100 mA. An LED indicator is included at the cable end of the switch. In lots of 1000, the switch costs $15.90. Small quantities are delivered from stock.

Gordon Products Inc.
67 Del Mar Dr.
Brookfield, CT 06804
(203) 775-4501
▶CIRCLE 660

▼ SLIDE SWITCHES HANDLE UP TO 6 A

Several options are available when ordering power slide switches from CUI/Stack. Single-pole or double-pole, double-throw contacts are offered as are five different terminations. Contact ratings are 6 A with a resistive load at 120 V ac or 28 V dc, and 2 A with a resistive load at 250 V ac. Initial contact resistance is 10 MΩ maximum. Pricing ranges from $.95 to $1.20, depending on configuration and quantity (1000 pieces minimum). Delivery is in 30 days.

CUI/Stack Inc.
9640 S.W. Sunshine Ct. G-700
Beaverton, OR 97005
(503) 643-4899
▶CIRCLE 661

SWITCH MANUFACTURERS

LSI Jennings
970 McLaughlin Ave.
San Jose, CA 95122
(408) 292-4025
(AP) (CO) (PC)
CIRCLE 409

LVC Industries Inc.
Co-Ord Switch Div.
23 Hanse Ave.
Freeport, NY 11520
(516) 868-1900
(SL)
CIRCLE 410

Lamb Industries Inc.
P.O. Box 25110
Portland, OR 97225
(800) 824-9374
CIRCLE 411

Line Electric Products
Div. of General Electric
P.O. Box 327
Hartford, CT 06141
(203) 659-3573
(PC) (IL) (PU) (TG)
CIRCLE 412

Lite-On USA Inc.
720 S. Hillview Dr.
Milpitas, CA 95035
(408) 946-4873
CIRCLE 413

Littelfuse-Tracor
800 E. Northwest Hwy.
Des Plaines, IL 60016
(708) 824-1188
(PU) (TG)
CIRCLE 414

Lucas Ledex Inc.
P.O. Box 427
Vandalia, OH 45377
(513) 898-3621
(IL) (KB) (KL) (PC) (PU)
(RO) (ST) (SM)
CIRCLE 415

Mantex Corp.
1800 Metamora Rd.
Oxford, MI 48051
(313) 628-8200
(KB) (MB) (PC) (PU)
CIRCLE 416

Marquardt Switches Inc.
Route 20E
Cazenovia, NY 13035
(315) 655-8050
(PC) (IL) (PU) (SL) (TG)
CIRCLE 417

Matrix Systems Corp.
5177 N. Douglas Fir Rd.
Calabasas, CA 91302
(818) 992-6776
(SM) (RO)
CIRCLE 418

McGill Mfg. Co. Inc.
1002 N. Campbell St.
Valparaiso, IN 46383
(219) 465-2200
(IL) (TG)
CIRCLE 419

Membrane Switch & Panel
1537G McFadden
Santa Ana, CA 92705
(714) 541-5775
CIRCLE 420

Memtron Technologies
1400 Weiss St.
Frankenmuth, MI 48734
(517) 652-2656
(MB)
CIRCLE 421

Micro Switch
Div. of Honeywell Inc.
11 West Spring St.
Freeport, IL 61032
(815) 235-5731
(AP) (IL) (PH) (PX) (PU)
(RK) (SA) (SM) (TG)
CIRCLE 422

Microavionics Corp.
3198 Airport Loop Dr. #K
Costa Mesa, CA 92626
(714) 957-6904
(RO)
CIRCLE 423

Micron Instrument Corp.
50 Alexander Ct.
Ronkonkoma, NY 11779
(516) 467-8000
CIRCLE 424

Minelco Inc.
Talley Industries
135 S. Main St.
Thomaston, CT 06787
(203) 283-8261
(PC) (RO) (SL)
CIRCLE 425

Mini-Circuits
P.O. Box 350166
Brooklyn, NY 11235-0003
(718) 934-4500
(PC) (SM)
CIRCLE 426

Molex Inc.
Switch Div.
2222 Wellington Ct.
Lisle, IL 60532
(708) 969-4550
(IL) (KB) (MB) (PC) (PU)
CIRCLE 427

NKK Switches
7850 E. Gelding Dr.
Scottsdale, AZ 85260
(602) 991-0942
(PC) (SM) (IL) (PU)
(RO) (SL) (TG)
CIRCLE 428

NMB Technologies
9730 Independence
Chatsworth, CA 91311
(818) 341-3355
CIRCLE 429

Noble USA Inc.
5450 Meadowbrook Ct.
Rolling Meadows, IL 60008
(708) 364-6038
(DP) (PC) (PU)
(RK) (RO) (SL) (SA)
CIRCLE 430

Oak Switch Systems Inc.
100 S. Main St.
Crystal Lake, IL 60014
(815) 459-5000
(IL) (KL) (PC) (PU) (RK) (RO)
CIRCLE 431

Omega Engineering Inc.
1 Omega Dr.
Stamford, CT 06907
(203) 359-1660
(RO)
CIRCLE 432

Omron Electronics Inc.
1 E. Commerce Dr.
Schaumburg, IL 60173
(708) 843-7900
(DP) (IL) (KB) (KL) (PC)
(PH) (PU) (RK) (RO) (SA)
(TH)
CIRCLE 433

Orbit Instrument
of California
6431 Global Dr.
Cypress, CA 90630
(714) 527-0561
(IL) (PU)
CIRCLE 434

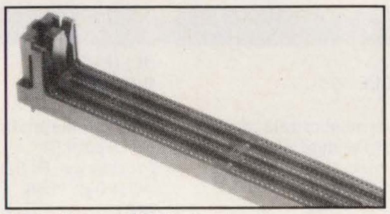
Oslo Controls Inc.
328 Industrial Ave.
Cheshire, CT 06410
(203) 272-2794
(IL) (KL) (PC) (PU) (RK)
CIRCLE 435

(continued on p. 122)

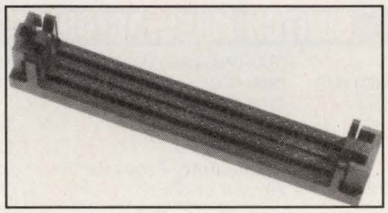
KEY

Switches
(AC) Acceleration
(AP) Air-pressure
(CO) Coaxial
(DP) DIP
(IL) Illuminated
(KB) Keyboard
(KL) Keylock
(MB) Membrane
(PC) Pc-mounted
(PH) Photoelectric
(PX) Proximity
(PU) Pushbutton
(RK) Rocker
(RO) Rotary
(SL) Slide
(SA) Snap-action
(ST) Stepping
(SM) Surface-mounted
(TH) Thumbwheel
(TG) Toggle

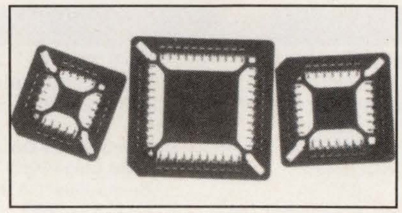
You need 'em. We got 'em. Let's talk sockets.



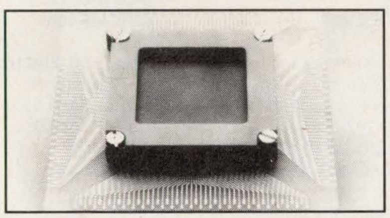
.050 Pitch SIMM Sockets 192
- Accepts SIMM modules with .010" thickness range
- Audible "snap in" feature
- User friendly insertion/withdrawal



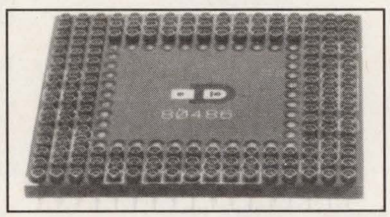
Rugged SIMM Sockets 193
- 100 cycle minimum durability
- Severe shock and vibration resistant
- Design eliminates latch breakage



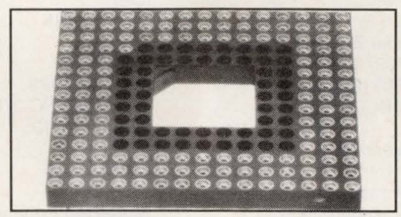
Low Profile SMT PLCC 194
- Easy visual inspection
- Footprint same as device
- Tape and reel packaging



Solderless SMT .025" PQFP Socket 195
- Made for bumpered PQFP's
- Designed for high speed applications
- Footprint matches device

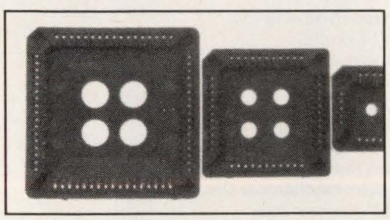


Customized PGA Sockets 196
- High density .050" interstitial
- For high speed microprocessors
- Integral decoupling capacitor reduces crosstalk

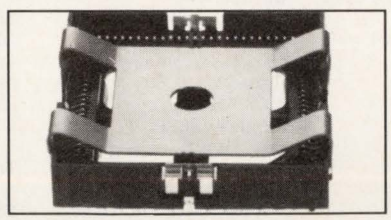


Ultra Low Force PGA Sockets 197

Contact Type	Insertion/Withdrawal Total (Based on 68 Pins)
Robinson Nugent Ultra-Low	**7.5/5.5 lb**
2-finger Tulip (Stamped & Formed)	10.3/6.7 lb
6-finger Staggered	14.8/8.7 lb



High Temp .050" PLCC Sockets 198
- Shock and vibration resistant
- Closed bottom design
- Extraction tool common for all sizes



Motorola SLAM PAK .050" Socket 199
- Custom design DSP socket
- Shock and vibration resistant
- Anti-wicking bottom cover

The Call is on Us.

800-338-8152

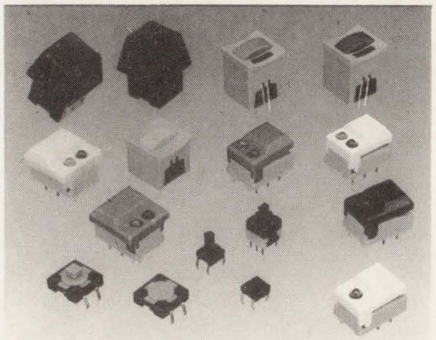
Robinson Nugent

P.O. Box 1208 • New Albany, IN 47150-1208 • 800/338-8152 • FAX 812/945-0804
6 Rue St. Georges, CH 2800 Delémont • (41) 66-22-9822 • FAX (41) 66-22-9813

CIRCLE 200

▼ VARIETY OF SWITCHES FOR BOARD MOUNTING

Long life in excess of five million operations and a variety of sizes and shapes distinguish a line of switches for board-mounted applications. Designers can select from sub-miniature (6 by 6 mm) up to standard keyboard sizes (17 by 17 mm) with LED illumination available for several models. These switches mount using industry-standard pin configurations and are offered in a choice of colors. Call for samples, pricing, and availability.



Oslo Controls Inc.
328 Industrial Ave.
Cheshire, CT 06410
(203) 272-2794
▶ **CIRCLE 662**

▼ LOW-PROFILE HOOKSWITCH HANGS UP PHONES

A low-profile hookswitch fills the bill in the latest slim telephone styles. The Series 45 switch stands just 0.362 in. tall and is suited for tasks in instrumentation, security equipment, and similar applications. Both double- and single-pole versions are available, and the double-pole version has sequential switching as standard. Three or more poles can be achieved by interlock ganging. The pc-board-mounted switch offers a choice of circuit forms and operating forces. Its silver contacts will switch up to 2 A at 250 V ac. Non-standard features include custom levers and brackets, gold contacts, and more. Call for pricing and availability.

ITW Switches
An Illinois Tool Works Co.
6615 W. Irving Park Rd.
Chicago, IL 60634
(312) 282-4040
▶ **CIRCLE 663**

SWITCH MANUFACTURERS

Otto Controls
2 E. Main St.
Carpentersville, IL 60110
(708) 428-7171
(PC) (PU) (TG)
CIRCLE 436

Pass & Seymour Inc.
P.O. Box 4822
Syracuse, NY 13221
(315) 468-6211
(IL) (KL) (TG)
CIRCLE 437

Preh Electronic Industries Inc.
470 E. Main St.
Lake Zurich, IL 60047-2578
(708) 438-4000
(PC) (PU) (RO) (SL)
CIRCLE 438

Pres:Air:Trol Corp.
1009 W. Boston Post Rd.
Mamaroneck, NY 10543
(914) 698-2026
(AP)
CIRCLE 439

SAIA Inc.
Burgess Switch Div.
1335 Barclay Blvd.
Buffalo Grove, IL 60089
(708) 215-9600
CIRCLE 440

Sage Laboratories Inc.
11 Huron Dr.
Natick, MA 01760-1314
(508) 653-0844
(CO) (TG)
CIRCLE 441

Satori Electric (America)
23717 Hawthorne Blvd.
Torrance, CA 90505
(213) 214-1791
(DP) (PC) (SM)
(IL) (PU) (SL) (TH) (TG)
CIRCLE 442

Schurter Inc.
P.O. Box 750158
Petaluma, CA 94975-0158
(707) 778-6311
(PC) (IL) (KL) (PU) (RO) (MB)
CIRCLE 443

Selco Prods Co.
7580 Stage Rd.
Buena Park, CA 90621
(714) 521-8673
CIRCLE 444

Semiconductor Specialists Inc.
195 Spangler Ave.
Elmhurst, IL 60126
(708) 279-1005
(DP)
CIRCLE 445

Shallco Inc.
P.O. Box 1089
Smithfield, NC 27577
(919) 934-3135
(DP) (RO)
CIRCLE 446

Shin-Etsu Polymer America
34135 7th St.
Union City, CA 94587
(415) 475-9000
(KB) (PU)
CIRCLE 447

Shogyo International Corp.
287 Northern Blvd.
Great Neck, NY 11021
(516) 466-0911
(CO) (DP) (PC) (PU)
(RK) (RO) (SL) (TG)
CIRCLE 448

SoLiCo/MEC
75 Locust St.
Hartford, CT 06114
(203) 527-3092
(IL) (KB) (PC) (PU) (SM) (TG)
CIRCLE 449

Square D Co.
Control Products Div.
Hwy. 64 East
Knightdale, NC 27545
(919) 266-8335
(AP) (CO) (IL) (KB)
(KL) (MB) (PC) (PH)
(PX) (PU) (RO) (SA)
(SM) (TG)
CIRCLE 450

Square D Co.
Data Entry Products Div.
302 3rd St. S.E.
Loveland, CO 80537
(303) 663-7337
(KB) (MB)
CIRCLE 451

Staco Switch Inc.
1139 Baker St.
Costa Mesa, CA 92626
(714) 549-3041
(PC) (SM) (IL) (PU)
CIRCLE 452

Standard Grigsby Inc.
88 North Dugan Rd.
Sugar Grove, IL 60554
(708) 556-4200
(PC) (SM) (KL) ((RO) (SL)
(MB)
CIRCLE 453

Standex Electronics
Standex International
4538 Camberwell Rd.
Cincinnati, OH 45209
(513) 871-3777
CIRCLE 454

Switchcraft Inc.
5555 N. Elston Ave.
Chicago, IL 60630
(312) 792-2700
(IL) (PU) (SL) (TH) (TG)
CIRCLE 455

T Bar Inc.
A Data Switch Co.
1 Enterprise Dr.
Shelton, CT 06484
(203) 926-1801
(SM) (RO) (TG)
CIRCLE 456

Tansitor Electronics
P.O. Box 230, West Rd.
Bennington, VT 05201
(802) 442-5473
(KL)
CIRCLE 457

Teledyne Microelectronics
12964 Panama St.
Los Angeles, CA 90066
(213) 822-8229
(DP) (PC) (SM)
CIRCLE 458

Texas Instruments
Materials & Controls
34 Forest St.
Attleboro, MA 02703
(508) 699-3800
(MB)
CIRCLE 459

Toko America Inc.
1250 Feehanville Dr.
Mount Prospect, IL 60056
(708) 297-0070
(DP) (KL) (PU) (RO) (MB)
CIRCLE 460

Topflight Corp.
Membrane Switch Div.
P.O. Box 2847
York, PA 17405
(800) 233-9386
(IL) (KB) (KL) (MB) (PC)
CIRCLE 461

Transco Products Inc.
1001 Flynn Rd.
Camarillo, CA 93011-6003
(805) 987-8007
(CO)
CIRCLE 462

Tricon Industries Inc.
Electromechanical Div.
2325 Wisconsin Ave.
Downers Grove, IL 60515
(708) 964-2330
(PU) (SA)
CIRCLE 463

Veetronix Inc.
Reach Electronics Inc.
Box 480
Lexington, NE 68850
(308) 324-4600
(IL) (PU)
CIRCLE 464

Wabash Magnetics
55 Dupont Dr.
Providence, RI 02907
(401) 943-2686
(PC)
CIRCLE 465

Westinghouse Electric Corp., Control Div.
P.O. Box 5715
Asheville, NC 28813
(704) 684-2381
(PC) (PU) (SL)
CIRCLE 466

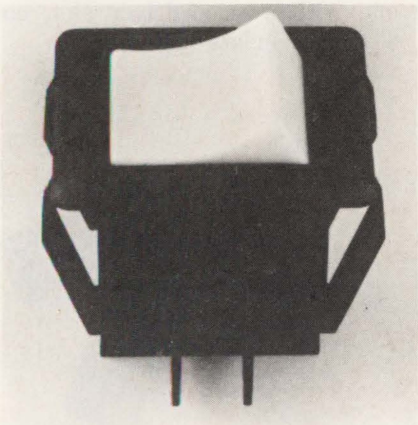
Wilbrecht Electronics
346 Chester St.
St. Paul, MN 55107
(612) 222-2791
(PU) (SL)
CIRCLE 467

KEY

Switches

(AC)	Acceleration
(AP)	Air-pressure
(CO)	Coaxial
(DP)	DIP
(IL)	Illuminated
(KB)	Keyboard
(KL)	Keylock
(MB)	Membrane
(PC)	Pc-mounted
(PH)	Photoelectric
(PX)	Proximity
(PU)	Pushbutton
(RK)	Rocker
(RO)	Rotary
(SL)	Slide
(SA)	Snap-action
(ST)	Stepping
(SM)	Surface-mounted
(TH)	Thumbwheel
(TG)	Toggle

▼ DOUBLE-POLE ROCKER SNAPS INTO PANELS



An attractive matte-finished rocker switch with snap-in bezel is designed for use in small appliances, power supplies, business equipment, machines, and other switch panels. Available in double- and single-throw models, the model 0825 switch fits a 1-by-1.25-in. cutout and has a 1/4-in. quick-disconnect terminal. UL and CSA ratings are pending at 15 A and 220 V ac, 20 A and 125 V ac, and 3/4 hp and 125 to 222 V ac. VDE-rated models are also offered.

