A CAHNERS PUBLICATION

AUGUST 3, 1989

EDN®

Troubleshooting analog circuits—Part 6

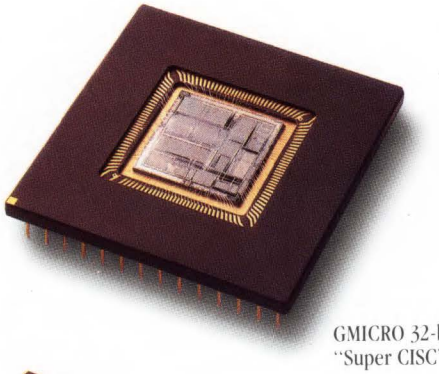
Icon language applications

IPI update

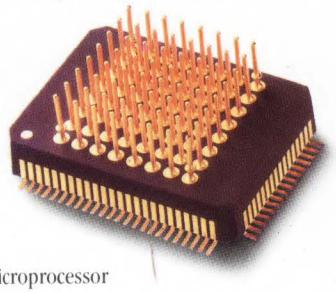
PC-based image processing

ELECTRONIC TECHNOLOGY FOR ENGINEERS AND ENGINEERING MANAGERS

High-resolution ADCs provide options in the design game

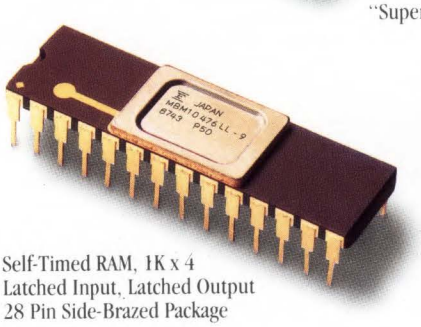


MB86220 DSP Emulation Processor
for Engineering Development

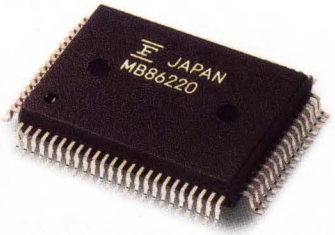


C2600AV 1.8 μ 2600 Gate
CMOS Gate Array

GMICRO 32-bit Microprocessor
"Super CISC"

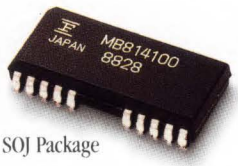


Self-Timed RAM, 1K x 4
Latched Input, Latched Output
28 Pin Side-Brazed Package



24-bit Floating-Point General Purpose DSP
1.2 μ CMOS 80 Pin Flat Package

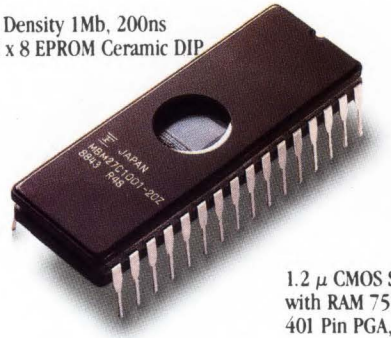
1.5 μ 12K Gate
CMOS Gate Array
with 152 I/O

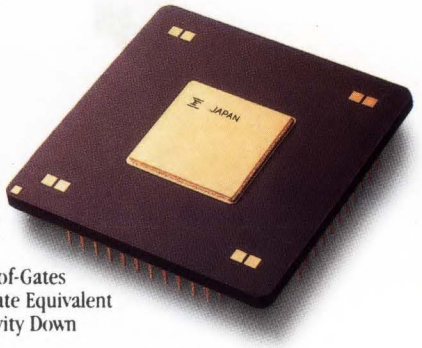


4Mb DRAM
300 MIL Wide, SOJ Package

Ultra High Speed ECL
2-Input, D-Flip-flop
(3.0 GHz typical)

High Density 1Mb, 200ns
128K x 8 EPROM Ceramic DIP





1.2 μ CMOS Sea-of-Gates
with RAM 75K Gate Equivalent
401 Pin PGA, Cavity Down

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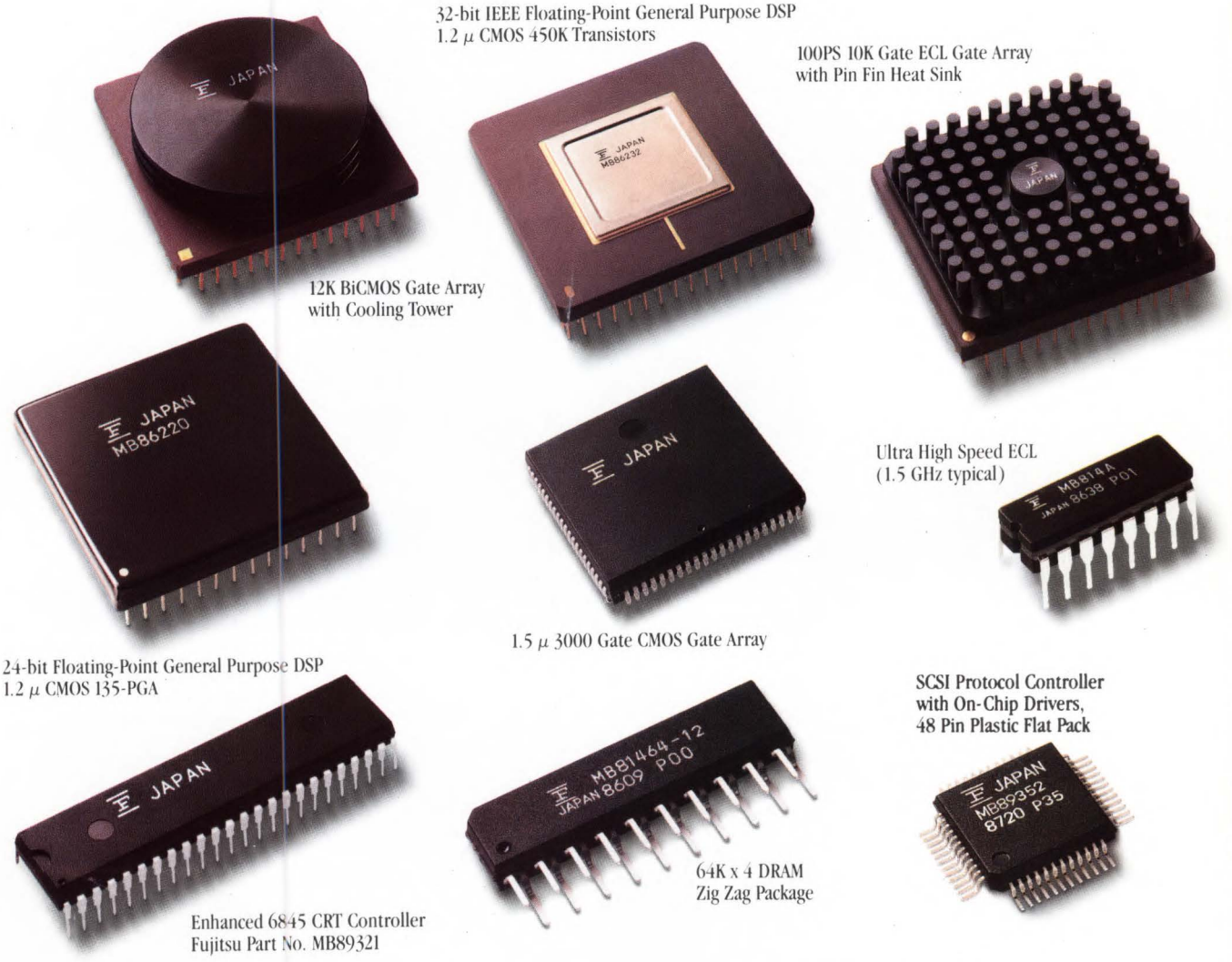
Every step of the way.[SM]

CIRCLE NO 1



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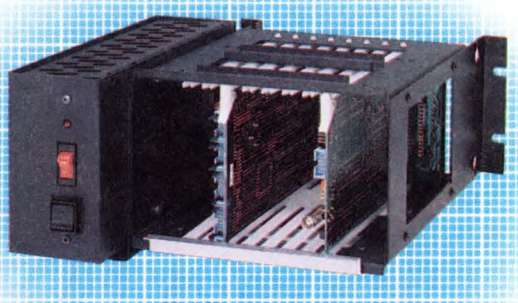
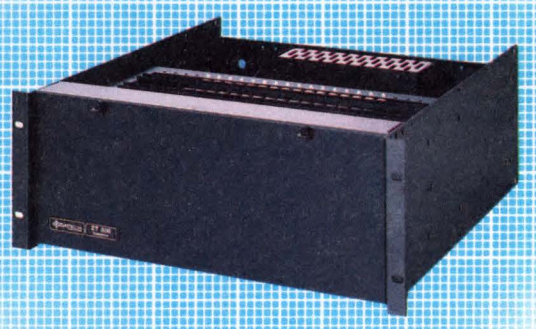


ZT 200 EMBEDDED COMPUTER



ZT 300 INDUSTRIAL COMPUTER

ZT 1000 INDUSTRIAL WORKSTATION

ZIATECH CORPORATION

Corporate Headquarters
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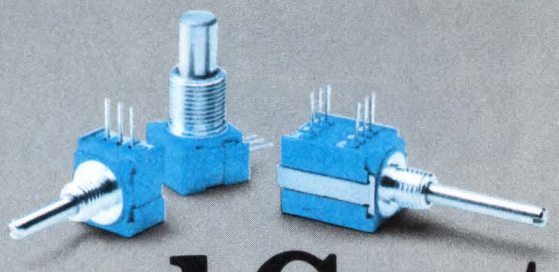
San Luis Obispo, California 93401 USA
ITT Telex 4992316
FAX (805) 541-5088
Telephone (805) 541-0488

Circle No. 101

BOURNS



Panel Control. Cost Control. Quality Control.

Total control is what you get with Bourns® Model 50 sealed panel controls.

The new Model 50 will help you control manufacturing costs by eliminating the extra processing expenses normally associated with unsealed panel controls. Because the Model 50 series is designed to withstand harsh soldering and boardwashing environments, you can:

- eliminate costly hand soldering
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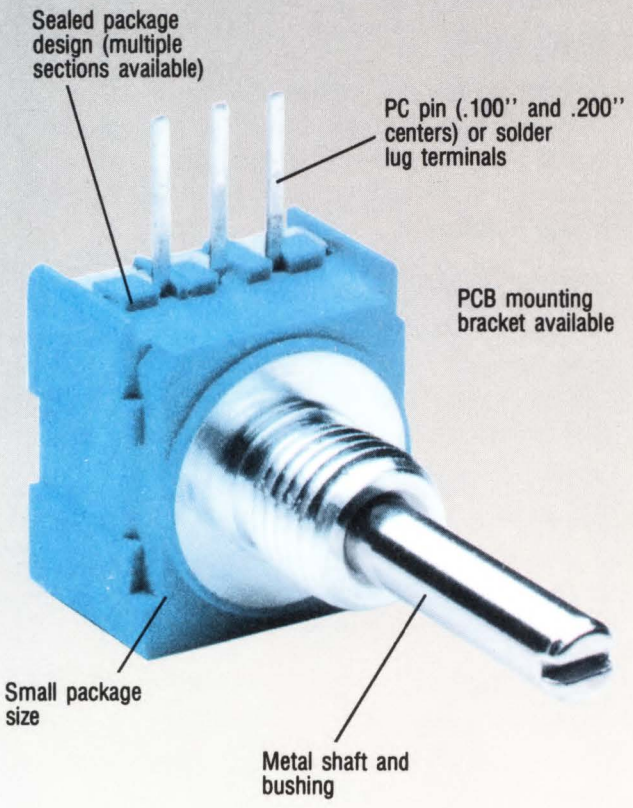
The Model 50 also gives you better quality control. By eliminating hand processing you get:

- improved consistency and reliability of solder joints
- reduced potential for board contamination and damage
- lower repair and replacement

Find out more about the sealed panel controls that give you total control. Call your local Bourns distributor today.



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THERE'S STILL NO EQUIVALENT

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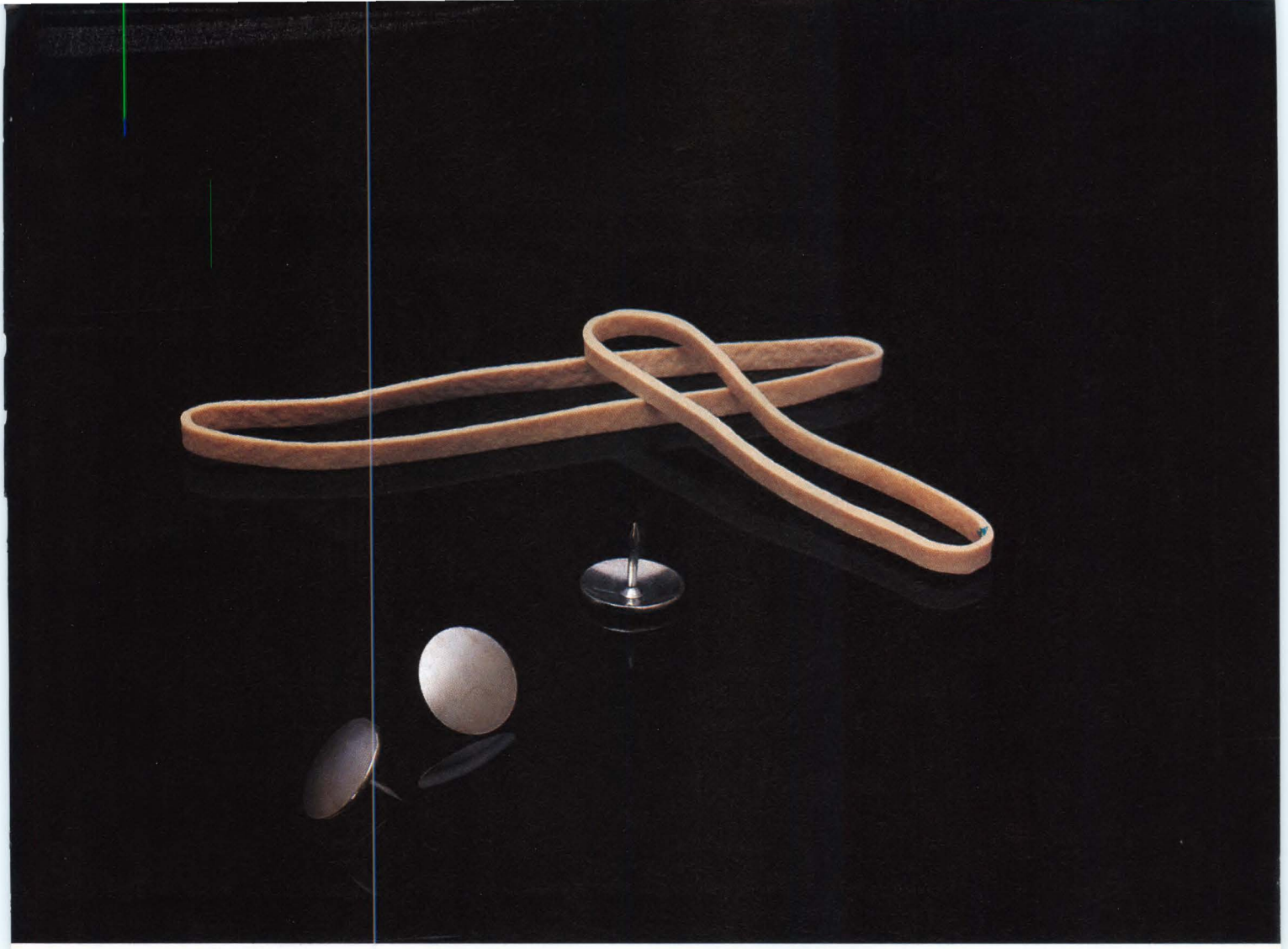
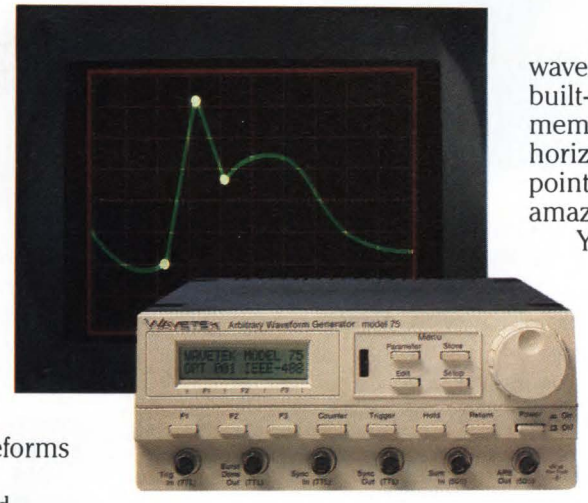


If you can use these simple tools, you can create any waveform.

The Model 75 Arbitrary Waveform/Function Generator lets you create and edit waveforms which it reproduces with digital precision. It's easy to do, because you use a thumb-tack and rubberband editing system to stretch and shape the waveform on the x-y axis while you watch the results on your oscilloscope.

No other arbitrary generator lets you design waveforms from the front panel this way.

You can also download and modify computer-generated waveforms. Or use one of the nine built-in functions. The Model 75 memory provides a grid of 8,000 horizontal and 4,000 vertical points for reproducing signals with amazing purity.



You can see that Model 75 is the wave of the future. And at less than $3,000, it's affordable now!

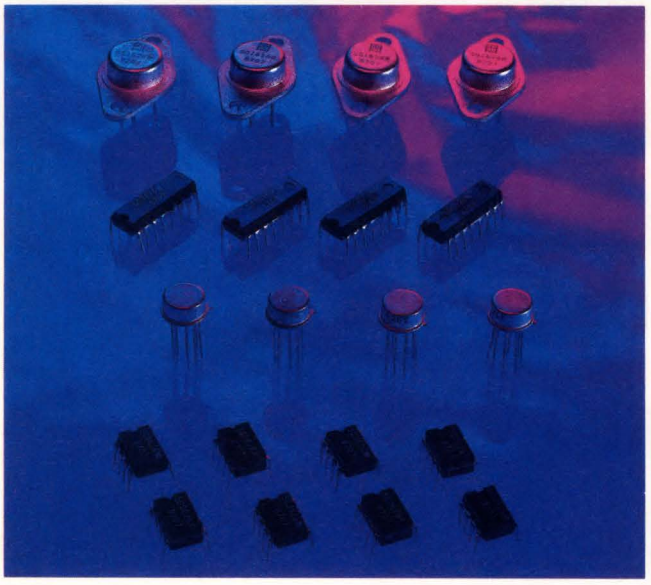
For literature or a hands-on demonstration of Model 75, call (619) 279-2200.

Circle 105 for Literature
Circle 106 for Demonstration

WAVETEK

Who drives Power Mosfets faster, at lower power, for less?

The General does.



Silicon General's new line of dual high speed drivers do the job of driving power MOSFETS better than anything else on the market today.

Against 3 out of 4 competitors, the new SG1626/SG3626 operates 1.5 to 3 times faster.

Versus the long time industry standard, the SG1626/SG3626 dissipates only half the power at similar switching times.

Compared to another competitor, the SG1626 is 50 percent faster on 2 critical parameters, TPLH (turn-on-delay) and TTHL (turn-off fall time).

Our prices are low. It's more than a tad unlikely anyone will beat them.

Ideal for switching power supplies and motor control.

The SG1626/SG3626 is a dual inverting driver ideally suited to drive power MOSFETs and other applications calling for the conversion of digital input signals to high speed outputs to drive large capacitive loads. A non-inverting version, the SG1644/3644, is also available.

These devices use high voltage schottky logic to convert TTL signals to high speed outputs up to 18 volts. Totem pole outputs have 3.0 amperes peak current capability so they can drive 2500 picofarad loads in less than 40 nanoseconds.

Pin for pin compatible.

The SG1626 is pin for pin compatible with National's DS0026, Motorola's MMH0026, Teledyne's TSC426 and Intersil's ICL7667.

Call us for samples and data.

Several packages are available including 8 pin plastic, cerdip, ceramic, TO-99, TO-66 and 16 pin batwing. Best temperature range is -55° C to 125° C. Other parts operate from -25° C to 85° C and 0° C to 70° C.

To arrange shipment of sample quantities and/or receive full technical information, please address Silicon General, Inc., Semiconductor Group, 11861 Western Avenue, Garden Grove, California 92641. Telephone (714) 898-8121. TWX: 910-596-1804. FAX (714) 893-2570.

SILICON GENERAL

CIRCLE NO 2

EDN Magazine Edition

Volume 34, Number 16 August 3, 1989

ELECTRONIC TECHNOLOGY FOR ENGINEERS AND ENGINEERING MANAGERS

On the cover: *No matter which way you turn, you can find a suitable high-resolution A/D converter for your specific need. See the Special Report, beginning on pg 102. (Photo courtesy Analogic Corp)*

SPECIAL REPORT

DESIGN FEATURES

Continued on page 7

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Inventors of the E^2CMOS PLD℠

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Circle 103 for Literature
Circle 104 for Employment Information

Continued from page 5

***You can transform a PC** into a low-cost image-processing system that provides many of the same capabilities as does an expensive, mainframe-based imaging workstation (pg 81).*

TECHNOLOGY UPDATES

PRODUCT UPDATES

DESIGN IDEAS

Continued on page 9

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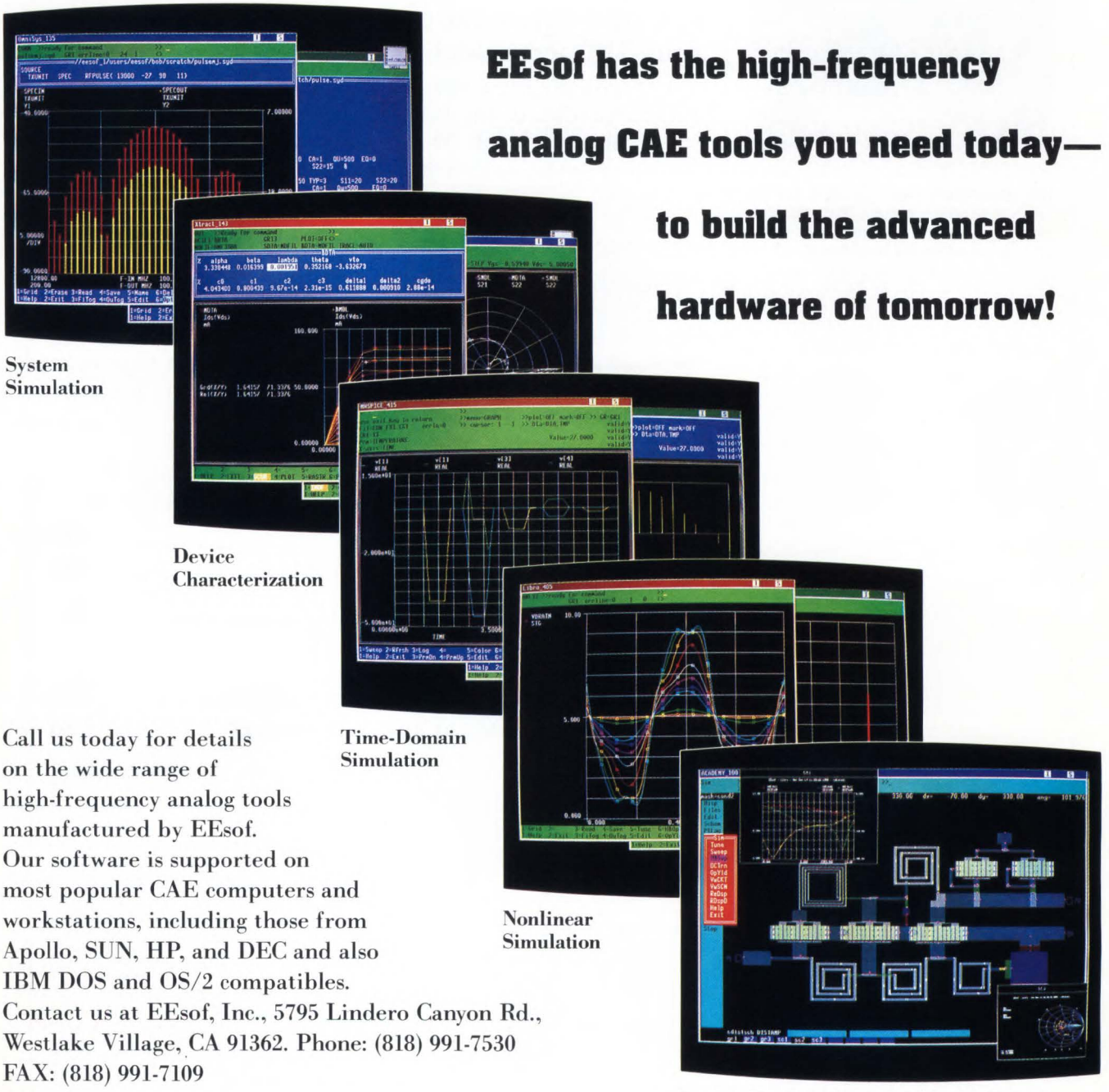
Analog CAE Solutions—from picoseconds to GHz



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Continued from page 7

EDITORIAL 59

Proponents of a US-based HDTV industry need to look at long-term solutions to financial and governmental ills. The quick fix just won't work.

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DEPARTMENTS

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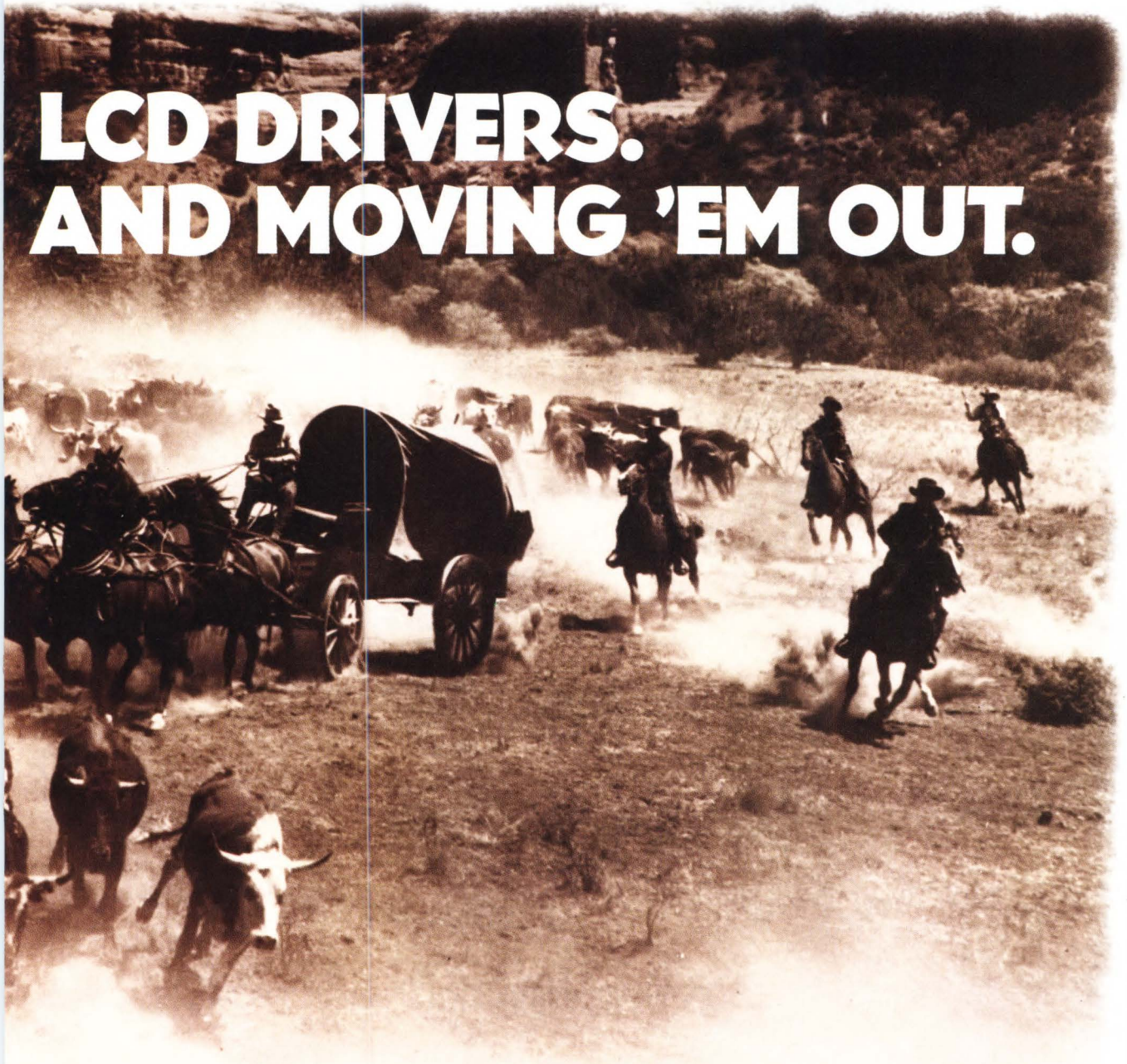
Device	Description	Package	Application
KS0061Q1	Common & segment driver	60 QFP	Character
KS0061Q2	Common & segment driver	64 QFP	Character
KS0062Q	Driver & controller	80 QFP	Character
KS0101Q	Common driver	80 QFP	Graphic
KS0102Q	Segment driver	100 QFP	Graphic
KS0081Q	Common & segment driver	100 QFP	Graphic
KS0082Q	Video LCD interface	80 QFP	Graphic



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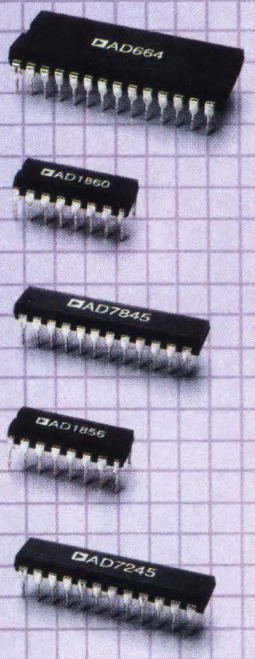

ANALOG DEVICES

SELECTION GUIDE

	AD662	AD664	AD7245	AD7248
Resolution	12 Bits	12 Bits	12 Bits	12 Bits
Power Dissipation (mW)	55	400	65	65
Power Supply Voltage	+5 V	+5 V, ±12 V or ±15 V	+15 V or ±15 V	+15 V or ±15 V
Bus Interface	Parallel	Nibble, Byte, Parallel	Parallel	Byte
Priced From ($ 1000s)	6.10	46.80	8.40	8.40
Comments	12-Bit DACPORT™	Four DACs, Multiplying Capability	12-Bit DACPORT	12-Bit DACPORT

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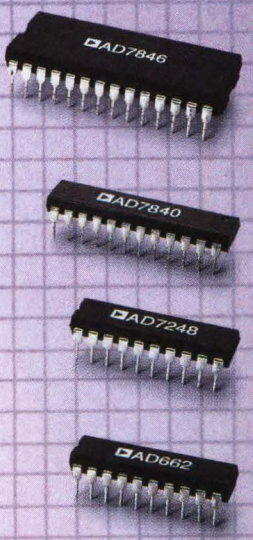

AD7845	AD7840	AD1856	AD7846	AD1860
12 Bits	14 Bits	16 Bits	16 Bits	18 Bits
210	70	110	100	110
±15 V	±5 V	±5 V to ±12 V	±15 V	±5 V to ±12 V
Parallel	Serial, Byte, Parallel	Serial	Parallel	Serial
6.30	8.93	10.70	16.20	13.95
Multiplying Capability	AC and DC Specifications	Audio Applications	Multiplying Capability	Audio Applications

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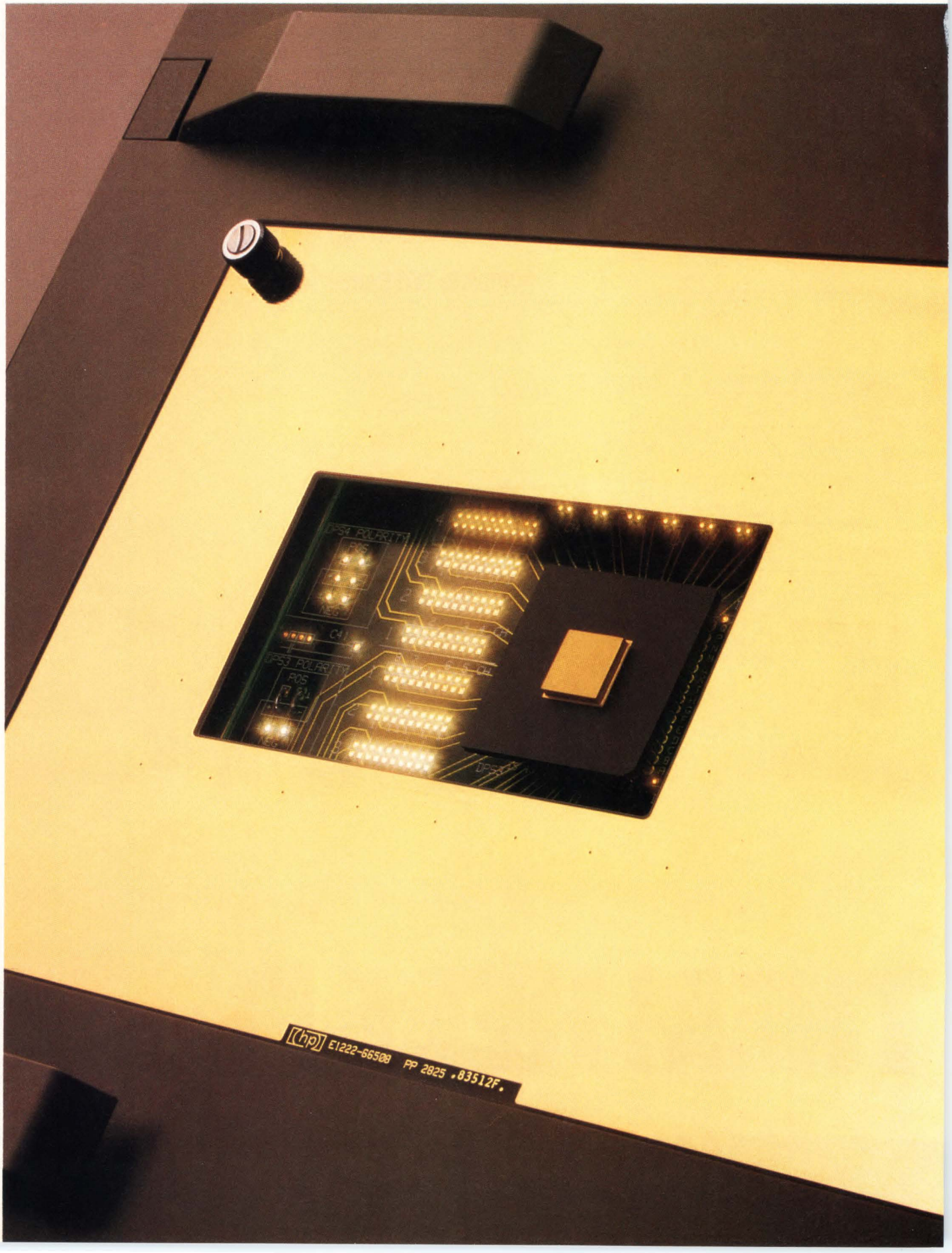
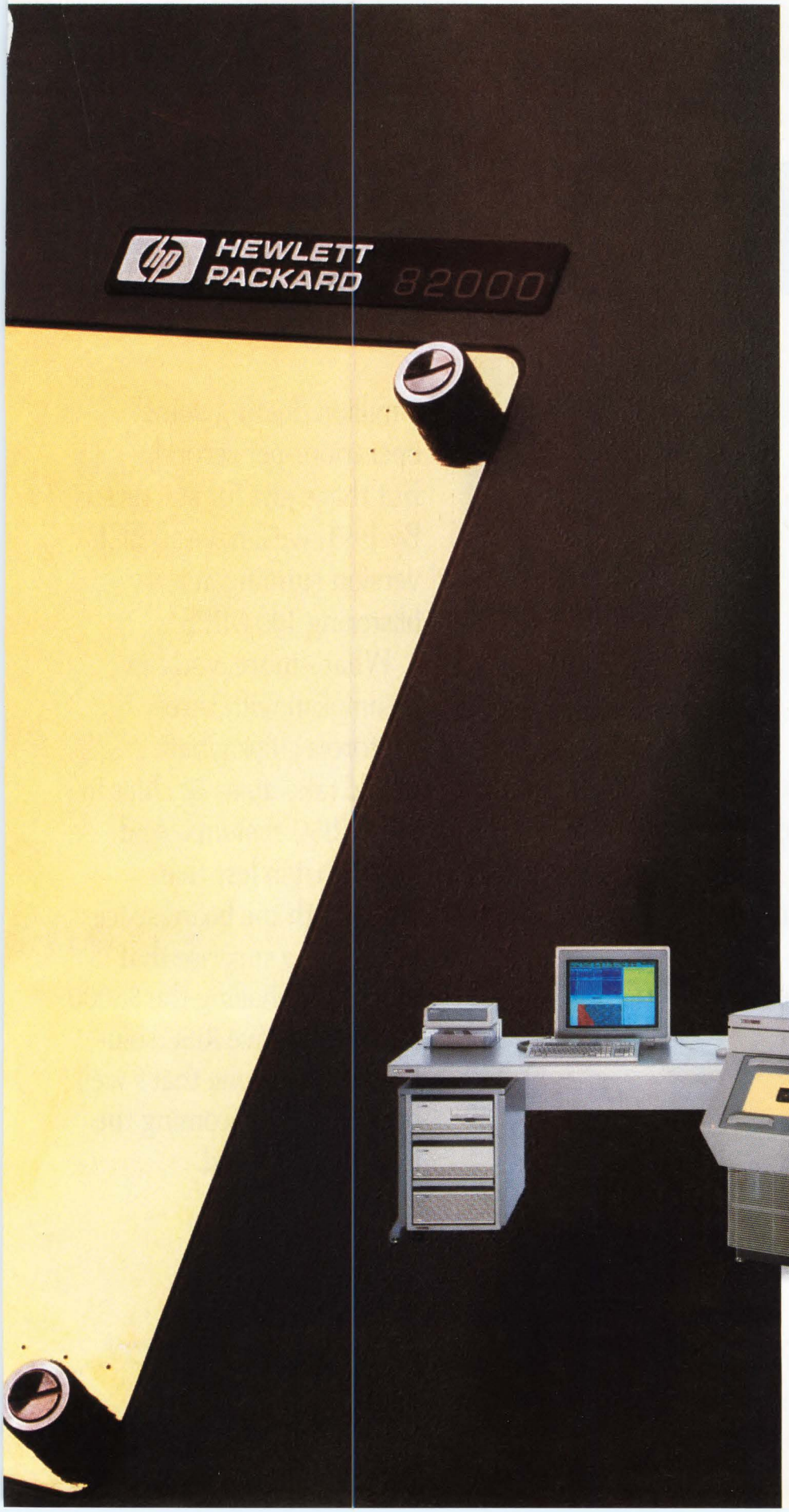


faster ASIC turnaround.