McGill Mfg. Co. Inc.
1002 N. Campbell St.
Valparaiso, IN 46383
(219) 465-2200
▶ CIRCLE 664

▼ TACTILE FEEDBACK AIDS MEMBRANE SWITCHES

An effective and economical means of incorporating tactile feedback in membrane switches is the use of polyester domes. The domes let designers choose from three different approaches. In one, the domes can be formed directly in the graphic faceplate of the switch. Another approach forms domes in a discrete sublayer of the switch's construction, A third tack is to form domes in the top layer. The polyester domes have been tested to over 5 million actuations. Operating force ranges from 8 to 14 ozs. Switch travel is from 0.020 to 0.040 in. typical. Call for pricing and delivery.

W.H. Brady Co.
Xymox Division
P.O. Box 571
Milwaukee, WI 53201-0571
(414) 355-8300
▶ CIRCLE 665

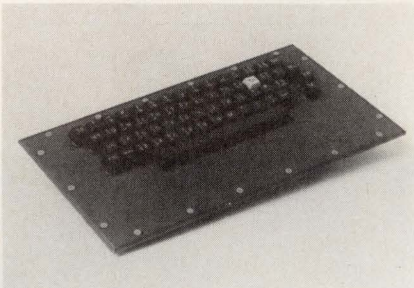
▼ CUSTOM REED SWITCHES IN BROAD SELECTION

Forty models ranging from the world's smallest reed switch (0.200-in glass length) to high-power models that handle 200 W are available. High-voltage switches feature dielectric capabilities up to 14 kV dc. Sixteen different single-pole, double-throw (Form C changeover) models are offered. Custom lead preparation, including bending, cutting, soldering, and more, is offered to prepare the switches for any application. Call for pricing and availability.

Hermetic Switch Inc.
Highway 92, P.O. Box 1325
Chickasha, OK 73023
(405) 224-4046
▶ CIRCLE 666

▼ FULL-TRAVEL KEYBOARD MEETS MILITARY NEEDS

A standard Type 1/Class 1, full-travel military QWERTY keyboard uses IEE's modular keyswitch technology. Model 30498-05 is made up of 59 metal-housed keyswitches that are mounted on a 15.1-by-7.6-by-0.25-in. metal base. The keyboard meets MIL-STD-810C standards as well as

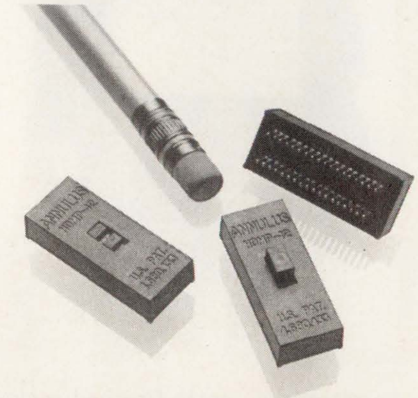


specifications for emi/rfi and Tempest. The keyswitches use conductive-rubber technology and are rated at over 20 million actuations. Keytravel is 5.8 mm and requires a nominal actuation force of 130 grams. In lots of 100, the keyboard costs $1095. Small quantities are available in eight to 10 weeks after receipt of order.

Industrial Electronic Engineers
Planar Products Division
7740 Lemona Ave.
Van Nuys, CA 91409
(818) 787-0311, ext. 236
▶ **CIRCLE 667**

▼ 12-POLE SWITCH ROUTES 12 CHANNELS

A 12-pole, double-throw snap-action switch features gold-plated stressed elliptical contacts. The HDMP-12 switch's contact mechanism has fewer parts than conventional switches. As a result, the switch can be built into a high-density package which occupies less than 1/2 in.^{2} with pin spacing of 0.050 in. The low 5-mΩ contact resistance (20-mΩ maximum) is transparent to circuit operation and well suited for routing 12 digital or analog channels. The contacts are compression-indexed for reliable actuation even when they are rarely actuated. Switch life is rated at 10,000 actuations. Two versions, one with an actuator knob and one with a screwdriver slot, cost $6.30 each in lots of 100.



Annulus Technical Industries Inc.
1296 Osprey Dr.
P.O. Box 7407
Ancaster, Ontario, Canada L9G 4G4
(416) 648-8100
▶ **CIRCLE 668**

RELAY MANUFACTURERS

AT&T
555 Union Blvd.
Allentown, PA 18103
(800) 372-2447
(OI) (DR) (DS) (TE)
CIRCLE 571

AT&T Microelectronics
2525 N. 12th St.
Box 13396
Reading, PA 19612
(215) 939-3345
(OI)
CIRCLE 572

Airpax Co.
Frederick Div.
P.O. Box 500
Frederick, MD 21701
(301) 663-5141
(AU) (CS) (HS) (MI) (PB) (PW) (TE)
CIRCLE 573

Allen-Bradley Co.
Rockwell International
1201 S. Second St.
Milwaukee, WI 53204
(414) 382-2000
(CS) (HD) (HS) (HF) (DS)
CIRCLE 574

American Electronic Components
1010 N. Main St.
Elkhart, IN 46515
(219) 264-1116
(CT) (HS) (TD)
CIRCLE 575

American Zettler Inc.
75 Columbia St.
Aliso Viejo, CA 92656
(800) 854-8474
(HD) (ML) (TE)
CIRCLE 576

Amperite Co. Inc.
600 Palisade Ave.
Union City, NJ 07087
(201) 864-9503
(CS) (HS) (TD) (VS)
CIRCLE 577

Antex Electronics Corp.
16100 S. Figueroa St.
Gardena, CA 90248
(213) 532-3092
(CT) (HD) (CS) (HS) (HF) (OI) (ML) (DS) (TD)
CIRCLE 578

Aromat Corp.
629 Central Ave.
New Providence, NJ 07974
(201) 464-3550
(AS) (AU) (DS) (DR) (FP) (HD) (HS) (HF) (IO) (ML) (OI) (PB) (PW) (TE) (TD) (VS)
CIRCLE 579

Augat Alcoswitch
1551 Osgood St.
North Andover, MA 01845
(508) 685-4371
(PB)
CIRCLE 580

Automatic Timing & Controls
201 S. Gulph Rd.
King of Prussia, PA 19406
(800) 441-8245
CIRCLE 581

Bivar Inc.
4 Thomas
Irvine, CA 92718
(714) 951-8808
CIRCLE 582

Brentek International
526 Windsor St.
Reading, PA 19601
(215) 375-7200
(DR) (HS) (IO) (PW) (TD)
CIRCLE 583

CP Clare Corp.
3101 W. Pratt Ave.
Chicago, IL 60645
(312) 262-7700
(AS) (DS) (DR) (MW) (PB)
CIRCLE 584

Communications Insts. Inc.
Box 520, Hwy. 74 E.
Fairview, NC 28730
(704) 628-1711
(CX) (CC) (FP) (HS) (ML) (MI) (PB) (PW) (RT) (TE)
CIRCLE 585

Cornell-Dubilier
Sangamo Components
1605 E. Rodney French Blvd.
New Bedford, MA 02744
(508) 996-8561
CIRCLE 586

Coto Wabash
a Kearney-National Co.
55 Dupont Dr.
Providence, RI 02907
(401) 943-2686
(CX) (CS) (DR) (HS) (HF) (ML) (MW) (PB) (TE) (VS)
CIRCLE 587

Cruzet Corp.
2445 Midway Rd.
Carrollton, TX 75006-2503
(214) 250-1647
(DS) (TD)
CIRCLE 588

Crydom Co.
6015 Obispo Ave.
Long Beach, CA 90805
(213) 865-3536
(AS) (DS) (FP) (IO) (OI) (TD)
CIRCLE 589

Deltrol Controls
Div. of Deltrol Corp.
2745 S. 19 St.
Milwaukee, WI 53215
(414) 671-6800
(HD) (ML) (TD)
CIRCLE 590

Dionics Inc.
65 Rushmore St.
Westbury, NY 11590
(516) 997-7474
(AS) (DS) (HS) (MI) (OI) (PW)
CIRCLE 591

Eaton Corp.
Aerospace & Commercial Control
4201 N. 27th St.
Dept. H129
Milwaukee, WI 53216
(414) 449-7487
(AS) (CT) (CS) (DS) (HD) (HS) (ML) (MI) (PW) (VS)
CIRCLE 592

Electronic Specialty
Div. of Elecspec
14511 N.E. 13th Ave.
Vancouver, WA 98668
(206) 574-5000
(HS) (ML) (DR) (DS) (TD)
CIRCLE 593

Erni Components
Div. of Odin
520 Southlake Blvd.
Richmond, VA 23236
(804) 794-6367
(DR) (TE)
CIRCLE 594

FR Industries Inc.
Celduc
557 Long Rd.
Pittsburgh, PA 15235
(412) 242-5903
(AS) (AU) (DS) (DR) (IO) (ML) (MW) (PB)
CIRCLE 595

Feme Electronics Inc.
Feme SPA
661 W. Germantown
Plymouth Meeting, PA 19462
(215) 828-5711
(HD) (HS) (TE)
CIRCLE 596

Fifth Dimension Inc.
801 New York Ave.
Trenton, NJ 08638
(609) 393-8350
(HS) (HF) (ML) (MW) (MI) (TE)
CIRCLE 597

Fujitsu Components of America
3330 Scott Blvd.
Santa Clara, CA 95054
(408) 562-1000
(AU) (DR) (FP) (HD) (PB) (PW) (TE)
CIRCLE 598

(continued on p. 126)

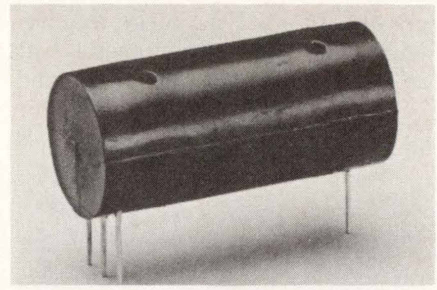
KEY

Relays

(AS)	Ac solid-state
(AU)	Automotive
(CX)	Coaxial
(CT)	Contactors
(CC)	Crystal-case
(CS)	Current-sensing
(DS)	Dc solid-state
(DF)	Differential
(DR)	Dry reed
(FP)	Flat-pack
(HD)	Heavy-duty
(HS)	Hermetically sealed
(HF)	High-frequency
(IO)	Input/output
(ML)	Magnetic latching
(MW)	Mercury-wetted reed
(MI)	Military/aerospace
(OI)	Optical isolation
(PB)	Pc-board
(PW)	Power
(RT)	Rotary
(TE)	Telephone
(TD)	Time-delay
(VS)	Voltage-sensing

▼ FIRE-RETARDANT RELAYS STAY BOUNCE-FREE

A series of bounce-free relays encapsulated in a fire-retardant package meets the requirements of UL standard 94VO. The Series FR relays pass a needle-flame test designed to

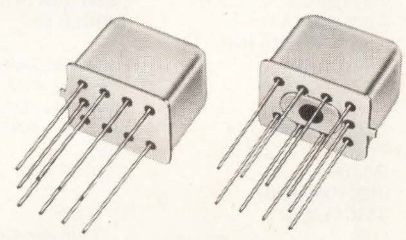


simulate the effect of open flames on nearby components. The mercury-film relays, which remain bounce-free in any mounting position, are available with 250-, 375-, and 500-mW coils at 5, 12, and 24 V dc. Relay contacts are Form A with a maximum resistance of 150 mΩ. Small quantities are delivered from stock. Call for pricing.

Fifth Dimension Inc.
801 New York Ave.
Trenton, NJ 08638-3982
(609) 393-8350
▶ **CIRCLE 669**

▼ HIGH-REL RELAYS MEET MIL-R-28776

A series of hermetically sealed relays with 0.10-in.-spaced terminals are fully qualified to MIL-R-28776/7 reliability specifications. The Series J MGST Minigrid relays feature all-welded construction, a balanced ar-

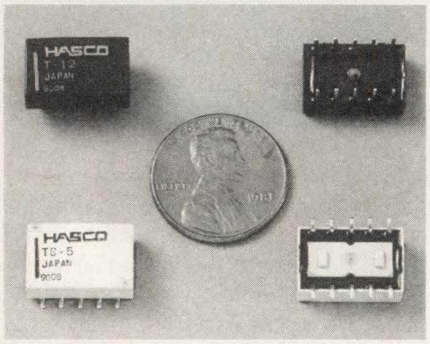


mature, a MOSFET driver, and diode-coil suppression. The relays are designed to operate in low- and medium-power switching circuits. They can switch from low levels to 1 A and feature 2 Form C contacts. List price is $43 with delivery in 10 weeks.

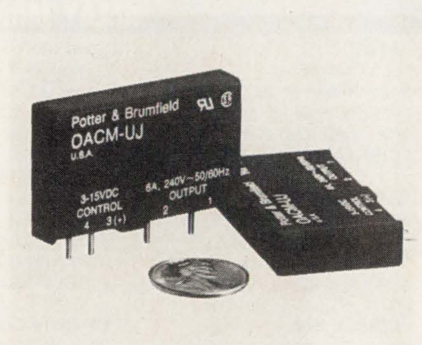
Struthers-Dunn Inc.
Lambs Rd.
Pitman, NJ 08071
(609) 589-7500
▶ **CIRCLE 670**

▼ SUBMINIATURE RELAY SUITS PC-BOARD JOBS

Dimensions of just 0.187 in. high, 0.354 in. wide, and 0.55 in. long are featured in the T series subminiature relay. The device, which is available in latching and two-coil-latching versions, meets FCC surge requirements of 1500 V and switches 1 A at 125 V ac/dc. The relay's also UL- and CSA-recognized. Mechanical life for the device's bifurcated contacts is rated at 100 million operations. The series offers both through-hole and surface-mounted models. A four-pole version is expected later this year. Call for pricing and delivery.



Hasco Components Inc.
247-40 Jericho Tpke.
Bellerose Village, NY 11001
(516) 328-9292
▶ **CIRCLE 671**



▼ PC-BOARD RELAYS SWITCH 6 A AT 280 V

Rated at 6 A from 12 to 280 V ac, the OACM-UJ solid-state relays incorporate surface-mounted components in a molded-case design. The relays measure just 0.37 by 1.7 by 1 in. and are UL-recognized and CSA-certified. They also meet VDE requirements. The switching capacity of the devices' 1 form A output switch derates linearly in free air from 6 A at 20°C to 1.8 A at 80°C. Operating from 3-V through 15-V dc input voltages, the relay provides zero-voltage turn-on of the load. In quantities of 500, the relay costs $5.94. Small quantities are delivered from stock and OEM quantities take six weeks.

Potter & Brumfield Inc.
200 S. Richland Creek Dr.
Princeton, IN 47671-0001
(812) 386-2194
▶ **CIRCLE 672**

RELAY MANUFACTURERS

GTE Corp
Control Devices
Route 35
Standish, ME 04084
(207) 642-4535
(TD)
CIRCLE 599

General Instrument Corp.
Clare Div.
3101 W. Pratt Ave.
Chicago, IL 60645
(312) 262-7700
(CX) (CS) (DF) (HD) (HS) (HF) (ML) (DR)
CIRCLE 600

Genicom Corp
Genicom Relays
One Genicom Dr.
Waynesboro, VA 22980
(703) 949-1471
(CS) (HS) (ML) (DR)
CIRCLE 601

Gordos Corp.
1000 N. Second St.
Rogers, AR 72756
(800) 643-3500
(HD) (DR) (DS)
CIRCLE 602

Grayhill Co.
561 Hillgrove Ave.
La Grange, IL 60525
(708) 354-1040
(AS) (DS)
CIRCLE 603

Guardian Electric Mfg. Co.
1425 Lake Ave.
Woodstock, IL 60098
(815) 337-0050
(CS) (HS) (DS)
CIRCLE 604

Hamilton Standard Controls
131 Godfrey St.
Logansport, IN 46947
(219) 753-7521
(CT) (CS) (HD) (TD)
CIRCLE 605

Hamlin Inc.
612 E. Lake St.
Lake Mills, WI 53551
(414) 648-3000
(CS) (DR) (HS) (ML) (MW) (PB) (PW) (TE)
CIRCLE 606

Hasco Components Inc.
247-40 Jericho Tpke.
Bellerose Village, NY 11001
(516) 328-9292
(AU) (DR) (FP) (HD) (ML) (MW) (PB) (PW) (TE)
CIRCLE 607

Hermetic Switch Inc.
P.O. Box 1325
Chickasha, OK 73018
(405) 224-4046
(HS)
CIRCLE 608

Hi-G Co.
Struthers-Dunn
Lambs Rd.
Pitman, NJ 08071-0901
(609) 589-7500
(MI)
CIRCLE 609

ITT Schadow Inc.
8081 Wallace Rd.
Eden Prairie, MN 55344
(612) 934-4400
(PB) (TE)
CIRCLE 610

Idec Corp.
1213 Elko Dr.
Sunnyvale, CA 94089
(408) 747-0550
CIRCLE 611

Inmark Corp.
147 W. Cedar St.
Norwalk, CT 06854
(203) 866-8474
(DS)
CIRCLE 612

International Rectifier
233 Kansas St.
El Segundo, CA 90245
(213) 772-2000
(HD) (OI) (DS) (TD)
CIRCLE 613

Kidde Inc.
Douglass Randall Div.
P.O. Box 506
Pawcatuck, CT 06379
(800) 447-6799
(CT) (CS) (DF) (HD) (HF) (ML) (OI) (DR) (DS) (TD)
CIRCLE 614

Kilovac Corp.
P.O. Box 4422
Santa Barbara, CA 93140
(805) 684-4560
(CT) (DR) (HD) (HS) (HF) (ML) (MI) (PB) (PW) (VS)
CIRCLE 615

LSI Jennings
970 McLaughlin Ave.
San Jose, CA 95122
(408) 292-4025
(CX) (CT) (HD) (HS) (HF) (ML) (MI) (PB) (PW)
CIRCLE 616