Finally, a family of testers to cut ASIC development time... the HP 82000 IC Evaluation Systems. Choose from high-performance or low-cost models. Both do prototype verification *and* IC characterization. They give you measures of confidence by making sure ASICs work right. Or showing you why if they don't.

Performance you weren't getting in verification systems.

Here's power to test fast, complex devices. Up to 200 MHz. 128 K vector depth. 384 true I/O channels. And ±250 ps accuracy. There's flexibility, too. True tester-per-pin architecture lets you define the parameters of each pin... individually.

Simplicity that ATE systems can't match.

For fast setups, automatic test generation taps your EDA databases. You get characterization of designs automatically. High-resolution displays speed analysis. And X Windows make these the friendliest test systems ever.

Call **1-800-752-0900, ext. 215G,** today for details on the right model to speed your ASICs to market. And ask about HP systems for parametric process control, mixed-signal testing and parameter extraction too.

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CIRCLE NO 8

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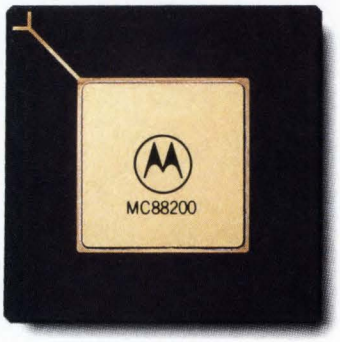

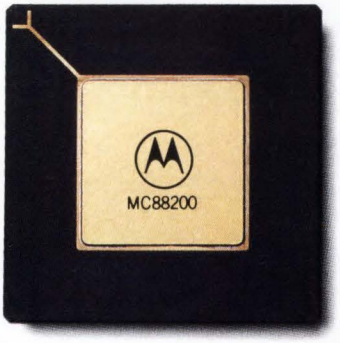

What's more, you can accomplish with three Motorola chips what would take up to 70 chips in other RISC systems. And you'll do it in less than one-eighth the board space.

So it's no surprise that experts are hailing the 88000 as the definitive RISC solution. And the one that's well on its way to becoming the industry standard.

*Reduced Instruction Set Computer. "Design environments shown above include Data General AViiON workstation, Tektronix DAS 9200 logic analyzer and target board with Macintosh II for software development. ***Software Vendors: Absoft, Aitech, Applied Logic Systems, Diab, Franz, Green Hills/Oasys, Language Processors, Inc., MBP Software, Micro Focus, NKR Research, Silicon Valley Software, Tadpole Technology, Telesoft, Translation Systems, Unisoft, Wollongong, Languages: ADA, BASIC, C++, C, COBOL, FORTRAN, LISP, Pascal, PL/M, Prolog, RPG-II,

RISK NOTHING.

This is why the 88000 is no risk at all.

It comes with a complete RISC design environment: assemblers, linkers, code simulators, compilers, emulators, logic analyzers and more.** From companies like Green Hills®/Oasys,® HP,® Language Processors, Inc.® and Tektronix,® to name a few.***

The 88000 also comes with the full support of the 88open, a consortium of over 50 leading hardware and software vendors devoted to making the 88000 the RISC microprocessor standard.

The 88open has already established a Binary Compatibility Standard for the 88000 family, and has mobilized over 30 companies who are developing UNIX application software for 88000 machines. Word Perfect,® Relational Technology,® Frame,® Access®—the list keeps growing.

So join the crowd. Call or write for more information on the 88000 and the companies behind it. Motorola Inc., P.O. Box 20912, Phoenix, AZ 85036. 1-800-441-2447.

It's not only the greatest RISC you can take. It's the safest.

Winner 1988 Malcolm Baldrige National Quality Award

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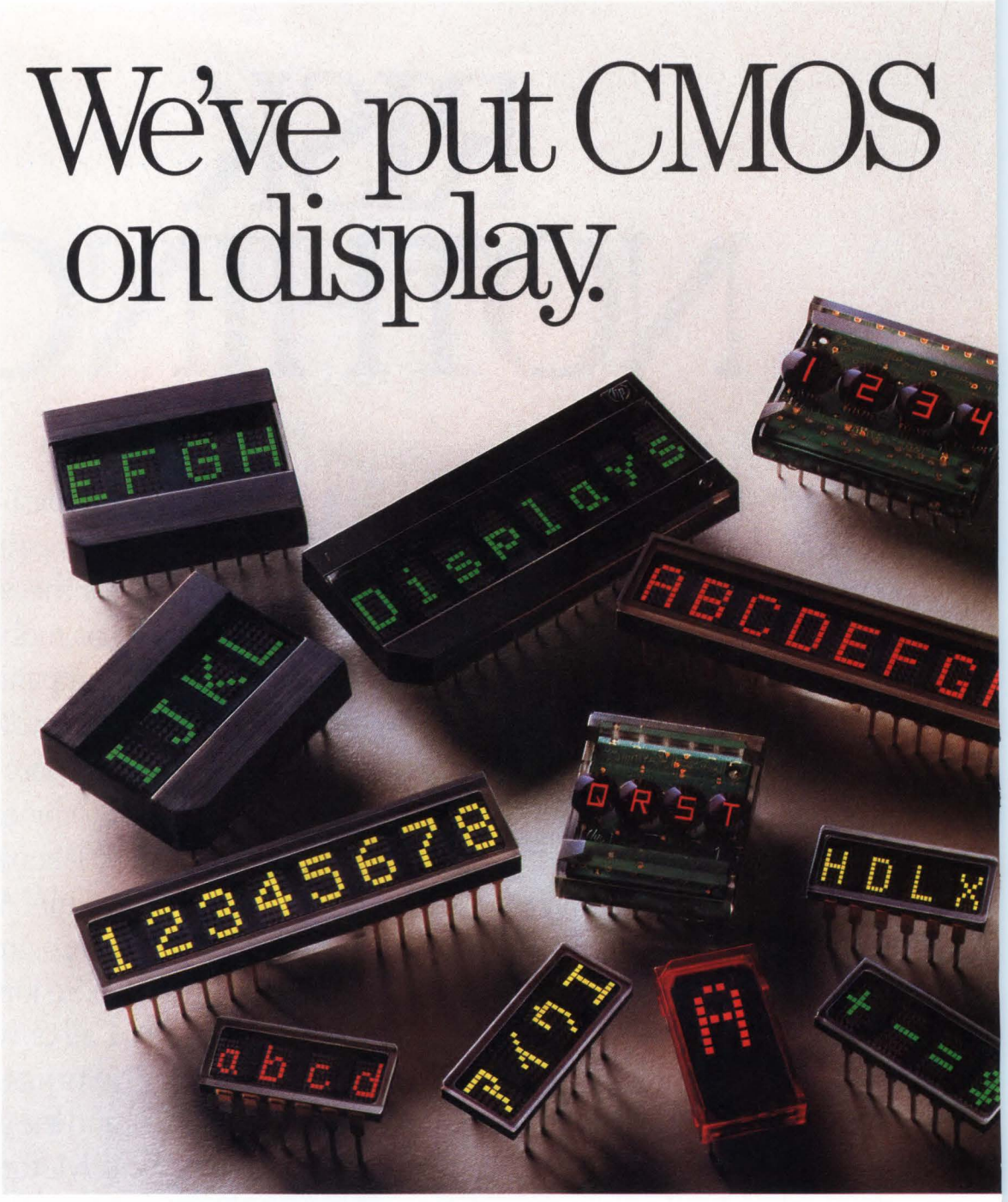

If you're looking for the right LED display solution, take a look at HP. We've got a full line of low-power, easy-to-use alphanumeric CMOS displays.

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CG08902

CIRCLE NO 9

NEWS BREAKS

EDITED BY JULIE ANNE SCHOFIELD

μP CONFERENCE TO OFFER A LOOK AT THE FUTURE

The second annual Microprocessor Forum will offer a look at the future of μP technology as well as a look at some of the new μPs slated for introduction later this year and in 1990. Scheduled for September 21 to 22 at the Fairmont Hotel in San Jose, CA, the conference will provide information about the decisions involved in designing these new chips. In addition, designers from such companies as Sun Microsystems, Silicon Graphics, Tektronix, and Data General will explain their computer products and justify their choice of μPs. Subscribers to the *Microprocessor Report* can register for $595; the registration fee for nonsubscribers is $795. For more information, contact Michael Slater at (415) 494-2677 or reach him by FAX at 415-494-3718.—Jon Titus

MOTOROLA AND INTERMETRICS SIGN SOFTWARE-TOOL PACT

Motorola's Microprocessor Products Group (Austin, TX, (512) 891-2030) and Intermetrics (Cambridge, MA, (617) 661-1840) have announced that Intermetrics will supply a new version of its Intertools software for Motorola's upcoming DSP96002 digital-signal-processor chip. The Intertools package will comprise an optimizing C compiler, an assembler, an XDB debugger, and a utilities library. The 96002 is a 32-bit, IEEE-standard, floating-point DSP μP in the final stages of development. The processor, an architectural superset of Motorola's 24-bit, fixed-point 56001 DSP, will be available in the fourth quarter of 1989; Intertools will be available in the first quarter of 1990.—Anne Watson Swager

LOGIC ANALYZERS OFFER IN-CIRCUIT EMULATION FUNCTIONS

Tektronix's (Portland, OR, (800) 245-2036) newest family of logic analyzers offers more functions than do competitive products and for only slightly more money. The Prism 3000 series, which begins at $8400, combines logic analysis with many of the functions normally associated with in-circuit emulation. These analyzers can perform state analysis on systems clocked at 33 MHz, simultaneously handle timing analysis at 200 MHz, devote 96 pins to a single μP, and accommodate multiprocessor architectures. The Prism 3000 packaging is unusual, too: One unit resembles a standalone analyzer; two others resemble desktop computers. Each unit accepts at least one μP-family-specific application module.—Dan Strassberg

LOG AMP COMPRESSES DATA OVER A 50-dB DYNAMIC RANGE

The AD640 from Analog Devices (Norwood, MA, (617) 329-4700) is a fully calibrated logarithmic amplifier with 50 dB of dynamic range for frequencies from dc to 120 MHz. The AD640 uses a successive-detection scheme to provide an output current proportional to the logarithm of the input voltage. You can convert this output current to a voltage by using internal resistors and an op amp. The AD640 has many instrumentation applications and can provide wideband signal compression for signals that are subsequently digitally processed. Such compression relieves the burden on the other signal-processing components in a system. The amplifier is available in 20-pin ceramic DIPs and LCCs and in versions specified for the −40 to +85°C and −55 to +125°C temperature ranges, over which the maximum specs are guaranteed. The AD640 in a DIP and specified for the industrial temperature range sells for $60 (100).—Anne Watson Swager

NEWS BREAKS

CAD TOOLS UNDER DEVELOPMENT FOR GaAs ASICs

Seattle Silicon Corp (Bellevue, WA, (206) 828-4422) and Gigabit Logic Inc (Newbury Park, CA, (508) 499-0610) have formed an alliance to develop tools for gallium arsenide ASICs. These GaAs CAD tools will share the design approach and interface of Seattle Silicon's ChipCrafter CMOS tools and will include user-configurable libraries, logic synthesis, automatic place-and-route, timing analysis, and links to schematic capture and simulation. With the toolset, you'll be able to build gigahertz-range ASICs that incorporate as many as 15,000 gates and feature low power consumption and high radiation tolerance.—Michael C Markowitz

GRAPHICS BOARD PROVIDES 1024×768-PIXEL RESOLUTION

The ACT3 graphics board is designed for IBM PC/AT-compatible computers and provides 1024×768-pixel resolution. Advanced Graphics Technology Inc (Taipei, Taiwan, FAX 886-2-564-1775) manufactures the $795 board, which uses an Hitachi HD63484-8 graphics processor chip, 1M byte of dual-ported video RAM, and an IDT75C458 RAMDAC as a color look-up table. The ACT3 also has a 64-MHz dot-clock generator and interfaces with noninterlaced analog monitors with 50-kHz horizontal and 60-Hz vertical synchronization frequencies. You can select 256 colors from a palette of 16.7 million colors and use either a cross-haired or a box cursor. The company supplies source listings for software drivers that draw circles, ellipses, filled polygons, pies, and arcs.—John Gallant.

QUAD-PORT MEMORY SOLVES TIMING AND SYNCH PROBLEMS

You can now use one multiport serial RAM to loosely couple as many as four computers, thus solving the contention and arbitration problems that occur when multiple computers try to exchange data. Using 4-way-access memory cells, the DS2015 chip from Dallas Semiconductor (Dallas, TX, (214) 450-0400) permits simultaneous message passing among four independent devices at transmission rates reaching 4M bps. This CMOS IC routes data from a given channel to any of the chip's four storage centers, stores the data until the intended recipient is ready for it, distributes the data, and produces a signal when the message transfer is complete. Available as either an 18-pin DIP or a small-outline package, the DS2015 sells for $6.25 (100).—J D Mosley

CAD-TOOL VENDOR SIGNS VHDL-SIMULATION AGREEMENT

In a move to provide full IEEE 1076 VHDL simulation capability, Silicon Compiler Systems (San Jose, CA, (408) 371-2900) has entered into an agreement with CAD Language Systems Inc (Rockville, MD, (301) 424-9445) to integrate and remarket CLSI's VHDL Tool Integration Platform (VTIP) with SCS's Explorer Lsim simulator. As part of this agreement, SCS will add VHDL capability to its existing proprietary hardware description language (HDL), M. M has analog and digital simulation capability, and as a result of the integration project, you'll be able to include VHDL in both pure-digital and mixed-signal designs. Explorer Lsim will directly compile VHDL models into optimized binary code to eliminate any potential confusion that might result from the translation of the VHDL source code to M. SCS will provide a VHDL translator to protect whatever investment you might have made in M-coded libraries.—Michael C Markowitz

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TMC2302: Imaging Engine, 24-bits/side 3D, 40MHz

Processes New Image

TMC2208: Fixed Pt. Mult./Accum., 8×8-bits, 25MHz
TMC2246: Image Filter, 10×11×4-bits, 40MHz
TMC2249: Video Mixer, 12×12×2-bits, 30MHz
TMC2250: Matrix Multiplier, 10×12×9-bits, 40MHz
TMC3211: Integer Divider, 32-bit, 20MHz

Displays Manipulated and Processed Image

TDC1018: D/A, 8-bits, 125 and 200MHz
TDC1318: D/A, Triple 8-bit, 200MHz
TDC1012: D/A, 12-bits, 20MHz
TDC1112: D/A, 12-bits, 50MHz

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CIRCLE NO 10

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0.5 to 1000MHz from $13.95 (10 to 24 qty)

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Internally the MAN amplifiers consist of two stages, including coupling capacitors. A designer's delight, with all components self-contained. Just connect to a dc supply voltage and you are ready to go.

The new *MAN*-amplifiers series... another Mini-Circuits' price/performance breakthrough.

MODEL	FREQ. RANGE (MHz) f_L to f_u	GAIN dB min	GAIN dB flatness††	MAX. OUT/PWR† dBm	NF dB (typ)	DC PWR 12V, mA	PRICE $ ea. (10-24)
MAN-1	0.5-500	28	1.0	8	4.5	60	13.95
MAN-2	0.5-1000	19	1.5	7	6.0	85	15.95
MAN-1LN	0.5-500	28	1.0	8	2.8	60	15.95
◇MAN-1HLN	10-500	10	0.8	15	3.7	70	15.95
*MAN-1AD	5.500	16	0.5	6	7.2	85	24.95

††Midband $10f_L$ to $f_{u/2}$, ±0.5dB †1dB Gain Compression ◇Case Height 0.3 In.

Max input power (no damage) +15dBm; VSWR in/out 1.8:1 max.

*Active Directivity (difference between reverse and forward gain) 30 dB typ.

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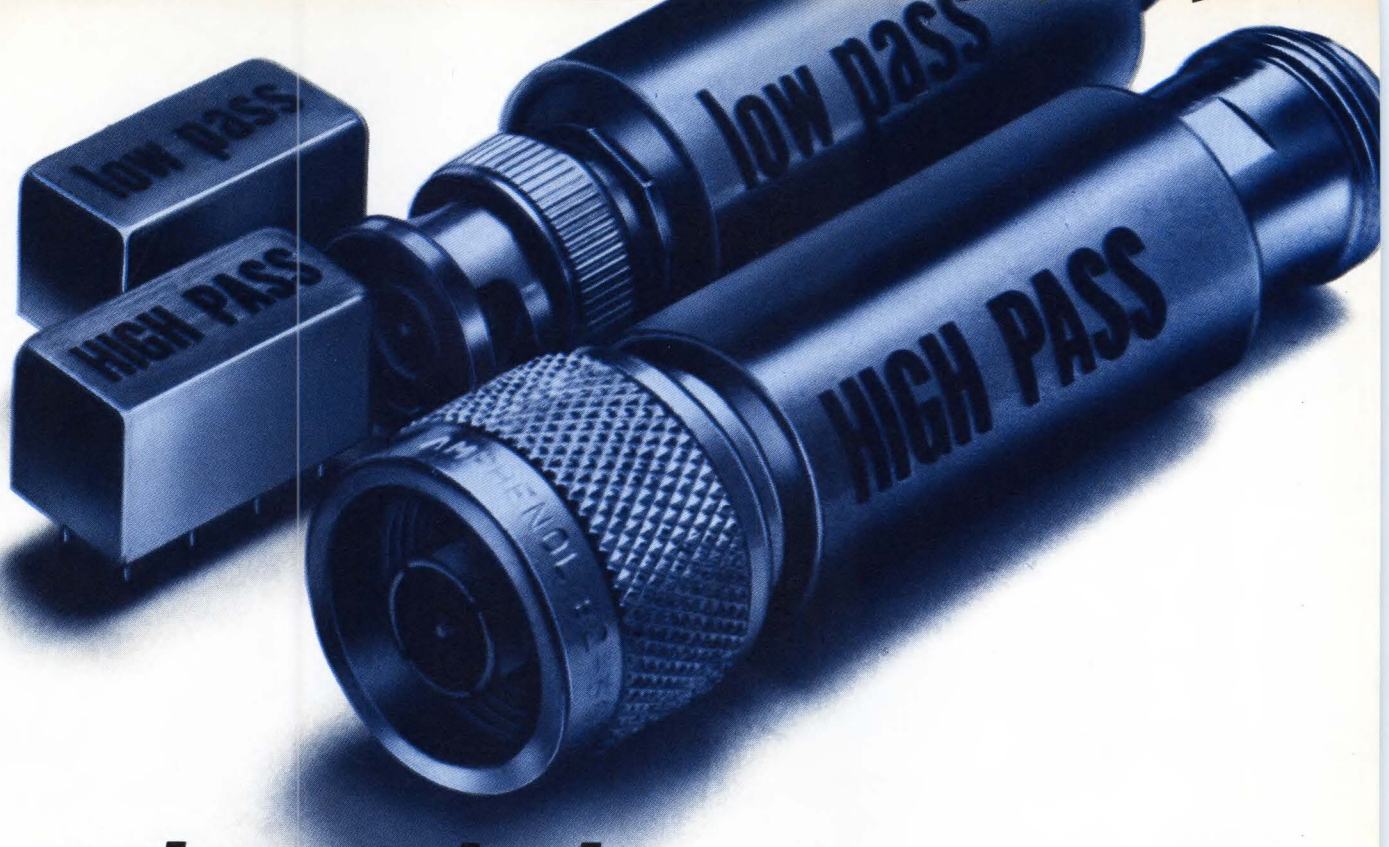
CIRCLE NO 12

C118 REV. E



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

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

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

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

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

C105 REV. E

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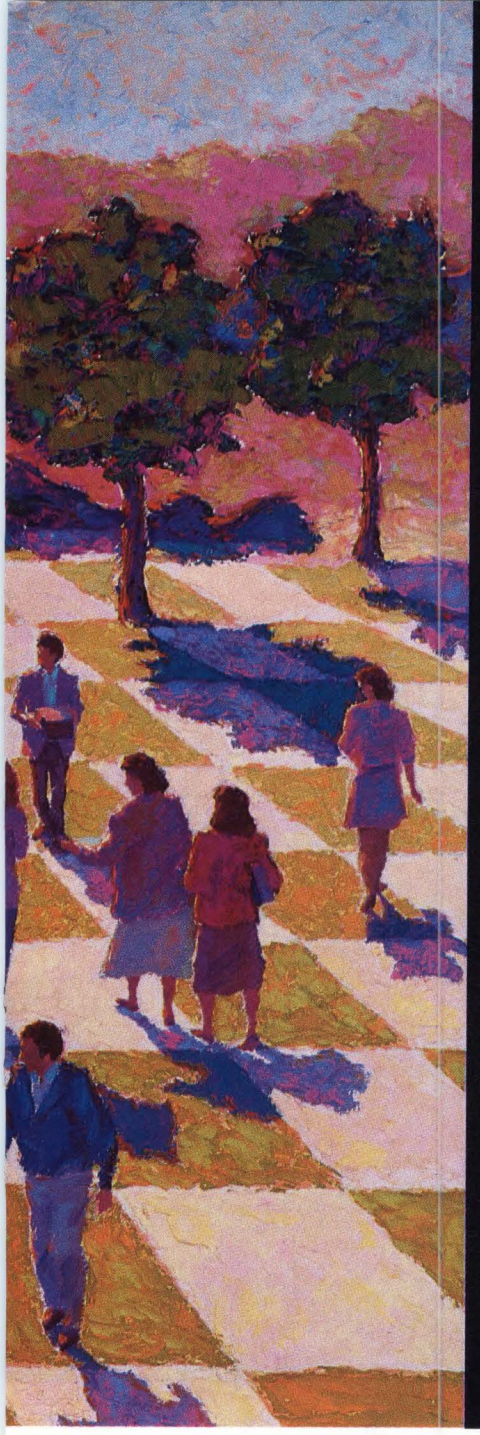


ASIC ACROSS THE BOARD.

building blocks containing accurate and fully functional timing models. You'll save time and money by performing complete simulations of your whole system before committing to silicon.

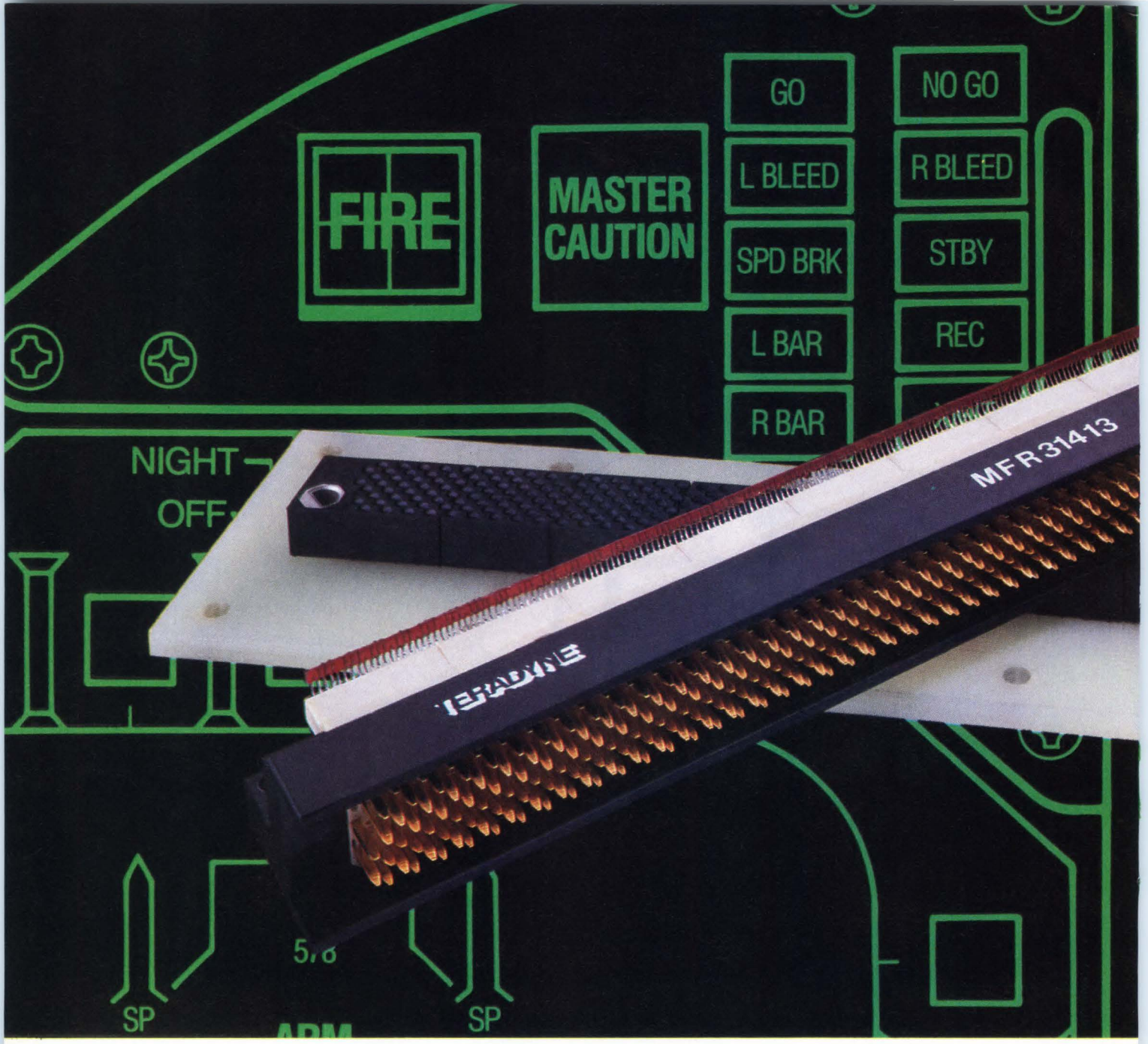
And our advanced technologies that can replace hundreds of standard devices with a single ASIC device: 0.7-micron technologies with up to 200,000 useable gates; Channel-Free™ array and cell-based architectures in CMOS or BiCMOS; integrated RISC technologies; three-layer metal; and plastic packaging so advanced you can specify up to 524 pins.

LSI Logic's ASIC Design Methodology. It's more than just a practical approach to system design. It's why we outperform other ASIC companies where it matters most.

Across the board.

LSI LOGIC®

ACROSS THE BOARD



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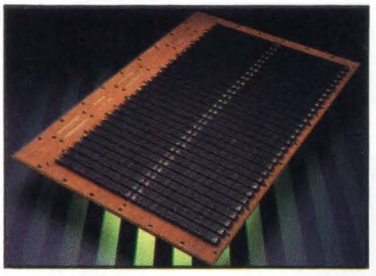
Teradyne's VHSICon UHD™ supports you with a complete backplane interconnection system and thorough up-front applications assistance

Today's advanced military/avionics applications are packed with complex electronics. And tomorrow's



designs will take density and sophistication to even higher levels. That's why, when it comes to interconnections, you need more than simple solutions. You need system support. That's what you get with Teradyne's VHSICon UHD (Ultra-High Density) backplane interconnection system.

connector system supports to interception.

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TERADYNE

CIRCLE NO 16

SIGNALS & NOISE

Free enterprise is at stake

I enjoyed Jon Titus's editorial "Manage innovation, not money" in the February 16, 1989, issue of EDN (pg 51). As a gray-haired engineer and an investor, and a loyal American, I was warmed by his valid and conscientious alarm about the state of innovation in the United States. The creativity of men's minds has gone to the area of "sucking value" from companies that to a large extent have been built by engineers. This "value-sucking" process reflects itself in leveraged buy-outs, acquisitions, mergers, and sales of whole companies to the enormous profit of individuals and groups, and, of course, investors.

What is being tested here is not whether people should resist investing in short-term value-suckers, but whether people should be more idealistic and limit their investments to long-term strategically planned companies. Alas, I fear that the great American system of total free enterprise is at stake here, not a localized situation. Long-term strategic planning is done by every smart person in the world—smart, yes, but rich, not necessarily. Is it more important to contribute to the growth of something through work and intrinsic contribution, or is it more important to suck value from the efforts of those who did make intrinsic contributions? That is the issue at hand, and it is one that Americans must think about seriously. We are on the brink of serious disaster; we are giving our country away by having a weak currency; we are destroying our industry by the value-sucking endeavors of hot-shot money men; we are destroying the moral consciousness of our people by rewarding people for the wrong activity. That is one way of looking at it.

Another way of looking at it is that the free-enterprise system and democracy are being tested. They are being tested by the very greed implicit in the system itself. If the free democratic system is any good, it will survive these incursions, as people see what they are doing. One implicit assumption behind the success of these systems is moral integrity. If it is lost, then we had nothing anyway. It is a broad issue that I believe will be resolved by our free-enterprise system. We will go through new growing pains as we suffer through the sale of our assets and the loss of power, prestige, and influence in the world.

Today, America is still a mecca for the unfortunate, a symbol of what fairness and decency can offer all mankind. This is our great strength, the moral fiber of our people, and this will prevail over every value-sucking activity. We have legions of strategic-thinking companies, and they will survive and grow in the environment of freedom.

J Van Horn
Wassenaar, The Netherlands

Low power shouldn't be confused with micropower

Peter Harold's article, "Micropower op amps hit new lows" (EDN, April 27, 1989, pg 117), was aimed at a target that it all but missed. It confused low power with micropower, and as a result scattered its shots at devices that lie outside the target. The generally accepted definition of micropower op amps includes op amps with a supply current of 100 μA or less. These op amps are intended to balance minimum power consumption with maximum achievable precision. The article included op amps with a supply current as high as 500 μA; these op amps are generally called "low power" in the industry.

Had the article really restricted itself to the accepted definition of micropower and included real measures of precision, it would have offered designers a useful comparison among available devices.

Peter's article, however, ignored the usual definition and pinned roses on devices such as the OP-97 (which, by the way, is not original but a second source for Linear's LT1012 precision op amp, and in any case is not a micropower device) and as-yet unavailable chopper-stabilized op amps that fall outside the article's own definition of micropower. As a result, the illustrations weren't pertinent, and the **table** ended up comparing apples with anchovies.

Noise, a critical parameter for precision, isn't even mentioned in the discussion or the **table**. Likewise, where pulldown resistors are required, many of the devices listed lose their micropower rating. The LT1078/9 and LT1178/9, which were included in the table but not mentioned in the text, have lower voltage noise than any other micropower op amps. In fact, they have lower noise than other op amps with 10 times their supply currents, and they require no pulldown resistors to go to ground.