Leach Corp.
Control Products Div.
6900 Orangethorpe Ave.
Buena Park, CA 90620-1386
(714) 739-0770
(DS)
CIRCLE 617

Leach Corp.
Relay Group
5915 Avalon Blvd.
Los Angeles, CA 90003
(213) 232-8221
(CT) (HD) (HS) (ML)
CIRCLE 618

Line Electric Products
Div. of General Electric
P.O. Box 327
Hartford, CT 06141
(203) 659-3573
(CT) (CS) (HD) (HS) (HF) (ML) (TE) (TD)
CIRCLE 619

Macromatic Inc.
4635 W. Lawrence Ave.
Chicago, IL 60630
(708) 291-8484
(ML) (TD)
CIRCLE 620

Magnecraft Electric Co.
1910 Techny Rd.
Northbrook, IL 60062
(708) 564-8800
(CX) (CS) (HD) (HS) (ML) (OI) (DR) (DS) (TE) (TD)
CIRCLE 621

Master Elec. Controls
P.O. Box 25905
Los Angeles, CA 90025
(213) 452-1336
(CX) (CT) (CS) (DF) (HD) (HS) (HF) (ML) (OI) (DR) (DS) (TE) (TD)
CIRCLE 622

Matrix Systems Corp.
5177 N. Douglas Fir Rd.
Calabasas, CA 91302
(818) 992-6776
(CX) (DS)
CIRCLE 623

Midtex Relays Inc.
Distributor Center
9-B2 Butterfield Tr.
El Paso, TX 79906
(915) 772-1061
(CS) (HS) (ML) (DR) (DS) (TE) (TD)
CIRCLE 624

National Controls Corp.
1725 Western Dr.
West Chicago, IL 60185
(708) 231-5900
CIRCLE 625

(continued on p. 127)

KEY

Relays

(AS)	Ac solid-state
(AU)	Automotive
(CX)	Coaxial
(CT)	Contactors
(CC)	Crystal-case
(CS)	Current-sensing
(DS)	Dc solid-state
(DF)	Differential
(DR)	Dry reed
(FP)	Flat-pack
(HD)	Heavy-duty
(HS)	Hermetically sealed
(HF)	High-frequency
(IO)	Input/output
(ML)	Magnetic latching
(MW)	Mercury-wetted reed
(MI)	Military/aerospace
(OI)	Optical isolation
(PB)	Pc-board
(PW)	Power
(RT)	Rotary
(TE)	Telephone
(TD)	Time-delay
(VS)	Voltage-sensing

RELAY MANUFACTURERS

Nytronics Inc.
Struthers-Dunn
Lambs Rd.
Pitman, NJ 08071
(609) 589-7500
(MI)
CIRCLE 626

Nytronics Inc.
Struthers-Dunn
700 Orange St.
Darlington, SC 29532
(803) 393-5421
(CT) (DR) (HD) (ML) (MW) (PB) (TD)
CIRCLE 627

Omega Engineering Inc.
1 Omega Dr.
Stamford, CT 06907
(203) 359-1660
(ML) (DS)
CIRCLE 628

Omron Electronics Inc.
1 E. Commerce Dr.
Schaumburg, IL 60173
(708) 843-7900
(AS) (AU) (CT) (DS) (FP) (HD) (HS) (HF) (IO) (ML) (OI) (PB) (PW) (TE) (TD)
CIRCLE 629

Opto 22
15461 Springdale St.
Huntington Beach, CA 92647
(714) 891-5861
(OI) (DS)
CIRCLE 630

Potter & Brumfield
A Siemens Co.
200 S. Richland Creek Dr.
Princeton, IN 47671-0001
(812) 386-1000
(AS) (AU) (CT) (CC) (CS) (DS) (DR) (FP) (HD) (HS) (IO) (ML) (MW) (MI) (OI) (PB) (PW) (RT) (TE) (TD) (VS)
CIRCLE 631

RLC Electronics Inc.
83 Radio Cir.
Mt. Kisco, NY 10549
(914) 241-1334
(CX) (ML)
CIRCLE 632

Regent Controls Inc.
39 Fanny St.
Shelton, CT 06484
(800) 243-3141
(AS) (CS) (DS) (HF) (IO) (OI) (TD) (VS)
CIRCLE 633

SSAC Inc.
P.O. Box 1000
Baldwinsville, NY 13027
(315) 638-1300
(CT) (CS) (ML) (OI) (DS) (ML)
CIRCLE 634

Schrack North America
1995 Pond Rd.
Ronkonkoma, NY 11779-7209
(516) 737-0099
(CT) (HD) (ML) (TE)
CIRCLE 635

Semiconductor Specialists Inc.
195 Spangler Ave.
Elmhurst, IL 60126
(708) 279-1005
(OI) (DS)
CIRCLE 636

Shogyo International Corp.
287 Northern Blvd.
Great Neck, NY 11021
(516) 466-0911
(AS) (CC) (DS) (ML) (PB) (TE)
CIRCLE 637

Solid State Electronics Corp.
18646 Parthenia St.
Northridge, CA 91324
(818) 993-8257
(DR) (DS) (TD)
CIRCLE 638

Sprecher & Schuh
15503 W. Hardy St.
Houston, TX 77060
(713) 931-1278x207
(CT) (PB) (TD)
CIRCLE 639

Square D Co.
Control Products Div.
Hwy. 64 East
Knightdale, NC 27545
(919) 266-8335
(AU) (CT) (CS) (HD) (HS) (ML) (PW) (TD) (VS)
CIRCLE 640

Stancor
9100 Airport Dr.
Fort Wayne, IN 46859
(219) 753-7521
(CT) (CS) (HD) (ML)
CIRCLE 641

Standex Electronics
Standex International
4538 Camberwell Rd.
Cincinnati, OH 45209
(513) 871-3777
(CS) (HS) (HF) (ML) (DR)
CIRCLE 642

Surcom Assoc. Inc.
2215 Faraday Ave., Suite A
Carlsbad, CA 92008
(619) 438-4420
CIRCLE 643

T Bar Inc.
A Data Switch Co.
1 Enterprise Dr.
Shelton, CT 06484
(203) 926-1801
(HS) (ML) (TE)
CIRCLE 644

Techmar Corp.
2232 S. Cotner Ave.
Los Angeles, CA 90064
(213) 478-0046
CIRCLE 645

Teledyne Microelectronics
12964 Panama St.
Los Angeles, CA 90066
(213) 822-8229
(HS) (HF) (ML) (OI) (DS) (TD)
CIRCLE 646

Teledyne Relays
Teledyne Inc.
12525 Daphne Ave.
Hawthorne, CA 90250
(213) 777-0077
(HS) (HF) (ML) (MI) (PB)
CIRCLE 647

Teledyne Solid State
12525 Daphne Ave.
Hawthorne, CA 90250
(213) 777-0077
(HS) (HF) (OI) (DS)
CIRCLE 648

Telemecanique Inc.
2002 Bethel Rd.
Westminster, MD 21157
(301) 876-2214
(CX) (CS) (HD) (HS) (ML) (OI) (DS) (TE) (TD)
CIRCLE 649

Texas Instruments
Materials & Controls
34 Forest St.
Attleboro, MA 02703
(508) 699-3800
(CS) (DS) (TD)
CIRCLE 650

Triridge Corp.
P.O. Box 12420
Pittsburgh, PA 15231
(412) 899-2288
(HF) (ML) (DR)
CIRCLE 651

Wabash Magnetics
55 Dupont Dr.
Providence, RI 02907
(401) 943-2686
(CS) (HF) (ML) (DR)
CIRCLE 652

Westinghouse Electric Corp.
Control Div.
P.O. Box 5715
Asheville, NC 28813
(704) 684-2381
(TD)
CIRCLE 653

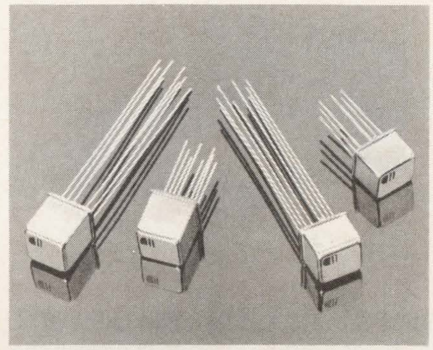
KEY

Relays

(AS)	Ac solid-state
(AU)	Automotive
(CX)	Coaxial
(CT)	Contactors
(CC)	Crystal-case
(CS)	Current-sensing
(DS)	Dc solid-state
(DF)	Differential
(DR)	Dry reed
(FP)	Flat-pack
(HD)	Heavy-duty
(HS)	Hermetically sealed
(HF)	High-frequency
(IO)	Input/output
(ML)	Magnetic latching
(MW)	Mercury-wetted reed
(MI)	Military/aerospace
(OI)	Optical isolation
(PB)	Pc-board
(PW)	Power
(RT)	Rotary
(TE)	Telephone
(TD)	Time-delay
(VS)	Voltage-sensing

▼ 0.100-IN-GRID RELAY IN MIL, COMMERCIAL TYPES

Military and commercial versions of the 0.100-in-grid relay from Communications Instruments are now available. The relays are built in accordance with MIL-R-39016 specifications. The devices are hermetically sealed, double-pole double-throw types and are offered in standard



and high-sensitivity versions. Contact ratings range from low levels to 1 A. Internal diodes for coil-transient suppression are optional. Coil voltages range from 5 to 36 V dc. Pricing ranges from $13 to $16 in lots of 1000 depending on the particular series. Delivery is in four to six weeks from receipt of order.

Communications Instruments Inc.
P.O. Box 520
Fairview, NC 28730
(704) 628-1711
▶ **CIRCLE 673**

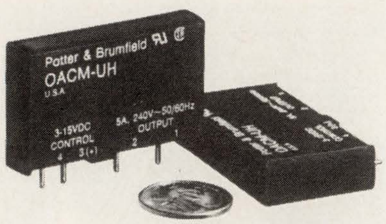
▼ 10-A RELAYS ADDED TO GENERAL-PURPOSE LINE

Nine general-purpose, multicontact 10-A relays have been added to the Series 10 (ac) and 11 (dc) octal-based plug-in relay line. Eight of the nine new devices have a push-to-test button, as indicated by a B suffix on their part numbers. One new device has an indicator lamp, as indicated by its N-suffixed part number. The Series 10 relays have operating voltages of 12 V and 120 V ac, while the Series 11 models operate from 12 and 24 V dc. Both are available in dpdt and 3pdt contact configurations. Call for pricing and delivery.

Philips Components
Discrete Products Div.
2001 W. Blue Heron Blvd.
Riviera Beach, FL 33404
(407) 881-3308
▶ **CIRCLE 674**

▼ SOLID-STATE RELAYS SWITCH 5 A ON BOARDS

Five-amp loads can be switched without a heat sink directly on pc boards by the OACM-UH solid-state relays. The switching capability of the compact devices' 1 form A contacts derates linearly from 5 A, 12 to 280 V ac



at 25°C to 1.3 A, 12 to 280 V ac at 80°C. A dv/dt snubber network across the output protects against false triggering by restricting the rise of most voltage transients to within acceptable limits. In OEM quantities, the relay costs under $3. Delivery is from stock to six weeks.

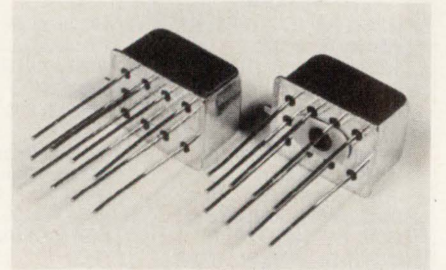
Potter & Brumfield Inc.
200 S. Richland Creek Dr.
Princeton, IN 47671-0001
(812) 386-2194
▶ CIRCLE 675

▼ POWER RELAYS COME IN FOUR CONTACT TYPES

Four contact arrangements are available for the JW sealed power relays. The devices come in 1 form A, 1 form C, 2 form A, and 2 form C types. Nominal switching capacity is 10 A, 277 V ac, and 30 V dc for the 1 form A and 1 form C types. Capacity for the 2 form A and 2 form C relays is 5 A, 277 V ac, and 30 V dc. The compact relays are sealed for automatic cleaning and offer coil voltages of 5, 6, 9, 12, 24, and 48 V dc. Pricing ranges from $1.16 to $1.32 in lots of 1000. Delivery is from stock to 12 weeks.

Aromat Corp.
629 Central Ave.
New Providence, NJ 07974
(201) 464-3550
▶ CIRCLE 676

▼ MINI DPDT RELAYS ACCEPT CMOS DRIVE

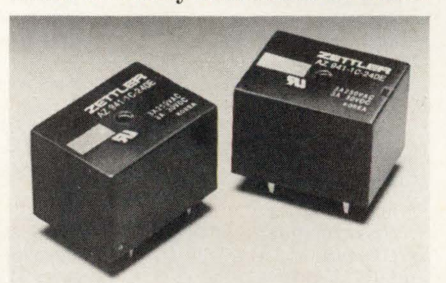


A series of ultra-miniature, hermetically sealed dpdt relays can be driven directly from CMOS logic. The Minigrid MGAT relays are qualified to MIL-R-28776/7 and feature 0.100-in.-spaced terminals. The relays' all-welded construction means high reliability and exceptional shock and vibration resistance. Switching is from low levels to 1 A using the devices' 2 form C, dpdt contacts. Standard coil resistance is available to 1560 Ω. Call for pricing and delivery.

Hi-G Co.
101 Locust St.
Hartford, CT 06114
(203) 522-8600
▶ CIRCLE 677

▼ MINI PC-BOARD RELAYS HANDLE FROM 3 TO 10 A

Contacts rated at 3, 5, or 10 A are available in the AZ 941 series relays from American Zettler. The UL-approved pc-board devices save space on boards and are a cost-saving alternative for many instrumentation and

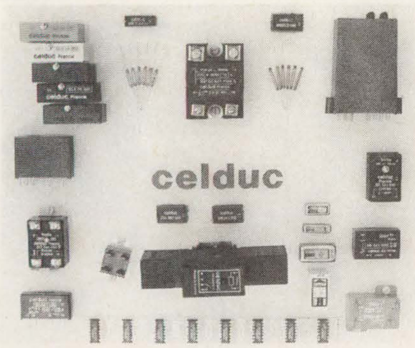


advanced industrial applications. The SPDT (1 Form C) relays last up to 10 million operations and can be delivered with epoxy seals for automatic wave soldering. A sealed 5-V, 3-A relay costs $.96 in lots of 1000. Delivery is in four to six weeks from receipt of order.

American Zettler
75 Columbia
Aliso Viejo, CA 92656
(714) 831-5000
▶ CIRCLE 678

▼ REED RELAYS, SWITCHES COME IN MANY TYPES

Reed relays, reed switches, solid-state relays, input-output modules, and proximity switches are available in a wide variety. Offerings include the most common relays used in telecommunications, data-processing



equipment, process control, and many other applications. Custom products are also available to satisfy specific application requirements. Call for pricing and availability.

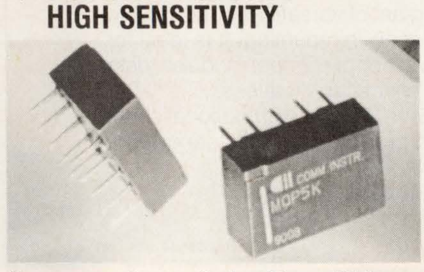
F.R. Industries Inc.
Celduc Division
557 Long Rd.
Pittsburgh, PA 15235
(412) 242-5903
▶ CIRCLE 679

▼ SENSING RELAY KEEPS EQUIPMENT SAFE

A low-voltage control circuit eliminates conduit to the guard-point switches in the SR552 sensing relays. Inexpensive magnetic-reed switches can be used to provide more safety for equipment operators. Multiple poles, stable pull-in sensitivity, and isolated dc electrode voltage make the relays a candidate for resistance-sensing industrial applications. Their ac-output poles can directly control 120-V ac loads such as solenoid valves, or serve as a logic input to programmable controllers. Call for pricing and delivery.

Regent Controls Inc.
39 Fanny St.
P.O. Box 767
Shelton, CT 06484
(800) 243-3141
▶ CIRCLE 680

▼ PCB RELAY SPORTS HIGH SENSITIVITY



Some versions of the Type MQ pc-board relay are rated at 60-mW sensitivity. The commercial-grade relay is 5 mm high, 14 mm long, and 9 mm wide. It's a double-pole, double-throw electromechanical device designed to switch from low levels to 1 A. Latching, non-latching, and surface-mounted versions are available. Applications include computers, communication equipment, security equipment, automobiles, test equipment, and more. Call for pricing and delivery information.

Communications Instruments Inc.
P.O. Box 520
Fairview, NC 28730
(704) 628-1711
▶ CIRCLE 681

▼ QUAD REED RELAY SAVES SPACE AND COST

Direct computer control of signals ranging from less to 100 μA to 30 VA is possible with the DRY5Q reed-relay output module. The unit, which is compatible with standard mounting racks and is fit for harsh industrial environments from –40 to +85°C. Quad outputs with separate logic-level inputs can be configured as 1 form A, 1 form B, or a combination of both. Each is indicated by an LED indicator for visual output-state annunciation. In single quantities, the module goes for $49.20.

Brentek International Inc.
526 Windsor St.
Reading, PA 19601
(215) 375-7200
▶ CIRCLE 682

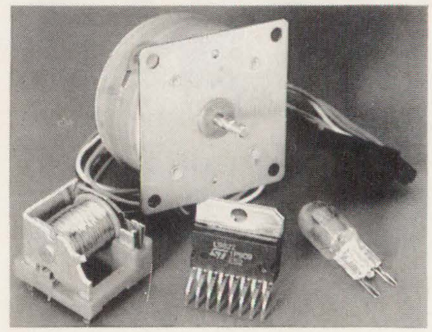
▼ GET 125 kV, 250 W IN A 5.25-IN. PANEL

High voltage, power to 250 W, and lab performance now come in a 5.25-in. package. The WR series of supplies includes three models that deliver output voltages from zero to 85 kV through zero to 125 kV. Three control-panel configurations are available: analog display, digital display, or blank for ATE applications. All versions feature full remote-control capabilities. Ripple is less than 0.1% of rated voltage at full load. Call for pricing and delivery.