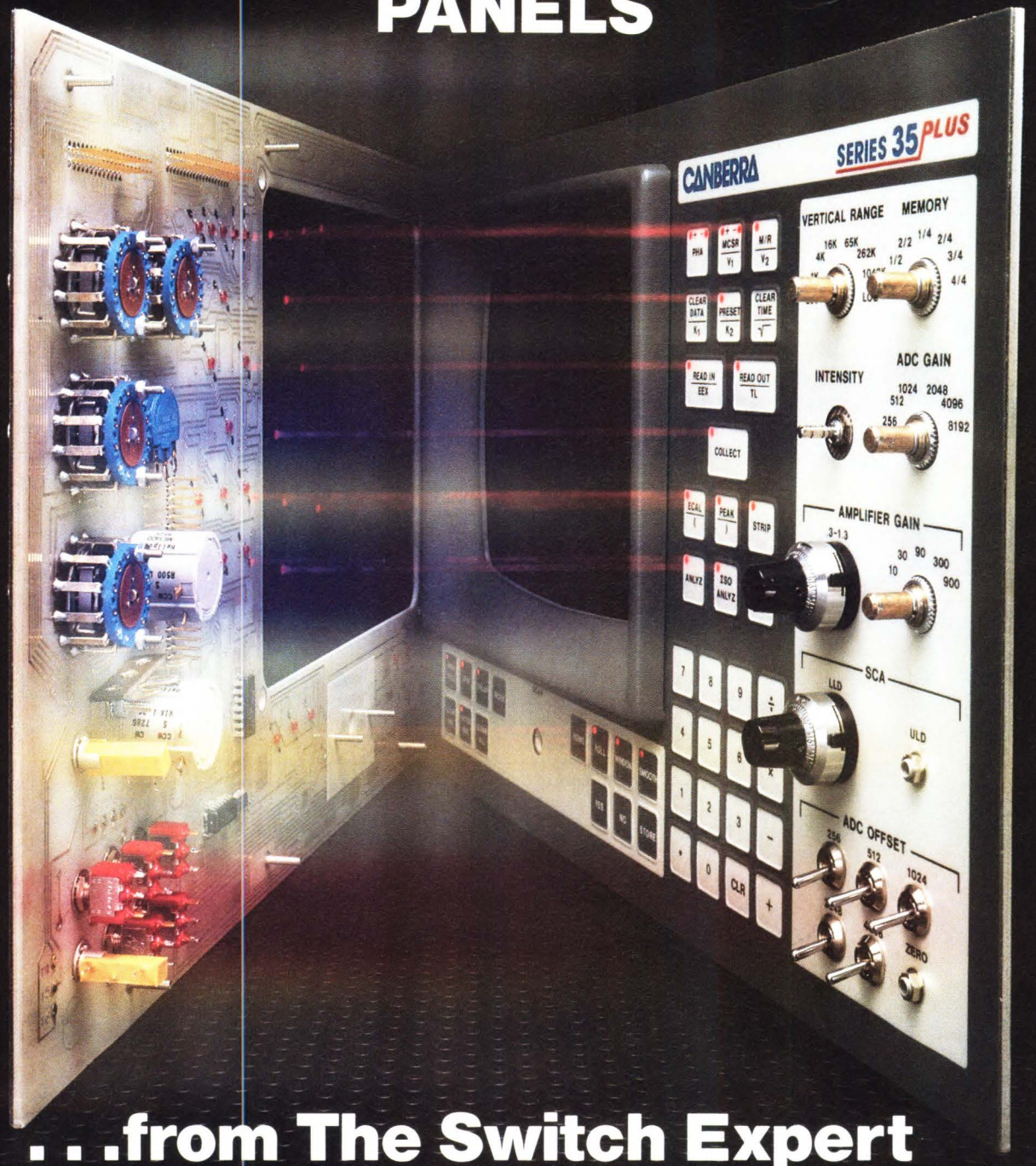
I'd like to see EDN revisit this topic as soon as possible, but with much closer attention to true micropower op amps and to precision performance so designers can make more meaningful comparisons among the devices.

Willian A Ehrsam
Vice President, Marketing
Linear Technology Corp
Milpitas, CA

Oops

MicroPlot Systems was inadvertently omitted from the list of vendors of graphing-software packages in Jon Titus's April 13, 1989, Technology Update on that subject (EDN, pg 53). The company can be reached at 1897 Red Fern Dr, Columbus, OH 43229; (614) 882-4786.

COMPLETE FRONT PANELS



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CIRCLE NO 11

PCs and scopes—"Never the twain shall meet"

Dan Strassberg's article, "Units transform PCs into DSOs" (EDN, May 11, 1989, pg 95), recalled my experiences with [my former employer, a major instrumentation manufacturer].

After what was touted to be a revolutionary idea—using [a personal computer] for a host of test equipment devices—the company set upon rebuilding one of its plants to manufacture modules to adapt [its PC to instrumentation tasks]. It rebuilt the facility, expending some $5 million, made hundreds of Beta-site models, advertised heavily, and subsequently shut the program off for lack of sales.

As I recall the scenario, [users refuse to] tie up a $5000 computer to do a $150 VTVM [vacuum-tube voltmeter] task, or they use a $10,000 scope with a $5000 PC that produces only half the value of a dedicated scope.

When you begin to rationalize what is being tied up, also consider the $500 to $2000 adapters. Oh yes, [PC-based instruments] can do lots of things in a 1-man shop, [which may need] only one piece of test equipment, but consider [what happens when you try to construct multitasking systems; for example, to monitor] power supplies (as many as six at once), a couple of oscillators, pulse generators, current meters, voltmeters, or recorders.

Does Dan's article attempt to revive a dead horse? Or is there another purpose? Check the demise of this "pioneer" effort and see [that one major company] went "eastward" rather than "westward ho."

Bill Steckowich
Sparta, NJ

(Ed Note: EDN's coverage of PC-based instruments is not indicative of any nefarious plot to revive a dead horse. The price of PCs has been coming down, and PCs' capabilities have been increasing. Tasks that didn't make sense for PC-based instruments a few years ago often do make sense now. PC-based instruments may never displace conventional instruments entirely, but PCs seem destined to assume a role of growing importance in instrumentation systems. Just ask the large number of vendors of PC-based instruments, many of which are listed in the ***box*** *entitled "For more information . . . " in the May 11 article.)*

Those plastic bags have to go

I was very glad to see the letter, "Chief Seattle Speaks," following Jon Titus's editorial, "Waste not,

TEXAS INSTRUMENTS

A PERSPECTIVE ON DESIGN ISSUES:

New ways to link digital brains to advanced analog worlds

IN THE ERA OF

MegaChip TECHNOLOGIES

Next-generation analog: Advanced Linear ICs

A new breed of linear chips, born of leadership processing at Texas Instruments, can help you design superperformance systems.

Sophisticated design and simulation tools shorten development cycles of TI's Advanced Linear ICs, helping you get to market faster. By using these tools, TI can offer as standard circuits many designs that previously would have had to have been customized.

The human brain has separate but dependent left and right sides. Similarly, an electronic "brain" or system has separate but dependent parts, one digital, one analog. Designers accustomed to the spectacular performance gains made in digital chips are now demanding comparable improvements in analog devices so that both parts of their systems can function to full potential. Leading the analog evolution: Advanced Linear circuits from Texas Instruments.

These new chips are called *advanced* for one or more reasons. They are more highly integrated than ever before, often combining digital and analog functions on a single chip. They offer higher performance and greater flexibility. They are often the result of advanced processing that may merge two or more technologies.

Better parameters from better processing

Because advanced analog system requirements for performance and flexibility vary greatly, a single workhorse technology typically can't do the job any longer. Nor can creative circuit designs alone. We at TI are convinced the key to driving the linear evolution lies in the excellence of our processing technologies.

TI is committed to developing and implementing a range of leadership wafer-fabrication processes (*see descriptions on back page*). The result: TI's Advanced Linear devices are already helping system designers link digital brains to advanced analog worlds more efficiently and with greater ease in many applications. Here are a few examples.

Advanced Linear: Displaying greater brilliance

Out of our pacesetting LinEPIC™ processing comes our high-performance Color Video Palette, operating at 125 MHz with a very high-resolution 1024 x 1024 pixel count. Because of one-micron CMOS processing, power consumption is reduced more than 40% compared to other CMOS implementations. Additionally, the device is pack-

...the key to driving the linear evolution lies in the excellence of processing technologies.

aged in reliable, economical plastic.

LinEPIC has also produced such high-speed, high-density interface chips as our Flash A/D and our Video DAC for use in graphics displays, imaging systems, monitors, and cameras. Both devices require about five times less power than bipolar equivalents.

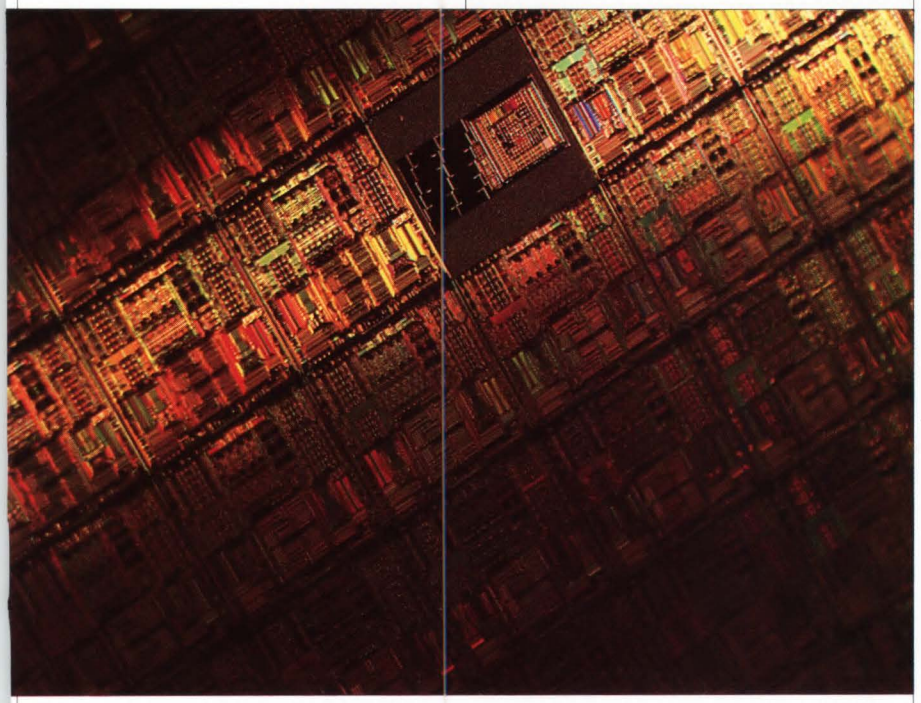
Advanced Linear: Intelligent power for every car

Chips fabricated with our Power DMOS-based BIDFET™ processing are replacing electromechanical relays in many automotive applications, such as driving headlamps and motors. Power BIDFET allows us to minimize power loss in the switch and add high-complexity logic functions.

Multi-EPI bipolar processing, a very cost-effective technology, is used to produce chips having inherent reverse battery protection and high operating voltages. Such chips are ideal for use in automotive antilock braking systems, electronic transmissions, and active suspension systems.

Either technology can produce devices with low-side drive, high-side drive, or H-bridge configurations.

In the future, these developments may lead to multiplexed systems for cars, replacing bulky wiring harnesses.



High-density Analog Interface Circuit chips demonstrate the greater integration achieved by TI's innovative linear processing technologies. These DSP interfaces allow you to alter circuit configuration under software control without external adjustments.

Advanced Linear: Enhancing modems and facsimiles

TI's dual driver/receiver is a good example of the integration achieved with advanced processing technologies. LinBiCMOS™ processing has enabled us to put the drivers and receivers needed for RS-232 voltage levels on the same chip with the charge pump required to generate the necessary split rails from a single 5-V supply. You eliminate external power supplies and get a device that's easier to design with—it is available in our LinASIC™ cell library for integration with digital ASICs.

A new family of Analog Interface Circuits (AICs) is emerging from our Advanced LinCMOS™ processing. The voice-band AICs, designed for modems and fax equipment, combine high-performance analog functions—14-bit A/D and D/A converters and switched capacitor filters—with digital functions such as control circuitry, program registers, and DSP interface. The usual clutter of resistors, capacitors, and pots is eliminated.

High-speed AICs are available for use in servo controllers and hard-disk-drive applications.

These AICs are also high-performance members of our LinASIC standard-cell library. Based on TI's proven digital ASIC methodologies, the LinASIC library has allowed us to develop complex, semicustom chips in as little as 16 weeks.

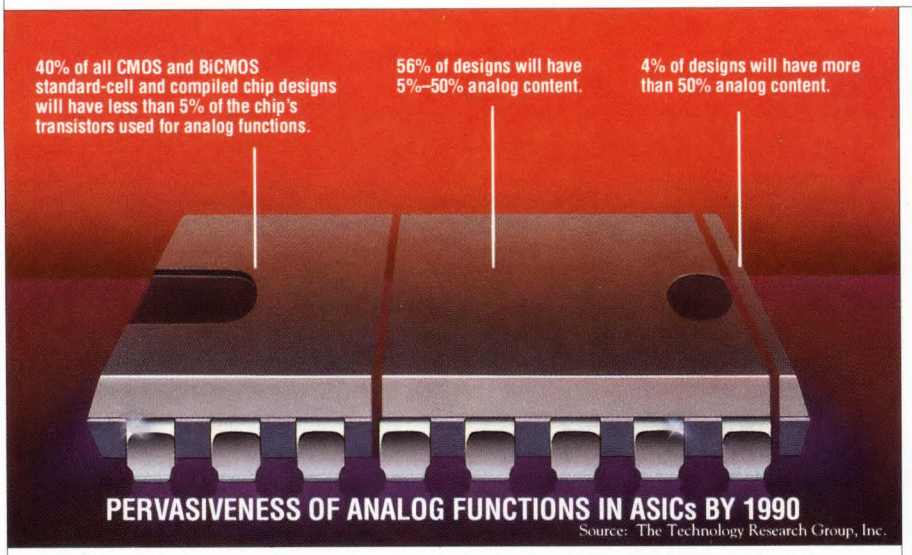
Advanced Linear: Boosting instrumentation accuracy

Even one of the most basic analog building blocks, the operational amplifier, is benefiting from TI's Advanced Linear technologies. Our Excalibur op amp family combines low power consumption with a 5X speed improvement while retaining low offset voltages. Offset-voltage drift has been cut from 300 μV to 60 μV to reduce your calibration, test, and measurement expenses.

For high-accuracy applications, Advanced LinCMOS is making possible Chopper Stabilized Op Amps with chopping frequencies 10 times higher than previously available (10 kHz). Noise levels are the lowest on the market.

The evolution in analog devices has only begun. Dramatic progress lies ahead throughout the 1990s. As the Advanced Linear leader, Texas Instruments is pledged to remain at the forefront, supplying you with new ways to link digital brains to advanced analog worlds.

For suggestions on choosing a linear supplier, turn the page.



Circuits combining analog functions with digital logic will soon be widespread in ASIC chip designs. TI is taking a leadership role with the development of its LinASIC methodology.

Checkpoints for choosing an analog supplier in the 1990s.

Questions and answers with Tom Engibous, Vice President, Semiconductor Group, and Manager, Linear Products, Texas Instruments Incorporated.

Q. What is the first thing to look for in choosing a linear supplier?

A. Product performance is definitely the first priority. Our customers are asking for ever-increasing linear device performance. At TI, we believe creative circuit designs alone won't meet the challenge. Advanced process technologies—note the plural—are becoming the keys to success in linear device performance of the '90s.

Q. What else should a designer look for?

A. Whether or not the supplier has experience with digital as well as analog devices. These two worlds are merging (*see chart above*). Functions once performed by analog are now done digitally, and a growing percentage of our Advanced Linear devices combines analog and digital circuitry on one chip.

At TI, we've leveraged our 30 years of digital expertise into the development of our Advanced Linear products and processing with highly satisfactory success. This has been especially noticeable with our LinASIC methodology.

Q. Do you expect ASICs to play a major role in your linear future?

A. Very definitely, as they already do today. Cell-based designs will be the rule in both user-specified functions and highly integrated standard products. Digital ASIC methodologies are also the key to cutting system design cycles. As our digital experience proves, suppliers who have advanced process technologies and fast, accurate design-automation tools will be the best equipped to deliver single-chip solutions.

Today, we have customers doing their own LinASIC designs using our advanced processes and design-automation tools.

Q. What role does manufacturing capability play in picking a supplier?

A. It is always a factor, and the need for efficient worldwide manufacturing facilities such as TI has in place will become even more important. Today's semiconductor market is global in nature. You can't serve worldwide customers from a single plant—you have to be "multilocal." This is particularly true with ASICs.

Q. Any other important factors?

A. Yes, I'd suggest that, in choosing a linear supplier, the designer find one he can live with for a long time. Close supplier-customer relationships are essential to the development of products that will provide the highest performance and lowest cost systems.

TI's Leadership Linear Processing Technologies

LinBiCMOS—Combines Advanced LinCMOS, digital ASIC CMOS, and up to 30-V bipolar technologies to allow the integration of digital and analog standard cells and handcrafted analog components on a monolithic chip.

LinEPIC—One-micron CMOS double-level metal, double-level polysilicon technology which adds highly integrated, high-speed analog to the high-performance digital EPIC process.

Advanced LinCMOS—An N-well, silicon-gate, double-level polysilicon process featuring improved resistor and capacitor structures and having three-micron minimum feature sizes.

Power BIDFET—Merges standard linear bipolar, CMOS, and DMOS processes and allows integration of digital control circuitry and high-power outputs on one chip. Primarily used for circuits handling more than 100 V at currents up to 10 A.

Multi-EPI Bipolar—A very cost-effective technology that utilizes multiple epitaxial layers instead of multiple diffusion steps to reduce mask steps by more than 40%. Used to produce intelligent power devices that can handle loads as high as 20 A and voltages in excess of 100 V.

Excalibur—A true, single-level poly, single-level metal, junction-isolated, complementary bipolar process developed for high-speed, high-precision analog circuits providing the most stable op amp performance available today.

Our just-published *Advanced Linear Circuits* brochure examines more fully the changes taking place in analog system design and their impact on linear devices. The brochure also describes TI's leadership processing technologies and explains the performance improvements that result. **For your copy, call 1-800-232-3200, ext. 3407, today.**

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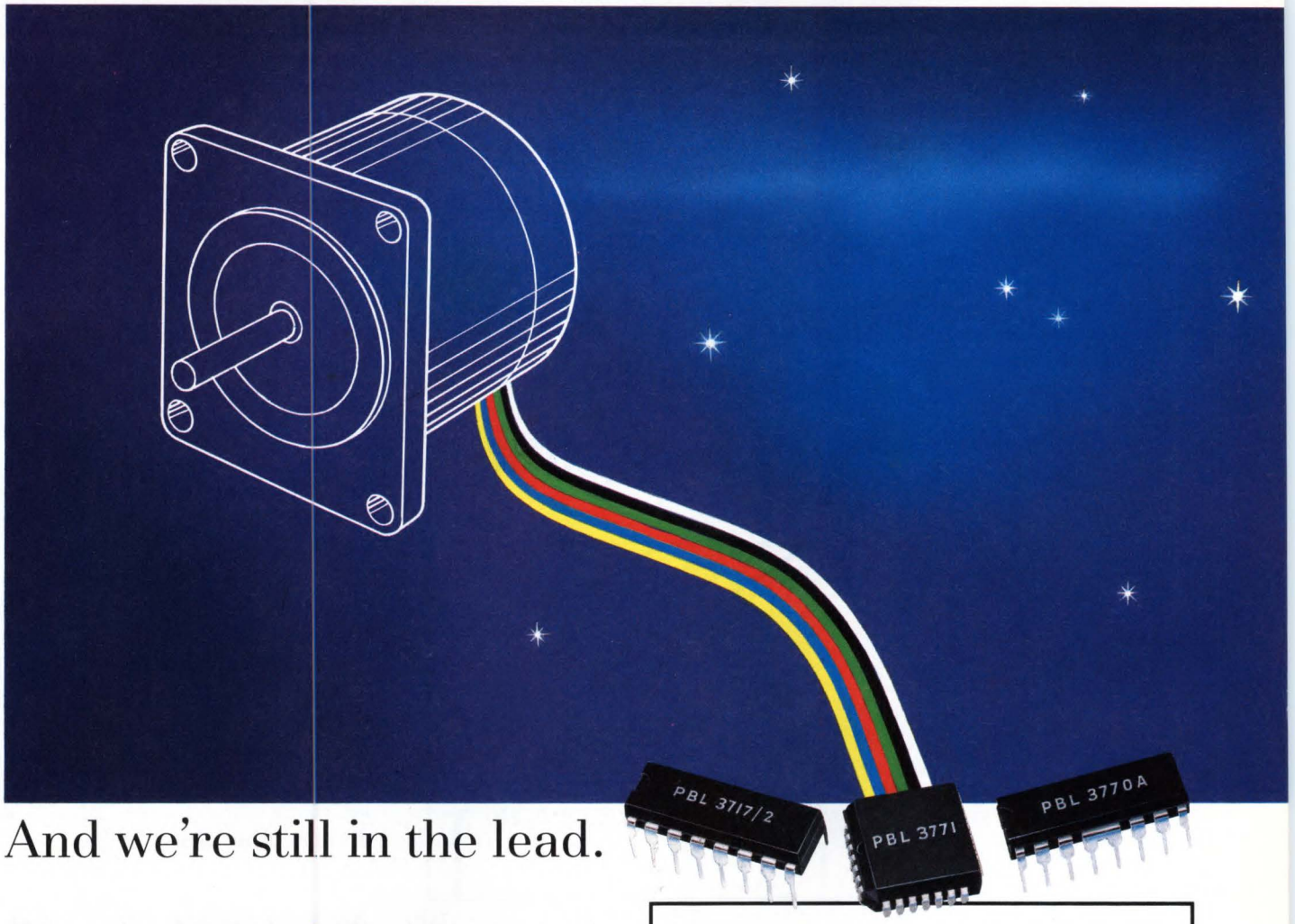

And we're still in the lead.

Ericsson Components is a leading manufacturer of Stepper Motor Driver ICs; for disk drives, printers, industrial instrumentation and robotics.
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- ★ PBL 3717/2. Improved version with 1000mA continuous output, plus half- and micro-stepping capability.
- ★ PBL 3770A. New world-leader, drives all kinds of stepper motors, with 1500mA continuous, 1800mA peak output.
- ★ PBL 3771 Dual Driver + PBM 3960 Dual D/A Converter. The industry-standard micro-stepping IC set.

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We're in the lead

CIRCLE NO 18

want not" (EDN, May 11, 1989, pg 51). It's about time we realize that everyone, including those of us who are in the electronics industry, must start taking a more responsible attitude concerning protection of our environment. I commend all of you at EDN for taking a stand on this very vital topic.

However, it's a sad irony that you chose to send your very next issue in nonbiodegradable plastic bags. I truly hope you will abandon this practice. Let your actions reflect your words—find a more environmentally acceptable means of mailing your publication.

In my opinion, EDN is the industry's best publication. I wouldn't mind in the least having to read an issue with a slightly soiled front page. On the other hand, I do mind having to rip off that plastic cover and throw it in the garbage, adding to the many tons of needless waste we generate daily.

Michael D Sullivan
Design Engineer
EG&G Energy Measurements
Los Alamos, NM

Errata

Our apologies go out to our readers and to Tim Lyons, whose article, "Chirp-Z transform efficiently computes frequency spectra," appeared in EDN's May 25, 1989, issue with a few errors.

On pg 167, in section (a) of **Table 1**, replace "nSEC" with "mSEC" in the first and second lines of the tabular data. And on pg 168 in **Fig 6, Eq 1**, the exponent of the first term to the right of the "=" sign contains an extra factor of "n" in its numerator, and the exponent of the last term should have "2N" in its divisor rather than "2n."

Address update

Hitachi America Ltd has moved from San Bruno, CA, since Maury Wright wrote his Special Report, "Winchester disk drives" (EDN, May 25, 1989, pg 134). The company's new address is

Hitachi America Ltd
2000 Sierra Point Pkwy
Brisbane, CA 94005
(415) 589-8300.

Sorry, wrong number

In the April 13, 1989, Technology Update on dual-port static RAMs (EDN, pg 83), the listing on pg 89 for Fujitsu Microelectronics included an incorrect phone number. The correct number is (408) 922-9000.

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Amphenol Interconnect Products has been producing a complete line of SCSI (Small Computer System Interface) cable assemblies and terminators since 1985. Our creative solutions to EMI shielding yields superior performance in FCC Class B testing. The use of 105 ohm cable reduces impedance mis-match which improves the compatibility of your equipment with other ANSI products. And, the thick film resistors in our terminators are laser trimmed to a ±5% tolerance. In addition to our standard products, we can customize molded assemblies with your logo and special color.

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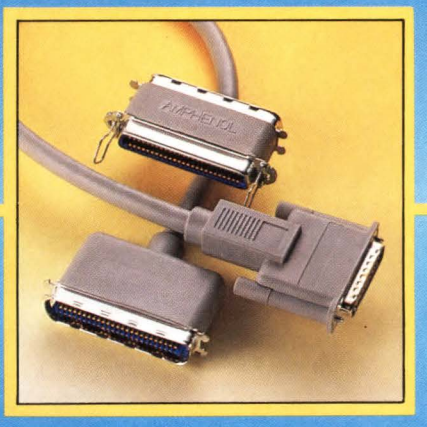

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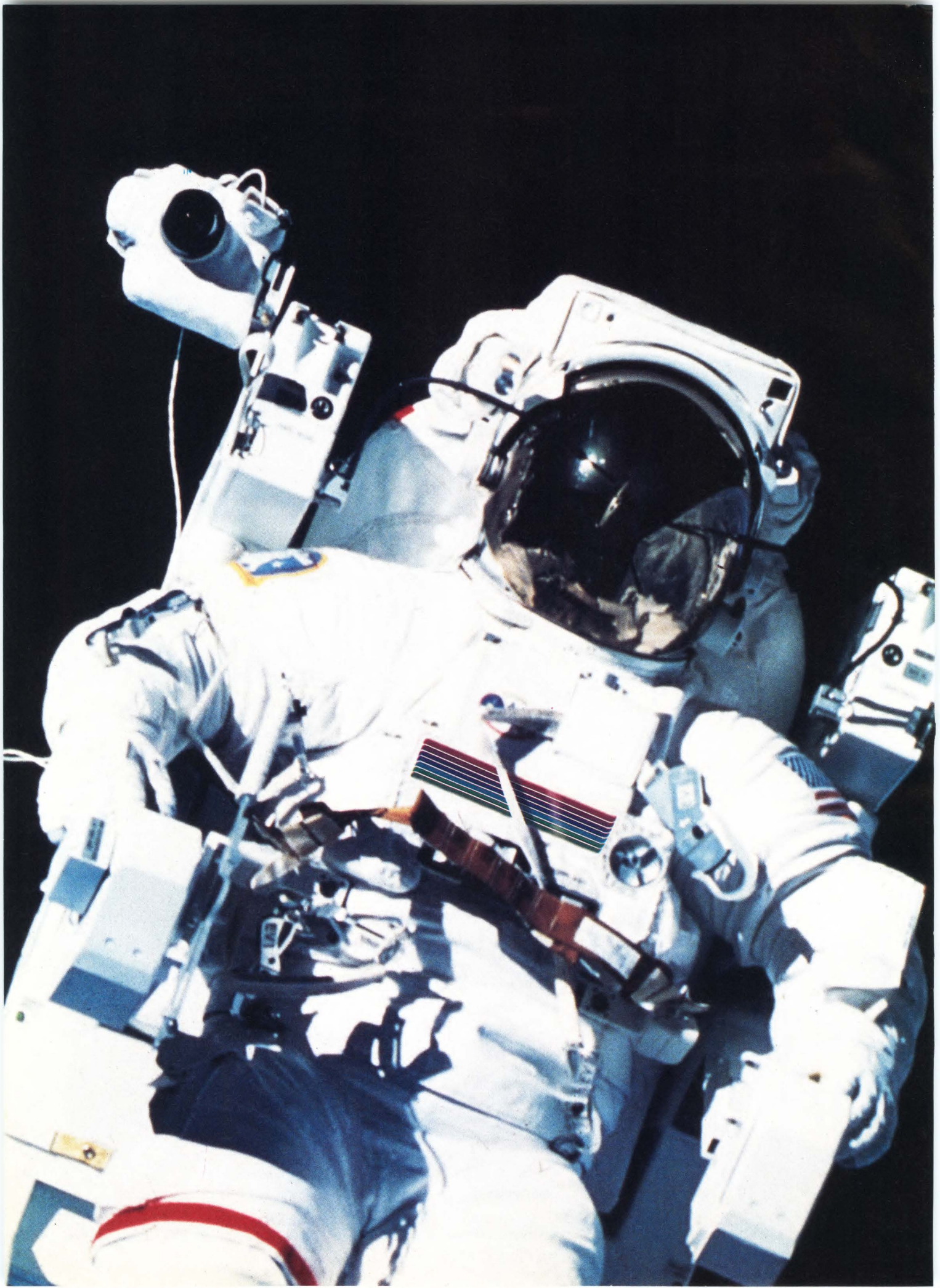
CIRCLE NO 20



Some designers already take enclosures very seriously.

If you don't, maybe you should look at the enclosure system that can add superior quality and protection to your ideas.

For example, are you insisting on the right solutions from your "packaging" supplier concerning: unique aesthetics, unlimited flexibility, perfect (100%) cost efficiency at the highest quality levels?

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Take your design all the way to perfection... switch to RITTAL.

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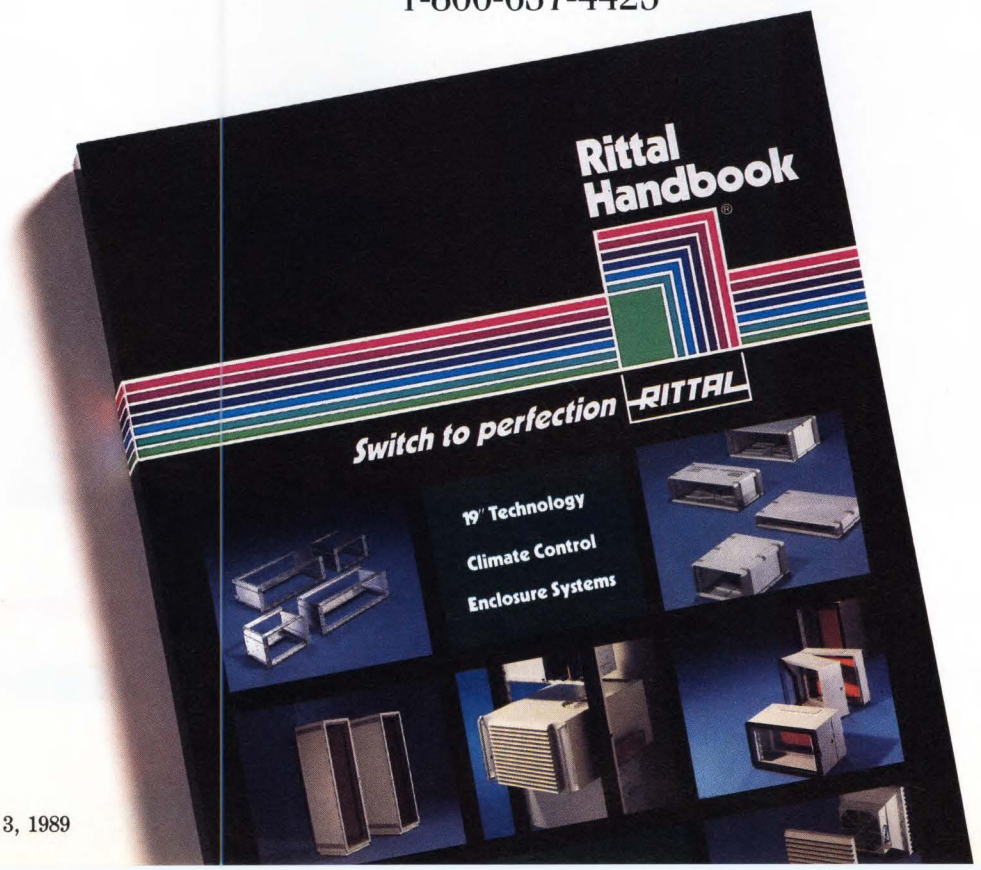

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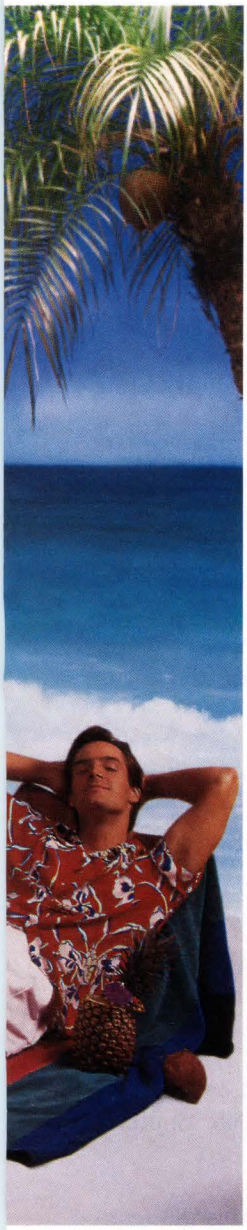
CIRCLE NO 21

ASIC design with all the excitement and none of the stress.

A S I C

Oki takes the pressure off with complete ASIC design support.



ASIC design opens a world of exciting possibilities for reducing size, improving system performance and increasing reliability, while lowering costs and power requirements. Make the most of this potential—and eliminate the stress—by working with Oki Semiconductor. Oki's unusually high level of design support will help you avoid the pitfalls and maximize the advantages of working with ASICs.

Complete ASIC design capabilities

Oki offers complete capabilities for channeled gate arrays, sea-of-gates, and standard cells, using advanced CMOS technology. We offer density to usable 40K gates and performance of < 0.46 ns. In addition, we support full custom design in high-voltage CMOS, BiCMOS, and bipolar technologies.

Experienced ASIC team at your service

Whether you're an ASIC design pro or tackling your first project, Oki's team of experienced design engineers is ready to assist you. We understand the pressures you're under. And we'll help you shorten development time, improve testability and manufacturability, and achieve first-time design success. We'll work with you to optimize your circuits or develop special cells. From start to finish, we'll do whatever it takes to help you succeed.

Comprehensive set of design tools

Oki has a full set of powerful mainframe design tools which ensure that your design will work, be efficient to manufacture, and perform reliably: logic, timing and fault simulations, automatic layout, detailed checking of design rules, and automatic test program generation. We support many popular workstations. Our large cell library includes many highly complex macrofunctions.

Flexible interface capabilities

We'll support your own design efforts with training, local field engineers, design kits, manuals, and libraries. Or you can work in our state-of-the-art design centers—independently or with our resident engineers—where we offer 24-hour access to private, secure, fully equipped work areas. And Oki can interface at any input level, from schematics to a simulated net list. In addition, we offer a variety of packaging options, including through-hole and surface mount, and we deliver reliable volume manufacturing.

At Oki, we can't promise an island paradise —but we can give you everything else you need for stress-free ASIC design. To get all the facts, call for our free brochure detailing Oki's ASIC capabilities.

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CIRCLE NO 22

CALENDAR

Basic Integrated Circuit Technology Seminar, Sunnyvale, CA. Integrated Circuit Engineering Corp, 15022 N 75th St, Scottsdale, AZ 85260. (602) 998-9780. FAX 602-948-1925. August 15.

Data Communication Concepts (seminar), Los Angeles, CA. Technology Transfer Institute, 741 10th St, Santa Monica, CA 90402. (213) 394-8305. August 23 to 25.

11th Quartz Devices Conference and Exhibition, Kansas City, MO. Electronic Industries Association, 1722 Eye St NW, Washington, DC 20006. (202) 457-4981. August 28 to 31.

International Test Conference 1989, Washington, DC. International Test Conference, Box 264, Mt Freedom, NJ 07970. (201) 895-5260. FAX 201-895-7265. August 29 to 31.

Surface Mount '89, San Jose, CA. MG Expositions Group, 1050 Commonwealth Ave, Boston, MA 02215. (800) 223-7126; in MA, (617) 232-3976. August 29 to 31.

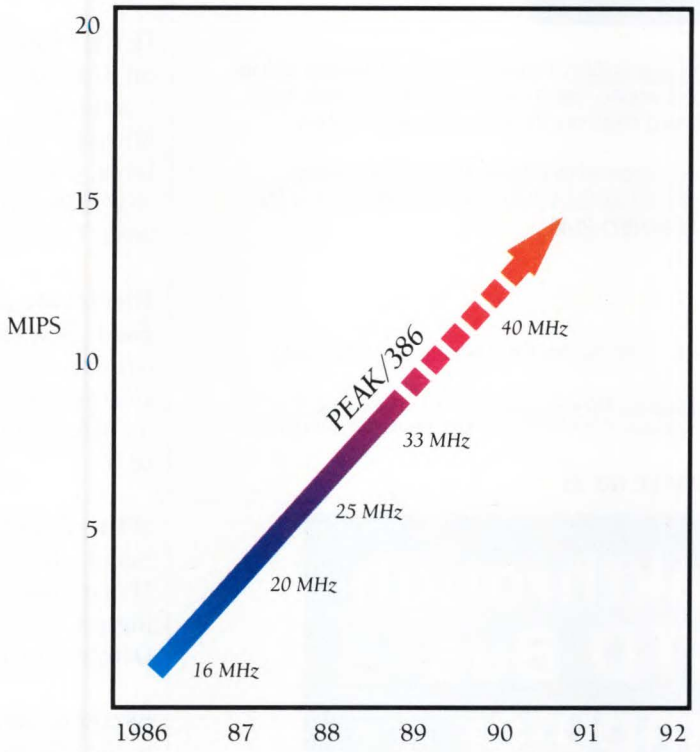
Real-time Structured Analysis & Design (short course), Washington, DC. John Valenti, Integrated Computer Systems, 6053 W Century Blvd, Los Angeles, CA 90045. (800) 421-8166; in CA, (213) 417-9700. FAX 213-410-2952. August 29 to September 1.

Midcon/89, Rosemont, IL. Midcon/89, 8110 Airport Blvd, Los Angeles, CA 90045. (213) 772-2965. September 12 to 14.

Aerospace & Electronics '89 (conference), Santa Clara, CA. National Computer Graphics Association, 2722 Merrilee Dr, Suite 200, Fairfax, VA 22031. (703) 698-9600. FAX 703-560-2752. September 12 to 15.

Expo SMT International, Las

How to make your 386 system scream.



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The PEAK/386 CHIPSet supports 20, 25, 33 and tomorrow's anticipated 40 MHz clock speeds. With the added performance of the industry's only integrated 128K byte cache.

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The PEAK/386 CHIPSet also tightly couples with our new 82C480 Graphics Controller which is 100% functionally compatible with the IBM® 8514/A Display Adapter. So your system can take full advantage of the new graphical interfaces like Presentation Manager and Windows™ software.

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We promise you it'll be a real scream.

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The CHIPSet *is* the system.

CALENDAR

Vegas, NV. Expo SMT, Box 1869, Los Gatos, CA 95031. (408) 354-0700. FAX 408-354-1036. September 25 to 27.

Diskcon, San Jose, CA. Julie Sunseri, 710 Lakeway, Suite 170, Sunnyvale, CA 94086. (408) 720-9352. FAX 408-736-2523. September 26 to 27.

IEEE International Conference on Computer Design (ICCD '89), Cambridge, MA. Giovanni De Micheli, Center for Integrated Systems, Room 129, Stanford University, Stanford, CA 94305. (415) 725-3632. October 2 to 4.

Electronic Imaging Conference East, Boston MA. MG Expositions Group, 1050 Commonwealth Ave, Boston, MA 02215. (800) 223-7126; in MA, (617) 232-3976. October 2 to 5.

20th Korea Electronics Show, Seoul, Korea. Joseph Burke, US Department of Commerce, Washington, DC 20230. (202) 377-5014. October 7 to 12.

Systems 89, Munich, West Germany. Gerald G Kallman, Kallman Associates, 5 Maple Ct, Ridgewood, NJ 07450. (201) 652-7070. FAX 201-652-3898. October 16 to 20.

Northcon/89, Portland, OR. Northcon/89, 8110 Airport Blvd, Los Angeles, CA 90045. (213) 772-2965. October 17 to 19.

Supercomputing World, San Francisco, CA. MG Expositions Group, 1050 Commonwealth Ave, Boston, MA 02215. (800) 223-7126; in MA, (617) 232-3976. October 17 to 20.

Unix Expo '89, New York, NY. National Expositions Co, 15 W 39th Street, New York, NY 10018. (212) 391-9111. FAX 212-819-0755. November 1 to 3.

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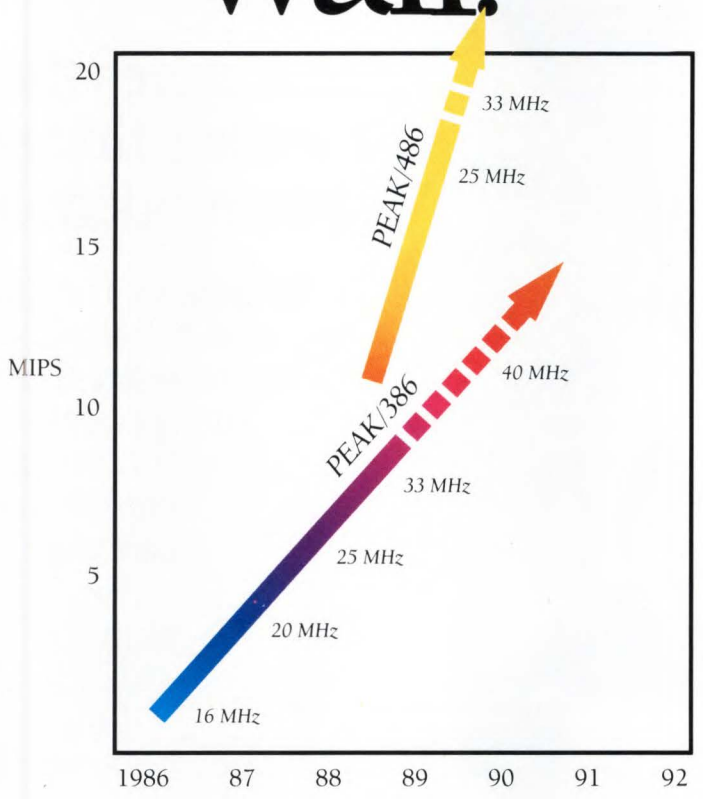

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And design a system that will take you through the top of the charts. Period.

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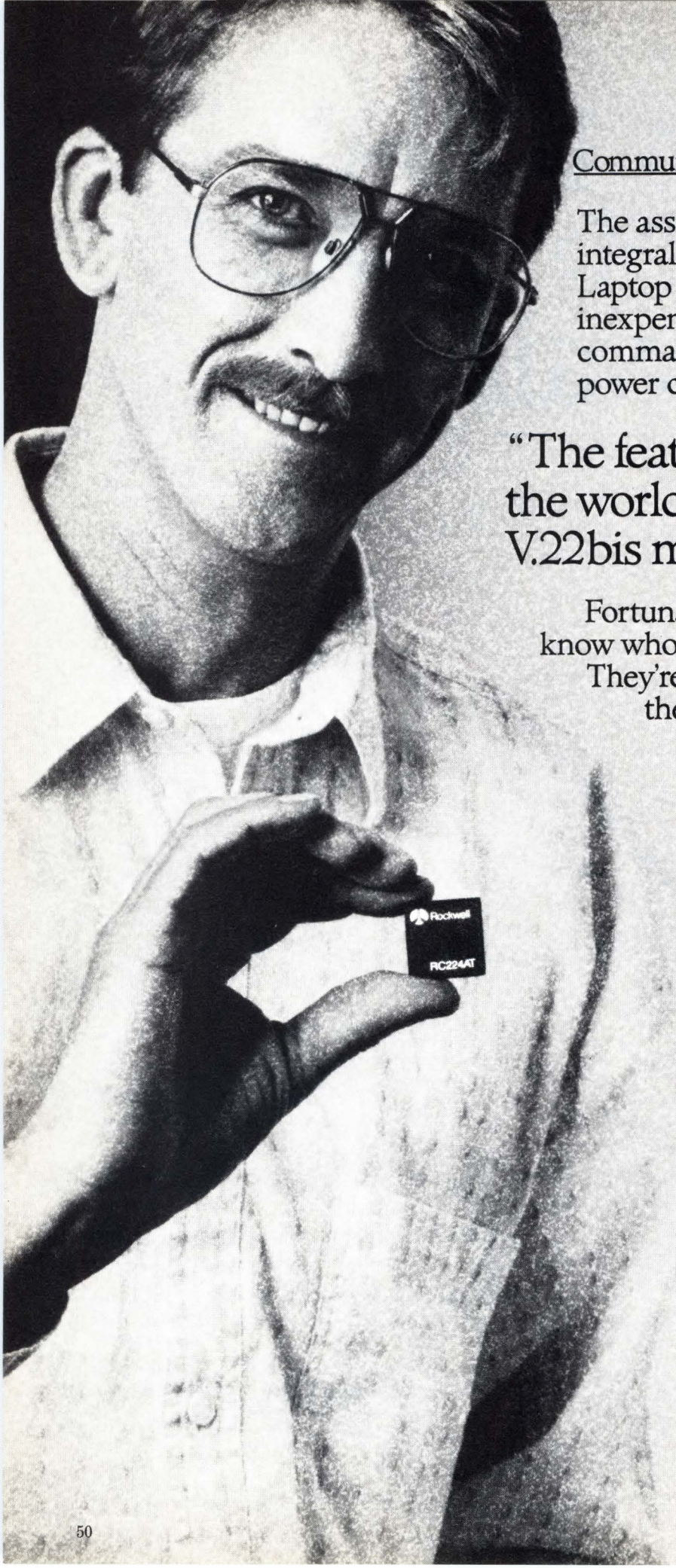
The CHIPSet *is* the system.



Communication solutions from Rockwell.

The assignment was demanding. The integral modem for the company's new Laptop would have to be compact and inexpensive. With the complete '88 AT command set, plus the lowest possible power consumption.

"The features they packed into the world's first single-device V.22bis modem blew us away."

Fortunately, the engineers already know who to call: Rockwell International. They're aware that no matter what the application, Rockwell's new V.22bis family provides capabilities nobody else can supply.

They've read how Rockwell stunned the industry with its RC224AT—the world's first fully integrated single-device modem solution. And how this one compact component offers CCITT V.22bis and V.22, as well as Bell 212A and 103 compliance, plus value-added features such as power-saving Automatic Sleep Mode. Not to mention the assurance of a five-year warranty.

Their call to Rockwell also reveals how the V.22bis family can help with future projects. They learn about the capabilities of Rockwell's RC2324DP chip set.

They hear how it provides HDLC/SDLC framing for implementing MNP 5™, X.25, LAPM and V.42 protocols, while offering unprecedented programming flexibility for custom and country-specific applications.

"And then we met the rest of the family."

A Rockwell technical advisor explains that it's the only chip set with Quad capability that meets CCITT V.22bis, V.22A/B, V.21 and V.23 requirements, as well as Bell 212A and 103 standards. He adds that the RC2324SME offers capabilities optimized for Europe, including MNP 5™ and V.25bis.

In no time, the Laptop project is ready for production. To management, the results—as well as the engineers responsible—couldn't look better.

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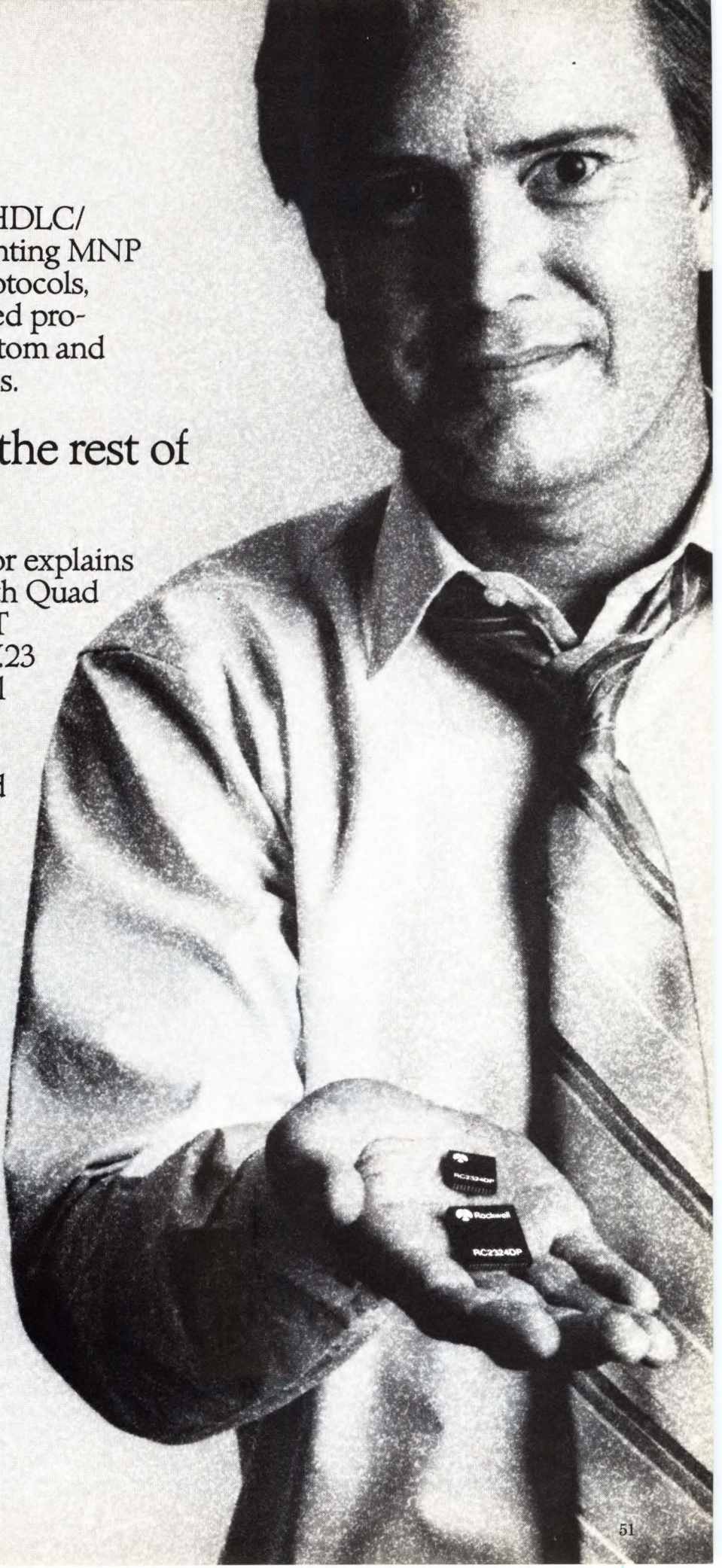

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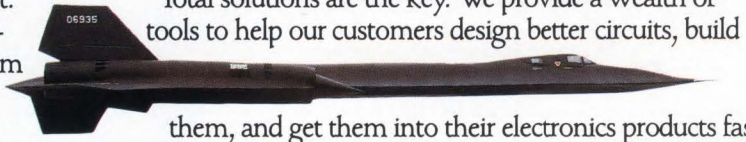

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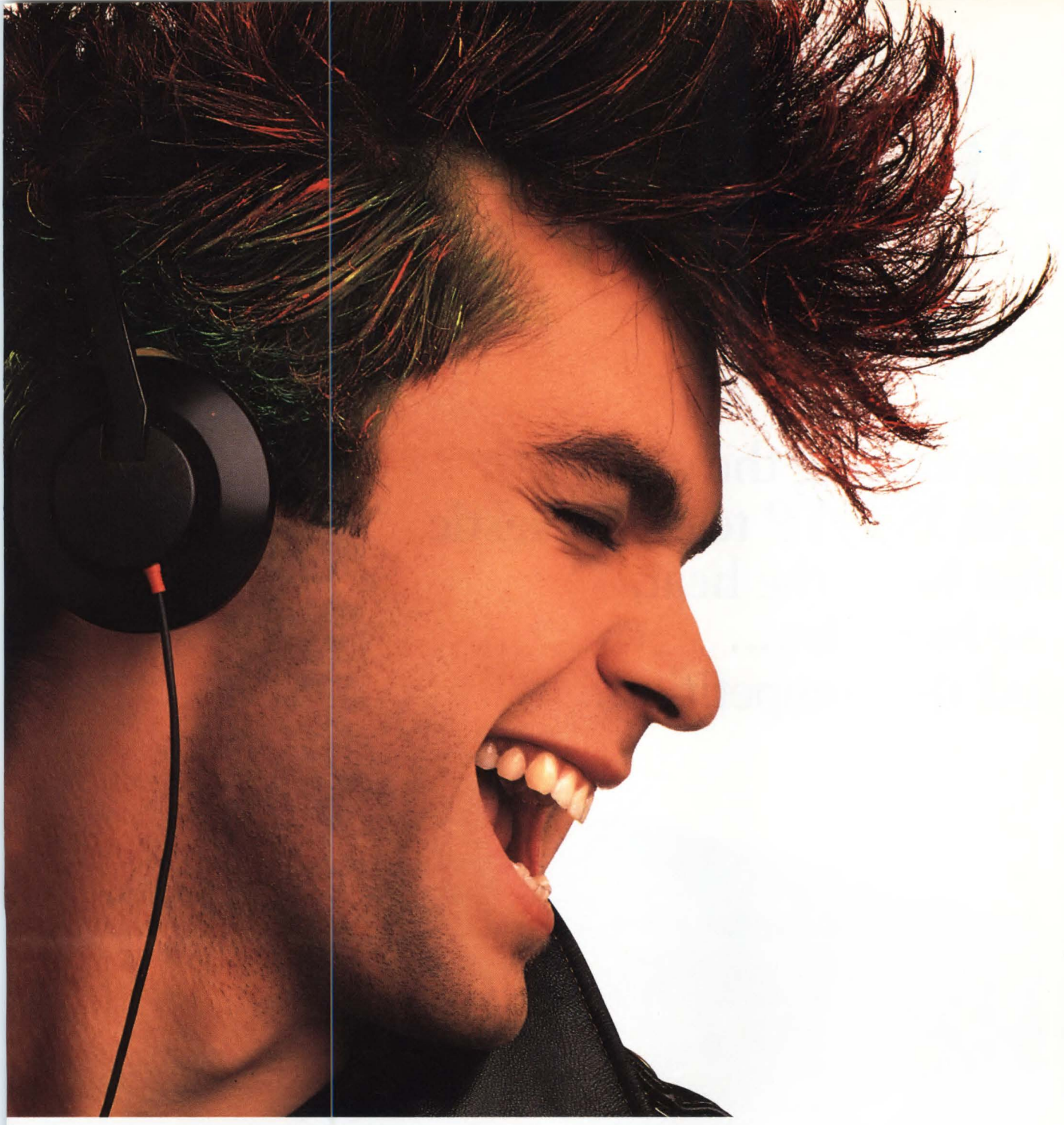

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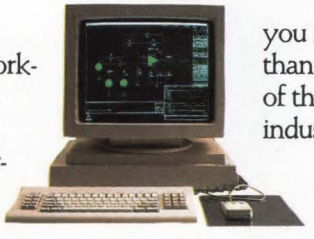

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TEXAS INSTRUMENTS REPORTS ON

RELIABILITY IN PLA

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TI VS. COMPETITOR OTPs MOISTURE RELIABILITY COMPARISON
(PERCENT DEFECTIVE AT HOURS OR CYCLES)

TEST	HOURS OR CYCLES	TI PC256 (CMOS)	A P256 (NMOS)	B P256 (NMOS)	C P256 (NMOS)	D P256 (NMOS)	E P256 (NMOS)
85°C/85% Humidity Moisture Test	1,000 Hours	0.0%	5.0%	0.0%	14.0%	1.0%	2.0%
Pressure Cooker Test	240 Hours	0.0%	32.5%	0.0%	26.0%	10.0%	0.0%
–65°C to 150°C Temperature Cycle	1,000 Cycles	0.0%	2.5%	24.0%	12.0%	92.0%	6.0%

Grueling heat and humidity tests prove the high reliability and superior moisture resistance provided by a proprietary plastic and wafer protective overcoat system used in TI's OTPs. Devices tested were TI 256K CMOS OTPs and 256K NMOS OTPs from five other leading U.S. and Japanese manufacturers.

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In fact, TI's new SNAP! Pulse algorithm speeds you through programming in less than one-tenth the time of earlier algorithms. For example, you can program one of our 256K OTPs in less than four seconds compared to the 132 seconds required by earlier algorithms.

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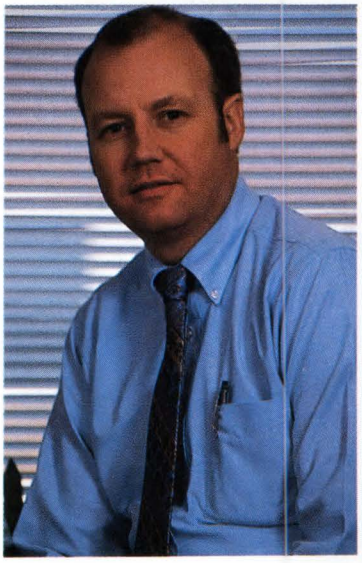
EDITORIAL

No more quick fixes



Recently, the American Electronics Association reported to the US Senate on a plan to re-establish a US-based television industry. The AEA wants an industry that would develop and produce high-definition television (HDTV) equipment. In short, the AEA proposes an equal split of research and development costs between industry and government, an industry-led advisory group, loans and loan guarantees, and research-and-development tax credits. The AEA would also like to see a reduction in capital gains taxes and the cost of money.

The AEA is headed in the right direction, but we've got to take a broader, longer-term approach to solving HDTV-type problems. Otherwise, the electronics industry's executives will spend more and more time begging for government assistance as competing businesses—and countries—leave us in the dust.

Let's be clear that the main problem really isn't competitiveness. If we let it, the US electronics industry can be very competitive. Unfortunately, most US companies are shackled by a financial community that wants fast returns on investments and by the government's tangle of rules, regulations, and taxes. So, instead of debating how to jump-start a US-based TV industry, we should discuss the broader issues that will affect many industries and new technologies.

Here are a few ideas to start you thinking:

1. Congress or an independent advisory board could identify emerging technologies and markets, such as HDTV, high-temperature fusion, and bioengineering. Any new company that devoted at least 80% of its efforts to commercially developing one of those technologies would be exempt from taxes for a set number of years. This measure would encourage investment in new, small companies, which is where most of today's innovations arise.

2. New laws already make it easier for companies to gather in a cooperative research group or consortium. If several companies wish to combine manufacturing, they're now subject to antitrust laws. It might be worth selling antitrust waivers—or trading them for future tax gains—so that companies can combine production skills and facilities without government interference. Again, the antitrust provisions would be in effect for a set time. This move would encourage large companies, such as AT&T, Zenith, and IBM, to form small dynamic joint ventures to tackle tough manufacturing problems.

3. It may be time to let banks invest a small amount of their assets directly in businesses. Although banks can make loans, they cannot own shares of a company. The close relationships between banks and businesses in Japan helps reduce the cost of capital. Japanese banks take a long-term approach to growth and will settle for less than the astronomical gains sought by venture-capital groups. Fostering a long-term bank-industry relationship in the US seems worthwhile.

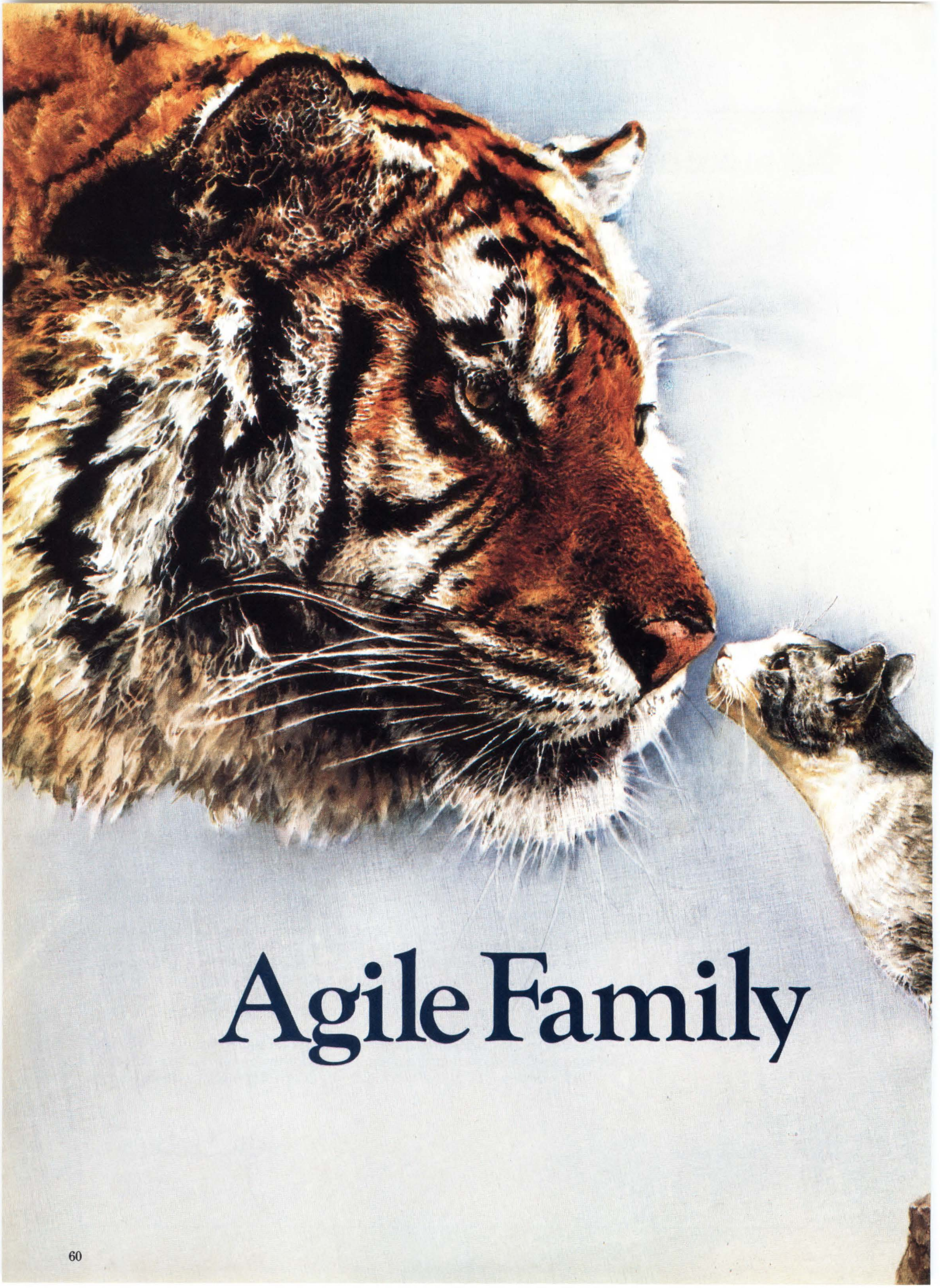
4. Today, capital gains are taxed as ordinary income. Let's restructure our capital-gains tax so that it again penalizes short-term speculation and rewards long-term investment. Also, to encourage long-term investments, we could exempt from taxes dividend and interest payments from investments held longer than 10 years. Further, dividend payments should be exempt from corporate income tax, a double taxation that hurts US businesses and investors.

5. I've said before that companies should consider issuing stock that requires at least a 6-month ownership before the owner can vote in corporate matters. It's still a good idea to get investors looking at long-term returns.

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

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

Jon Titus
Editor



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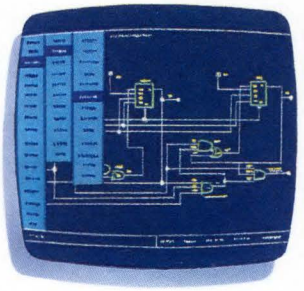
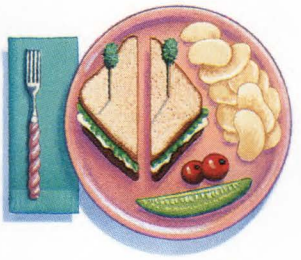
7:05 am: Breakfast
Suddenly, between bites, the answer to that new system design jumps right into your brain. But how to make it work in silicon? Use an Actel field programmable gate array!



8:50 am: Design
You warm up the design program on your 386 and put in the final touches. Then a quick rule check and 25 MHz system simulation with the Action Logic System software.

11:00 am: Place & Route
You watch the system place and route all 1700 gates (out of 2000 available) in under 40 minutes. 100% automatically! A final timing check. Then think of something to do until lunch.



12:00 pm: Lunch
Remember lunch? Normal people actually *stop working* and have a nice meal—right in the middle of the day! With Actel's logic solution, this could become a habit.

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Breakfast And n By Dinner.

1:15 pm: Program
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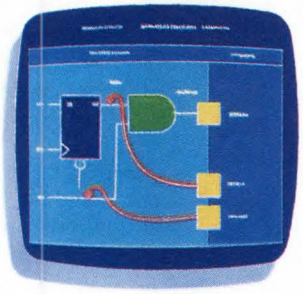

1:25 pm: Test
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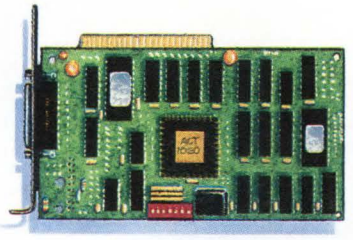
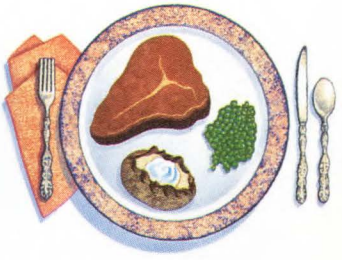


4:00 pm: Production
Your pride and joy is designed, created, tested, and off to the boys in Production. And you're finished *way* ahead of schedule! Better think of something to do until 5:00.



6:00 pm: Dinner
Remember dinner? Normal people actually *go home* and eat with their families. On your way, start thinking about how Actel's logic solution can help you be brilliant tomorrow.

placement and routing. Guaranteed. So you finish fast, and never get stuck doing the most tedious part of the job by hand. And design verification is quick and easy, with on-chip Actionprobes™ that work with your logic analyzer to provide 100% observability of internal logic signals. Guaranteed.

All this is made possible by Actel's invention of the revolutionary PLICE™ antifuse programming element. Developed specifically for logic integration, PLICE antifuses and Actel's gate array architecture let you pack more functionality into much smaller spaces. No more splitting equations across multiple PLDs. Or being short on flip flops. Or running out of connections halfway through routing.

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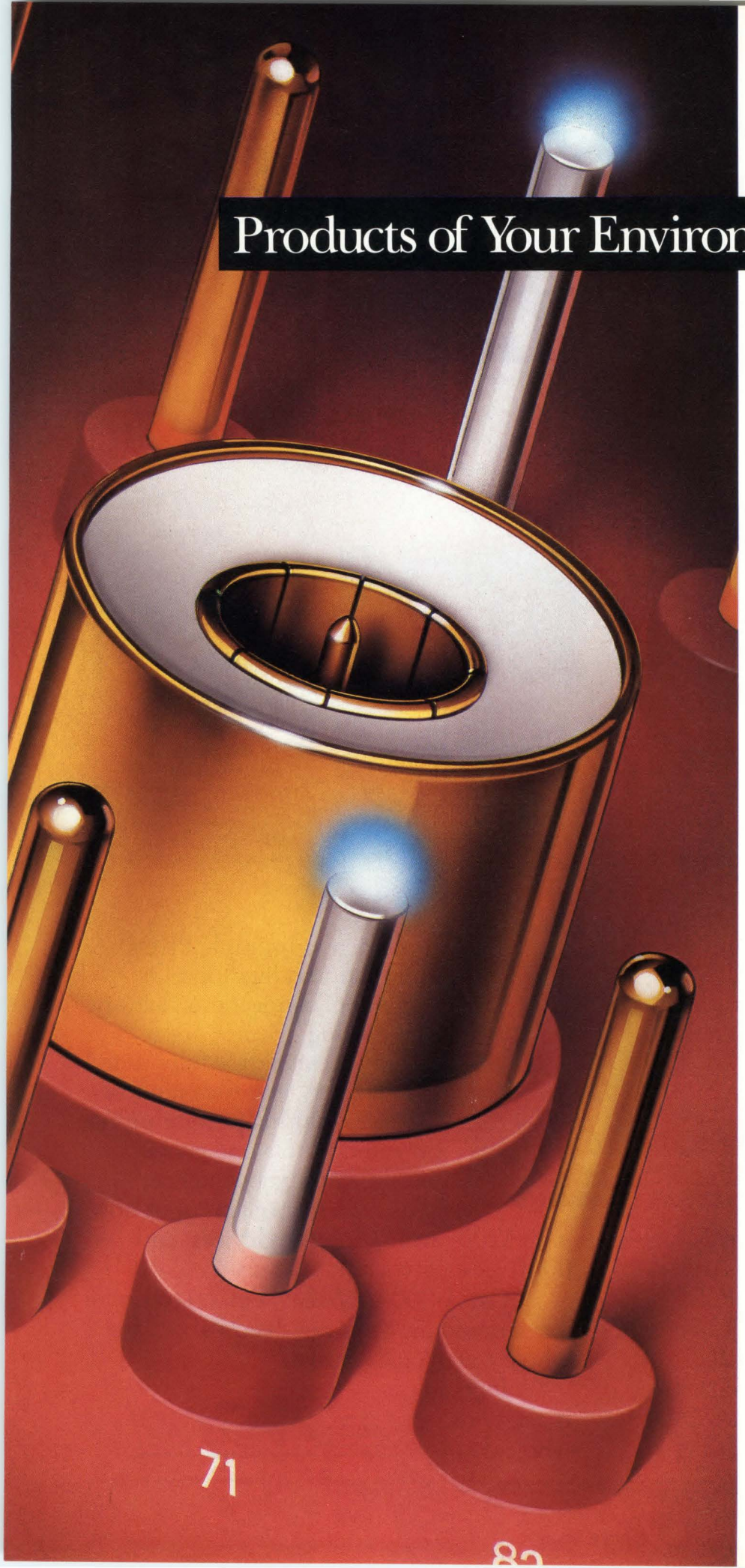
Actel



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CIRCLE NO 33

Fast disk data rates spur IPI acceptance

IPI-based I/O subsystems hold the promise of data-transfer rates in excess of 50M bytes/sec, but you have few IC or board products to build such systems now.