Glassman High Voltage Inc.
P.O. Box 551
Whitehouse Station, NJ 08889
(201) 534-9007
▶ CIRCLE 683

▼ SMART DRIVER IC FITS AUTOMOTIVE JOBS

An octal low-side smart driver IC incorporates fault diagnostics and protection features that make it particularly suited for automotive applications. The type L9822 driver IC is designed to drive solenoids, lamps, and relays. Housed in a 15-lead

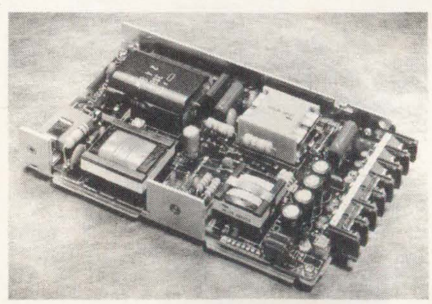


Multiwatt power package, the device includes eight drivers, each of which can deliver up to 750 mA continuously. All eight drivers can be actuated at once. In quantities of 1000, the L9822 driver IC costs $3.50. Small quantities are available from stock.

SGS-Thomson Microelectronics
1000 E. Bell Rd.
Phoenix, AZ 85022
(602) 867-6100
▶ CIRCLE 684

▼ SWITCHING SUPPLIES ACCEPT WIDE INPUTS

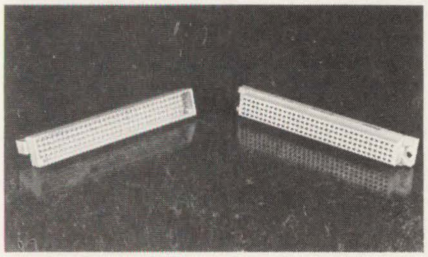
A universal input of 85 to 264 V ac can be used with the FAW series of switching power supplies. The series of low-profile supplies now includes



27 models ranging from 15 to 150 W. All models include a built-in FCC Class B, VDE0871 Class B emi filter. A power-OK logic signal is standard. The 15-, 25-, and 50-W models are under 1-in. thick.

Kepco Inc.
131-38 Sanford Ave.
Flushing, NY 11414
(718) 461-7000
▶ CIRCLE 685

▼ FOUR-ROW DIN CONNECTORS MEET HIGH-DENSITY NEEDS

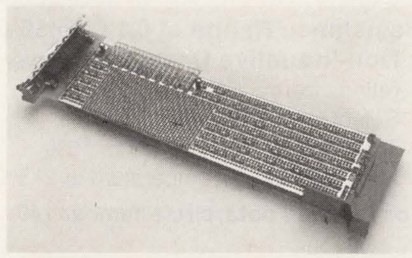


Four rows of 32 contacts each for a total of 128 contacts are contained within a series of Eurocard DIN connectors. The male version of the Type C + 1 Series 106 connectors is available with straight pins for either wave soldering or two-level wire-wrap, or with right-angle pins for wave soldering or right-angle press-fit pins. Female connectors come with straight pins for two- or three-level wire-wrap, and with two pin lengths for wave soldering.

Panduit Corp.
17301 Ridgeland Ave.
Tinley Park, IL 60477-0981
(800) 777-3300
▶ **CIRCLE 686**

▼ PACKAGING PANELS FOR PS/2 ARCHITECTURE

Offered in wire-wrap and Unilayer II logic styles, a line of Micro Channel packaging panels for the IBM PS/2 architecture are available. The panels come in 16- and 32-bit versions designed with appropriate power and ground commitments on a 0.050-in. connector. A 32-pin D-submini connector footprint is also included on

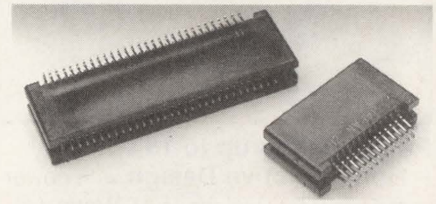


all prototype boards. Pricing for quantities of one to four boards starts at $440.58 for standard panels and $771.72 for extended panels.

Augat Interconnect Products
33 Perry Ave.
Attleboro, MA 02703
(508) 222-2202
▶ **CIRCLE 687**

▼ CARD-EDGE CONNECTOR CUTS BOARD PROFILES

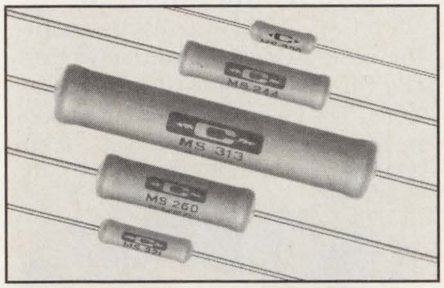
With the FCN228 card-edge connector, designers can obtain a lower profile for board-to-board interconnections. The connector measures 0.283 in. tall and features two rows of sur-



face-mounted contacts, on 0.050-in. centers, on one side of the connector. Most other connectors use a four-row array. Contacts are solder-mounted to the top and bottom edges of the daughter board, allowing it to be plugged into the mother board in the same plane. A 26-pin configuration goes for $5.21 in lots of 1000. A 60-pin version costs $9.

Fujitsu Component of America
3330 Scott Blvd.
Santa Clara, CA 95054
(408) 562-1000
▶ **CIRCLE 688**

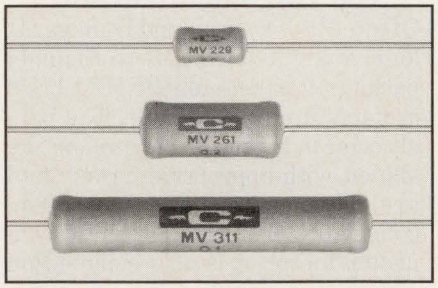
Type MS Precision Power Film Resistors



Power Rating up to 15 Watts
- **Non-Inductive Design** with power ratings from 2 Watts to 15 Watts
- Select from 17 Models
- Voltage ratings from 200 V to 6 KV
- Resistance Range 20 Ω to 30 Meg
- Tolerance of 1% (available to 0.1%)
- Max. Operating Temperature of 275°C

For Type MS data, circle number 139

Type MV Low Resistance Power Film Resistors

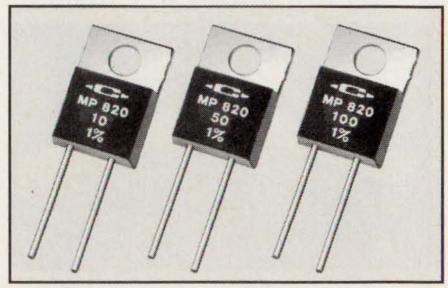


Resistance Range of 0.1 Ω to 50 Ω
- **Non-Inductive Design** with power ratings from 1.5 Watts to 10 Watts
- Select from 5 Models
- Tolerance of 1%, 2%, 5% or 10%
- Max. Operating Temperature of 275°C

For Type MV data, circle number 140

Type MP Kool-Tab® Power Film Resistors

New



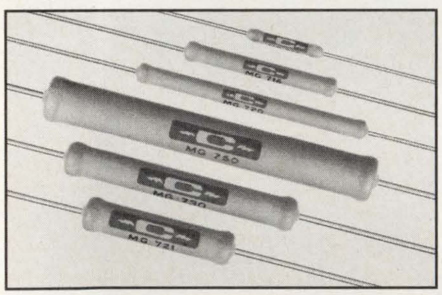
20 Watts in the TO-220 Package
- **Non-Inductive Design**
- Resistance Range 1 Ω to 10 K
- 20 Watts at 25°C Case Temperature
- Tolerance of 1%, 2%, 5% or 10%

For Type MP data, circle number 141

CADDOCK® Resistor Technology

High Performance Power Resistors and High Voltage Resistors with a 25 year record for solving problems across the board!

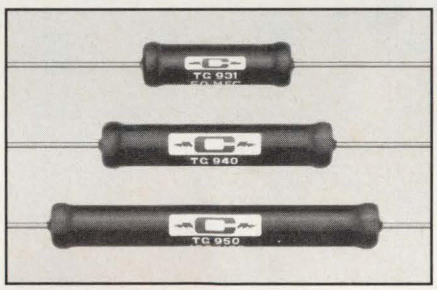
Type MG Precision High Voltage Resistors



Voltage Ratings from 600V to 48KV
- 80 ppm/°C, -15°C to 105°C, ref. 25°C
- Resistance Range up to 10,000 Meg
- Select from 23 Models
- Tolerance of 1% (available to 0.1%)
- Stability of 0.5% per 1,000 hours

For Type MG data, circle number 142

Type TG Low TC Precision High Voltage Resistors

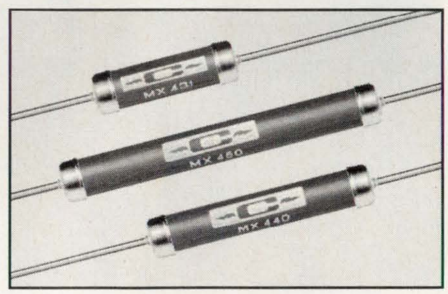


TC of 25 ppm/°C, -55°C to +125°C
- Resistance Range 1 Meg to 1,000 Meg
- 7 Models with Voltage Ratings from 4 KV to 48 KV
- Voltage Divider Match Sets with **Ratio TC to as tight as 10 ppm/°C**
- Tolerance of 1% (available to 0.1%)
- Stability of 0.25% per 1,000 hours

For Type TG data, circle number 143

Type MX Lab Grade High Voltage Resistors

New



New Cost Efficient Design
- 80 ppm/°C, 0°C to 70°C, ref. 25°C
- Resistance Range 1 Meg to 2,000 Meg
- 7 Models with Voltage Ratings from 7.5 KV to 48 KV
- Tolerance of 1%, 2%, 5% or 10% (available to 0.1%)
- Stability of 0.5% per 1,000 hours

For Type MX data, circle number 144

More high performance resistor products from

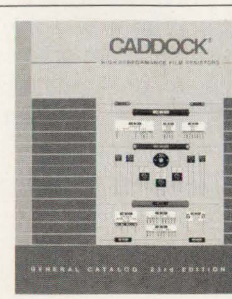
CADDOCK

ELECTRONICS, INCORPORATED

These products are manufactured with Caddock's exclusive Micronox® or Tetrinox® Resistance Film Technologies. For your copy of the Caddock General Catalog call or write:

Applications Engineering
Caddock Electronics, Inc.
1717 Chicago Avenue
Riverside, California 92507
(714) 788-1700

The Caddock General Catalog includes specifications on over 200 models of high performance resistor products.



L121.119

▼ MODULAR ENCLOSURES HAVE CONTEMPORARY LOOK

A contemporary squared appearance, and strong fully welded steel construction set apart the ESQ line of modular enclosures. The enclosures come in both 19- and 24-in. panel widths and include vertical, desk, and counter height frames. Other frame types include sloped front, low silhouette, wedge, turret, and work writing-tops. To complete the enclosure system, many accessories are available.

Emcor Products
1600 4th Ave. N.W.
Rochester, MN 55901
(507) 289-3371
▶ CIRCLE 689

▼ MEMORY-CARD CONNECTORS BOOST RELIABILITY

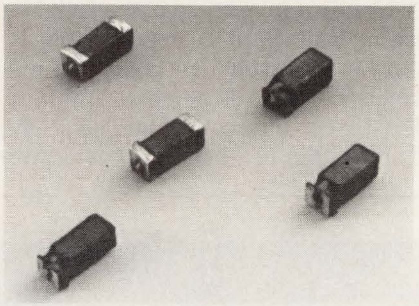
A significant increase in the reliability of Star Card IC memory cards during numerous insertion and extraction cycles is promised by the DICM III interconnection system. The system has been designed into the cards, which are a portable add-on memory alternative. The connectors feature card guides which eliminate any need for additional card-guide devices and ensures correct alignment of the card. Pricing for the connector is $5.25 in quantities of 100 and delivery is in four to six weeks.

ITT Cannon
Components Div.
1851 E. Deere Ave.
Santa Ana, CA 92705
(714) 757-8337
▶ CIRCLE 690

PASSIVES

▼ HIGH-VALUE CAPACITORS FILL MILITARY VOID

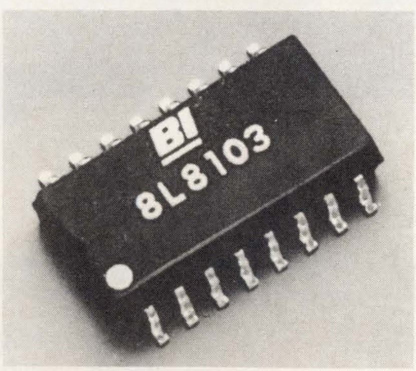
An industrial equivalent of the newly created CWR12 military-style capacitors is offered in Philips Components's 49XC extended-capacitance tantalum chip series. Philips's series offers a low equivalent series



resistance at 100 kHz. Features include hot solder-dipped (60/40) terminals and 47 standard capacitance voltage ratings as ±10% or ±20% tolerance product. Capacitance values range from 0.10 μF to 220 μF over the voltage range of 4 to 50 V dc. Call for pricing and availability.

Philips Components Inc.
Discrete Products Div.
2001 W. Blue Heron Blvd.
Riviera Beach, FL 33404
(407) 881-3308
▶ **CIRCLE 691**

▼ LADDER NETWORKS OFFER HIGH ACCURACY

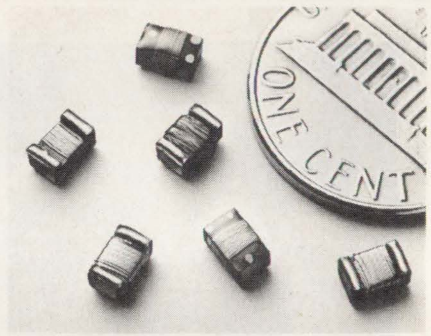


A line of thick-film R/2R ladder networks are offered in 8 bits with an accuracy of ±1/2 LSB over the zero-to-70°C temperature range. The model 628L networks come in standard ladder impedances of 10 kΩ/20 kΩ, 25 kΩ/50 kΩ, 50 kΩ/100 kΩ, and 100 kΩ/200 kΩ. The 16-pin gull-wing surface-mounted package is 0.220 in. wide and has 60/40 tin-lead-dipped copper leads for excellent heat dissipation and corrosion resistance. Applications include low-cost DAC and ADC circuits as well as binary attenuators. Call for pricing and availability.

Beckman Industrial Corp.
4141 Palm St.
Fullerton, CA 92635
(714) 447-2345
▶ **CIRCLE 692**

▼ SURFACE-MOUNT INDUCTORS IN STANDARD FOOTPRINT

Complementing an existing line of compact, high-Q surface-mounted inductors is a new series for higher inductance with a standard 1812



footprint. Twenty-four values cover the inductance range from 12 to 1000 μH with Q values up to 45. Wraparound terminals assure trouble-free soldering, and flat-top jacketing permits precise automatic placement. The inductors are available from stock and cost $.25 each in lots of 10,000.

Coilcraft
1102 Silver Lake Rd.
Cary, IL 60013
(708) 639-6400
▶ **CIRCLE 693**

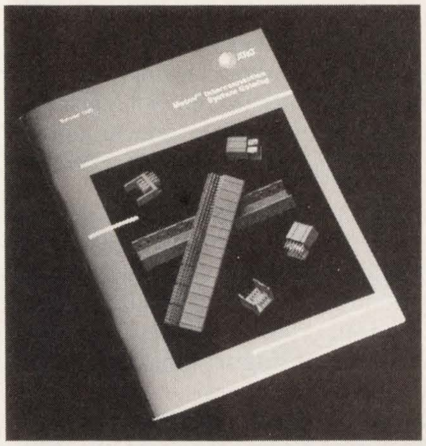
▼ TRIMMER CAPACITORS NOW IN GULL-WING STYLE

Gull-wing-leaded models have been added to the Surftrim line of surface-mounted, ceramic-dielectric trimmer capacitors. The GKG series includes seven capacitance ranges with values from 1.7 to 3 pF to 13 to 50 pF. Each corresponds with the ranges for the J-leaded models in the series. The trimmers' voltage rating is 100 V dc, and they operate from –25 to +85°C. A process seal protects against contamination. Call for pricing and availability.

Sprague-Goodman Electronics
134 Fulton Ave.
Garden City Park, NY 11040
(516) 746-1385
▶ **CIRCLE 694**

▼ CATALOG DESCRIBES METRAL CONNECTORS

The Metral interconnection system, a modular connector family on a 2-by-2-mm grid, is described in a full-line catalog. Jointly developed by AT&T and DuPont, the system



meets next-generation system needs in telecommunications and data-processing applications. The family includes four module sizes of 4 by 6, 4 by 12, 4 by 24, and 4 by 48 contacts that can be stacked end-to-end on the cardedge or backplane. Up to 456 signal I/Os can be jammed on a standard double-high Eurocard.

AT&T Microelectronics
Dept. 52AL300240
555 Union Blvd.
Allentown, PA 18103
(800) 372-2447
▶ CIRCLE 695

▼ RF CONNECTORS COVERED IN LARGE CATALOG

Information on rf-connector selection, theory, and application are featured in AMP's 208-page catalog #80-570. The book details virtually all of AMP's coaxial connectors, including BNC, TNC, N, C, SHV, UHF, SMA, SMB, and SMC types. Also included are triax connectors, twinax connectors, and others. The catalog's theory and application section offers information of basic rf theory and cable and connector types. Also included is information on typical cable specs, maximum power-handling capability, and nominal-loss characteristics for cables.

AMP Inc.
P.O. Box 3608
Harrisburg, PA 17105-3608
(800) 522-6752
▶ CIRCLE 696

▼ MIL, AEROSPACE RELAYS DETAILED IN CATALOG

The full line of military and aerospace relays from Struthers-Dunn/Hi-G Co. are highlighted in a 32-page catalog. Indexes by product type and military specification help designers find the correct relay for their application. Each product is the subject of a full description of its specifications. Also featured is a selection of tracks and sockets for relays and timers. Characteristic-curve charts for eight relay series are included to aid in device selection.