Maury Wright,
Regional Editor

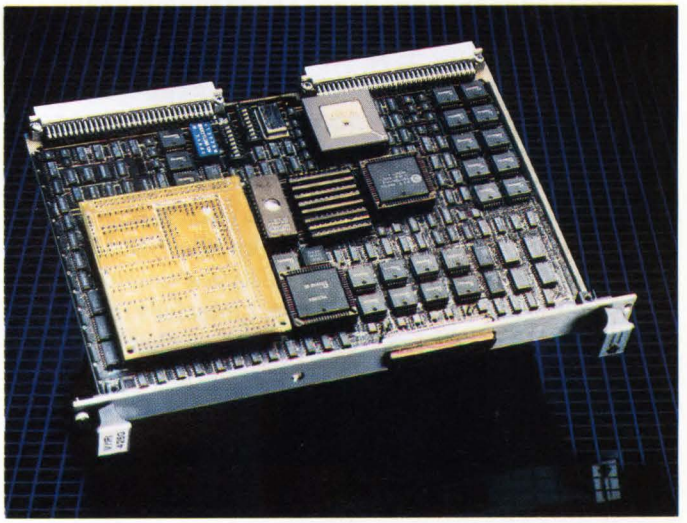
Although it's some two years later than many industry experts predicted, the Intelligent Peripheral Interface (IPI) will be this year's interface of choice for high-performance I/O subsystems. Disk drives with data channels faster than 3M bytes/sec are now available with IPI. Designers finally have at least a few options for IPI VLSI ICs and boards.

The IPI standard is made up of a number of specifications that define a modular layered interface. The interface consists of a physical layer (IPI-0 and IPI-1), a time-dependent device-level layer (IPI-2), and a time-independent device-generic I/O system bus layer (IPI-3) (**Ref 1**). The committee that developed the IPI standard consisted of system manufacturers who needed a new high-speed I/O bus and system and disk manufacturers who recognized the need for a native disk interface that was faster than serial interfaces such as SMD (Storage Module Drive).

The IPI specification initially defined a 16-bit parallel physical interface that could operate as fast as 10M bytes/sec. The latest (although not published) version of the specification allows for 50M-byte/sec transfers over a 50m cable using 16 bits. You can transfer data even faster using wider data paths or shorter cable lengths. (For more information on the status of the various IPI specs, see **box,** "IPI—yesterday, today, and tomorrow.")

More than two years ago several mainframe manufacturers, led by IBM, adopted IPI-3 as a standard system I/O channel. Mainframe prices often justify the use of an IPI channel with or without VLSI ICs. The IPI standard meets the performance requirements of mainframes, and the interface supports dual porting at the host adapter, controller, and drive levels. The dual-porting capabilities of the IPI make it a natural choice in system applications such as mainframes where fault tolerance is important.

The IPI has been slow to catch on in smaller system designs. The SCSI bus can serve the system I/O needs for most nonmainframe systems. However, an IPI channel might be a better choice for many applications. Furthermore,



By including the Buspacket Interface and MACSI *software interface, Interphase made the VMEbus Cougar IPI board a faster plug-and-play replacement for its ESDI and SMD products.*

manufacturers of disk drives, controllers, and systems have managed to increase the transfer rate of the SMD interface to 3M bytes/sec. This rate matches the typical maximum data rates of available drives.

Most observers agree that drives with data rates that exceed 3M bytes/sec will necessitate the use of a parallel device-level interface. IPI-2-based I/O subsystems can serve applications ranging from high-end workstations and imaging systems to supermicrocomputers that require high data rates and a native drive interface.

Imprimis recently announced a 6M-byte/sec 8-in. disk drive that employs IPI-2 as its native interface. The Imprimis drive employs dual read channels—each channel services half of the platters—to attain the high rate. You can expect other drive vendors to follow with dual-channel drives.

In the coming year, most manufacturers of 8-in. drives plan to ship single-channel products that transfer data at 4.5M bytes/sec. The drives will most likely maintain the 3600-rpm rotational speed common in drives available now, but will feature bit-density increases that provide storage of 75k bytes/track. IPI-2 will be the only device-level interface offered for 4.5M-byte/sec drives because the SMD or ESDI (Enhanced Small Device Interface) interfaces can't match the data rate. You may, however, also see manufacturers offer the drives with embedded IPI-3 or SCSI controllers.

The final boost to the use of IPI-2 will come from manufacturers of 5¼-in. drives. Drives featuring the smaller form factor nearly match 8-in. offerings in capacity, performance, and reliability, but they cost far less. Simulex, using its VLSI technology, has demonstrated its ability to build a 5¼-in. IPI controller. Once again, expect Imprimis to lead the industry with the first IPI-2-based 5¼-in. product. The company is rumored to be planning a 1G-byte, 5¼-in. drive, which might be introduced later this year. The drive will feature a faster rotational speed (5400 rpm) and a 3M-byte/sec transfer rate.

Drive vendors have offered IPI-2 drives for two years, but these products have been SMD drives retrofitted with IPI-2 interfaces for evaluation purposes. During the same two years, vendors have

IPI—yesterday, today, and tomorrow

The idea for the Intelligent Peripheral Interface (IPI) originated in 1978, serious development started in 1981, and today ANSI committee X3T9.3 continues to add to and enhance the standard. The committee originally envisioned a layered master-slave interface with one or more modular specifications defined for each layer. The approach has enabled the committee to update, enhance, and define new specifications in an orderly manner.

However, the layered-interface concept creates a problem—you have to constantly keep up with the status of several different specifications. An update on the activities of ANSI committee X3T9.3 follows.

The first portion of the IPI spec published, labeled X3.129, defines the physical layers know as IPI-0 and IPI-1. IPI-0 refers to the electrical and mechanical characteristics of the physical interface. IPI-1 refers to the bus states and sequences that define the use of the physical interface. Originally published in 1986, X3.129 defined a synchronous 5-MHz, 16-bit data transfer that resulted in a maximum 10M-byte/sec rate.

Recently, the committee completed work on an enhanced version of the physical interface. The new spec is under public review and should be published within six months. It includes the option of using current-mode, voltage-mode, or ECL drivers and receivers. At a maximum cable length of 50m, current mode will reach a transfer rate of approximately 25M bytes/sec, voltage mode will also reach 25M bytes/sec, and ECL drivers and receivers will reach 50M bytes/sec. You can make the interface run even faster by shortening the cable length.

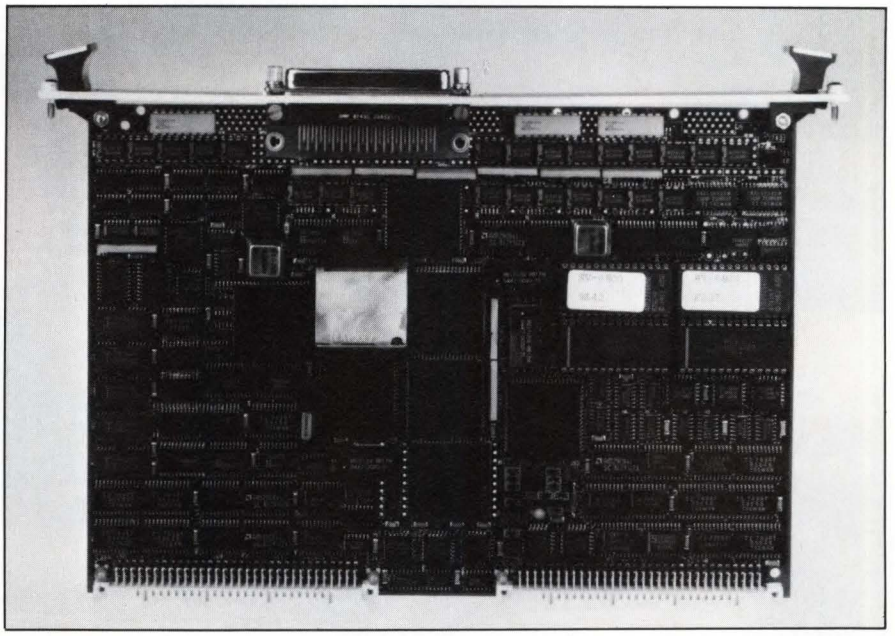
In addition, point-to-point implementations can operate at approximately double the usual rates. (Most IPI installations daisy chain a cable to several devices.) The spec provides for the use of wider data transfers. A 32-bit single-cable interface can double the transfer rate. You can use a 2-cable implementation to ensure downward compatibility with 16-bit devices. You can even continue to add more cables. Each will add 16 bits to the data path.

The committee plans to add a physical layer based on fiber optics. In fact, the committees that work on the IPI, SCSI, and HSC (High Speed Channel) standards have agreed to adopt an identical fiber-optic-based physical interface. The new interface will be called the Fiber Channel. Fiber optics gives you the luxury of connecting peripheral interfaces with very long cables. You can expect the addition

promised controller products when fast drives become available.

Now both drives and controllers are available. Drive companies such as Imprimis offer IPI-3 to IPI-2 controllers, and Interphase and Xylogics recently introduced IPI-2 controllers for the VMEbus. No companies offer IPI-3 host adapters for the VMEbus or other open buses yet, but you can expect products late this year. You can buy IPI test and development equipment now from Simulex.

However, the lack of commercially available IPI VLSI ICs will continue to slow the acceptance of IPI. Drive manufacturers originally funded Simulex to design two ICs for IPI-2 disk drives, and it has since designed four more ICs. **Fig 1** shows the Simulex ICs and where



***A 10M-byte/sec IPI transfer rate** and 35M-byte/sec VMEbus transfer rate make the SV6800 and SV7800 IPI-2 boards from Xylogics suitable for I/O subsystem use in applications such as RISC-based systems.*

of the Fiber Channel to the spec to take more than two years.

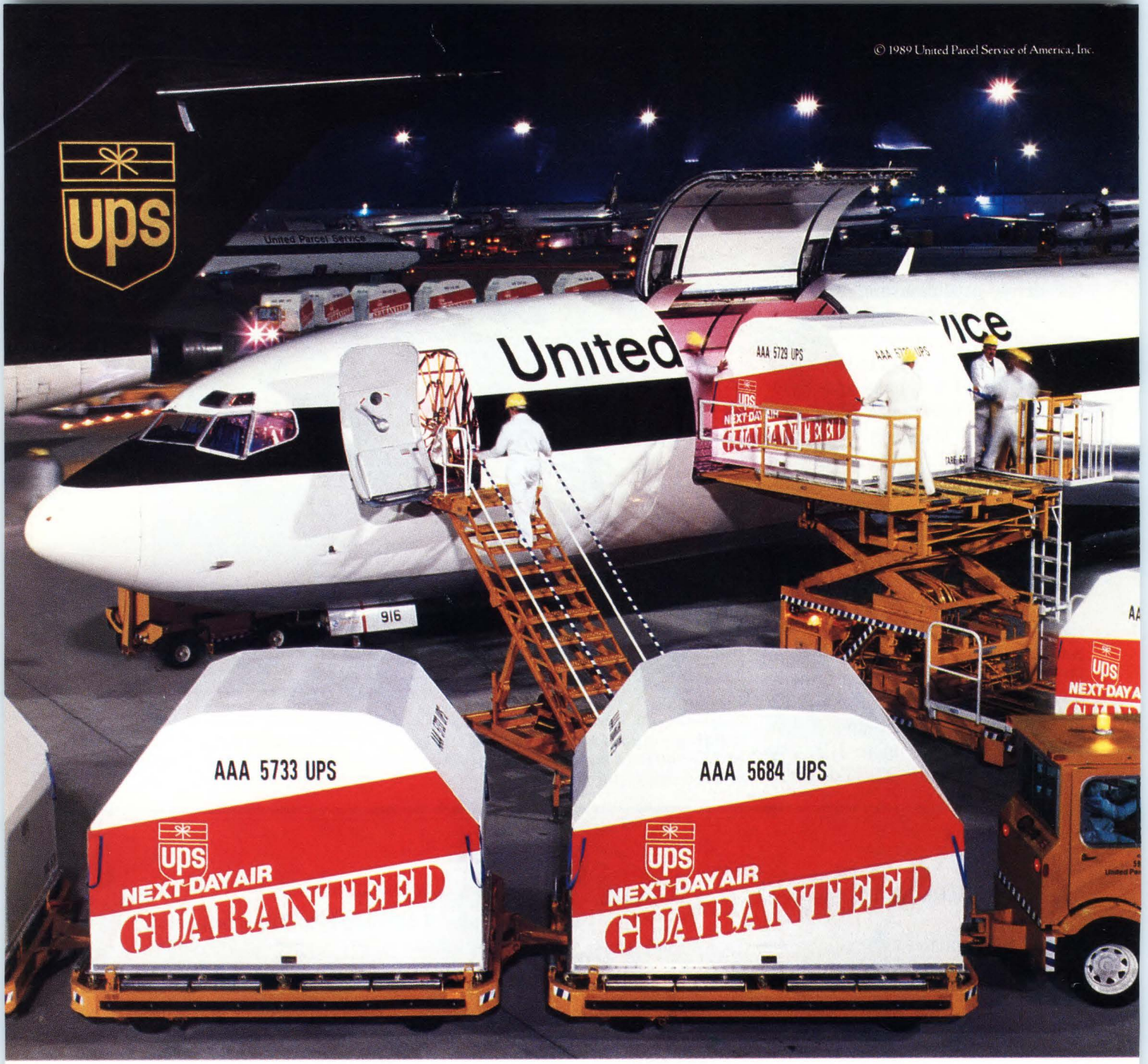
The committee also defined a device-specific, timing-dependent logical layer to be placed above its physical layer. Its specs define logical commands relative to device-unique components, such as heads and cylinders for disks. The published IPI-2 spec, labeled X3.130, defines a set of logical commands to control magnetic disk drives. The committee plans to start work on a revision to X3.130 soon. The revision will add features such as spindle synchronization capability and provisions for drives with multiple data channels. The committee has also developed an IPI-2 spec for tape drives. It is under public review and should be published within six months.

IPI-3 layer specs define device-generic, timing-independent command sets, such as the read/write logical block command. The third layer is essentially a system-level I/O bus. IPI-3 and IPI-2 both use the same physical layer. You can have IPI-3 slaves that include embedded controllers or IPI-3 slave stand-alone controllers. The stand-alone controllers bridge IPI-3 host interfaces to IPI-2 or other device-level interface peripherals. Most IPI tape drives include an embedded IPI-3 controller. Disk subsystems tend to use bridge controllers.

ANSI spec X3.132 defines an IPI-3 magnetic- and optical-disk interface. ANSI spec X3.147 defines an IPI-3 tape interface. The committee has also completed a spec for communication devices that is under public review and should be published within six months.

The IPI physical-layer spec makes provisions for layers 4 and 5 as well. Layer 4 will be data specific (random, sequential, input, output), and layer 5 will require file structure and organization to be embedded in the slave. However, the details of the spec have yet to be defined.

You can obtain copies of the IPI specs in two ways. You can buy individual copies of ANSI specs from Global Engineering, Irvine, CA (phone (800) 854-7179). You can also contact the Computer and Business Equipment Manufacturers Association in Washington, DC, at (202) 626-5741 for information about becoming an observing member of X3T9.3. Members can purchase an annual subscription and receive all revisions of the various specs.



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they fit in an IPI subsystem. But Simulex is the only company that has designed a complete set of IPI chips, and it is not an IC vendor.

Simulex does sell licenses to its IC technology. The licensee can then buy parts from a semicustom-IC vendor. Licensees can also build the ICs themselves or modify the designs and build the ICs, but only for their own internal use. Simulex hopes to offer the ICs commercially. Currently, however, demand doesn't support such an effort.

A number of other companies have designed IPI ICs, but none currently offers the ICs commercially. Gould (Fort Lauderdale, FL) designed an IPI IC for use in its systems, and Gould/AMI (Pocatello, ID) briefly offered it for sale as a standard product. Fujitsu and Siemens have contemplated selling ICs developed for internal use but have yet to announce their plans. Xylogics will license or sell an IC it developed for its VMEbus board on a limited basis. Imprimis may license several of its IPI ICs but has no plans to market them.

The complexity of the IPI has discouraged traditional semiconductor houses from designing IPI ICs. Unlike SCSI that uses a peer-to-peer interface, the IPI specs define a master/slave interface, and interface ICs for master and slave devices differ. Furthermore, IPI-2 and IPI-3 devices have different requirements. Time-critical level-2 interface ICs must decode and respond to commands embedded in bus-protocol octets. Time independent IPI-3 devices receive commands in packets following the octets. A single interface IC can't do for IPI products what the relatively simple NCR 5380 did for SCSI drives, controllers, and host adapter products.

Simulex has designed a wide variety of ICs to serve an entire IPI subsystem. Its first chips targeted IPI-2 disk drives. The SX1601 interface protocol circuit handles the

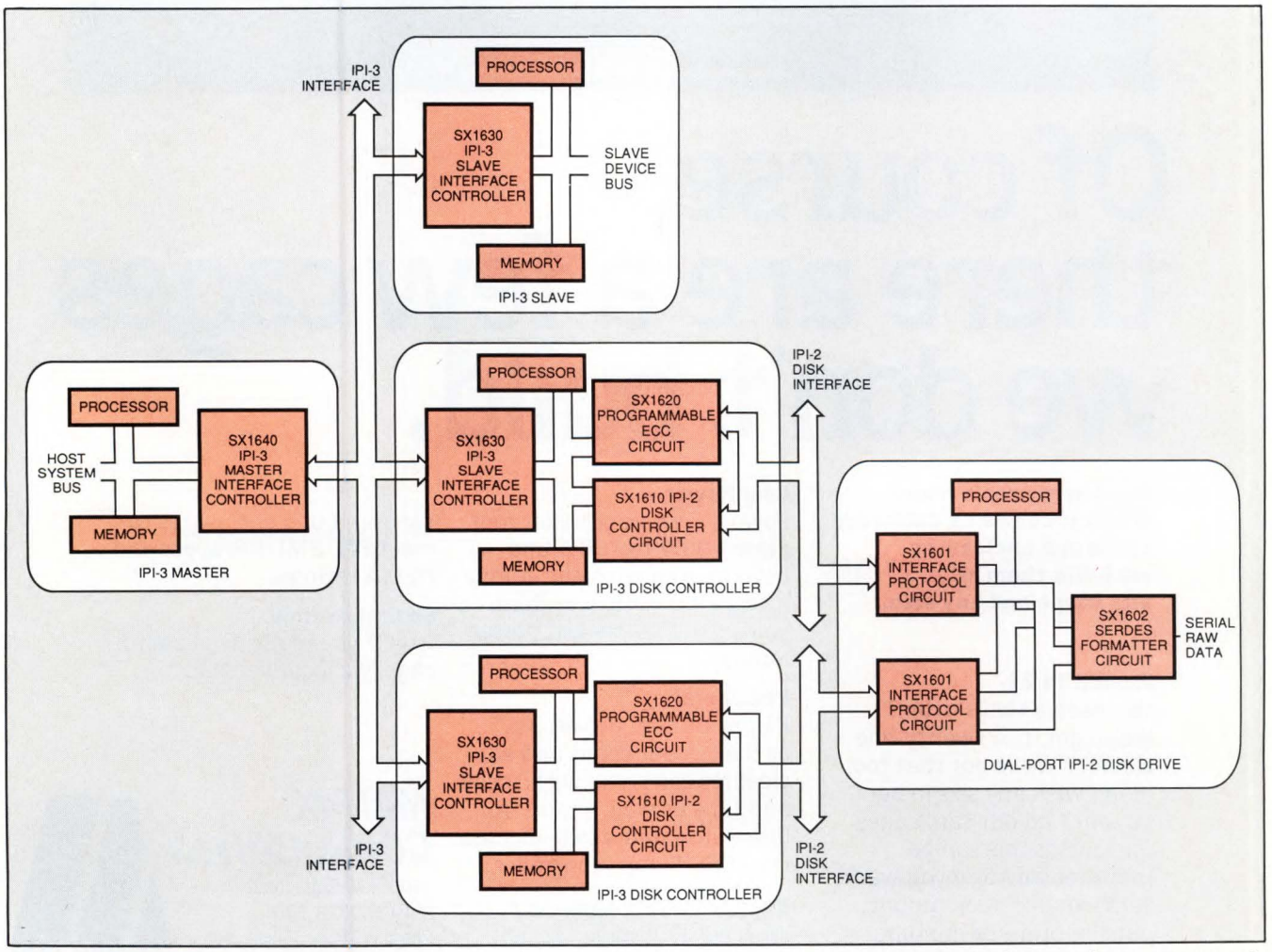

Fig 1—The layered IPI supports dual porting *and as many as eight slave devices for each master. As the diagram shows, you can mix and match controllers and devices with embedded controllers. The diagram also illustrates the diversity of IPI ICs required to implement the master and slave sides IPI-2 and IPI-3. The Simulex ICs shown are available through licensing agreements.*

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slave side of the IPI-2 interface. The SX1602 Serdes/Formatter chip handles serialization of data and performs all required disk-control functions. A single SX1602 can arbitrate between two SX1601s for dual-port operations. You can license the chips for $50,000 each. The ICs will cost about $10 each.

Recently Simulex completed work on the SX1610 IPI-2 disk controller circuit and the SX1620 programmable ECC circuit. They were designed for use in IPI-2 master disk controllers. For example, the ICs can fit in IPI-3 to IPI-2 bridge controllers or VMEbus-based IPI-2 controllers. The SX1610 supports eight IPI-2 disk drives, includes all of the IPI-2 master-bus-interface functions, and supports 12M-byte/sec transfers.

The SX1620 ECC chip can protect data fields as long as 128k bytes. It includes five ECC algorithms ranging from a 2-byte cyclic redundancy check to 16-byte double-burst Reed-Solomon codes. The IC supports corrections on the fly and can operate at a 12M byte/sec IPI data rate. Prototypes of both the SX1610 and the SX1620 are available now. Simulex licenses the SX1610 for $85,000 and the SX1620 for $65,000. Expect prices in the $20 to $25 range for the SX1610 and $10 to $15 range for the SX1620.

Imprimis has also designed a 2-chip set for IPI-2 master-disk-control applications. The set includes an IPI-2 interface combined with an ECC circuit on one chip and an I/O processor on the other. The interface chip automatically handles bus sequences and includes a 96-bit Reed-Solomon ECC. The chip handles all disk control functions, including read, write, and defect management.

The I/O processor, essentially a fast and simple ALU, controls the IPI protocol chip. Imprimis also provides code for the I/O processor that allows the chip set to control

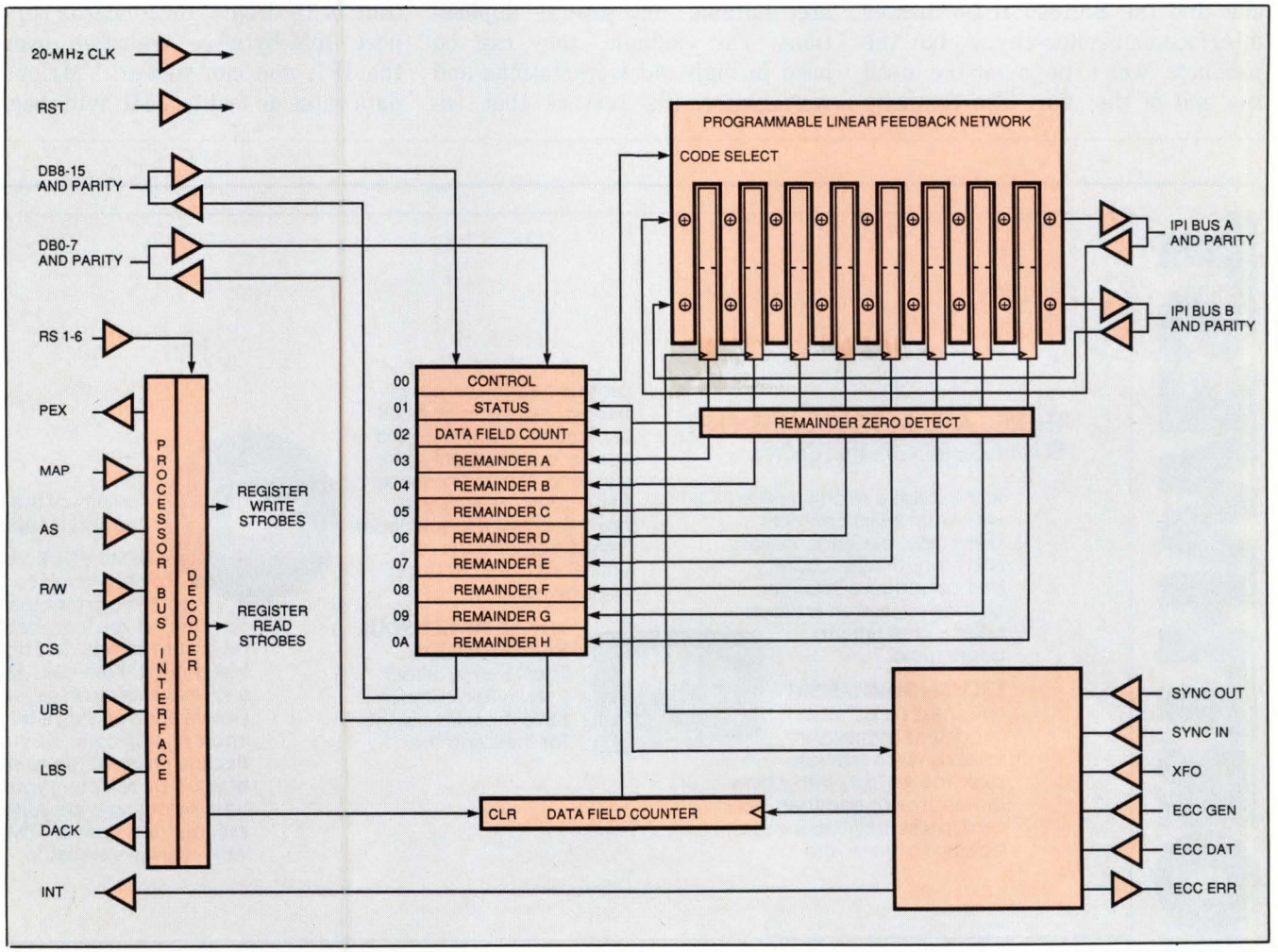

***Fig 2—CRC, computer generated, and Reed-Solomon ECC codes**—selectable via software—make the SX1620 ECC IC from Simulex suitable for IPI disk control applications. You can use the IC in embedded controllers, in IPI-3 to IPI-2 bridge controllers, and in dedicated bus-resident IPI-2 controllers.*

its IPI-2 disk drives. Imprimis doesn't quote a set price for a license. It negotiates each one based on factors such as other existing licensing agreements and vendor/customer relationships.

Currently, no company even offers licenses for IPI-3 chips. Imprimis intends to have an IPI-3 master chip set finished by the fourth quarter of this year. It plans to license the chips, and it's also interested in joint ventures for chip development.

IPI-3 ICs available this year

Simulex has designed the SX1630 IPI-3 slave interface controller circuit and the SX1640 IPI-3 master interface controller circuit, but the products won't be available until the end of the year. The company plans to license the chips for $75,000 each, and expects the ICs to cost from $15 to $20. Both the SX1630 and SX1640 will execute all IPI-3 bus sequences without CPU intervention and will support 15M-byte/sec transfer rates.

After several years of closely following the development of the specification and the marketplace, Xylogics and Interphase recently began shipping IPI-2 disk-controller boards. Both companies offer VMEbus-compatible boards that give system vendors a quick and clean approach to implementing fast disk subsystems.

VMEbus IPI-2 disk subsystems are suitable for several applications. For example, they can be used in high-end workstations and workstation file servers that require disk drives with fast data rates, as well as in graphics and imaging systems that require fast rates to load and store bit-mapped images. In addition, many systems, such as supermicrocomputers that employ proprietary system buses that operate at 200M bytes/sec or faster, employ the VMEbus to handle I/O subsystem chores.

Controller handles 16 drives

Xylogics offers two new IPI-2 disk controllers—the SV6800 and the SV7800. The boards cost $3995 and $4995, respectively. The SV6800 can control eight IPI-2 disk drives. The dual-port SV7800 can control 16 drives. Both boards support 10M-byte/sec transfers over the IPI, and can sustain VMEbus data rates as fast as 35M bytes/sec.

Xylogics' Universal Bus Silicon controller architecture enables the company to design products based on different buses, such as Multibus or VMEbus, as well as products that serve different interface standards, such as ESDI, SMD, SCSI, and IPI. Therefore, the architecture guarantees that there will be little or no impact on operating system driver software.

Xylogics believes its IPI-2 design

For more information . . .

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

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FAX 214-352-4124
Circle No 701

Simulex Corp
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can be scaled up to higher IPI transfer rates. It chose to use the SX1620 ECC chip from Simulex, but implemented its own IPI-2 master interface chip. According to senior vice president Chap Cory, the ECC chip from Simulex filled the needs of the Xylogics controller, but the company designed its own interface chip to better fit the Universal Bus Silicon architecture.

IC may serve two masters

Interphase chose to build its IPI-2 disk-controller boards without either of the Simulex ICs. According to director of product marketing Ernest Godsey, Interphase designed a programmable IPI-master interface IC that can serve in IPI-2 and IPI-3 applications. Interphase, like Xylogics, employs an architecture that simplifies the development of operating system software. All Interphase VMEbus boards use the Buspacket Interface that transfers data at speeds as fast as 36M bytes/sec. In addition, Interphase's MACSI (Multiple Active Command Software Interface) architecture provides a common software interface for a number of controller boards.

Interphase is currently sampling its V/IPI 4260 Cougar ($4995) that can control eight IPI-2 disk drives. It has also announced the dual-port Model V/IPI 4460 Griffin IPI-2 controller board ($4850) in a 9U (Sun-compatible) VMEbus package. Although the company introduced the standard-size (6U) Cougar first, it expects to ship production units of the Griffin before the Cougar.

IPI-3 host adapters available soon

Both Xylogics and Interphase are interested in marketing IPI-3 host adapters. Most IPI tape drives employ an embedded IPI-3 controller. IPI-3 to IPI-2 bridge controllers will connect the fast IPI-2 disk drives to IPI-3 host adapters. In addition, a board could act as a master to both an IPI-3 tape drive and an IPI-2 disk drive because both specs utilize the same physical interface.

Interphase's Godsey says that the protocol IC designed by Interphase will enable the company to build an IPI-3 host adapter with an architecture similar to the IPI-2 disk controllers. Neither Interphase nor Xylogics, however, will commit to a date for an IPI-3 product introduction.

In the next year or two you can expect to see boards that mix IPI implementations with other peripheral interfaces. VMEbus boards that mix ESDI and SCSI are available now. In the future a very attractive product would be a board that includes an IPI-2 interface for high-speed disk transfers and a SCSI connection to other slower peripherals such as tape, optical disks, communication devices, printers, and scanners. EDN

Reference

1. Wright, Maury, "Intelligent Peripheral Interface standard permits data-transfer rates of 10M bytes/sec," *EDN*, January 8, 1987, pg 105.