Struthers-Dunn/Hi-G Co.
Lambs Rd.
Pitman, NJ 08071-0901
(609) 589-7500
▶ CIRCLE 697

LINK FOREIGN SYSTEMS TO REAL-TIME OS

The OS-9 real-time operating system has been expanded to include the OS-9 Network File System (NFS). OS-9 NFS, developed by Microware Systems Corp., Des Moines, Iowa, supplies a high-level communications link between systems running OS-9 and any other system running Internet, regardless of the underlying hardware, operating system, network, or transport protocol. OS-9 NFS is also ROMable, enabling application programs, data files, and development tools to reside on remote file systems in diskless applications. NFS is a standard means of sharing file systems across a network. OS-9 also includes a new file manager called NFSRBF, which allows foreign file systems (such as Unix) to be accessed from OS-9 processes through the standard OS-9 I/O interface. OS-9 NFS is priced at $250 and is available immediately. Full client and server source code costs $20,000. *RN* **CIRCLE 468**

SOFTWARE SQUEEZES PLDS INTO ONE FPGA

Engineers can now quickly convert multiple programmable-logic devices (PLDs) into one field-programmable gate array (FPGA) with the Actel Logic Enhancer and Synthesizer (ALES 1). Created by Actel Corp., Sunnyvale, Calif., ALES 1 accepts PLD designs expressed in Palasm 2 source code and translates them into Actel net lists. In addition, ALES 1 also accepts Actel net-list files generated by Minc's PGADesigner. The software operates in four passes that use different algorithms designed to efficiently map logic into the Actel channeled-array architecture. Engineers can use ALES 1 to translate designs while also reducing propagation delay or maximizing device utilization. ALES 1 works with Actel's design-automation system, the Action Logic System (ALS). ALS connects to many third-party design-entry and simulation tools. ALES 1 runs on 80386-based PCs, and Apollo and Sun workstations. The PC version, which is shipping now, costs $995. The workstation versions cost $1495 and will ship early next year. *LM* **CIRCLE 469**

I/O ENGINE USES ONE SLOT, FREES UP VMEBUS

The MVME337, the first in a family of I/O engines for the VME architecture, operates multiple I/O modules from one VME slot and standardizes I/O communications through the VME Subsystem Bus (VSB). Hailing from Motorola Inc., Tempe, Ariz., the MVME337 is based on the company's 68020 microprocessor. The engine is suited for I/O-intensive applications because it supports multiple I/O modules without taking up the customary number of slots. In addition, by using the VSB interface exclusively for I/O data transfer, the VMEbus is freed up for other tasks. The board can be configured either at 16 MHz with 4 Mbytes of DRAM, or at 20 MHz with 1 Mbyte of DRAM. Other features include 32-bit address and data paths, a watchdog timer, and a VMEbus interrupt handler. The 20-MHz model costs $1995; its 16-MHz counterpart costs $2495. *RN* **CIRCLE 470**

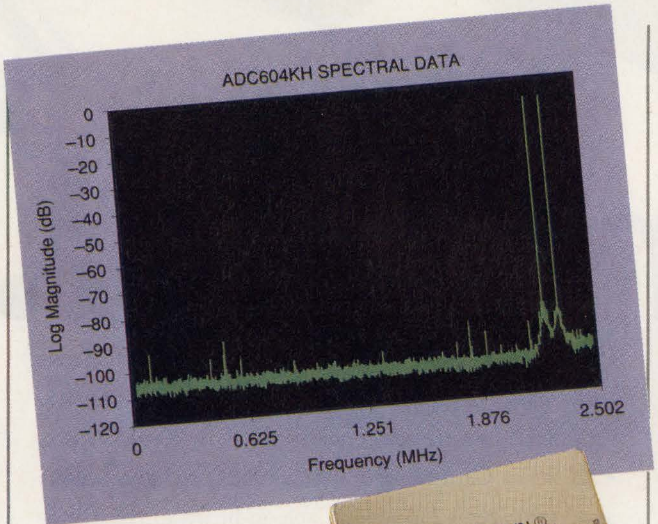
500-V HIGH/LOW-SIDE DRIVER COMES IN SOIC

Designed to drive power MOSFET/IGBT half-bridges in power supplies and motor controls running off the 120/240-V ac line, the IR2110 from International Rectifier, El Segundo, Calif., now comes in a 16-pin SOIC. The 500-V high/low-side driver was first introduced two years ago in a DIP. With its new package, bridge-converter topologies in space/volume-sensitive products are feasible. Examples include high-density power supplies for high-performance laptop PCs, off-line peripherals, and motor controls that must be "tucked away." The SOIC chip has all of the features of the DIP version, including its high-voltage dual, independent, channel drives with floating high-side output and ground-referenced low-side output. The IC switches at greater than 500 kHz, with rise times below 20 ns, into a 500-pF load. As a result, it's useful in power modules for high-frequency switchers. In quantities of 1000, the IR2110S goes for $5.36 each. Call Arnold Alderman, (213) 607-8899. *FG* **CIRCLE 471**

IMAGE-PROCESSING SYSTEM GOES FOR $20,000

A true-color, fully programmable imaging system that sells for under $20,000 is now available. The VITec-30, from VITec Inc., Plano, Tex., is the second in a family of single-board imaging computers. The first, the VITec-50, is a higher-performance model that was released earlier this year. The VITec-30 incorporates an advanced silicon design that enables true-color and gray-scale processing of digitized images. The 175-MOPS computer can function in a standalone system or as a node in a networked environment. As part of its open-system architecture, it takes advantage of available standards, such as C, Unix, X-Windows, and Motif. It's also fully compatible with the company's PICES software, which makes it possible for users to develop their own applications. The computer can hold up to 16 Mbytes of configurable DRAM and VRAM. For more information, contact Bill Morris at (214) 596-5600. *RN* **CIRCLE 472**

New 5MHz Sampling A/D Converter Tops 83dB Spurious-Free Dynamic Range



Sets Dynamic Performance Standards

ADC604 is our new, complete 12-bit, 5MHz sampling A/D converter. It offers designers unmatched dynamic range for spectrum analysis and digital receiver applications requiring high sampling speed. Its excellent linearity results in near **14-bit distortion performance.**

Key Specifications

- 83dB SFDR
- 68.6dB SNR
- −83dBc THD
- −83dBc IMD
- 12-bit Resolution
- DC - 5MHz Sampling Rate
- ±1.25V Input Range
- ±0.4LSB DLE

ADC604 is a hybrid subsystem containing ADC, sample/hold amp, precision voltage reference, and timing and error-correction circuitry. To insure the highest performance, high grade (KH) units are not only thoroughly DC and AC tested, but they are also shipped with FFT and Swept-Power (see Figure 1) test data at no additional charge.

Need more speed? ADC604 is pin-compatible with our 12-bit, 10MHz ADC603; it's easy to make speed and dynamic range trade-offs by simply plugging in an ADC603 or ADC604. Both devices dissipate 6W and are available in 46-pin ceramic and metal DIPs.

More High Speed, High Performance Products

We offer a full line of linear products designed for high speed, high resolution applications. These include current- and voltage-feedback op amps, 12- to 16-bit ADCs and DACs, sample/hold amps, PC-based ADC design and test systems, and a selection of demonstration boards to aid in product evaluation. Our new *High Speed Linear Products* brochure describes our line and contains valuable test and applications tips. Ask your Burr-Brown representative for a free copy, or call **1-800-548-6132** for immediate assistance.

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Tucson, AZ 85734 USA

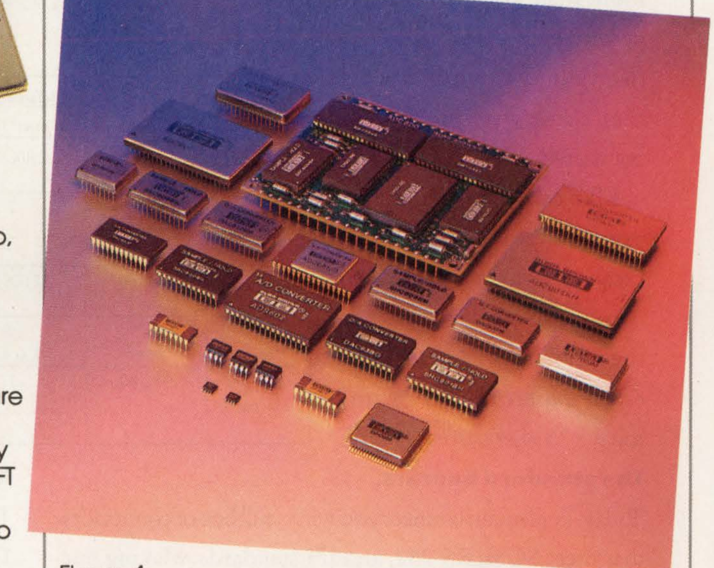
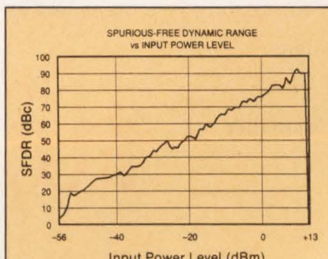


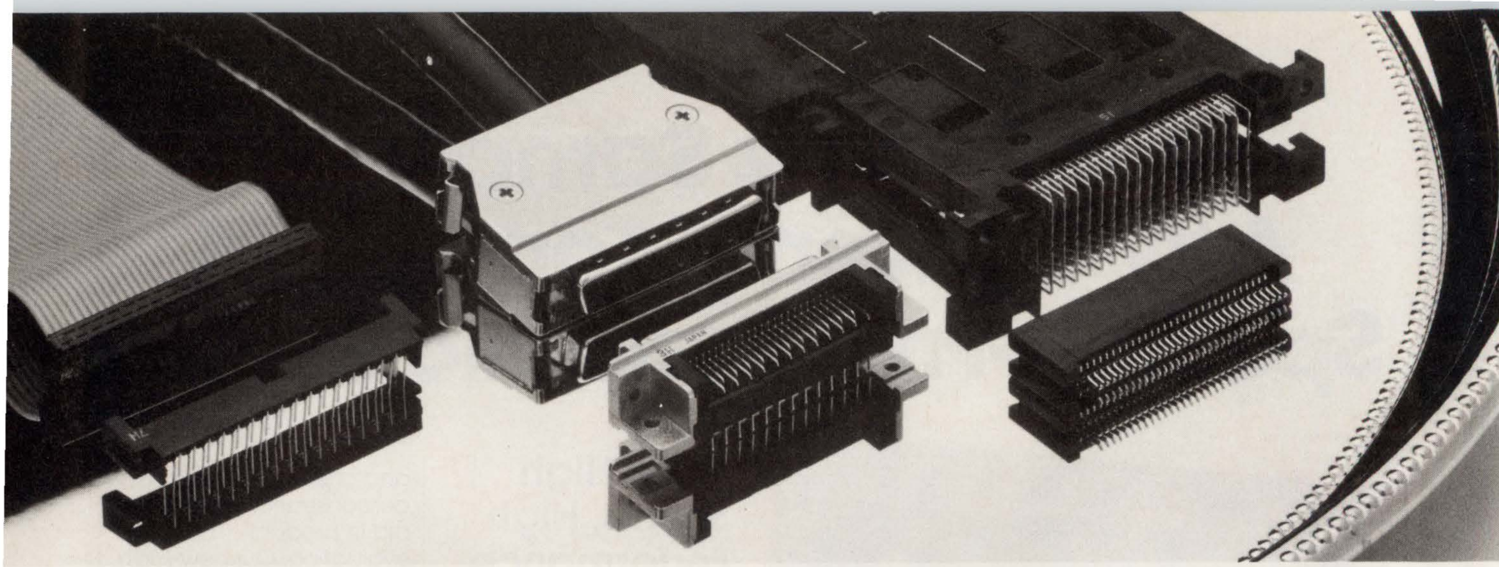
Figure 1



Typically, an A/D's spurious signal levels show a variation with input signal power. Swept-Power testing demonstrates that these spurs remain at levels acceptable over the complete range of input signal amplitudes. The test measures "worst-case" spurious signal levels as the input is decreased in very small increments from an over-driven amplitude to near the ADC noise level.

BURR-BROWN®

CIRCLE 133



Control Network Keeps Nodes Simple

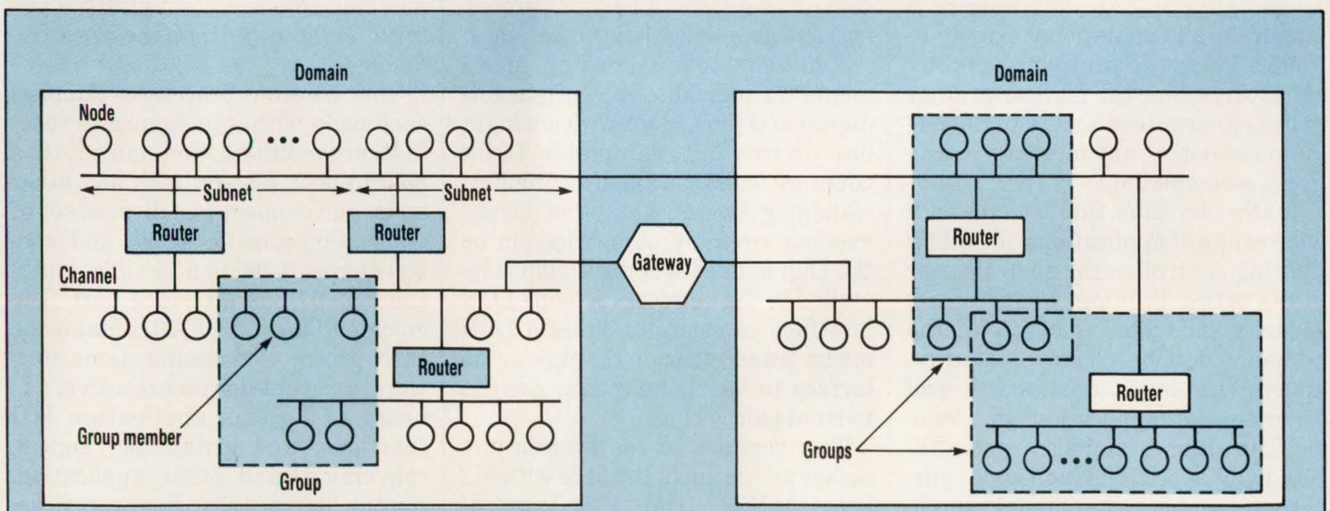
Multifunction Node Control Chips And A Rugged, Robust Protocol Let A Local Operating Network Offer Flexible, Low-Cost Control.

DAVE BURSKY

When designers think of networks, the main question that comes to mind is "what's the throughput?" That's because most networks are intended to transfer thousands of bytes of data from one point to another at multi-megabit rates. However, in control systems, the amount of data moving from one place to another during any one transfer is often minimal—a few bytes to control a machine, one word to turn off an indicator, and so on. As a result, control networks needn't be extremely fast. But they must be robust, flexible, easy to use, and low cost to meet the needs of most industrial and consumer applications.

Taking all of those requirements into account, Echelon undertook a two-year project with Motorola Inc. and Toshiba Ltd. to develop a technology that allows designers to implement what it calls a local operating network (LON). Echelon's technology to implement LONs—LONworks—consists of chips, development tools, and hardware aids. The LON consists of intelligent devices that are represented by nodes, interconnected by one or more types of communication media, and share a common, message-based communication protocol. Nodes can be further defined as objects programmed to respond to their environment, including messages from other nodes. Then they can take appropriate actions in response. Such actions include sending messages to other nodes.

That definition sounds very similar to that of a local-area network because it shares many features, such as multivendor interoperability, open technology standard, modularity and configurability, predictable performance, and good overall system reliability. However, there are some differences. LANs



MULTIPLE LONS can be interconnected through routers or gateways to form large control networks. Nodes can be addressed individually, in subnet groupings, in groups formed by individual nodes on multiple subnets, or as a domain formed from multiple subnets.

are designed for transferring larger blocks of data, and raw throughput is typically defined in megabits/s. In contrast, LONs are designed to support sense and control functions, and performance is usually measured in the number of completed transactions/s and response time.

To bring the LONs to reality, Echelon defined several chips and a robust yet flexible communication protocol. It also created an easy-to-use set of network setup and development tools. At the heart of each node resides one of two Echelon-defined Neuron single-chip devices. Each chip offers communications, control, and I/O processing. The first two Neuron processors are jointly defined by Echelon with Motorola and Toshiba—the companies that will actually manufacture the chips and offer them on the open market. Typically, each Neuron chip is accompanied by a media-interface transceiver. Media interfaces have been defined for twisted-pair wiring, power-line wiring, and for short-range rf (under 10 m). More are planned for infrared light, fiber-optic cables, and other media.

Data rates over twisted-pair wiring can go up to 1.25 Mbits/s. Short-distance rf delivers 5 kbits/s, and the power-line scheme permits up to 10 kbits/s. Over twisted-pair wiring, the 1.25-Mbit/s data rate translates to over 500 completed transactions/s. For applications that require a maximum allowable delay to be specified, a Priority feature in the protocol assures that the highest-priority node is guaranteed access to the medium as soon as any message in progress is completed.

LONs can thus find a home in a wide range of applications, including lighting control on the shop floor or in the office; lighting, temperature, security and watering control in the home; and door closure, security, speed, fuel-level, dashboard, and other sensing applications in a vehicle. The ultimate simplistic network, the LON would let someone purchase a number of intelligent switches and appliances or lighting fixtures, either preprogrammed or configurable, and then just stick them where they're needed with no additional cabling. The programmed light switch will send its message over the LON to turn on or off a specific light or group of lights, or control a specific machine or appliance.

A formal, patented, protocol definition has been set forth so that any licensed manufacturer can create subsystems or chips that are able to communicate with the LON. The first two manufacturers in this group are Motorola and Toshiba. The LONtalk protocol conforms to the Open Systems Interconnection reference model for communication protocols and includes various access levels to meet specialized needs.

High system reliability can be assured because the protocol supports end-to-end acknowledgements with automatic retries to ensure that a message gets through. In the Request/Response mode, the node that receives a request confirms that it took the requested action when it sends back a reply. The reply can also contain new data.

The Basic Processor

The primary component in the LON is the Neuron chip, which is essentially a triple 8-bit CMOS microprocessor. In addition to the triple CPUs, the Neuron chips contain electrically erasable memory and analog circuitry. The three processor blocks on the chip include a media-access control processor, a network processor, and an applications processor.

Additional chip circuitry implements 11 individually configurable digital I/O pins, clock-division logic, one or two programmable 16-bit counter-timers, wake-up circuitry, watchdog timers, and other housekeeping circuitry. A service pin on the chip is used when the chip is installed in the network. A 5-line LON interface connects to either a LON media transceiver or through an interface to baseband media, such as twisted-pair wiring.

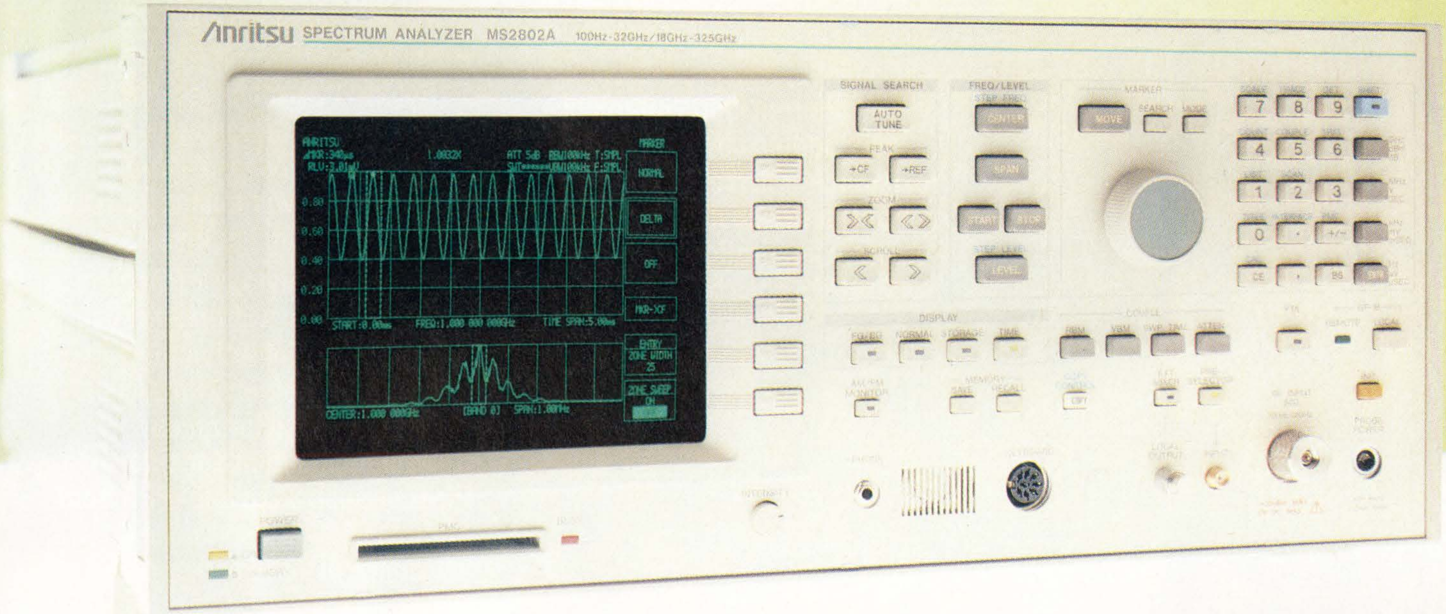
Two versions of the Neuron processor are defined: the 3120 with 512 bytes of EEPROM, 1024 bytes of RAM, and 10 kbytes of ROM; and the 3150 with the same 512 bytes of EEPROM, no ROM, an additional 1024 bytes of RAM, and a second 16-bit counter-timer. The 3120 is intended for simple nodes where low power, size and cost are most critical; the 3150 handles more complex tasks and can address up to 64 kbytes of external memory. Each Neuron chip has a unique 48-bit node identifier code irreversibly programmed into six of the EEPROM bytes.

When running at its top clock speed of 10 MHz, the Neuron processor draws about 25 to 30 mA from a 5-V supply. That power level basically scales linearly downward as the clock speed decreases. Using the software-controlled power-down and hardware wakeup features, many applications can leave the chip in a low-power state for 90 to 99% of the time. During that time, the processor is inactive and draws just a few microwatts; if battery powered, the node's battery could last for a couple of years.

To ensure that the Neuron processor's internal timing characteristics remain unchanged as the external clock frequency is set (from 10 MHz down to 612.5 kHz in factors of 2), internal logic corrects all timing relationships. When the desired frequency is programmed into the chip, all internal clocks are retimed to ensure that the communications protocol stays unchanged, and all counter and bus interface signals are generated at the proper time. The protocol's maximum data rate is typically a factor of eight lower than the clock frequency.

The Neuron processor supplies each node with intelligence to react to local conditions, communicate in a peer-to-peer fashion with any other node, and connect to a diverse set of application-specific sense and control elements using a flexible, multifunction 11-line interface port. The on-chip ROM of the 3120 contains the LON protocol communications software, an event-driven executive, a library of built-in application I/O functions, and arithmetic, logical, conversion, and other application-routine libraries. The firmware is designed to keep programs short and is also designed to simplify the programming of the Neuron processor

New Possibilities Across a Wider Range—100Hz to 32GHz



The MS2802A Microwave Spectrum Analyzer opens up new potential for accurate, stable frequency and level measurements. The MS2802A's expanded range covers 100Hz to 32GHz. Plus, a fully synthesized local oscillator and automatic level calibration function assure high performance. That means better frequency resolution, reduced sideband noise and improved frequency response.

It's also the clear choice when you need to analyze digital communications or radar. We've added new display modes—foreground/background and time display—along with burst waveform spectrum analysis.

And, for external, automated and memory control, two GPIB interfaces, a PTA (Personal Test Automation) function, and a PMC (Plug-in Memory Card) come standard. All of this makes it easy to construct software applications and ATE systems.

Features

- Frequency range: 100Hz to 32GHz, expandable up to 325GHz when using the external mixer
- Sideband noise: −103dBc/Hz (4GHz, 10kHz offset)
- Measurement range: −135 to +30dBm, with ±1.1 to ±2.6dB accuracy
- Resolution bandwidth: 10Hz to 3MHz (3dB)
- Plug-in Memory Cards
- Burst Signal Spectrum Analysis

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CIRCLE 80

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Ryton® PPS sets the industry standard in electrical/electronic applications. As a foundation, it offers: **inherent flame retardance . . . outstanding chemical resistance . . . excellent temperature resistance . . . low moisture absorption.** Plus, Ryton® PPS goes beyond the basics:

- The *excellent flow and dimensional stability* of Ryton® PPS are right for today's 50 mil center connectors, with *new toughness* for snapfit designs.
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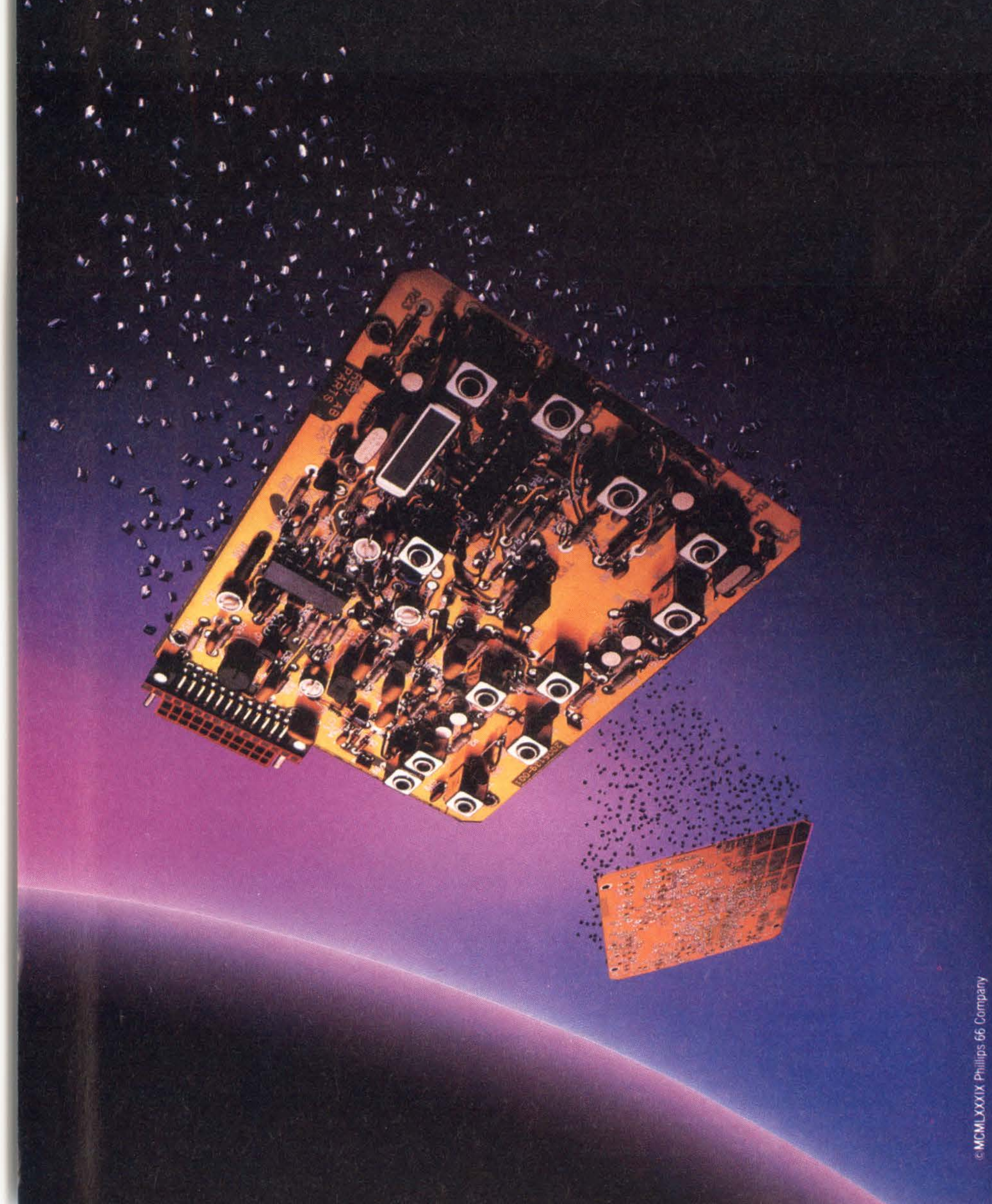

CIRCLE 137

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PHILLIPS 66

for network applications.

LON-based systems can be as simple as several devices interconnected within a room, or as complex as a multi-site facility with multiple subnetworks interconnected with routers and gateways *(see the figure)*. Nodes can address another node, an entire subnet of nodes, a grouping of nodes across multiple subnets, or a domain consisting of multiple subnets interconnected with routers. Up to 32,000 nodes can exist in a single LON domain, including nodes on different media. Up to 255 subnets can exist within a domain, and as many as 127 nodes in each subnet. Multiple domains can also be tied together, making possible networks of arbitrarily large sizes. In the special request/response mode, when the response is requested, up to 63 members of a group can respond, while if a group can go unacknowledged, all of the domain nodes can respond.

For software and network development, Echelon decided to first enhance the C language with some constructs that simplify the creation of networks and I/O device management. Added to the draft ANSI C standard are the following: a new class of data defined as Network Variables (to simplify data sharing between nodes), a new "When" statement type (to introduce events and define temporal ordering), a new set of I/O data types (to simplify and standardize multifunctional I/O), and support for explicit-message transactions (for complex application-task interactions).

By using the Network Variables, designers don't have to worry about low-level communication details. In the LONworks operating system, nodes are objects linked together by network variable inputs and outputs. This object-oriented approach simplifies network and node design, making it possible for nodes to be used in many applications.

Along with the enhanced C programming language, Echelon created some additional tools—the LONbuilder's developer's workbench. LONbuilders is a development system based on an IBM PC/AT or compatible that includes an integrated set of software and hardware tools. The tools are tightly integrated with the LONtalk protocol, and directly support the LONworks operating system. Developers can thus program, test, and debug nodes and networks using object-oriented programming concepts. A hardware emulator, single-board computer, and media-interface modules will be available for prototyping entire systems.

A key element of LONbuilder is the network-management software, which enables designers or network managers to assign node addresses, specify multicast message groups, modify communication speeds, and define routers and bridges. The software also includes a protocol analyzer that lets designers view node communication statistics, or selectively monitor, collect, and display network-traffic data. During system development, the software also helps debug the system by permitting designers to interact with nodes and observe the response from one or more nodes. The software can also download applications into the node memories over the network.□

PRICE AND AVAILABILTY

Samples of the 3150 Neuron processors will be available next quarter from Motorola and Toshiba, and will sell for less than $10. The ROM-based 3120 is expected to be released in the second half of 1991. The media-interface transceivers will first be available as evaluation units to be used with the LONbuilder for the short-distance rf link and the twisted-pair media. A LONbuilder starter kit contains the IBM-PC/AT or compatible interface card, a seven-slot development system with control processor, two LONbuilder emulators, and complete node hardware and software. It sells for $14,965. Volume production of the Neuron chips will start in the second half of 1991.

Echelon Systems Corp., 4015 Miranda Ave., Palo Alto, CA 94304; Richard Kagan, (415) 855-7400. CIRCLE 512

Motorola Inc., MOS-Digital Analog Div., 3501 Ed Bluestein Blvd., Austin, TX 78721; Ron Katchinoski, (512) 928-6888. CIRCLE 513

Toshiba America Inc., Electronic Components, 9775 Toledo Way, Irvine, CA 92718; Jerry Goestch, (714) 455-2283. CIRCLE 514

HOW VALUABLE?	CIRCLE
HIGHLY	550
MODERATELY	551
SLIGHTLY	552

10-W SWITCHING REGULATOR IC RUNS OFF 220-V LINE

A 3-W, 115-V, OFF-LINE SWITCHING-REGULATOR IC EXPANDS TO A FAMILY WITH 20-W, 115-V AND 10-W, 220-V MEMBERS.

FRANK GOODENOUGH

New semiconductor chips come and go, but seldom does the first IC of a new design become a six-member family in less than a year. Such an achievement is particularly unlikely if each new IC device offers additional performance or a different function. However, that's exactly what Power Integrations has done with their high-voltage off-line switching-regulator-IC technology.

The company's first device was the PWR-SMP3, an IC that can be used to build 3-W switching power supplies that run off the rectified-filtered 115-V ac line (ELECTRONIC DESIGN, *March 22, p. 35).* That first chip has evolved into a six-member family consisting of five switching regulators and a switching-regulator controller *(see the table).* Voltage and power-handling performance have increased to 10 W off of a 220-V ac line with the PWR-SMP210, 20 W off of a 115-V ac line with the PWR-SMP120, and 20 W off of a 220-V ac line (by adding an external 800-V MOSFET) with the PWR-SMP520.

The basic control circuitry for the chips remains constant—only the power switch has changed. And the chips have stayed in the same 16-pin power DIP.

With the exception of the PWR-SMP520 controller, these devices are complete voltage-mode pulse-width-modulated switching regulators. They contain a controller and an n-channel MOSFET switch. The controller IC, a handful of passive parts, and a few diodes builds a complete 1-MHz switching power supply. Though optimized for a flyback topology, the ICs can employ other architectures.

These chips aren't "minimum" design PWM ICs. They incorporate the functional and self-protection features expected of today's switching regulators. Functional features include an on-chip bandgap voltage reference and a self-contained clock needing no external parts. The chips operate directly from the line at power-up time. They switch over to low-voltage bootstrap power, from the inductor's feedback winding, once the circuit is running.

The switching-regulator chips typically operate with clock oscillators whose frequency is 800 kHz. On all devices except for the original SMP3, however, connecting a capacitor to pin 8 sets the frequency to as low as 100 kHz.

Self-protection features include thermal shutdown, programmable overvoltage and undervoltage lockout, and cur-

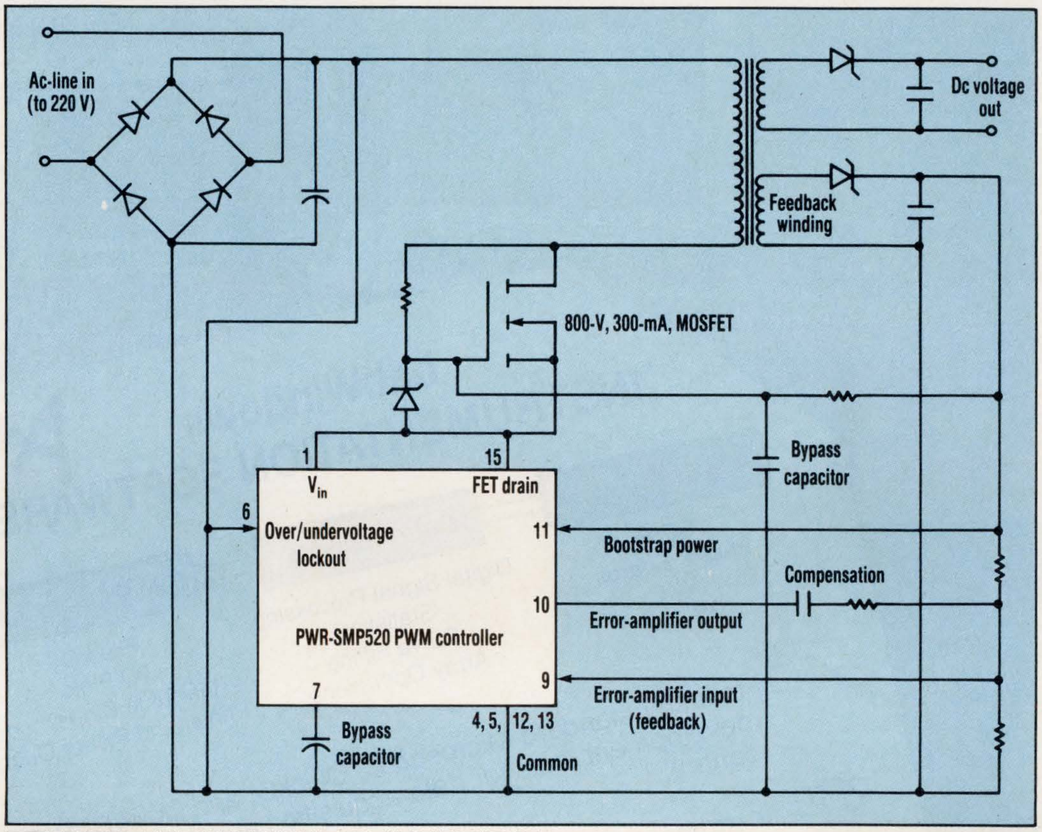
HIGH-VOLTAGE SWITCHING-REGULATOR/CONTROLLER ICS

Model	Power (W)	Input voltage (V)	Price (1000s)
PWR-SMP3 regulator	3	36-200 (rectified 115-V ac line)	$1.93
PWR-SMP400 regulator	5	30-100 (48-V telecom)	$2.97
PWR-SMP110 regulator	10	36-200 (rectified 115-V ac line)	$2.36
PWR-SMP120 regulator	20	36-200 (rectified 115-V ac line)	$2.63
PWR-SMP210 regulator	10	72-400 (rectified 220-V ac line)	$3.85
PWR-SMP520 controller	20	72-400 (rectified 220-V ac line; needs external 800-V DMOSFET)	$1.75

rent limiting. Current limiting is simplified because the MOSFET switch is a senseFET.