Article Interest Quotient
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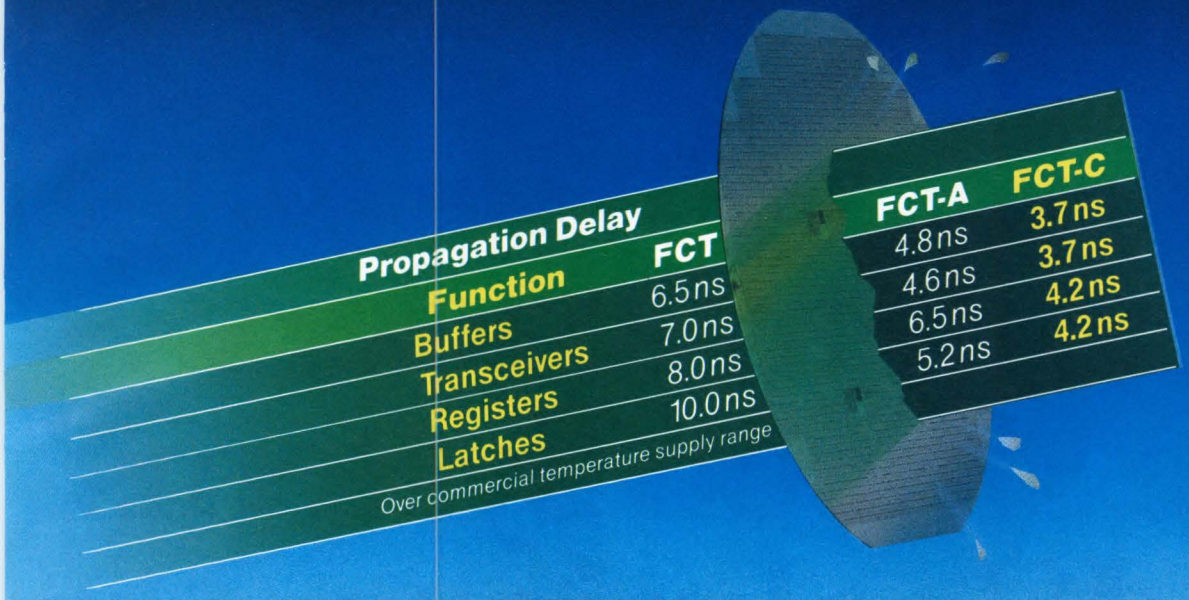
High 512 Medium 513 Low 514

Breaking the TTL Speed Barrier



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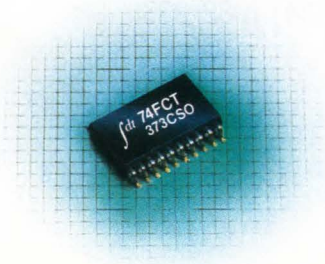

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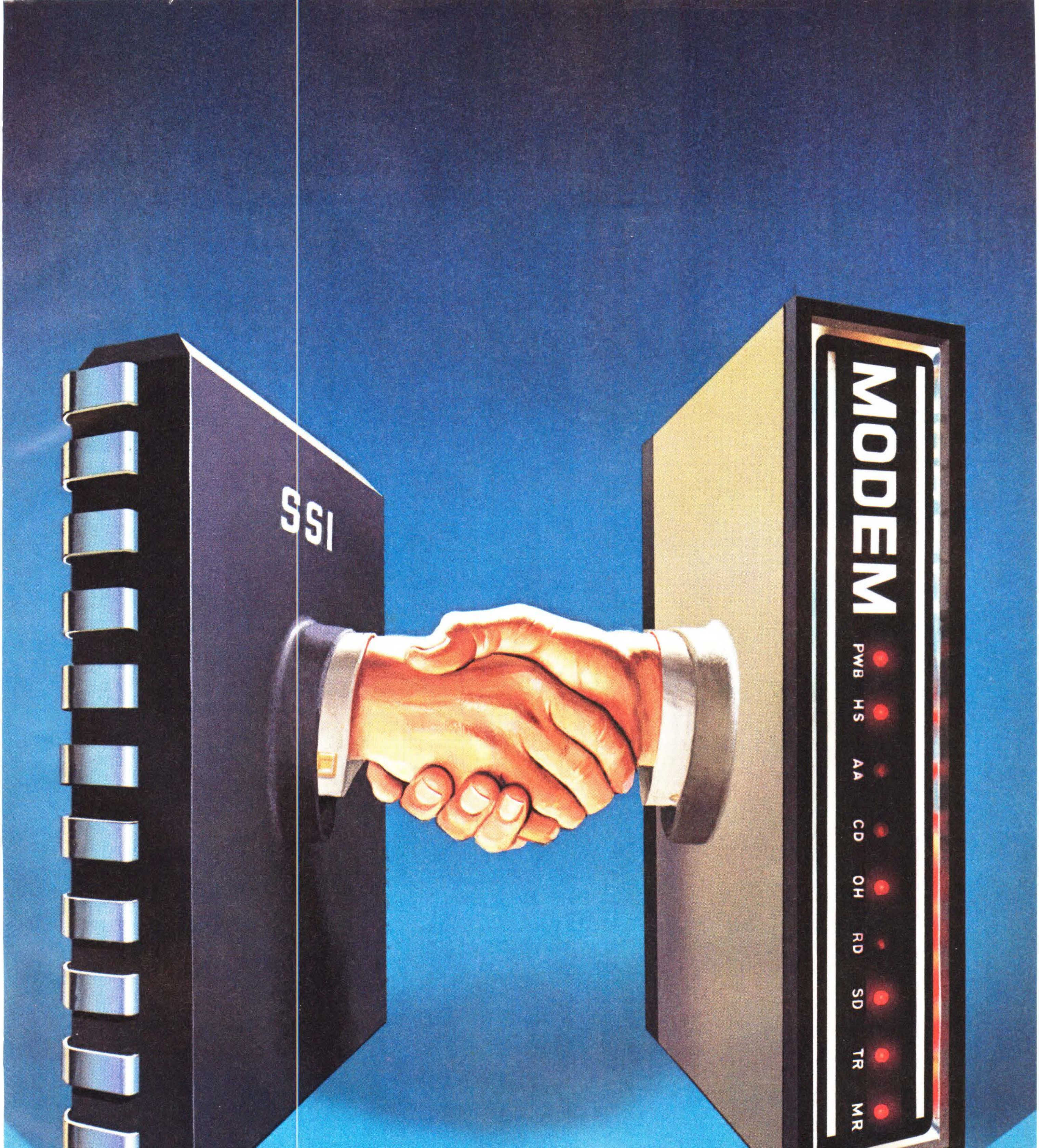
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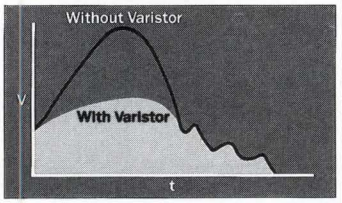

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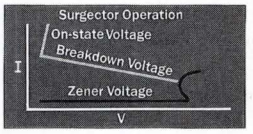

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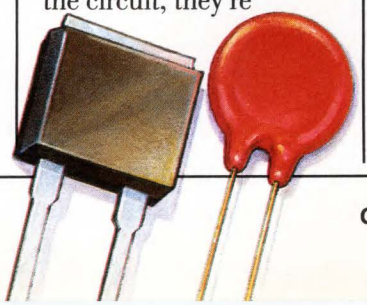

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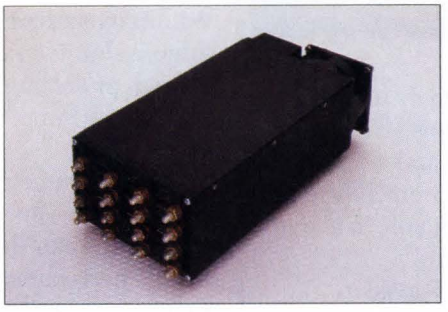

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SP1-1802	5 @ 240				
SP1-1803	12 @ 100				
SP1-1804	15 @ 80				
SP1-1805	24 @ 50				
SP1-1806	28 @ 42				
SP1-1807	48 @ 25				
Dual Output					
SP2-1801	2 @ 120	5 @ 120			
SP2-1802	5 @ 120	5 @ 120			
SP2-1803	5 @ 120	12 @ 66			
SP2-1804	12 @ 66	12 @ 66			
SP2-1805	15 @ 53	15 @ 53			
Triple Output					
SP3-1801	5 @ 180	12 @ 16	12 @ 16		
SP3-1802	5 @ 150	12 @ 33	12 @ 16		
SP3-1803	5 @ 180	15 @ 13	15 @ 13		
SP3-1804	5 @ 150	15 @ 26	15 @ 13		
Quad Output					
SP4-1801	5 @ 150	12 @ 16	12 @ 16	5 @ 30	
SP4-1802	5 @ 150	15 @ 13	15 @ 13	5 @ 30	
SP4-1803	5 @ 150	12 @ 16	12 @ 16	24 @ 8	
SP4-1804	5 @ 150	15 @ 13	15 @ 13	24 @ 8	
Five Output					
SP5-1801	5 @ 120	12 @ 16	12 @ 16	5 @ 30	24 @ 8
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No longer are the fields of image-processing and image-analysis strictly the domain of expensive dedicated systems. New software and hardware products let you put together a sophisticated PC-based image-processing system for less than $15,000 that includes a full-color frame grabber (video-image digitizer), analog RGB monitor (your standard EGA monitor will not suffice), and image-processing software that will suit such applications as multispectral analysis, machine vision, and photographic enhancement.

Admittedly, such a PC-based configuration is no contender for a dedicated high-resolution virtual-imaging or complex scientific-analysis system; what you can accomplish in milliseconds using a dedicated workstation may take you several minutes when using a PC-based equivalent. However, if your applications don't demand the 172-MIPS processing speed and 32k × 32k-pixel resolution offered by today's mainframe-based imaging workstations, you'll find that you can replicate virtually any of the capabilities provided by the high-end systems in a PC-based configuration at a fraction of the cost.

As usual, cost versus performance is the ultimate tradeoff, but incompatibilities among the hardware and software currently available may also force you to compromise as you build your PC imaging station. You'll find that certain manufacturers' lists of supported devices are carved in stone; substituted items can actually cause damage to other pieces of equipment. Use extreme caution when assembling untested components to ensure that your system will operate as planned. Input devices, monitors, frame grabbers, software, and your computer's present video card must all function in concert—unfortunately, no industry-standard specifications exist to simplify the match-making task.

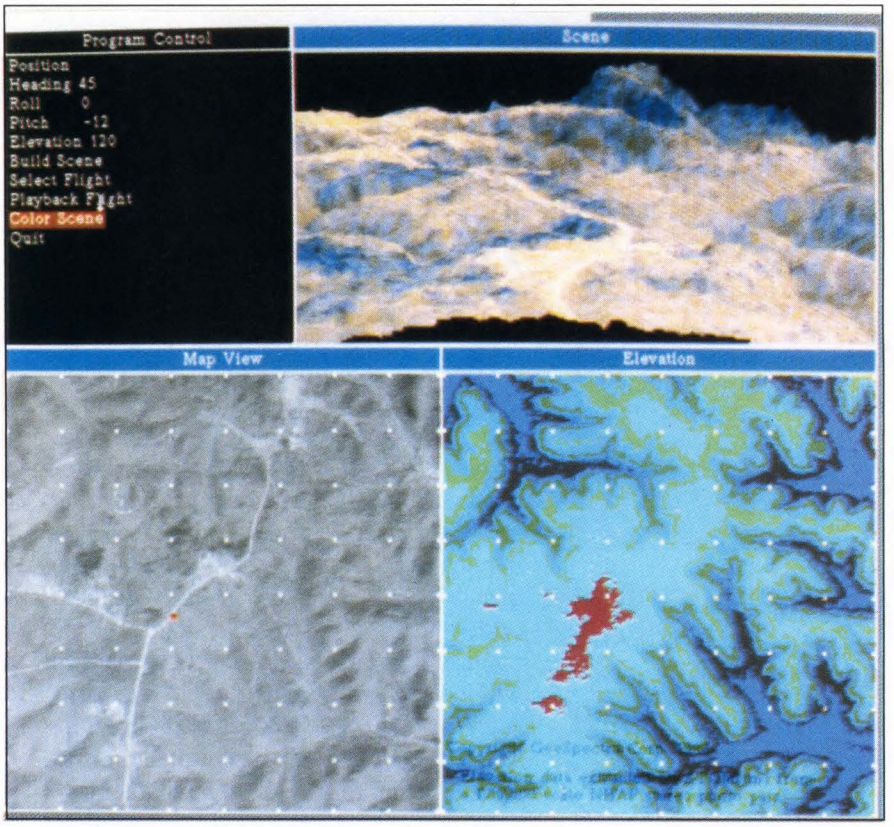
In addition, you have to decide whether to let software or hardware determine which components you'll use to build your image-processing system. If you anticipate manipulating only monochrome or pseudo-colored images, you should select a software package that suits your application and purchase hardware that the program supports.

On the other hand, if you intend to work with full-color images, the

Capable of turning your PC into a sophisticated image-analysis system, *BioScan's Optimas Image Analysis software performs automatic image vectorization, measurement, and classification.*

hardware currently available will dictate the support devices and software you should purchase. In addition, vaporware is a very real problem in the PC realm of image processing, so make sure that the board you select is actually in distribution and not merely a figment of the manufacturer's specifications.

Finally, the type of PC you select significantly affects your imaging system's performance. A high-performance 33-MHz 80386-based IBM-compatible PC from such manufacturers as Compaq and Dell Computers will give you the fastest access to your application software and frame grabber. However, using a standard 80386-based PC from IBM will prevent any system-incompatibility problems that could arise when the host computer is not strictly IBM-compatible. But, for the purpose of this article, I used a 3-year-old, nondescript, 10-MHz 80286-based PC clone without any major hardware or BIOS conflicts.



Demonstrating capabilities beyond those offered by PCs, *dedicated image-processing systems like the VITec Image Computer can perform such functions as three-dimensional ray tracing and animation for applications such as flight planning and terrain reconstruction.*

Plug-and-play exists!

Of the PC-based imaging boards reviewed for this article, the $2235 Oculus-300 from Coreco was the easiest to get up and running; the board came with everything needed to make it work flawlessly the first time I plugged it into my PC clone. The basic Oculus-300 is a frame grabber that can digitize a 512×1024-pixel image at a rate of 12.5 million pixels per second with 8 bits-per-pixel resolution. You select from internal or external signal synchronization and use as many as four cameras for video input. For full-color digitization at a resolution of 24 bits per pixel, you can add an optional $2975 color-expansion daughter board to the Oculus-300 and boost the basic board's 512k bytes of video RAM to 1M byte. Without the expansion card, a pseudo-color mode lets you work with 256 colors from a palette of 16.7 million colors, or view images in 256 shades of gray. You can also add a $420 double-input LUT (DI-LUT) processor that enables the Oculus-300 to perform real-time image averaging, addition, subtraction, division, and multiplication; for 256×256-pixel images you can accomplish any of these operations in 8.3 msec, and perform image dilation, erosion, and 3×3-pixel convolutions in 83 msec.

With a library of four software modules available in a consistently well-documented format, software support for the Oculus-300 is, like the board itself, orderly and functional. The board comes with the FG3 Macro Programming Tool, which includes an interpreter for interactive control of board operations, commands for 75 image-processing functions that you can call from the C language, macro definitions for controlling instruction sequences, source code, and test programs for the Oculus-300. System integrators will want to order the $995 Oculus Kernel System (OKS), which includes drivers and interfaces that simplify programming, porting, and interfacing software for all of the manufacturer's imaging boards.

Media Cybernetics' Image-Pro II software costs $1500. This module provides a menu-driven program for performing image editing, enhancing, digitizing, annotating, archiving, scaled measuring, contour following, object tracking and counting, and motion analysis. The fourth module, also menu-driven, is the $1195 Industrial Inspector, which provides subpixellation gauging and character recognition.

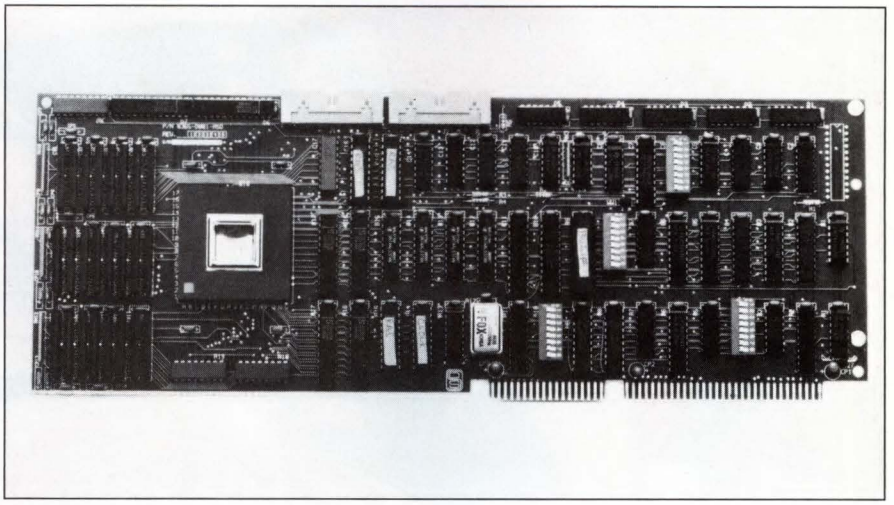
Matrox Electronic Systems supplied three boards that offered a

wide range of image processing, including the ability to overlay video and graphics for professional-looking presentations of the digitized images you have enhanced and analyzed. Using the Matrox VGO-AT overlay board in conjunction with either the Matrox Vision Processor MVP-AT board or the Matrox Professional Image Processing (PIP) board, you can genlock a standard National Television System Committee (NTSC) signal from a video camera or video-tape recorder and superimpose 640×480-pixel EGA graphics or text onto the video image.

The $1545 VGO-AT board replaces your PC's EGA monitor card and provides separate outputs for NTSC and RGB monitors. A Microsoft Windows driver lets you use this board in 640×480-pixel and 720×480-pixel resolution modes. You can use the VGO-AT with a $295 program called Video Titler from Entropy Engineering (Rockville, MD, (301) 770-6886) to create broadcast-quality characters that roll across your screen, fade in and out, or wipe on and off, thus giving your final presentation the polished look of a professionally developed production.

The MVP-AT sells for $5495 and comes with the hardware necessary to accomplish real-time logical-image and statistical-image processing at speeds reaching 12 million pixels per sec—speeds resulting from an onboard Arithmetic Logic Unit (ALU) and a statistical processor. This double-board unit contains four 512×512×8-bit image buffers for color and monochrome frame grabbing. A 2:1 and a 4:1 hardware zoom on the input, and a 2:1, 4:1, and 8:1 zoom on the output allow you to perform independent, nondestructive image manipulation.

For an additional $4000 you can add a Neighborhood Processor (NP) daughter board to boost the MVP-AT's image-processing speed to 576 million pixels per sec by simultaneously processing 12 pixels in parallel. As a result, in binary mode the board can perform 12×8-pixel pattern matches on a 512×512-pixel frame buffer in 1/15th of a second. Panning and scrolling are also accomplished in hardware. Two separate pan, scroll, and zoom windows let you view one part of a frame buffer while the board digitizes another part. The NP board also performs line thinning, connectivity analysis, convolutions, inter-image arithmetic, real-time frame averaging, and color processing.



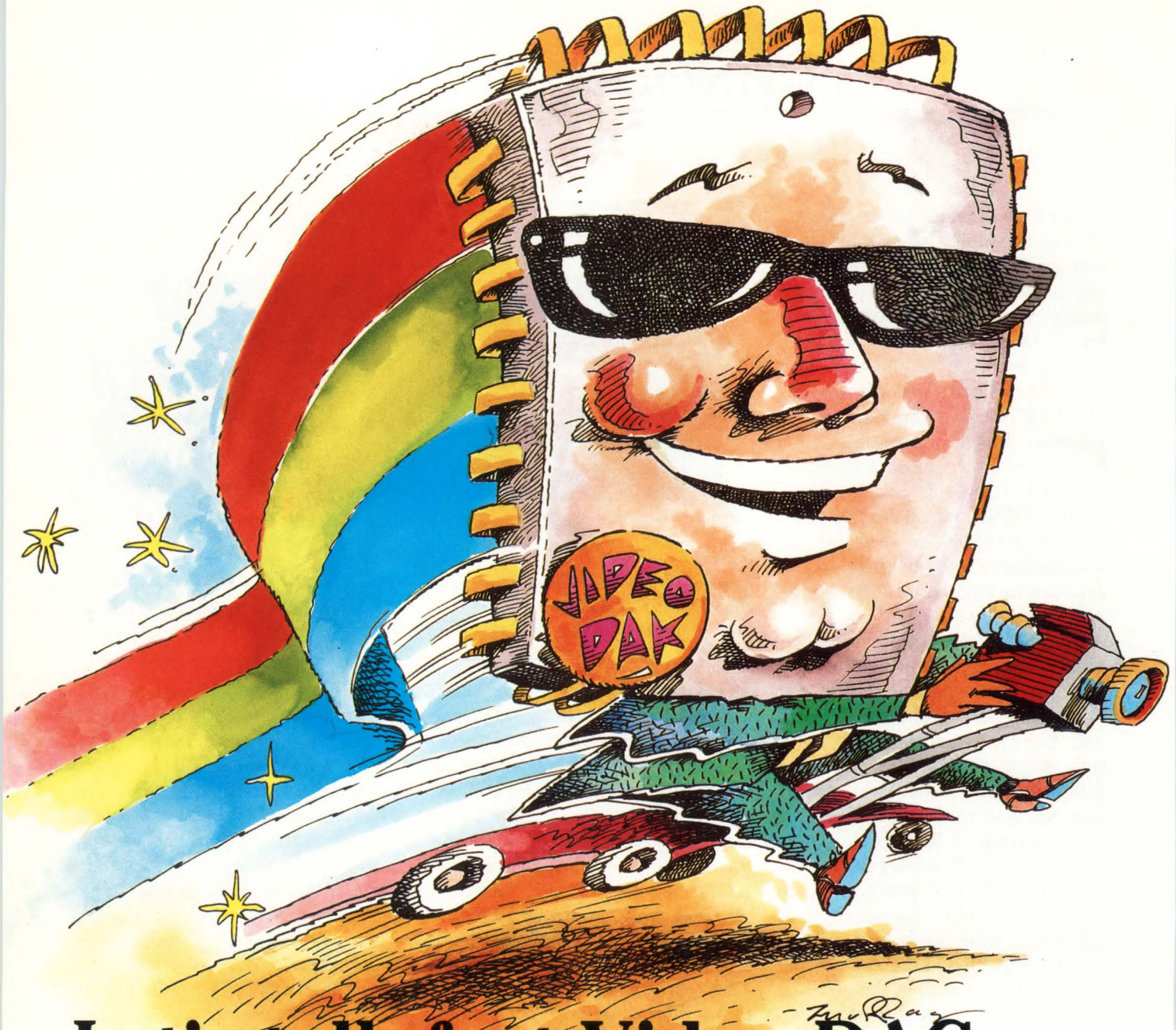
Using a 32-bit T9506 DSP for processing speeds stated in nsecs, *Toshiba's 9506 PC/AT Image Processor Board, scheduled for full production in the third quarter of 1989, may demand attention.*

Software support for the MVP-AT includes Matrox's Imager-AT and Imager-AT/NP programs, which give you access to more than 150 library routines that are callable from Microsoft C compilers. Using either of these programs simplifies your OEM programming task by providing subroutines for erosion, dilation, graphic overlays, ALU functions, bus transfers, windowing, LUT manipulations, and complex convolutions. Media Cybernetics also sells a version of Image-Pro for the MVP-AT.

The PIP board is an 8-bit flash frame grabber that provides 1024×1024-pixel digitization at 7.5 Hz. You use one PIP to display in one of 256 colors or shades of gray, or you connect three PIP boards to manipulate true-color images. The $1645 Matrox PIP-512B also works with BioScan's Optimas image-processing and -analysis software, a $3995 Microsoft Windows-based application program that can perform such sophisticated imaging functions as automatically tracing the shape of an object, manipulating the LUT using hyperbolic cuberoot and logarithmic functions for improved image contrast, posterization for displaying binary thresholds, colorization of a gray-scale image, and customized complex convolutions.

Software completes the picture

Optimas comes with filters for 3×3-pixel and 5×5-pixel convolutions, dilation, erosion, vertical and horizontal-edge detections, Laplace highlighting, Roberts Edge highlighting, and jitter elimination. The software also provides electronic-image retouching with airbrush tools, scaling regions of interest, creating multiple mirror images, and contrast controls. Threshold, classification, editing, sorting, tracking, data extraction, and cali-



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PC-based image processing

bration tools round out the Optimas processing and analysis algorithms. You can also export your image data to such programs as the Microsoft Excel spreadsheet.

Optimas is compatible with several manufacturers' imaging boards, including the $2495 full-color Spectrum NTSC image-digitizing board from Redlake Corp. You can connect the Spectrum NTSC to a VGA monitor card for 800×600-pixel resolution overlays. However, Optimas performs image processing and analysis only in gray scale. Other boards supported by Optimas include Truevision's Targa M8, and Imaging Technology's Series 100 and PCVision frame grabbers.

Targa M8 is a plug-in module that provides real-time, true-color capture and display. It offers 256 colors per screen from a palette of 16 million colors, and comes with 256k bytes of RAM that support a screen resolution of 512×482 pixels and 8 bits per pixel. Alternate screen resolutions give you 2 pages of 512×256-pixel or 4 pages of 256×256-pixel screen resolution. Also, the board comes with hardware capabilities that let you mix and overlay images from as many as four video sources. Other standard features include a zoom function, horizontal and vertical panning, input and output LUTs, a field index, and a raster counter.

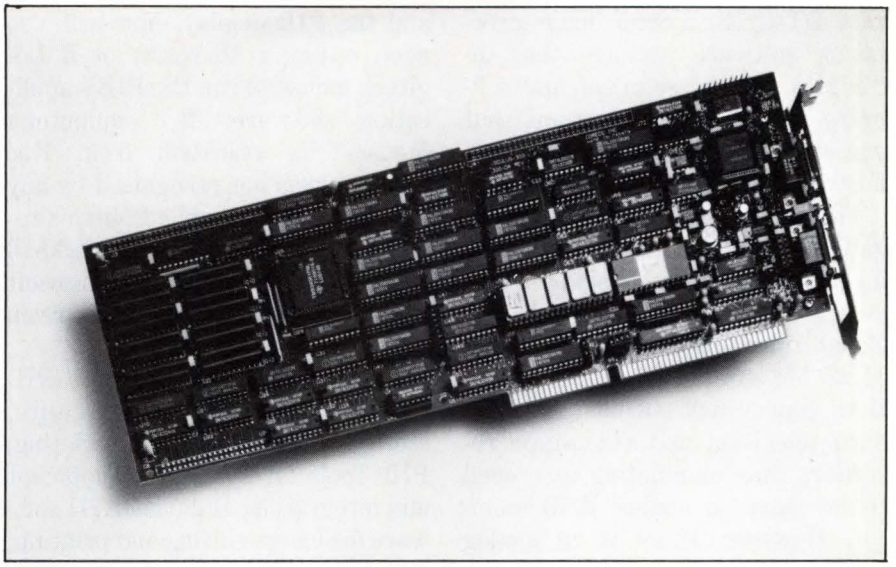
The PCVision Plus and Series 100 boards also offer real-time digitization and image processing for PCs. PCVision Plus is a frame grabber with a 1024×512×8-bit frame memory that can store multiple images; it also lets you pan, scroll, and zoom in hardware with individual bit-plane write-protection, eight input LUTs, and 24 output LUTs. You can plug three PCVision Plus boards into your PC to operate in true-color.

The single-board Series 100 is a real-time digital-image processor that offers true-color processing with a resolution of four bits per color. Alternatively, you can strap three Series 100 boards together for 24-bit, true-color resolution. The board's Advanced Frame Memory Architecture (AFMA) permits you to randomly access individual pixels from the frame memory or move and manipulate groups of pixels in a single operation. You can configure the frame buffer as a 1024×512-bit or a 1024×1024-bit space. A software-selectable dual-scan mode lets you access and display different portions of the board's frame memory.

The Series 100 also offers variable-scan digitizing rates that extend to a maximum frequency of 14 MHz for interfacing the board with nonstandard image sensors. A 12-bit digital-input port accepts predigitized video signals to reduce noise and eliminate pixel jitter.

Specifying image-processing speeds that are 250 times faster than those of an ordinary IBM PC/AT, Data Translation sells a $1995 DT2851 Frame Grabber and a $1895 DT2858 Auxiliary Frame Processor board. The DT2851 contains enough video RAM for two 512×512×8-bit images for parallel processing of multiple images. Eight input and eight output LUTs let you display in either pseudocolor or 256 levels of gray. A full-screen hardware cursor lets you use a cross hair to locate the X,Y coordinates of specific pixels.

The DT2858 can calculate a 3×3-pixel convolution on a 512×512×16-bit image frame in 0.85 sec. Its pipelined arithmetic performs 2.5 million additions or multiplications per sec and 700,000 divisions per sec. The board performs hardware zooming in 2:1, 4:1, and 8:1 ratios, as well as hardware pans and scrolls. A read/write conversion table and a 16-bit ALU process the image data before it is written to memory. Standard board functions include computing convolutions, generating histograms, and averaging frames. Six consecutive 16-bit I/O registers control the board's data-flow operations. The DT2858 and DT2851 communicate via their I/O ports for data-transfer rates that are faster than the AT bus's. In addition, Data Translation mar-



Taking a modular approach to image processing, *Coreco's Oculus-300 lets you add a true-color daughter board and a double-input LUT (DILUT) processor to the basic video-digitizer board.*

PC-based image processing

kets DT-IRIS, a $995 image-processing software package that includes a tutorial segment and a library of subroutine functions that you can call from Basic, Pascal, C, Fortran, and assembler programs.

For those who want to investigate the realm of image processing for less than $2000, consider Atronics' $995 512×256-pixel Professional Image Board (PIB) or the $1295 512×512-pixel PIB+ board. Both boards will output to a standard television and video-tape recorder, thus eliminating any need to purchase an analog RGB monitor. However, there is an analog RGB output on the board for higher-resolution viewing. The PIB also lets you connect your EGA or CGA monitor card to the imaging board so that you can use a single multisync monitor for both the PC and the PIB display. You will also need either a Microsoft or a Logitech mouse to run the PIB's application software. My computer's Mouse-Trak trackball from Itac Systems was not recognized by any of the software supplied for this review, although the same trackball works flawlessly with Microsoft Windows and other mouse-driven application programs.

The PIB boards come with PIB Image software for image capture, storage, retrieval, and printing; PIB Tools for system development and integration; Halovision III software for image editing and printing; and VImage software for generating EGA and VGA image. It's interesting to note that the list prices for the bundled software amount to more than the price you'll pay for the PIB. For an additional $495, you can order a program called dBImage, which lets you associate images with dBase records, thereby adding pictures to your dBase III+ applications. Another available program is the $195 PIB Compress, which lets you reduce the file size of captured video images for efficient and compact disk storage.

In addition, the PIB works with software from at least fifteen different third-party developers, including VideoCAD from Mathematica, which lets you combine AutoCAD drawings with video images. Another program, the $3995 Chromatic Color Image Analysis System from Leading Edge, lets you perform feature discrimination by pointing to a region of interest. The program creates a white graphic overlay to highlight the detected areas, and you can then process the

REPRESENTATIVE IMAGE-PROCESSING AND IMAGE-ANALYSIS BOARDS

MANUFACTURER	BOARD NAME	TRUE COLOR OUTPUT	MONOCHROME	VIDEO RAM (MAX)	RESOLUTION (MAX)	H/W ZOOM RATIO	NUMBER OF INPUTS	SOFTWARE*	PRICE
ATRONICS	PROFESSIONAL IMAGE BOARD	NO	YES	256k BYTES	512×256, 32k COLORS	N/A	1	C, H	$995
	PROFESSIONAL IMAGE BOARD-PLUS	YES	YES	512k BYTES	512×512, 32k COLORS	N/A	1	C, H	$1295
CORECO	OCULUS-300	NEEDS OC300-TE	YES	1M BYTE	1024×512×8	N/A	4	I	$2235
DATA TRANSLATION	DT2851	NO	YES	512k BYTES	512×512×8	N/A	1	D	$1995
	DT2858	NO	YES	512k BYTES	512×512×16	2:1, 4:1, 8:1	1	D	$1895
IMAGING TECHNOLOGY	PCVISION PLUS	NO	YES	1M BYTE	1024×512×8	2:1	2	I, O	
	SERIES 100	YES	YES	1M BYTE	1024×1024×12	2:1, 4:1, 8:1	4	I, O	
IMAGRAPH	IMAGE 32	YES	YES	4M BYTES	1024×1024×24 (+8)	1:1 TO 16:1	1	H, I	$8995
MATROX ELECTRONIC	VGO-AT	YES	YES	256k BYTES	720×480	N/A	1	EGA	$1545
	PROFESSIONAL IMAGE PROCESSING	NO	YES	1M BYTE	1024×1024×8	N/A	1	I, O	$1645
	MVP-AT	YES	YES	1M BYTE	1024×1024×8	N/A	1	I	$5495
REDLAKE	SPECTRUM NTSC	YES	YES	256k BYTES	800×600	2:1, 4:1	1	I	$2495
TOSHIBA AMERICA	IP 9506	YES	YES	4M BYTES	1280×1024×24 (+8)	1:1 TO 16:1	1	I	$5995
TRUEVISION	TARGA M8	YES	YES	256k BYTES	512×512×8	2:1, 4:1, 8:1	4	H, I, M, O	$1995
	TARGA 32	YES	YES	1M BYTE	512×512×32	2:1, 4:1, 8:1	4	H, I, M, O	$4995

***SOFTWARE LEGEND:**
C = CHROMATIC IMAGE ANALYSIS SYSTEM
D = DT-IRIS
H = HALOVISION
I = IMAGE PRO
M = MATHEMATICA
O = OPTIMAS

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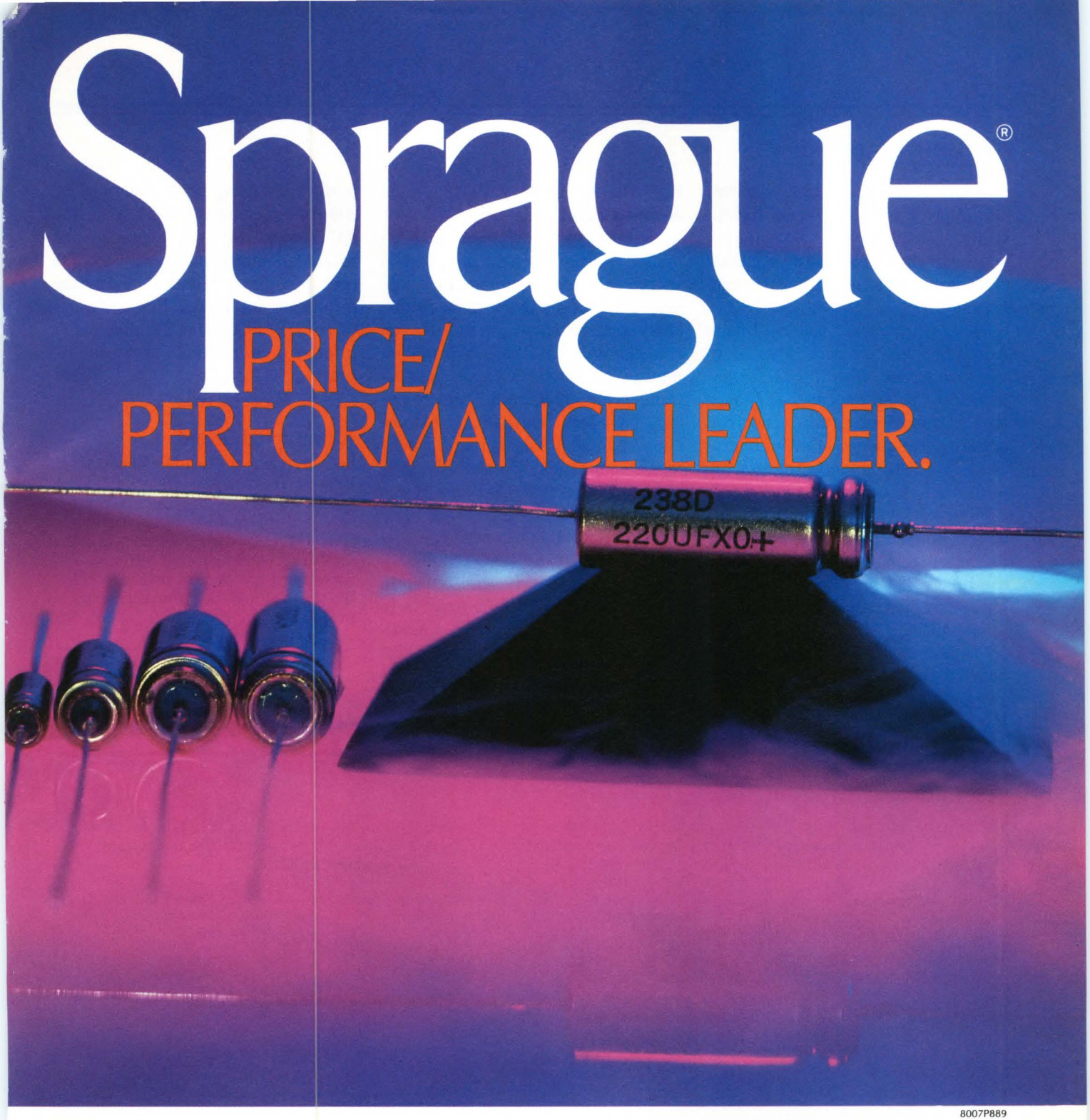

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overlaid area by erosion, dilation, outlining, void filling, and fusion. Using the overlay as a template, you can measure features using area, perimeter, density, and edge parameters.

The Chromatic Color Image Analysis System also lets you convert image data files to DIF format for export to spreadsheet or statistical graphics programs. You can organize a sequence of menu operations into a command-program file for automatic operation.

For $8995 you can purchase one of the newest boards to enter the PC-based image-processing arena, the Image 32 board from Imagraph. Using 1M-bit video RAM chips and a Hitachi ACRTC HD-63484 graphics coprocessor, this 32-bit imaging board occupies only one slot in your PC/AT's chassis, although an optional piggyback board lets you stuff the Image-32 with 4M bytes of video RAM. The Image 32 spec sheet boasts a drawing speed of 1.3 million pixels per sec and 32,500 vectors per sec, assuming an image resolution of 40 pixels per vector. Dual-port memory access lets you transfer data at a rate of 3 million 8-bit pixels per sec. Graphic instructions include pattern fill, 16:1 zooming, bit block transfer), hardware clipping, and Boolean read/modify/write commands. Compatible software includes AutoCad and Media Cybernetics' Image-Pro.

An expected newcomer is Toshiba's $5995 IP 9506 PC/AT image-processor board. Announced in April, the manufacturer expects to begin shipping production quantities of the board during the third quarter of 1989. Featuring Toshiba's proprietary T9506 DSP chip and 3M bytes of RAM, this unit can perform imaging math functions in 200 nsec, compute a 1024-point 32-bit complex FFT in 4 msecs, and rotate an image as quickly as 200 nsec per pixel. Media Cybernetics is porting its Image Pro software to the IP 9506, and Toshiba plans to offer a 70-function subroutine library. EDN

Acknowledgment

Special thanks to Alan McConnell of Everest Technologies (Houston, TX), and to Bill Morris and Scott Harmon of Visual Information Technologies (Plano, TX) for their assistance in offering background material, technical observations, and market information in the areas of high-performance image processing and analysis.