The SMP210, with double the voltage rating of the other ICs, is technologically the most significant. Operating from dc inputs between 72 and 400 V, it's designed for use in products expected to have worldwide distribution. It can run off rectified U.S., European, or Asian power lines—if those lines are within their specified minimum and maximum voltage range. Absolute maximum drain voltage of the SMP210 is 800 V.

The rest of the regulators, except for the SMP400, are designed to operate off the rectified 115-V ac line with dc inputs between 36 and 200 V. The 5-W SMP400 aims at 48-V telecommunications applications, handling input voltages between 30 and 100 V. Its on-resistance is typically just 4 Ω, while those of the SMP3 and SMP210 are 14 and 25 Ω, respectively. Typical on-resistance of the 20-W SMP120 is also 4 Ω.



WITH AN EXTERNAL 800-V DMOSFET, the PWR-SMP520 switching-regulator controller IC can supply 20 W of regulated power from a 220-V ac line.

Off-line power supplies for a wide range of portable and main/battery-powered products represent major applications. The applications range from modems, monitors, and computer peripherals, to laptop computers. They include laboratory and medical instruments, and as regulator-IC prices drop, even some consumer items.

Cascode Control

The PWR-SMP520 supplies up to 20 W of regulated power from the rectified 220-V ac line. Its internal circuit is identical to that of its SMP regulator kin. As a result, unlike the common PWM controllers that drive the base or gate of their power switch, it operates in a cascode, or common-gate, mode. The drain of the internal FET switch is connected to the source of the external FET *(see the figure)*. The controller provides a fixed bias for the 800-V DMOSFET (such as a BUZ78), while its low on-resistance (16-Ω) 120-V internal FET switches the source of the high-voltage FET by pulling it negative with respect to the gate. The technique is used with bipolar transistors, in high-voltage supplies, to combine their high-voltage standoff capability and low forward drop, with MOSFET speed.

At power-up, the external FET is biased to turn on from the primary side of the transformer through pin 1. Once gate voltage is available, the FET supplies current from its source, also through pin 1, to the linear bias regulator within the SMP350. Then it charges the bypass capacitor connected to the external FET's gate. When sufficient voltage is available, the PWM control circuit begins an orderly startup and the internal FET begins to switch the external FET. In addition to high-voltage, high-speed operation, the technique eliminates the need for a high-voltage gate-drive supply and offers overcurrent protection (all of the current flows through the current-limited internal switch).□

Price And Availabilty

All five PWR-SMP switching-regulator ICs, and the PWR-SMP520 controller, are contained in 16-pin plastic power DIPs (sometimes called "batwings"). The the center pair of pins on each side (pins 4, 5, 12, and 13) are connected together and to the die mounting pad of the leadframe for maximum heat transfer to the copper foil of the pc board. The devices are rated for operation from 0 to 70°C. Pricing is shown in the table.

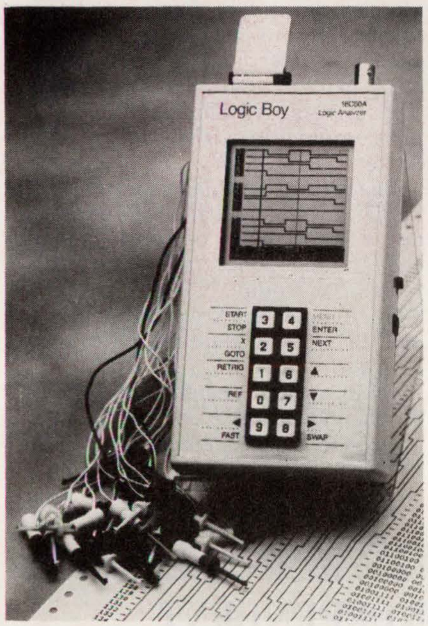
Power Integrations Inc., 411 Clyde Ave., Mountain View, CA 94043; Doyle Slack, (415) 960-3572. CIRCLE 515

How Valuable?	Circle
Highly	553
Moderately	554
Slightly	555

Handheld 16-Channel Logic Analyzer Works To 50 MHz

The Logic Boy is the first full-featured handheld logic analyzer. The instrument runs at 50 MHz on all 16 channels, and its size (4 by 7.6 by 1.8 in.), weight (21 oz.), and keyboard layout let users hold and operate it with one hand.

The analyzer performs state and timing analysis and is compatible with TTL and CMOS logic levels. Features include a 1-kword by 16-bit capture and reference memory, four-level combinatorial event sequencing, synchronous and asynchronous clocking, a clock qualifier, and programmable trigger delay. The system setups and reference memory are nonvolatile. An IBM-compatible printer port is standard. With the unit's BNC trigger output terminal, the Logic Boy can operate as a 16-bit, four-level word recognizer when connected to the external trigger input of most oscilloscopes.



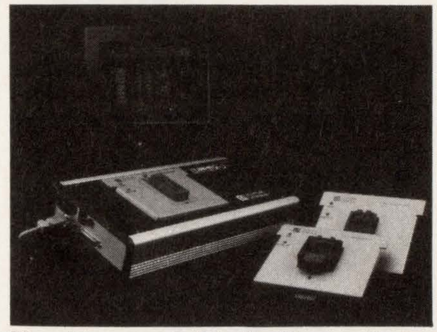
The analyzer's twist liquid-crystal display holds 12 channels of acquisition or reference timing waveforms, and a scroll feature lets users view the rest. The display shows differences between the acquisition and reference waveforms in reverse-field for easy analysis. Delta-time measurements are made automatically and updated with a cursor. Instrument setup is made easier by menus that prompt users.

The Logic Boy is available from stock with probes, ac adapter, IBM printer cable adapter, and NiCd batteries for $1795.

Trace-Tek Instruments Inc., 1301 N. Denton Dr., Suite 204, Carrollton, TX 75006; (214) 446-9906. **CIRCLE 700**

■ *JOHN NOVELLINO*

Device Programmers Avoid Ground Bounce



Now incorporated in the Turpro Series IC programmers is a new hardware technology called Turbo-Mapping, which improves programming and testing of fast CMOS devices. A Turbo-Mapping ASIC in the programmers switches the device inputs one at a time with nanosecond speed. This technique cuts noise levels, including those caused by ground bounce and V_{CC} over or undershoot. The Turpro-1 is a PC-based universal programmer with 40-pin DIP capability for all programmable memory and logic devices. The Turpro-832 handles EEPROMs and flash EPROMs from 4-kbits to 8-Mbits in 24- to 32-pin packages. The Turpro-1 costs from $1450 to $2450, depending on the device support selected. The Turpro-832 costs $1950, an optional 8-Mbit RAM board goes for $500, and a PLCC adapter costs $1495.

System General Corp., 244 S. Hillview Dr., Milpitas, CA 95035; (408) 263-6667. **CIRCLE 703**

E-Beam Prober Creates 0.1-μM, 1-NA Beam

The E1340 submicron e-beam probe station creates bright, sharp images by generating a 0.1-μm probe beam with more than 1-nA beam current at 1-keV of beam energy. The system, used for noncontact probing and measurement of submicron and multilayer devices, features a new automatic CAD navigation package. The software streamlines and automates the preparation of design data needed by the probe station. By incorporating library routines into the typical tape-out process, the package translates device design data without additional layout and schematic comparisons. The E1340 can be directly docked to ATE systems for various cavity-up, as well as cavity-down, packaging. Two base personality modules handle all package types.

Advantest America Inc., 300 Knightsbridge Pkwy., Lincolnshire, IL 60069; (708) 634-2552. **CIRCLE 701**

Boundary Scan Software Tests ICs

Designed in conformance with the IEEE 1149.1 boundary-scan architecture, the Tapdance software package detects potential flaws in IC designs. Using Tapdance, engineers can access and test individual components on circuit boards from the board's edge connector. The software accepts manually entered IC-design parameters through an interactive system of menus and help screens. It then generates an optimized sequence of test vectors to rigorously test the circuit design. Various standard output options enhance readability and simplify the user interface. The licensing fee for Tapdance is $5000 per CPU. The first-year maintenance fee of $750 includes point-release upgrades and telephone support.

AT&T Intellectual Product Div., 10 Independence Blvd., Warren, NJ 07059-0911; (800) 462-8146 or (201) 580-6229. **CIRCLE 704**

SCSIbus Analyzer Does Fast Tracing, Emulation

The DSC-202 STE is a standalone, nonintrusive SCSIbus tracer/analyzer. The instrument incorporates an NCR 53C700 SCSI processor that makes it possible to emulate a SCSI host or target at up to 6 Mbytes/second in synchronous and 5 Mbytes/second in asynchronous operation. The analyzer's tracing mode has been tested to over 10 Mbytes/second. Either a dumb terminal or an IBM PC-compatible host computer can control the DSC-202 STE. Trace memory capacity is 128 kbits by 7 bytes with event-driven recording. Time-stamp resolution is 40 ns, and test routines are programmable in C. The analyzer permits pre-, post-, center, or external triggering.

Ancot Corp., Mid-Peninsula Business Park, 1755 E. Bayshore Rd., Suite 18A, Redwood City, CA 94063; (415) 363-0667. **CIRCLE 702**

Speedy Bus Logic Trims I/O Propagation Delay

Able to sink 64 mA or source 15 mA, the FASTr family of bipolar bus-interface logic chips offer the shortest propagation delays for TTL-compatible systems. The chips from National Semiconductor will have a maximum propagation delay of just 3.9 ns (an octal buffer), forming an ideal companion for many of the latest microprocessors that must operate with clock speeds in the 33-to-50-MHz range. The FASTr family will not be an all-inclusive family of logic circuits, but will be concentrated around signal-busing and clock-distribution needs in high-speed systems.

Transceivers in the family will be able to sink up to 64 mA on both their A and B outputs, making it possible for the chips to drive symmetrical differential lines. Furthermore, the circuits were designed to have reduced static power consumption vs. standard FAST logic—about 10 to 30% lower, depending on the device. And dynamic power consumption is actually less than the power levels claimed by high-speed CMOS or biCMOS processes. All devices are rated at speeds of more than 25 MHz when driving heavy capacitive loads (250 pF).

Propagation delay ratings are guaranteed when multiple outputs are simultaneously switched with 50- and 250-pF ac loads. Output timing skew is also guaranteed to be less than 750 ps on the clock drivers, and will be guaranteed for output-to-output across a single part, as well as from part-to-part. Initial chips to be released include 8- and 9-bit buffers and transceivers, 8-bit clock drivers, and 16-bit buffers and transceivers. All 8-bit logic chips are pin-compatible with existing FAST buffers.

The logic chips will be housed in plastic DIPs, small-outline IC packages, and PLCCs (16-bit devices). Commercial- and industrial-temperature-range versions will be available. Prices for the 8-bit noninverting transceiver IC start at $2.20 each in 100-unit lots. Delivery is from stock.

***National Semiconductor Corp.**, 2900 Semiconductor Dr., Santa Clara, CA 95052; (408) 721-5000.* **CIRCLE 705**

■ *DAVE BURSKY*

Programmable Power-Management Chip Is Processor-Independent

The HT191 is a processor- and chip-set-independent programmable power-management chip that enables system designers to support numerous peripheral configurations for portable computers. The chip, from Headland Technology Inc., is a companion device that extends the battery life of portable PC/AT computers by monitoring, adjusting, and/or shutting down the system's peripherals when not in use.

The design for the device stems from the increased demand for system-level power management. The system-level manager monitors the activity and controls the powering of all the system peripherals as well as the chip set, CPU, and memory.

The HT191 acts as an interface or mailbox point between the AT bus and an 80C51 microcontroller. The microcontroller remains on to monitor system activity. Whenever it senses a key stroke, a mouse movement, or even a coprocessor action, it powers up the system. It's important to monitor devices other than the keyboard like a mouse because many applications don't require much keyboard use, especially those based on Windows. The HT191 also acts as a port expander, enabling the 80C51 to talk to more peripheral devices.

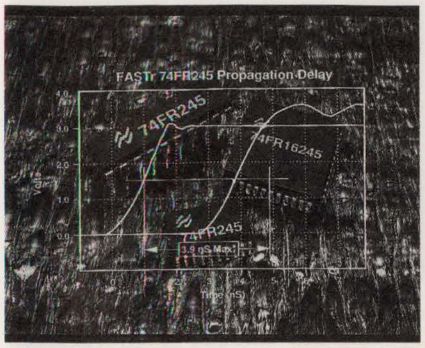
The HT191's advanced power-management features let a system conserve power by slowing or halting the microprocessor, dimming or blanking the display, and placing modems and other devices in standby, sleep, or other power-saving modes. Headland supplies all of the code that's needed for the 80C51 to monitor and control the peripherals. The power-management part has a CMOS design and is packaged in a 100-pin plastic quad flat pack. It costs $19 in quantities of 1000 and is available now.

***Headland Technology Inc.**, 46221 Landing Pkwy., Fremont, CA 94538; (415) 656-7800.*

CIRCLE 706

■ *RICHARD NASS*

16-BIT MICROCONTROLLERS SOLVE REAL-TIME NEEDS



Boasting a powerful 16-bit CPU core, the μPD7832X series of microcontrollers from NEC Electronics aims squarely at real-time control applications. An on-chip 8-channel 10-bit ADC with a sample-and-hold amplifier and a high-performance interrupt handling subsystem enable the chip to tackle automotive engine and braking-control, as well as disk- and tape-control applications.

The microcontroller's CPU runs at a maximum clock rate of 16 MHz, executing most instructions in just 250 ns each. A three-byte instruction prefetch queue is included to help ensure that the CPU rarely has to wait for its next instruction.

The command set includes 16-bit multiplication and division instructions. It also includes Stop and Halt commands for low-power standby modes, as well as 1- and 8-bit logic operations and string instructions. On-chip memory includes 640 bytes of RAM and either 16 kbytes of ROM (model 78322) or no ROM (model 78320).

Both model 78322 and 78320 versions have an interface to a dedicated memory chip, the μPD78301, which includes memory, interface circuitry, and an instruction prefetch pointer. When using the chip, instructions can be fetched from external memory at the same speed as they can be read from the on-chip ROM.

Interrupts can be handled in any of three ways: vectored, context switching with hardware save for all general registers, and macroservice functions through an intelligent I/O subsystem. Up to 55 I/O lines are available for the controller, as are two serial communication channels (with each channel featuring a dedicated baud-rate generator). Also available are multiple counter-timers with capture and compare registers, as well as a watchdog timer.

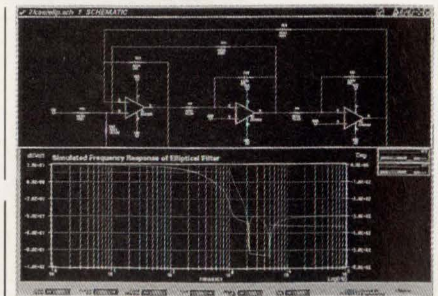
The μPD78322A 16-bit microcontroller is immediately available in two different package styles. It is available in either a 68-lead plastic leaded chip carrier or in a 74-lead plastic quad-sided flat package. In lots of 10,000, the PLCC version is priced at $15 each.

NEC Electronics Inc., 401 Ellis Street, P.O. Box 7241, Mountain View, CA 94039; Marc Birnkrant, (415) 960-6000. **CIRCLE 707**

■ *DAVE BURSKY*

MIXED-MODE SIMULATOR EMPLOYS ONLY ONE ENGINE

A mixed-mode simulator from Intergraph Corp. uses a single-engine methodology to eliminate coupling and other problems associated with traditional "glued" engine approaches to analog-digital simulation. The simulator, called ISIM-se, disposes of the overhead needed for data transfer between two autonomous simulation engines. In addition, designers needn't input special junction specifications, define interfaces between analog and digital components, or partition circuitry.



Users can simulate at several levels of accuracy and speed. Models can range from the primitive to the behavioral level. The effects of overshoot and undershoot, ringing, spikes, and damping factors are simulated and then viewed through the optional Analog Analysis Interface (AAI). In addition, users may view analog and digital waveforms at the same time.

The AAI also facilitates using the company's new Filter Synthesis Module. The filter package offers a framework to specify, design, and synthesize common analog filters.

ISIM-se is available now. Existing CSpice users can upgrade for free; the cost for new users is $10,000.

***Intergraph Corp.**, One Madison Industrial Park, Huntsville, AL 35807-4201; (205) 772-2700.*

CIRCLE 708

■ *LISA MALINIAK*

FIVE CAE TOOLS AID IN IC PROCESS DESIGN

Five tools from Silvaco International help engineers with the IC process portion of a design. The first tool, Master, is a software package for generating device cross sections from layout and process-flow information. Predict, another new tool, is a one-dimensional, multilayer silicon process simulator originally developed by the Microelectronics Center of North Carolina. The third tool is S-Creep, which is a 2D viscous creep-flow simulator. Also, S-MINIMOS5 is a tool for numerical simulation of MOS and MESFET devices. Finally, Spayn is a relational database for statistical parameter analysis. All five products are shipping now and run on DEC, HP/Apollo, Sony, and Sun workstations. Master, Predict, S-Creep, S-MINIMOS5, and Spayn cost $15,000, $25,000, $15,000, $25,000, and $25,000, respectively.