Article Interest Quotient
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High 515 Medium 516 Low 517

For more information . . .

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

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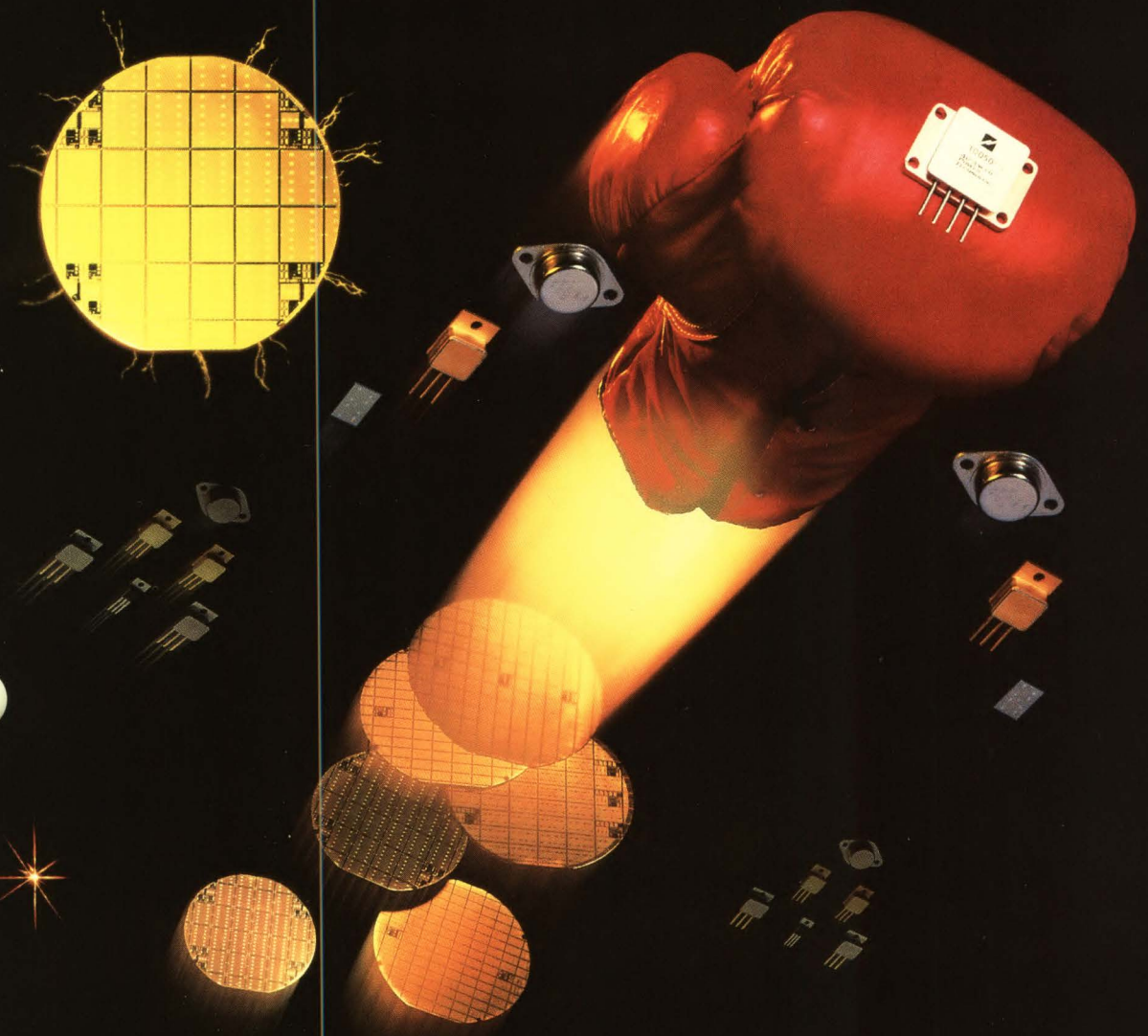

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0.021 - 0.21	95.0 - 39.0	380 - 156	9000 - 13000	360 - 675	0.738 × 0.585 (108)
0.04 - 0.40	83.0 - 20.5	332 - 82	4500 - 6500	160 - 370	0.588 × 0.388 (107)
0.20 - 1.30	26.0 - 8.5	104 - 34	1800 - 2950	60 - 130	0.414 × 0.254 (106)
0.30 - 2.40	18.5 - 5.0	74 - 20	1300 - 1800	45 - 105	0.290 × 0.250 (105)
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1000	0.110				76.0[PCE]		1560	26000	1350	108	10011PCEN
1000	0.200				41.0[PBE]		800	13000	740	107	10020PBEN
1000	0.210				39.0[HCE]	40.0[DF]	830[F] 780[HCE]	13000	675	108	10021[ ]N
1000	0.400				20.5[SAE]	24.5[CF]	595[F] 400[SAE]	6500	370	107	10040[ ]N
1000	0.400				20.5[HBE]		400[HBE]	6500	370	107	10040[ ]N
1000	1.100	9.5	10.5			9.5[H]	310[B] 250[H]	2950	180	106	1001R1[ ]N
1000	1.300	8.5	10.0			9.0[H]	230[A]	2950	180	106	1001R3[ ]N
1000	2.000	6.0	7.0	5.5			240[B] 198[A]	1800	105	105	1002R[ ]N
1000	2.400	5.5	6.5	5.0			150[C]	1800	105	105	1002R4[ ]N
1000	4.000	3.9	4.4	3.6		3.3[G]	180[B] 150[A]	950	55	104	1004R[ ]N
1000	4.200	3.5	4.0	3.3		3.0[G]	125[C] 100[G]	950	55	104	1004R2[ ]N
900	0.110				76.0[PCE]		1560	26000	1350	108	9011PCEN
900	0.200				41.0[PBE]		800	13000	740	107	9020PBEN
900	0.210				39.0[HCE]	40.0[DF]	830[F] 780[HCE]	13000	675	108	9021[ ]N
900	0.400				20.5[SAE]	24.5[CF]	595[F] 400[SAE]	6500	370	107	9040[ ]N
900	0.400				20.5[HBE]		400[HBE]	6500	370	107	9040[ ]N
900	1.100	9.5	10.5			9.5[H]	310[B] 250[H]	2950	180	106	901R1[ ]N
900	1.300	8.5	10.0			9.0[H]	230[A]	2950	180	106	901R3[ ]N
900	2.000	6.0	7.0	5.5			240[B] 198[A]	1800	105	105	902R[ ]N
900	2.400	5.5	6.5	5.0			150[C]	1800	105	105	902R4[ ]N
900	4.000	3.9	4.4	3.6		3.3[G]	180[B] 150[A]	950	55	104	904R[ ]N
900	4.200	3.5	4.0	3.3		3.0[G]	125[C] 100[G]	950	55	104	904R2[ ]N
800	0.080				91.0[PCE]		1560	26000	1350	108	80M80PCEN
800	0.150				47.0[PBE]		800	13000	740	107	8015PBEN
800	0.160				45.0[HCE]	47.0[DF]	830[F] 780[HCE]	13000	675	108	8016[ ]N
800	0.300				23.5[SAE]	29.0[CF]	595[F] 400[SAE]	6500	370	107	8030[ ]N
800	0.300				23.5[HBE]		400[HBE]	6500	370	107	8030[ ]N
800	0.750	11.5	13.0			11.5[H]	310[B] 250[H]	2950	130	106	8075[ ]N
800	0.900	10.5	12.0			10.5[H]	230[A]	2950	130	106	8090[ ]N
800	1.200	8.0	9.0	7.0			240[B] 198[A]	1800	105	105	801R2[ ]N
800	1.400	7.5	8.5	6.5			150[C]	1800	105	105	801R4[ ]N
800	2.400	5.0	5.5	4.5		4.3[G]	180[B] 150[A]	950	55	104	802R4[ ]N
800	2.800	4.5	5.0	4.0		4.0[G]	125[C] 100[G]	950	55	104	802R8[ ]N
750	0.080				91.0[PCE]		1560	26000	1350	108	75M80PCEN
750	0.150				47.0[PBE]		800	13000	740	107	7515PBEN
750	0.160				45.0[HCE]	47.0[DF]	830[F] 780[HCE]	13000	675	108	7516[ ]N
750	0.300				23.5[SAE]	29.0[CF]	595[F] 400[SAE]	6500	370	107	7530[ ]N
750	0.300				23.5[HBE]		400[HBE]	6500	370	107	7530[ ]N
750	0.750	11.5	13.0			11.5[H]	310[B] 250[H]	2950	130	106	7575[ ]N
750	0.900	10.5	12.0			10.5[H]	230[A]	2950	130	106	7590[ ]N
750	1.200	8.0	9.0	7.0			240[B] 198[A]	1800	105	105	751R2[ ]N
750	1.400	7.5	8.5	6.5			150[C]	1800	105	105	751R4[ ]N
750	2.400	5.0	5.5	4.5		4.3[G]	180[B] 150[A]	950	55	104	752R4[ ]N
750	2.800	4.5	5.0	4.0		4.0[G]	125[C] 100[G]	950	55	104	752R8[ ]N
600	0.045				122.0[PCE]		1560	26000	1350	108	60M45PCEN
600	0.085				64.0[PBE]		800	13000	740	107	60M85PBEN
600	0.090				61.0[HCE]	63.0[BF]	830[F] 780[HCE]	13000	675	108	60M90[ ]N
600	0.170				32.0[SAE]	39.0[AF]	595[F] 400[SAE]	6500	370	107	6017[ ]N
600	0.170				32.0[HBE]		400[HBE]	6500	370	107	6017[ ]N
600	0.400	15.5	18.0			16.5[H]	310[B] 250[H]	2950	130	106	6040[ ]N
600	0.450	14.5	17.0			15.5[H]	230[A]	2950	130	106	6045[ ]N
600	0.600	11.5	13.0	10.5			240[B] 198[A]	1800	105	105	6060[ ]N
600	0.700	10.5	12.0	9.5			150[C]	1800	105	105	6070[ ]N
600	1.300	6.5	7.5	6.5		5.5[G]	180[B] 150[A]	950	55	104	601R3[ ]N
600	1.600	6.0	6.5	5.5		5.0[G]	125[C] 100[G]	950	55	104	601R6[ ]N

Notes:

*Package style is defined by letters in brackets (to be included in APT part number).
The only available package styles are those shown with specific values for I_D (amps); $I_{DM} = 4 \times I_D$.

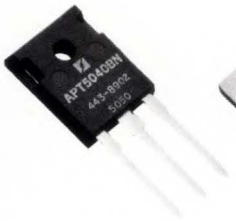
**Die products are offered in individual die and whole wafer forms. Maximum continuous current (I_D) for dice depends on packaging conditions (thermal resistance).

***Complete part number requires "APT" prefix and package style, i.e., APT1001R3BN (for package style [B]).

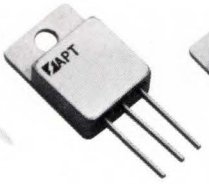
BV_{DSS} Volts	$R_{DS(ON)}$ Ohms	*I_D (Amps) vs Package Style					P_D Watts	C_{iss} pF (Max)	Q_g nC (Max)	**DIE NO. [D]	***APT PART NO.
		TO-3 [A]	TO-247 [B]	TO-254 [C]	MODULE [SAE][HBE] [HCE][PBE] [PCE]	F-PACK [AF] - [DF] TO-257 [G] TO-258 [H]					
550	0.045				122.0[PCE]		1560	26000	1350	108	55M45PCEN
550	0.085				64.0[PBE]		800	13000	740	107	55M85PBEN
550	0.090				61.0[HCE]	63.0[BF]	830[F] 780[HCE]	13000	675	108	55M90[ ]N
550	0.170				32.0[SAE]	39.0[AF]	595[F] 400[SAE]	6500	370	107	5517[ ]N
550	0.170				32.0[HBE]		400[HBE]	6500	370	107	5517[ ]N
550	0.400	15.5	18.0			16.5[H]	310[B] 250[H]	2950	130	106	5540[ ]N
550	0.450	14.5	17.0			15.5[H]	230[A]	2950	130	106	5545[ ]N
550	0.600	11.5	13.0	10.5			240[B] 198[A]	1800	105	105	5560[ ]N
550	0.700	10.5	12.0	9.5			150[C]	1800	105	105	5570[ ]N
550	1.300	6.5	7.5	6.5		5.5[G]	180[B] 150[A]	950	55	104	551R3[ ]N
550	1.600	6.0	6.5	5.5		5.0[G]	125[C] 100[G]	950	55	104	551R6[ ]N
500	0.030				152.0[PCE]		1560	26000	1350	108	50M30PCEN
500	0.055				80.0[PBE]		800	13000	740	107	50M55PBEN
500	0.060				76.0[HCE]	78.0[BF]	830[F] 780[HCE]	13000	675	108	50M60[ ]N
500	0.110				40.0[SAE]	49.0[AF]	595[F] 400[SAE]	6500	370	107	5011[ ]N
500	0.110				40.0[HBE]		400[HBE]	6500	370	107	5011[ ]N
500	0.250	20.0	23.0			21.0[H]	310[B] 250[H]	2950	130	106	5025[ ]N
500	0.300	18.0	21.0			19.0[H]	230[A]	2950	130	106	5030[ ]N
500	0.400	14.5	16.0	13.0			240[B] 198[A]	1800	105	105	5040[ ]N
500	0.500	13.0	14.0	11.5			150[C]	1800	105	105	5050[ ]N
500	0.850	8.5	9.5	8.0		7.0[G]	180[B] 150[A]	950	55	104	5085[ ]N
500	1.100	7.5	9.0	7.0		6.5[G]	125[C] 100[G]	950	55	104	501R1[ ]N
450	0.030				152.0[PCE]		1560	26000	1350	108	45M30PCEN
450	0.055				80.0[PBE]		800	13000	740	107	45M55PBEN
450	0.060				76.0[HCE]	78.0[BF]	830[F] 780[HCE]	13000	675	108	45M60[ ]N
450	0.110				40.0[SAE]	49.0[AF]	595[F] 400[SAE]	6500	370	107	4511[ ]N
450	0.110				40.0[HBE]		400[HBE]	6500	370	107	4511[ ]N
450	0.250	20.0	23.0			21.0[H]	310[B] 250[H]	2950	130	106	4525[ ]N
450	0.300	18.0	21.0			19.0[H]	230[A]	2950	130	106	4530[ ]N
450	0.400	14.5	16.0	13.0			240[B] 198[A]	1800	105	105	4540[ ]N
450	0.500	13.0	14.0	11.5			150[C]	1800	105	105	4550[ ]N
450	0.850	8.5	9.5	8.0		7.0[G]	180[B] 150[A]	950	55	104	4585[ ]N
450	1.100	7.5	9.0	7.0		6.5[G]	125[C] 100[G]	950	55	104	451R1[ ]N
400	0.021				183.0[PCE]		1560	26000	1350	108	40M21PCEN
400	0.040				95.0[PBE]		800	13000	740	107	40M40PBEN
400	0.042				92.0[HCE]	95.0[BF]	830[F] 780[HCE]	13000	675	108	40M42[ ]N
400	0.080				47.0[SAE]	58.0[AF]	595[F] 400[SAE]	6500	370	107	40M80[ ]N
400	0.080				47.0[HBE]		400[HBE]	6500	370	107	40M80[ ]N
400	0.200	22.5	26.0			23.5[H]	310[B] 250[H]	2950	130	106	4020[ ]N
400	0.250	20.0	23.0			21.0[H]	230[A]	2950	130	106	4025[ ]N
400	0.300	17.0	18.5	15.0			240[B] 198[A]	1800	105	105	4030[ ]N
400	0.400	14.5	16.0	13.0			150[C]	1800	105	105	4040[ ]N
400	0.650	10.0	11.0	9.0		8.5[G]	180[B] 150[A]	950	55	104	4065[ ]N
400	0.800	9.0	10.0	8.0		7.5[G]	125[C] 100[G]	950	55	104	4080[ ]N
350	0.021				183.0[PCE]		1560	26000	1350	108	35M21PCEN
350	0.040				95.0[PBE]		800	13000	740	107	35M40PBEN
350	0.042				92.0[HCE]	95.0[BF]	830[F] 780[HCE]	13000	675	108	35M42[ ]N
350	0.080				47.0[SAE]	58.0[AF]	595[F] 400[SAE]	6500	370	107	35M80[ ]N
350	0.080				47.0[HBE]		400[HBE]	6500	370	107	35M80[ ]N
350	0.200	22.5	26.0			23.5[H]	310[B] 250[H]	2950	130	106	3520[ ]N
350	0.250	20.0	23.0			21.0[H]	230[A]	2950	130	106	3525[ ]N
350	0.300	17.0	18.5	15.0			240[B] 198[A]	1800	105	105	3530[ ]N
350	0.400	14.5	16.0	13.0			150[C]	1800	105	105	3540[ ]N
350	0.650	10.0	11.0	9.0		8.5[G]	180[B] 150[A]	950	55	104	3565[ ]N
350	0.800	9.0	10.0	8.0		7.5[G]	125[C] 100[G]	950	55	104	3580[ ]N
200	0.011				257.0[PCE]		1560	26000	1350	108	20M11PCEN
200	0.020				137.0[PBE]		800	13000	740	107	20M20PBEN
200	0.021				131.0[HCE]		780[HCE]	13000	675	108	20M21[ ]N
200	0.040				68.0[SAE]	83.0[BF]	595[F] 400[SAE]	6500	370	107	20M40[ ]N
200	0.040				68.0[HBE]		400[HBE]	6500	370	107	20M40[ ]N

APT Package Styles (Maximum Outline Dimensions in Inches, Excluding Leads)

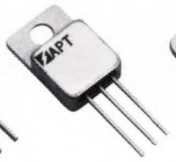
[A]
TO-3 (TO-204AA)
1.54 × 1.050 × 0.360
Steel, Non-Isolated



[B]
TO-247
0.845 × 0.640 × 0.208
Plastic, Non-Isolated



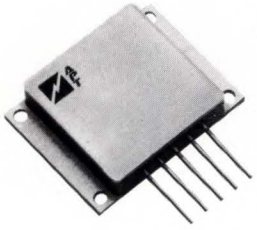
[C]
TO-254
0.800 × 0.545 × 0.255
Hermetic, Isolated



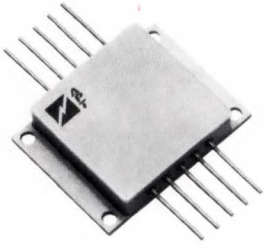
[G]
TO-257
0.655 × 0.420 × 0.185
Hermetic, Isolated

[H]
TO-258
0.800 × 0.695 × 0.255
Hermetic, Isolated

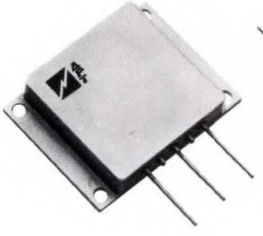
[PBE] [HBE]
3.70 × 1.34 × 1.38
Plastic, Isolated
[HCE] [PCE]
4.25 × 2.44 × 1.457
Plastic, Isolated



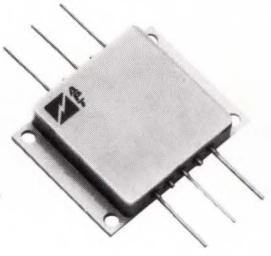
[AF]
F-PACK (350-600V)
1.506 × 2.006 × 0.360
Hermetic, Isolated



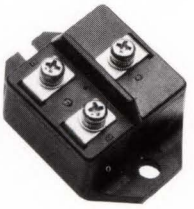
[BF]
F-PACK (350-600V)
1.506 × 2.006 × 0.360
Hermetic, Isolated



[CF]
F-PACK (750-1000V)
1.506 × 2.006 × 0.360
Hermetic, Isolated



[DF]
F-PACK (750-1000V)
1.506 × 2.006 × 0.360
Hermetic, Isolated

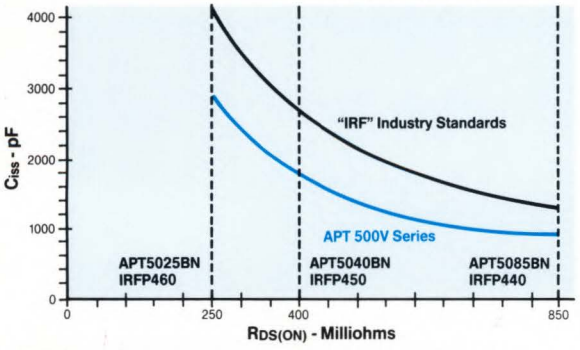


[SAE]
2.11 × 1.44 × 1.11
Plastic, Isolated

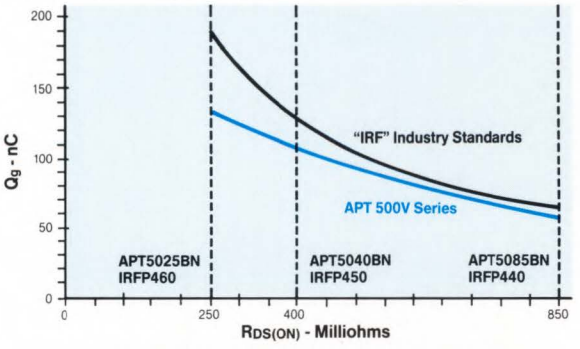
APT Power MOSFETs Provide the Most Efficient Electrical/Mechanical Designs

Comparisons of 500V APT and "IRF" Standard Parts for $R_{DS(ON)}$ vs C_{iss}, Q_g, t_{rr}, and $R_{\theta jc}$

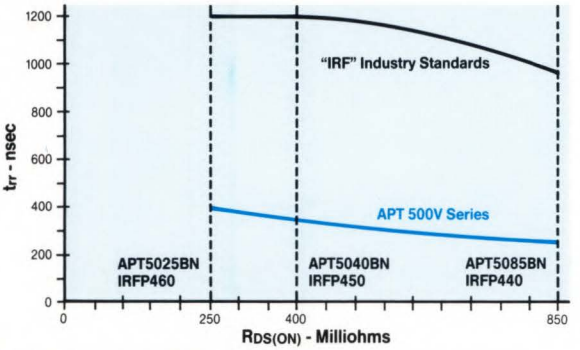
Note: Data extracted from current manufacturers' data sheets.



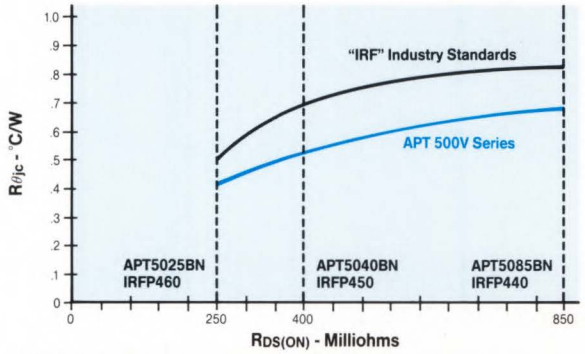
APT Advantages: Simpler, Less Costly Drive Circuits and Higher Frequencies.



APT Advantages: Simpler, Less Costly Drive Circuits and Higher Frequencies.



APT Advantages: Lower Switching Losses, Lower Recovery Transients and Less Heat.



APT Advantages: Higher Power/Current Capability and Cooler Operation.

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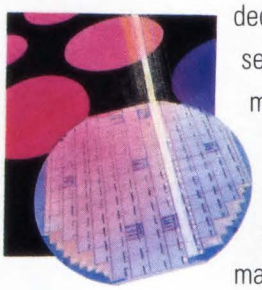

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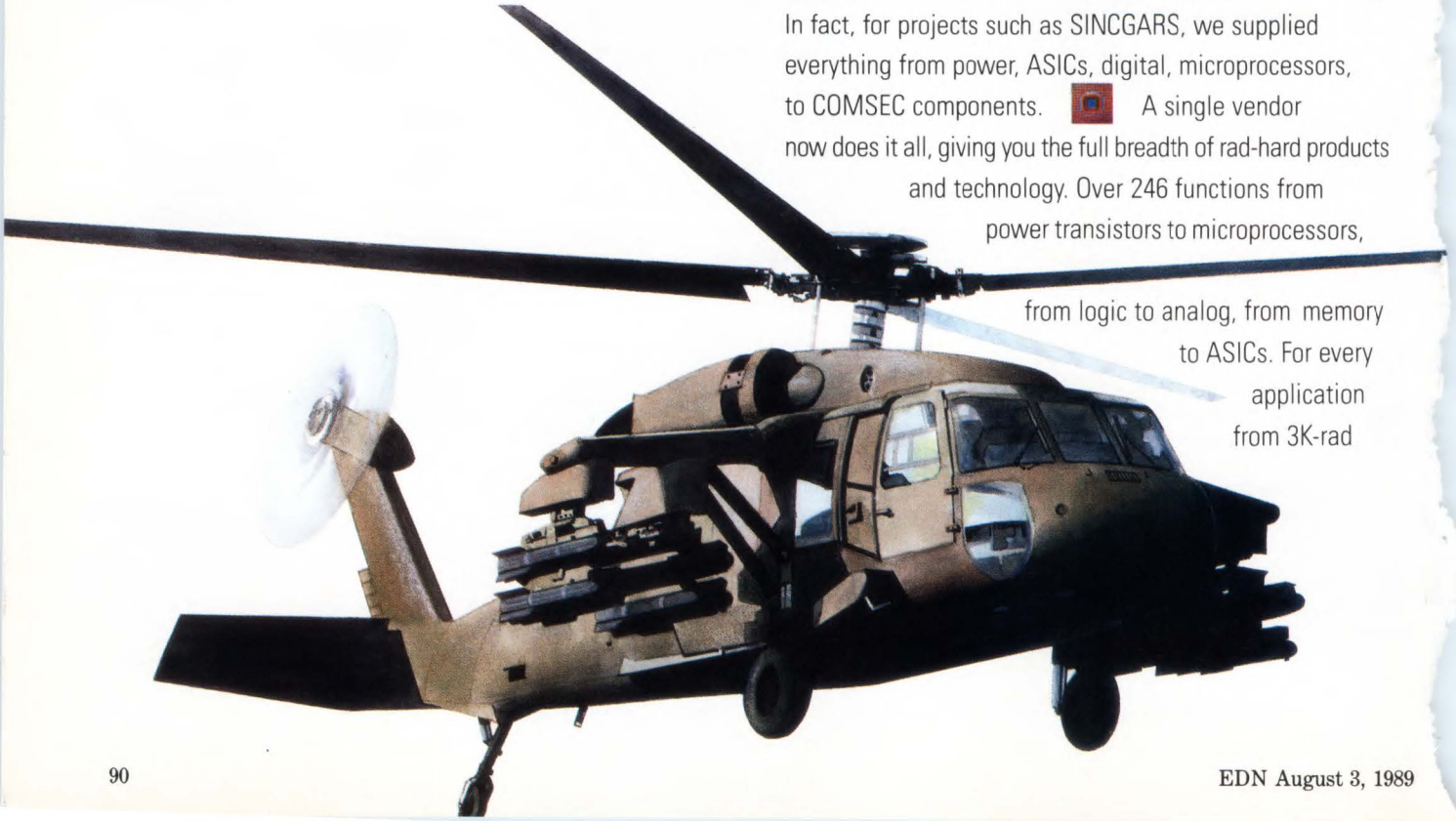

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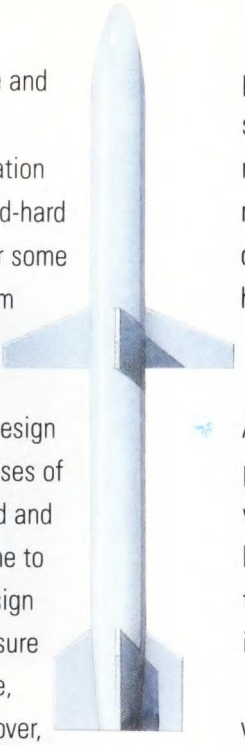

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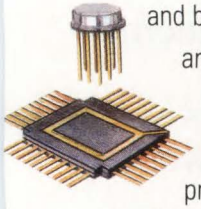

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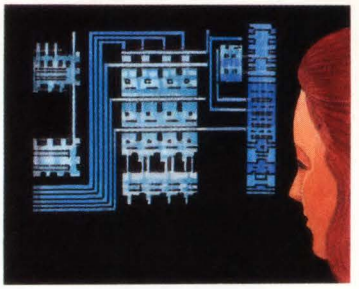

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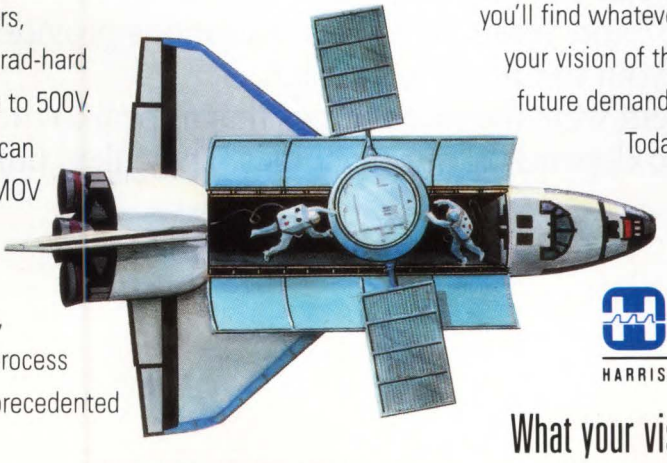

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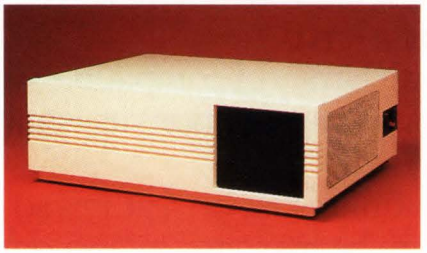

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CIRCLE NO 45

256k-bit static RAM has 35-nsec access time

Although, with the help of Toshiba, Motorola has recently re-emerged as a domestic dynamic-RAM (DRAM) supplier, the company, along with most other US suppliers, virtually abandoned the DRAM market several years ago. Instead of beating its head against the wall of below-cost selling prices offered by the market-share-driven Japanese, Motorola elected to focus its resources on becoming a world leader in fast static RAMs. Witness the latest addition to its broad line.

Organized in a 32k × 8-bit configuration, the 256k-bit MCM6206 static RAM features a maximum access time of 35 nsec. Designed for use in high-speed main-memory or cache-memory applications in desktop personal computers and workstations, the MCM6206 is particularly suited for use with 32-bit μPs that require larger and faster memories than their predecessors. In most cases, the MCM6206 allows the μP to operate with no wait states. Personal computers can also take advantage of the MCM6206's 32k × 8-bit configuration for their byte-wide organization.

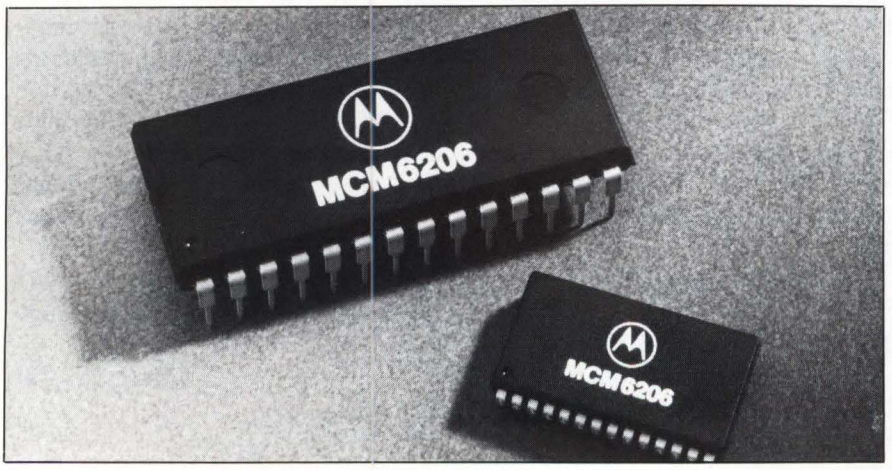
The MCM6206, which operates from a 5V supply, is fully static—no clock or timing strobes are necessary. Other features include an automatic power-down function that reduces power requirements, an output-enable function that allows 15-nsec access to the memory contents, and 3-state outputs.

Fabricated in the company's 1.2-μm silicon-gate HCMOS technology, the MCM6206 is available in either a 28-pin plastic DIP or a 28-lead space-saving SOJ surface-mount package for $60 (1000).

According to the company, future members of the 256k-bit family will attain even faster performance with 1-μm processing. For example, the 64k × 4-bit MCM6208 and MCM-6209, as well as a sister device, the 256k × 1-bit MCM6207, will operate at 20 nsec. The company expects to have these products available for sampling in the fourth quarter of 1989.—***Dave Pryce***

Motorola Inc, MOS Memory Products Div, Box 6000, Austin, TX 78762. Phone (512) 928-6700.

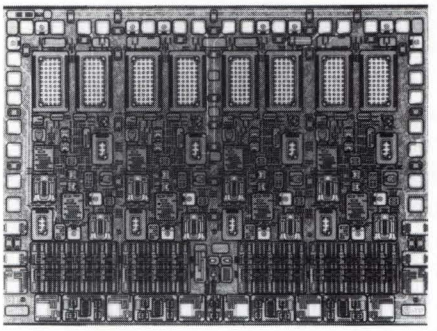
Circle No 731



Available in 28-pin DIP and 28-lead SOJ packages, *the MCM6206 32k × 8-bit static RAM has a maximum access time of 35 nsec, which allows most microprocessors to operate at designed speeds with no wait states.*

Analog/digital array is rated at 350V

Combining high-voltage DMOS and PMOS linear devices with low-voltage CMOS logic, the ALA501 semicustom array from AT&T is suitable for use in a wide range of applications, including bidirectional analog switching, display driver, industrial control, automotive, and telecommunications. Using dielectric isolation in the fabrication process, the ALA501 is free from parasitic latch-up problems that sometimes plague junction-isolated technologies.



The ALA501 semicustom analog/digital array *combines 350V DMOS transistors with CMOS logic. The monolithic chip also contains zener diodes and polysilicon resistors.*

Using its CMOS logic and 350V-rated DMOS/PMOS devices, the AL501 accepts TTL or CMOS logic inputs—such as those from a microprocessor—and interfaces to a high-voltage load, such as a motor or a solenoid. The ALA501 mixed-mode array can interface directly with high-voltage power supplies or with an ac power line. As a result, the ALA501 can perform functions traditionally reserved for discrete high-voltage FET devices.

The monolithic array, which consists of four identical high-voltage tiles and four logic tiles, contains a wide variety of uncommitted active and passive components. The high-voltage section contains eight large DMOS transistors, eight small DMOS transistors, eight small PMOS transistors, and eight diodes. The large DMOS transistors' typical on-resistance is 65Ω at 10 mA.

The control circuitry devices include eight p-channel FETs, four 26V zener diodes, 16 8V zener diodes and 104 polysilicon resistors. The resistors range in value from 10 to 800 kΩ and have a 30% tolerance.