Silvaco International, 4701 Patrick Henry Dr., Santa Clara, CA 95054; (408) 988-2862. CIRCLE 709

80386 LENDS PROCESSING POWER TO PCB EDITOR

Users of the DC/CAD pc-board design system can increase speed and capacity by upgrading to the 80386 version of the system's Draftsman-EE editor. The integrated 80386 module, from Design Computation, has high capacity for large pc-board designs containing hundreds of ICs. The 386 Draftsman-EE module operates at least twice as fast as other versions of the software by using the protected mode of the 80386 processor. Processors working in the protected mode perform 32-bit operations and can directly address up to 16 Mbytes of memory. The module works with extended memory or an expanded-memory manager. It obtains all of the available memory from the manager and converts it to extended memory, which eliminates the time delays associated with using expanded memory. The Draftsman-EE 386 enhancement must run on a PC powered by a 80386, 80386SX, or 80486 processor. The enhancement is shipping now for $995.

Design Computation Inc., Sherman Square, Route 33, Farmingdale, NJ 07727; (908) 938-6661. CIRCLE 710

PLD TOOL ENHANCEMENTS CUT DEVELOPMENT TIME

Enhancements to the Snap line of programmable-logic device (PLD) design tools cut development time, improve testability, and boost the performance of low- and medium-density PLD designs. New to Snap version 1.6 are a fault simulator, logic optimizer, Boolean-equation extractor, a friendly user interface, and revised documentation. The logic-optimization program is the Expresso Minimizer from the University of California at Berkeley. Users can input waveforms, Boolean and state equations, and Orcad and Futurenet schematics. Snap merges these inputs, synthesizes a net list, and performs functional and fault simulation. The fault simulator produces a report that lists undetected faults, potentially undetected faults, coverage efficiency, and other valuable data. Snap version 1.6 is available now. The $795 cost includes one year of upgrades.

Signetics Co., a div. of North American Philips Corp., 811 E. Arques Ave., P.O. Box 3409, Sunnyvale, CA 94088-3409; (408) 991-2000. CIRCLE 711

SYNTHESIS TOOLSET IS TAILORED FOR FPGAS

The FPGA Compiler is a logic-synthesis, optimization, and design-analysis tool that's dedicated to supporting field-programmable gate arrays (FPGAs). It contains synthesis and optimization algorithms specific to FPGA technology. Users can input with standard methods, such as Palasm descriptions, VHDL models, and EDIF net lists. FPGA Compiler is targeted at the turnkey and systems markets. To address the turnkey market, single technology configurations are made available to FPGA vendors for resale. To address the systems market, multiple technology configurations are being integrated into system vendors' EDA frameworks. FPGA Compiler with the Palasm input path is shipping now. The EDIF and VHDL input paths will ship early next year. Pricing for the product will range from $2000 to $20,000, depending on the input options and output technologies. The initial release of the FPGA Compiler supports optimization for Xilinx and Actel devices.

Exemplar Logic Inc., 2550 Ninth St., Suite 102, Berkeley, CA 94710; (415) 849-0937. CIRCLE 712

SYNTHESIZE, OPTIMIZE DIGITAL LOGIC ON A PC

Designers working on a PC can synthesize and optimize digital logic with Instant Logic 2.2. Instant Logic creates optimized net lists and schematics from truth tables, logic equations, or state machines. The optimization programs analyze and improve existing net lists or schematics by minimizing either circuit size or delay. Instant Logic is compatible with Orcad's schematic design tools and such design languages as CUPL and Open Abel. The basic software package includes a generic library with more than 100 combinational and flip-flop primitives. Instant Logic 2.2 runs on 80286- and 80386-based PCs with EGA, VGA, or Hercules graphics. It's shipping now, and its $795 price tag includes telephone support and free upgrades for one year. A workstation version is now available on the Sun workstation for $4800. It has the same features, but can synthesize much larger designs.

Integrated Silicon Systems Inc., P.O. Box 13665, Research Triangle Park, NC 27709; (919) 361-5814. CIRCLE 713

486-BASED EMBEDDED VME SYSTEM RUNS PC SOFTWARE

Primarily used as a front-end computer and operator interface, the EPC-5 is a system subassembly that can be embedded into sophisticated computer-controlled equipment and machinery. The board's CPU module consists of a 25- or 33-MHz 80486 microprocessor, up to 16 Mbytes of system memory, and a VGA graphics controller.

The mass-storage module includes a 40-, 100-, or 200-Mbyte hard disk and a 3.5-in. floppy disk drive. Applications include industrial automation, semiconductor-manufacturing equipment, telecommunications, and diagnostic medical equipment. The EPC-5 brings workstation-level performance and functionality, as well as PC software, to embedded applications.

With a dual-bus architecture, the workstation has maximum flexibility. The local EXM bus is similar to the PC/AT bus, and is used to expand PC peripherals. The EXM modules available from RadiSys include an Ethernet port, controllers for solid-state and floppy disk drives, and a SCSI controller. Otherwise, the system can be expanded through the VMEbus.

The board fits the standard VMEbus form factor and takes up two slots. It contains two serial ports, a parallel port, and a battery-backed time-of-day clock. The EPC-5 is available now for $7495. Mass-storage modules start at $990 and EXM expansion modules begin at $370. Also available is a system development kit that includes the EPC-5, mass-storage and expansion modules, software, a keyboard, and a mouse.

RadiSys Corp., 19545 NW Von Neumann Dr., Beaverton, OR 97006; (503) 690-1229. **CIRCLE 714**

■ *RICHARD NASS*

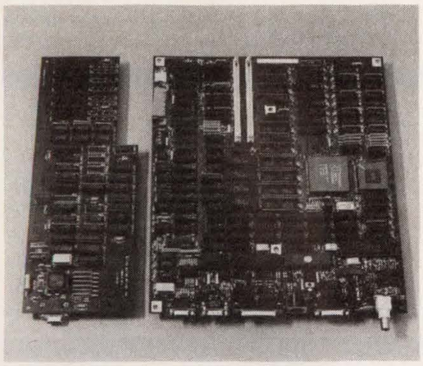
3U VME CPU CARD SUPPLIES 20 MIPS

Based on the 25-MHz 68040 microprocessor, the VM40 CPU board boasts 20 MIPS and 3.5 MFLOPS. The 3U VME board is equipped with 4, 8, or 16 Mbytes of 32-bit RAM, supporting a burst-fill mode. The board is initially stocked with DRAM, but local-memory modules can be configured for single- or dual-ported SRAM with battery backup. Because the memory modules are self-configurable, no PLA change or jumpers are required to upgrade any memory configuration.

The CMOS CPU needs less than 7 W. It can be expanded with various I/O or memory extensions using a second 3U module. Communication between the two modules is done through a 32-bit high-speed local extension bus. Available in the first quarter of 1991, the VM40 costs $2600 each in large quantities.

Pep Modular Computers Inc., 600 North Bell Ave., Carnegie, PA 15106; (412) 279-6661. **CIRCLE 715**

Am29000 Directs Color X-Window Controller



By running AGE's Xoftware A290 X-Windows server software, the XQC-8200 color X-Window controller exceeds 40,000 X-stones. The controller, based on AMD's 20-MHz Am29000 RISC processor, supports resolutions of 1024-by-768, 800-by-600 (Super VGA), and 640-by-480 (VGA) pixels. It also supports 8-bit color, giving users 256 colors from a palette of 16 million. Multiple levels of DRAM expansion memory, ranging from 2 to 16 Mbytes, are available. ROM can be expanded from 64 kbytes to 2 Mbytes for system boot, hard loading of X-server software, and font storage. The controller is now available for OEM licensing at a cost of $75,000, with hardware royalties starting at $10 per unit.

Doctor Design Inc., 5415 Oberlin Dr., San Diego, CA 92121; (619) 457-4545. CIRCLE 716

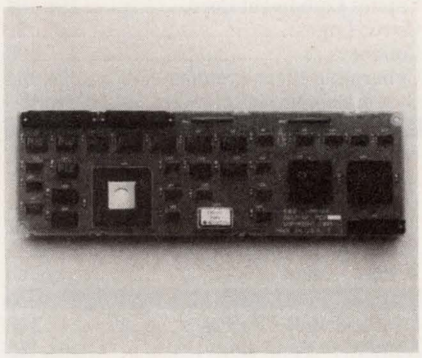
Translate 12-Bit/Pixel Images To 8 Bits/Pixel

By adding the LMX personality module to Imagraph's 1210 display controller board, users can get real-time window leveling of X-ray and medical modality images in sizes up to 2 k by 2.5 k by 12 bits. The LMX is a 12-to-8-bit lookup-table transformation module. It connects to the 1210 using one slot. Three versions of the 1210 make it suitable for the ISA, EISA, and VME buses. The personality module supplies window leveling of 12-bit pixel images through a hardware transformation operation that processes 12 million pixels/s. The LMX supplies from 4 to 12 Mbytes of memory to store images. The lookup table can be changed to affect only certain regions, which can either be a window, a portion of an image, or an entire image. The LMX also offers 4-bits/pixel overlay. Different versions of the 1210 board are designed for the ISA, EISA, and VME buses. The personality module starts at $1795. The 1210 display controller begins at $3995.

Imagraph Corp., 11 Elizabeth Dr., Chelmsford, MA 01824; (508) 256-IMAG. CIRCLE 717

VMEbus Interfaces To Token-Ring LAN

The VMM-34, a serial mezzanine board, adds wide-area-networking capabilities to SBE's VCOM-33, a high-performance communications controller that connects VMEbus systems to local-area networks. The VCOM-33 is a 68030-based controller that supplies a software-selectable interface to a 4- or 16-Mbit/s token-ring LAN. By adding



the VMM-34, users can get serial communications at speeds up to 2.048 Mbits/s (E1). Available with four channels, the mezzanine board can supply a combination of E1, T1, fractional-T1, and 64-kbit/s service on all four channels. It also supports asynchronous, bisynchronous, and bit-synchronous protocols.

SBE Inc., 2400 Bisso Ln., Corcord, CA 94520; (800) 347-2666 or (415) 680-7722 CIRCLE 718

See Multimedia On A PC

For just $695, users can have multimedia on their PC/AT or MCA bus systems. Super VideoWindows allows full-motion video and stereo audio to play from a camera, VCR, videodisk or cable TV in any size window, placed anywhere on the computer screen. Functions include scale, crop, zoom, pan, freeze, and graphics and text overlay. Individual video frames can be stored to disk or ported to other applications such as desktop publishing or CAD/CAM. The board is available now. Optional companion modules are also available including a VGA board, a TV tuner, and a compression board.

New Media Graphics Corp., 780 Boston Rd., Billerica, MA 01821; (508) 663-0666. CIRCLE 719

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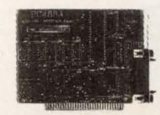

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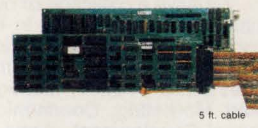

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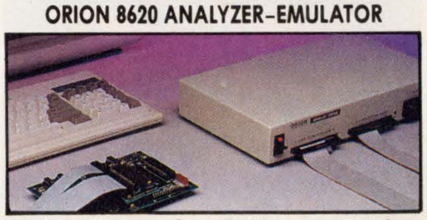

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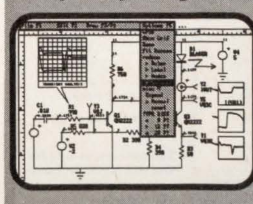

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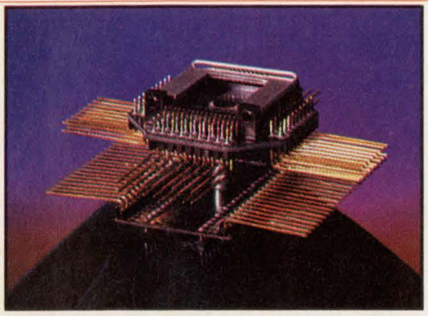

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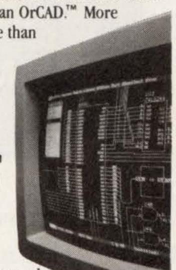

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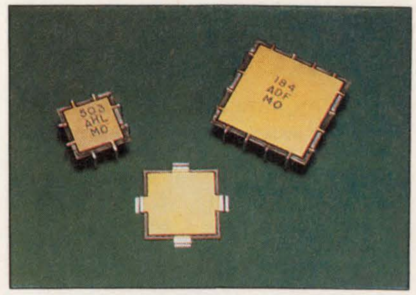

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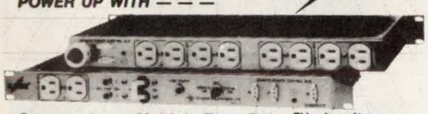

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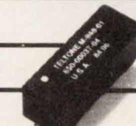

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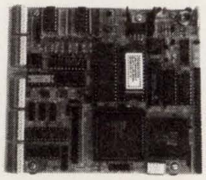

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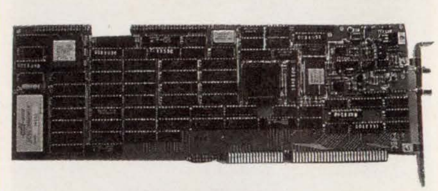

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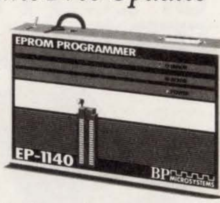

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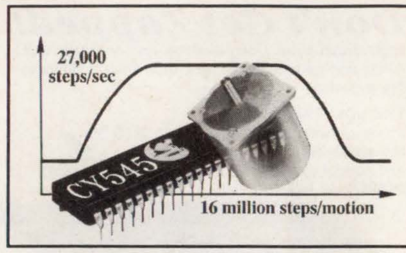

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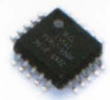

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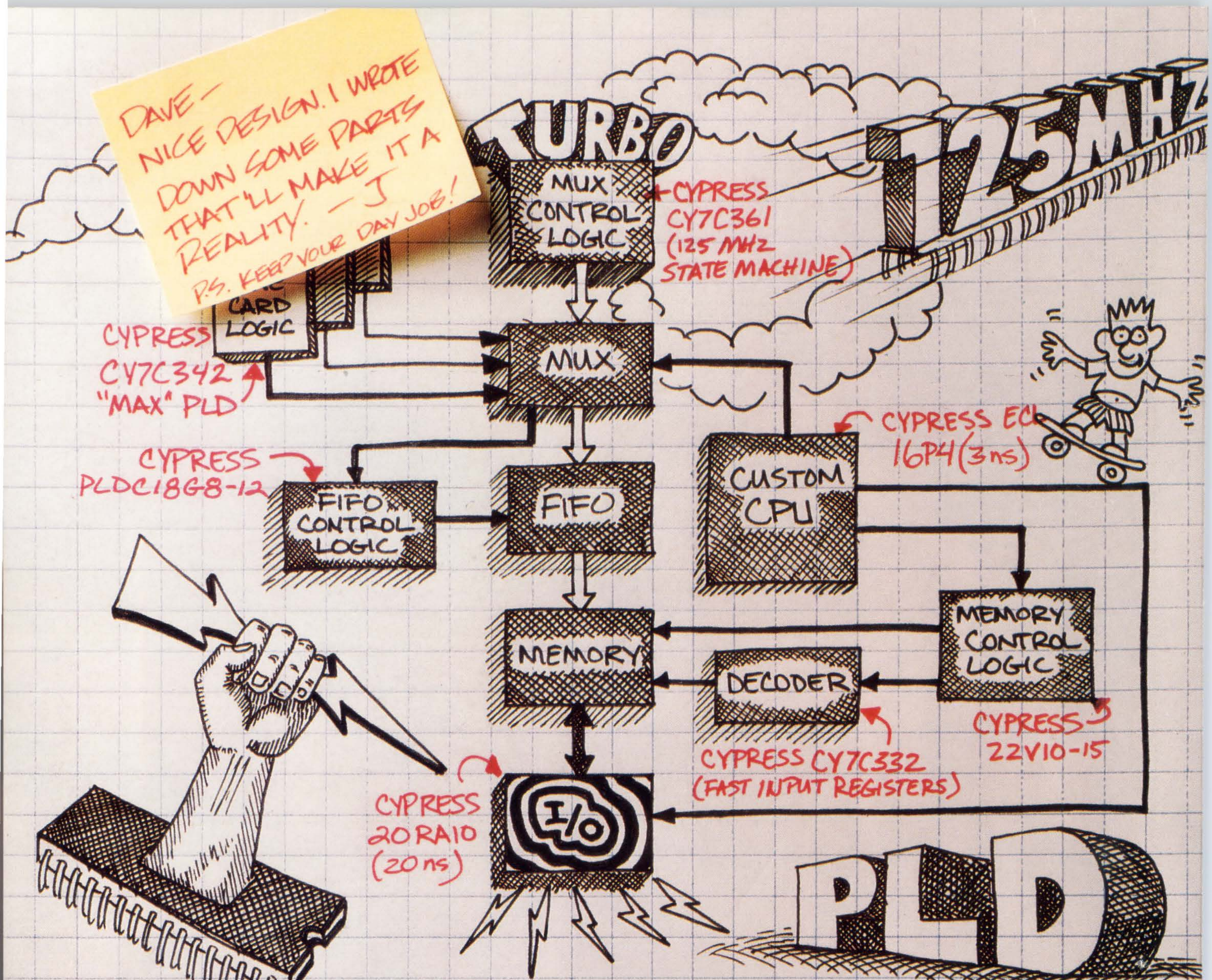

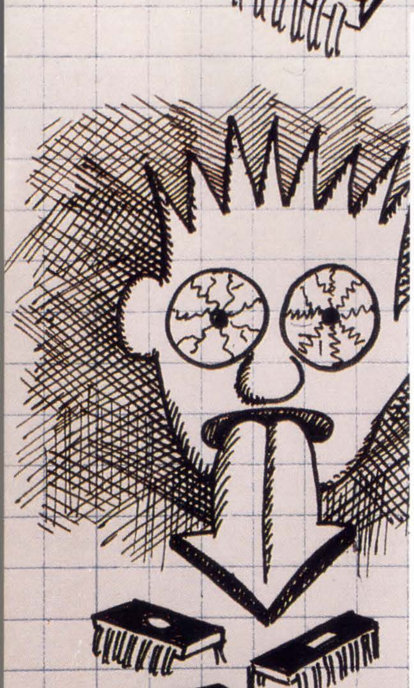

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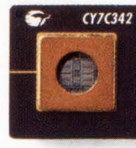

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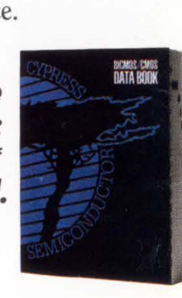

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