The logic section features 35 equivalent gates of 5-μm CMOS logic in a cellular arrangement. Each cell contains five PMOS and five NMOS devices from which it is possible to construct 2.5 equivalent logic gates. Also contained on the array are 36 ESD-protected bonding pads and a thermal shutdown circuit.

AT&T's design kits include Spice models, kit parts for breadboarding, a technical design guide, and layout plots. Using this kit, customers can design and lay out a proprietary circuit. AT&T then does a design review, develops test procedures for the device, and returns functioning prototypes to the customer within six to eight weeks after design acceptance. Pricing for the ALA501 is $6 in die form and $7 in a plastic DIP (10,000).

—Dave Pryce

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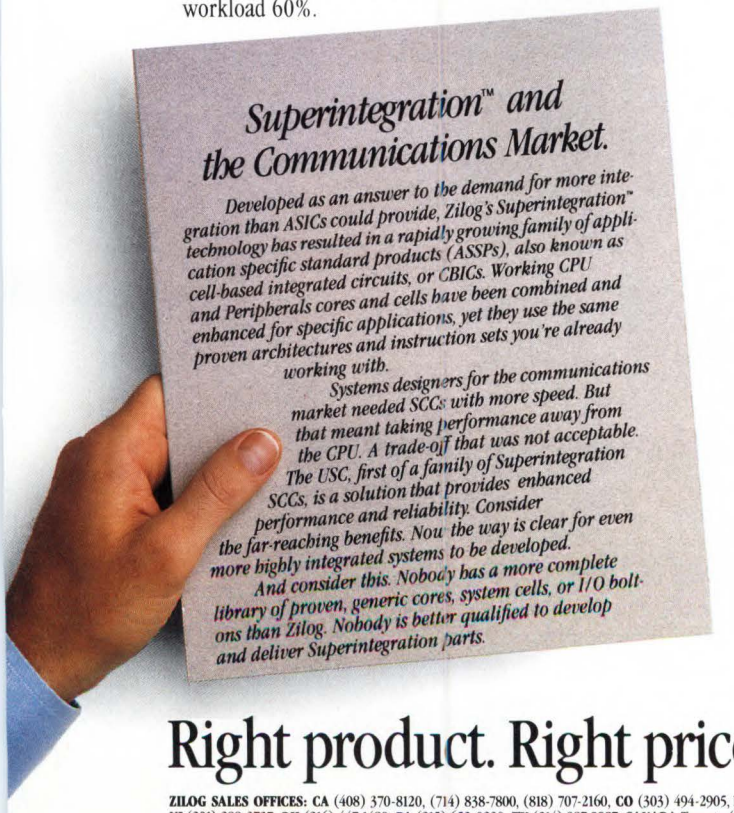

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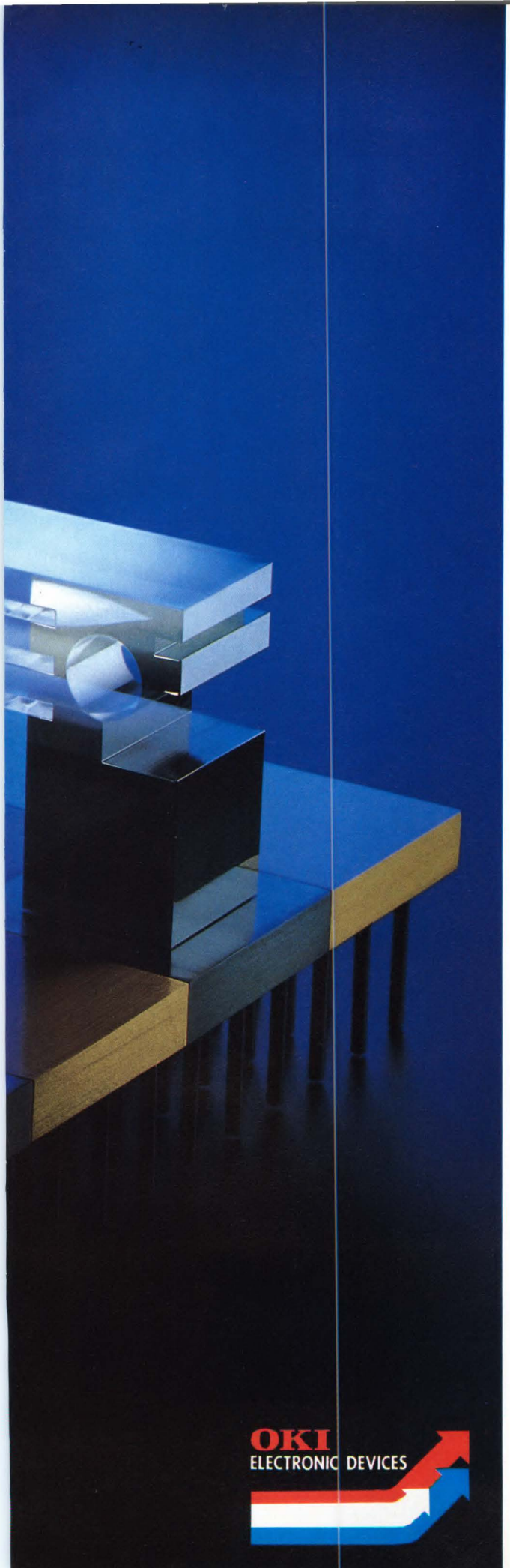

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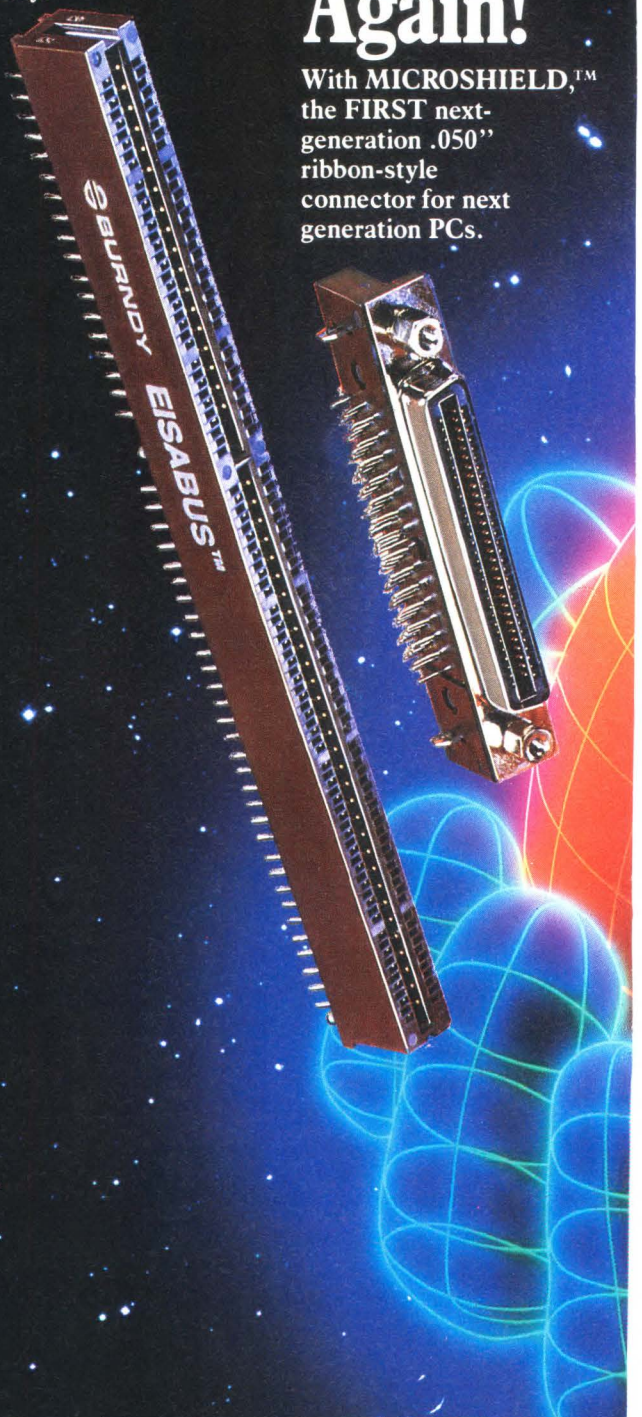

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Higher-resolution A/D converters are challenging designers to create systems that take advantage of the ADC's increased performance.

Among the newly available A/D converters are those designed for specific applications, such as digital audio, analytic instrumentation, and precision measurement systems. (Photo courtesy Micro Networks)

EDN SPECIAL REPORT

High-resolution A/D converters

Anne Watson Swager, *Associate Editor*

Designers' seemingly insatiable appetite for higher resolution and faster conversion speed has spawned a new generation of A/D converters that provide a flexibility not previously available. The new 22-bit converters combine high accuracy, an extremely wide dynamic range, and microprocessor compatibility in a modular package. These features make them an attractive alternative to bulky benchtop DVMs. In addition, new oversampling techniques have significantly reduced the cost of 16- to 20-bit converters over those using more traditional techniques.

Three manufacturers currently offer oversampling (also known as sigma-delta and delta-sigma) converters and others are planning to enter the market soon (see **box**, "Converters couple analog and digital filtering"). Many of the manufacturers of high-resolution products are mainstream players in the data-converter marketplace. Analog Devices, Analogic, Burr-Brown, and Micro Networks all have experience designing high-reso-

The oversampling architecture achieves high-resolution at a low cost.

lution ADCs. However, Thaler Corp's first converter is a 20-bit high-accuracy ADC, and Motorola has entered the field with an oversampling converter. Prema Precision Electronics, a West German manufacturer of precision multimeters, produces a 25-bit ADC that is the highest-resolution converter available. These high-resolution converters are dedicated ADCs, not products that include internal ADCs and DACs and function as analog interface circuits.

According to many ADC manufacturers, the main reason for the movement toward higher and higher resolution is that data-acquistion-system designers

Converters couple analog and digital filtering

The fundamental function of oversampling converters, also called delta-sigma or sigma-delta converters, is to perform a simple, low-resolution conversion and reduce the resulting quantization noise with analog and digital filtering. To accomplish this task, these converters utilize an analog modulator and a digital filter. The modulator simultaneously samples the analog signal and shapes the large amount of quantization noise.

A simplified model of a first-order modulator (**Fig A**) illustrates the noise-shaping principle. The summing node to the right of the integrator represents a comparator. It's here that sampling occurs and quantization noise is injected into the model.

The signal and noise transfer functions that correspond to this block diagram, also shown in **Fig A**, illustrate the modulator's main action. As the loop integrates the error between the sampled signal and the input signal, it low-pass filters the signal and high-pass filters the noise. In other words, the signal is left unchanged as long as its frequency content doesn't exceed the filter's cutoff frequency, but the loop pushes the noise into a higher frequency band. Grossly oversampling the input causes the quantization noise to spread over a wide bandwidth and the noise density in the bandwidth of interest to significantly decrease.

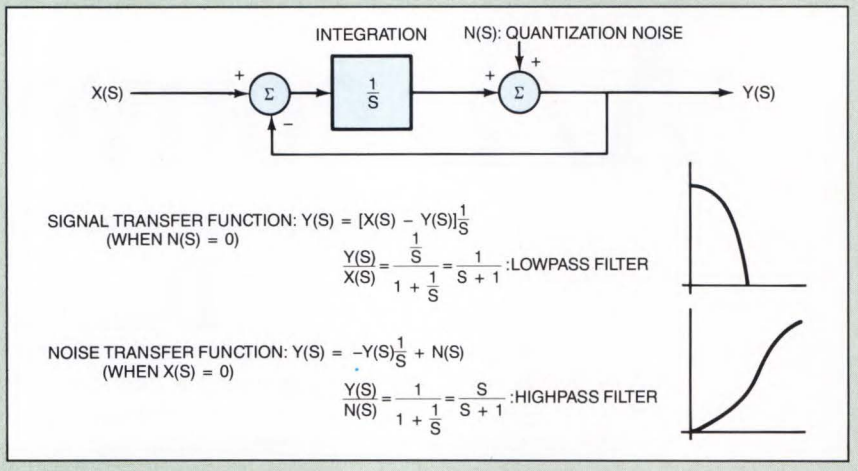


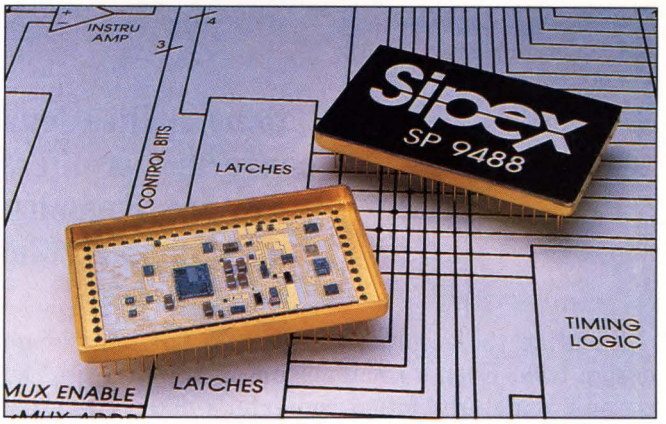
***Fig A—A simplified model** of a first-order sigma-delta modulator and its corresponding signal and noise transfer functions illustrate the modulator's main purpose: to high-pass filter the quantization noise and to push it into a higher-frequency band. (Diagram courtesy Motorola)*

Filtering noise is the primary purpose of the digital filtering stage. Its secondary purpose is to take a 1-bit data stream that has a high sample rate and transform it into a 16-bit data stream at a lower rate. This process is known as decimation. Essentially, decimation is both an averaging function and a rate reduction function performed simultaneously. The output word rate will be some ratio of the internal sampling rate.

Fig B is a spectral representation of the sigma-delta conversion process. Note that a delta-sigma ADC doesn't provide noise rejection in the region around integer multiples of the sampling rate. If system noise exists in these bands, you can usually remove it at the converter's input with a simple, single-pole RC filter.

Although all sigma-delta converters perform the same functions, each does them with its own, generally proprietary circuit. For instance, the modulator stage can be second order, such as in Crystal's CS5317 and CS5503; third order, as in Motorola's 56ADC; or fourth order, as in Crystal's CS5326. The ratio of the internal sampling rate to the input signal's maximum bandwidth can also vary. The CS5317

want to make use of every bit of their transducers' resolution. They feel that if there has to be a limiting factor in the system it should be the transducer, not the ADC. Another reason is that higher-resolution converters can provide additional and often critical details about a set of data.



Many 16-bit products are complete data-acquisition systems. *Sipex's 9488 has an instrumentation amplifier, a user-selectable 8-or 16-channel mux, and a 16-bit successive-approximation ADC.*

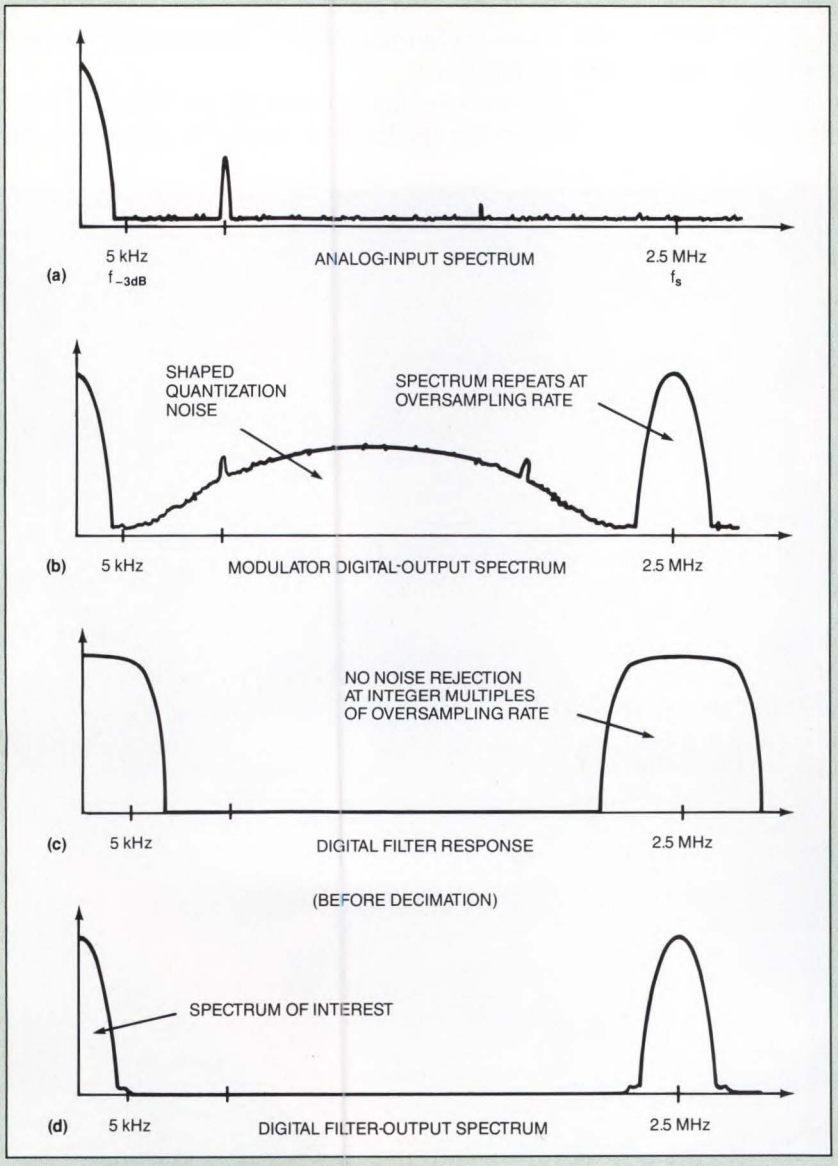


Fig B—The delta-sigma conversion process takes place in two major steps: *oversampling and modulation* ***(b)****, and digital filtering* ***(d)****. (Diagram courtesy Crystal Semiconductor)*

samples at 2.5 MHz—500 times the input bandwidth of 5 kHz. The 56ADC samples at 6.4 MHz, which is equivalent to 64 times the converter's output rate. A converter's S/N ratio and distortion specs are derived from the combination of oversampling rate and modulator order. You shouldn't judge an oversampling converter exclusively on either one of these internal-architecture features.

There are many advantages inherent in this new converting technique. Digital filtering removes the need for external antialiasing filters. Because this filtering resides behind the A/D conversion, noise injected during the conversion process, such as power-supply ripple, voltage-reference noise, or noise in the ADC itself, is rejected. Because of the high sampling rate and the low precision A/D conversion, an S/H circuit is not needed. Sigma-delta converters are inherently linear and don't suffer from appreciable differential nonlinearity; the S/N ratio is independent of the input signal level. The last, but certainly not the least, consideration is cost. Attaining a high level of performance at a fraction of the cost of hybrid and modular designs is probably the greatest advantage of all.

As communications applications for high-resolution converters proliferate, more manufacturers are dynamically specifying their high-resolution products.

Ensuring the accuracy of this data is a very tough design task. Even a small amount of system noise can corrupt a high-resolution converter's data. The usual solution to this problem is careful layout and grounding, which will improve system accuracy to the limits of the ADC. However, it's difficult to find a truly accurate 16-bit converter. Many 16-bit converters, for instance, have only 14 bits of accuracy. This level of accuracy is especially true of many of the successive-approximation types. Although a converter's integral nonlinearity may be 14 bits (equivalent to ±0.003% FSR), it may still provide no-missing-codes performance at 16 bits. Note that the linearity of some 14-bit ADCs matches that of many of the 16-bit products.

The world of high-resolution A/D converters is somewhat fragmented. Many converters are intended for very specialized markets. The successive-approximation converters serve many general-purpose data-acquisition systems. Other converters are closely tied to specific applications. Fortunately, every converter fits into one of two general classifications: those designed for the highest-possible dc accuracy in the dc sense, and those designed for signal processing and good ac specs. Two general applications are associated with these categories: precise measuring systems and DSP applications.

Many oversampling converters are intended for signal-processing applications, therefore their data sheets

Sigma-delta converters are well suited *for many signal processing applications. Motorola's entry into this market, the 56ADC, easily interfaces with many digital signal processors.*

usually quote complete dynamic specifications. But this trend isn't confined to oversampling converters. As DSP applications proliferate, so does the number of high-resolution converters specifically aimed at these applications. To help designers evaluate and compare converters' ac performance, many new converters are fully tested and specified for dynamic characteristics such as S/N ratio and THD.

Table 1 gives you an idea of the variety of high-resolution products available. For applications that require the highest possible dynamic range, take a look at the high-resolution integrating converters. These high-accuracy converters are a world unto themselves. ATE, process control, and weighing systems are typical application areas for them. These ultrahigh-resolution converters are also used in medical and scientific instrumentation that must be able to distinguish extremely small differences in element or chemical concentrations.

Achieving high resolution and high accuracy

Prema Precision Electronics' 25-bit converter with its 0.001% nonlinearity and typical temperature coefficient of 0.5 ppm/°C suits weighing systems and precise data collection. The converter utilizes a patented multiple-ramp method that continuously integrates the measured signal to cancel interference. In order to use this ADC you must develop your own microprocessor control. For integration times of 20 msec, 200 msec, 2 sec, and 20 sec, you can achieve a 15-, 18-, 21-, and 25-bit result, respectively. The software also controls the handling of gain and offset adjustments. A key feature of the ADC 5601 is its compact $2 \times 2 \times 0.4$-in. size.

Analog Devices' 22-bit AD1175 was designed for data-acquisition systems that had relied on DVMs and DMMs to make dedicated measurements. Its resolution and accuracy compete with 6.5-digit DVMs. The AD1175 data sheet quotes a wide dynamic range of 133 dB. This range is higher than what 2^{22} indicates because the part's accuracy is guaranteed for inputs to 10% above the nominal full-scale input range.

Unlike Prema's ADC 5601, the AD1175 is a complete microcomputer-based measurement subsystem. It consists of three major elements: a linearized, autozeroed integrator, a single-chip microcomputer, and a custom CMOS controller/bus interface chip.

You don't need any external components for the AD1175, and all its digital inputs and outputs are LSTTL compatible. The analog input is a high-impedance, 1-GΩ, high-CMRR, true differential-input pair. The AD1175 interfaces to any microprocessor-based system via an 8-bit data bus. Analog Devices recently announced a PC-compatible evaluation card for the AD1175 priced at $495. This card comes with simple Basic software that allows you to send commands to the AD1175 and test its performance.

***With its 133-dB dynamic range**, ±1-ppm maximum integral nonlinearity, and modular package, Analog Devices' AD1175 competes with 6.5-digit DVMs.*

The AD1175 utilizes a multislope-integrating principle that's similar to the classic dual-slope technique. The input signal is integrated during an integer number of line cycles, then the ADC makes a digital measurement of the time required for a known reference voltage to drive the integrator output back to zero. You can select the integration time for maximum line-frequency noise rejection at either 60 or 50 Hz. Internal autozeroing occurs at every conversion, without reducing the throughput rate. During each autozero cycle, the device offsets and low-frequency noise of the converter's main elements are acquired and held; they will be cancelled in the conversion. This circuitry holds the AD1175's input-offset drifts to less than 0.5 μV/°C.

High accuracy requires stability

The ADC100 is Thaler's first entry in the A/D converter market. Their design focus in the past has been reference technology. Like the AD1175, the ADC100 has an onboard microprocessor that controls all internal functions, and a PC evaluation card for it will be available soon. You need two external parts to apply the ADC100: a 25-MHz crystal and an integration capacitor, both of which Thaler supplies. The company quotes the ADC100's analog-input impedance as 200 GΩ.

Thaler's ADC100 has some advantages over the

TABLE 1—REPRESENTATIVE HIGH-RESOLUTION CONVERTERS

MANUFACTURER AND MODEL	RESOLUTION (BITS)	THROUGHPUT OR CONVERSION RATE	ARCHITECTURE	DIFFERENTIAL NONLINEARITY (NMC = NO MISSING CODES)	INTEGRAL NONLINEARITY	INPUT VOLTAGE RANGE	POWER SUPPLY (V)	
ANALOG DEVICES AD ADC72	16	50 μSEC	SUCCESSIVE APPROXIMATION	NMC to 14 BITS	±0.003% FSR	±2.5, ±5, ±10 0 TO 5, 0 TO 10, 0 TO 20	±15, 5	
AD376	16	17 μSEC	SUCCESSIVE APPROXIMATION	NMC TO 14 BITS	±0.003% FSR	±2.5, ±5, ±10 0 TO 5, 0 TO 10, 0 TO 20	±15, 5	
AD1170	18	50 CONVERSIONS/SEC	INTEGRATING	±0.0008% FSR (TYP FOR 60-Hz INTE GRATION TIME)	±0.001% FSR (TYP)	±5	±15, 5	
AD1175	22	20 CONVERSIONS/SEC	INTEGRATING	±0.5 LSB	±1 PPM	±5	±15, 5	
AD1376	16	16 μSEC	SUCCESSIVE APPROXIMATION	NMC TO 14 BITS	±0.003% FSR	±2.5, ±5, ±10 0 TO 5, 0 TO 10, 0 TO 20	±15, 5	
AD1377	16	10 μSEC	SUCCESSIVE APPROXIMATION	±0.003% FSR	±0.003% FSR	±2.5, ±5, ±10 0 TO 5, 0 TO 10, 0 TO 20	±15 ,5	
AD1380	16	14 μSEC	SUCCESSIVE APPROXIMATION	NMC TO 14 BITS	±0.003% FSR	±2.5, ±5, ±10 0 TO 5, 0 TO 10, 0 TO 20	±15, 5	
ANALOGIC ADAM-846	16	333 kHz	3-PASS SUBRANGING	±0.75 LSB	0.003% FSR	0 TO 10 ±10	±15, 5, −6	
ADC-4201/02/03	16	86 kHz	SUCCESSIVE APPROXIMATION	NMC TO 16 BITS	±0.003% FSR ±0.0015% FSR	0 TO 5 ±5	±5	
AM40516	16	200/125 kHz	3-PASS SUBRANGING	±0.75 LSB NMC OVER TEMP	±0.003% FSR	±15, ±5	±5	
AM40016/40116	16	500 kHz	3-PASS SUBRANGING	±0.75 LSB NMC OVER TEMP	±0.003% FSR	0 TO 10, ±10	±15, ±5 −6	
AM40316	16	200 kHz	3-PASS SUBRANGING	±0.75 LSB NMC OVER TEMP	±0.003% FSR	0 TO 10, ±5	±15, 5	
AM41016/41116/ 41216	16	500 kHz	3-PASS SUBRANGING	±0.85 LSB MAX NMC OVER TEMP	±0.003% FSR	0 TO 10 ±10, ±5	±15, 5, −6	
AH 30217	17	300 CONVERSIONS/SEC	INTEGRATING	±0.2 PPM FSR	±7.5 PPM	±10	±15, 5	
ANALOG SOLUTIONS ZAD2716	16	100 kHz	3-PASS SUBRANGING	±0.5 LSB	±0.002% FSR	±5	±15, 5	
ZAD2846	16	300 kHz	3-PASS SUBRANGING	±0.75 LSB	±0.003% FSR	±5	±15, 5	
BURR-BROWN ADC71	16	56.7 μSEC	SUCCESSIVE APPROXIMATION	±0.003% FSR (TYP)	±0.003% FSR	±2.5, ±5, ±10 0 TO 5, 0 TO 10, 0 TO 20	±15, 5	
ADC72	16	56.7 μSEC	SUCCESSIVE APPROXIMATION	±0.003% FSR (TYP)	±0.003% FSR	±2.5, ±5, ±10 0 TO 5, 0 TO 10, 0 TO 20	±15, 5	
ADC76	16	17 μSEC	SUCCESSIVE APPROXIMATION	±0.003% FSR (TYP)	±0.003% FSR	±2.5, ±5, ±10 0 TO 5, 0 TO 10, 0 TO 20	±15, 5	

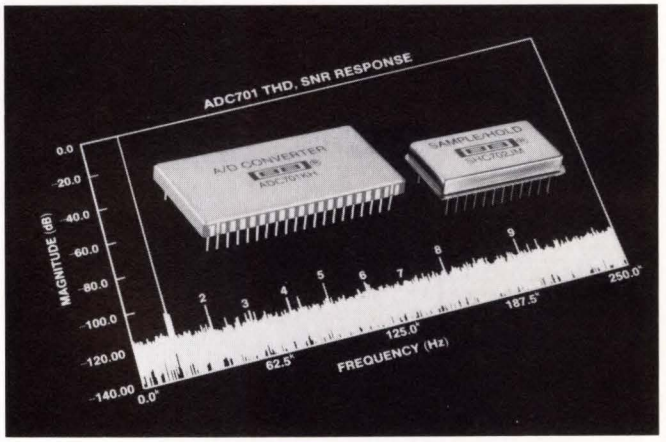
NOTES: NS = NOT SPECIFIED.
NA = NOT APPLICABLE.

POWER DISSIPATION (mW)	INTERNAL S/H	DYNAMICALLY SPECIFIED	PARALLEL I/O	SERIAL I/O	PACKAGE	PRICE (100)
645			•	•	32-PIN HYBRID DIP	$175
1100			•		32-PIN HYBRID DIP	$223.90
910			•		1.24×2.5× 0.55-IN. MODULE	$98
2750			•		3.7×5.2× 0.53-IN. MODULE	$495
645			•	•	32-PIN HYBRID DIP	$103
600			•	•	32-PIN HYBRID DIP	$140
900	•		•	•	32-PIN TRIPLE-WIDTH HYBRID DIP	$126
4300	•	•	•		3×5× 0.44-IN. MODULE	$574
120	•	•	•	•	40-PIN MONOLITHIC DIP	$80/$137/ $156
1675/1975	• (40516)	•	•		3×4× 0.44-IN. MODULE	$249
4000	•	•	•		3×4× 0.44-IN. MODULE	$846
2450	•	•	•		3×5× 0.44-IN. MODULE	$425
4000	•	•	•		3×5× 0.44-IN. MODULE	$853
600			•		40-PIN HYBRID DIP	$153
2000	•	•	•		3×4× 0.44-IN. MODULE	$231
3500	•		•		3.8×4.5× 0.56-IN. MODULE	$656
550			•	•	32-PIN CERAMIC HYBRID	$60.40/ $74.70
550			•	•	32-PIN METAL HYBRID	$172.33- $193.65
525			•	•	32-PIN CERAMIC	$100-$231

AD1175 in offset and gain stability. Although the ADC100 has lower accuracy and throughput, it is fully specified for operation from −25 to +85°C. The AD1175's range is 0 to 70°C. In addition, the ADC100's maximum offset and scale-factor error of 0.1 and 0.5 ppm/°C compare favorably with the AD1175's ±0.5 μV/°C and ±1-ppm/°C errors. The ADC100's onboard microprocessor performs autozeroing automatically at start-up, but Thaler recommends that you repeat it after the ADC is fully warmed up to ensure maximum accuracy.

Thaler stresses that you must take temperature effects into account when calculating system accuracy (**Ref 1**). The company warns that even in a standard laboratory environment, temperature effects can significantly degrade a system's accuracy. In order to calculate the accuracy, you must take both the converter's and the internal or external reference's gain error into account. The maximum error over temperature is the converter's linearity error plus the product of the combined gain TC and the temperature.

V/F converters can also offer high resolution. A V/F converter coupled with a counter/timer IC allows you to trade resolution for conversion time and vice versa. Dymec's 2824 instrumention A/D converter and the 5024 programmable counter/timer ($15) together form an A/D system that supports both frequency-counting and period-averaging measurement techniques. At 10 conversions/sec this ADC achieves a sensitivity of 10 μV, which is the equivalent of 20 bits of resolution in a 10V signal. For a conversion time of 1 sec, the sensitivity of this system is 1.1 μV or 23 bits. The analog



Manufacturers now provide dynamic specifications *for many high-speed converters. The ADC701 and SHC702 pair (Burr-Brown) feature a spurious-free dynamic range of 107 dB with an input of 20 kHz. The conversion rate extends from dc to 500 kHz.*

TABLE 1—REPRESENTATIVE HIGH-RESOLUTION CONVERTERS (CONTINUED)

MANUFACTURER AND MODEL	RESOLUTION (BITS)	THROUGHPUT OR CONVERSION RATE	ARCHITECTURE	DIFFERENTIAL NONLINEARITY (NMC = NO MISSING CODES)	INTEGRAL NONLINEARITY	INPUT VOLTAGE RANGE	POWER SUPPLY (V)
ADC700	16	17 μSEC	SUCCESSIVE APPROXIMATION	NMC TO 14 BITS	±0.003% FSR	±2.5, ±5, ±10 0 TO 5, 0 TO 10, 0 TO 20	±15, 5
ADC701	16	500 kHz	3-PASS SUBRANGING	NMC TO 16 BITS	±0.003% FSR	±5, ±10, 0 TO 5, 0 TO 10	±15, ±5
PCM75	16	17 μSEC	SUCCESSIVE APPROXIMATION	±0.003% FSR (TYP)	NS	±2.5, ±5 ±10	±15, 5
PCM78	16	5 μSEC	SUCCESSIVE APPROXIMATION	NMC TO 14 BITS	±0.003% FSR	±3	±5 TO ±15, 5
CARILLON TECHNOLOGY CTI/DBX F410/D20C10/ A1520	USER CONFIG-URABLE TO 20	48 kHz	OVERSAMPLING	0.000000019%	NS	NS	5, 9
CRYSTAL SEMICONDUCTOR CS5101	16	100 kHz	SUCCESSIVE APPROXIMATION	NMC TO 16 BITS	±0.003% FSR	±5, 0 TO 5	±5V
CS5102	16	10 kHz	SUCCESSIVE APPROXIMATION	NMC TO 16 BITS	±0.003% FSR	±5, 0 TO 5	±5V
CS5317	16	20 kHz	DELTA-SIGMA	NMC TO 16 BITS	NS	±5	±5
CS5326	16	30 TO 50 kHz	DELTA-SIGMA	NMC TO 16 BITS	NS	±3.68	±5
CS5501	16	4 kHz	DELTA-SIGMA	NMC TO 16 BITS	±0.0015%	±2.5, 0 TO 2.5	±5
CS5503	20	4 kHz	DELTA-SIGMA	NMC TO 19 BITS	±0.0003% FSR (TYP)	±2.5, 0 TO 2.5	±5
DATEL ADC-800	15 + SIGN	2.5 CONVERSIONS/SEC	INTEGRATING	±0.5 LSB	2 LSB	±3.27	±5
ADC-974	16	2.5 μSEC	2-PASS SUBRANGING	±0.003% FSR	±0.003% FSR	±5	±13, ±5
DYMEC 2824	USER PRO-GRAMMABLE TO 24 BITS	USER PROGRAM-MABLE 100 NSEC TO 16 SEC	V/F	0.1 PPM	±0.05% FSR	0 TO 10, 0 TO 1	±15, +5
MAXIM MAX133/134	±3¾ DIGIT	20 CONVERSIONS/SEC	INTEGRATING	5 COUNTS	±10 COUNTS	±400 mV TO ±4000V	±5, 9
MICRO NETWORKS MN5280/82	16	100 μSEC/50 μSEC	SUCCESSIVE APPROXIMATION	NMC TO 14 BITS	±0.006% FSR OVER TEMP	±2.5, ±5, ±10 0 TO 5, 0 TO 10, 0 TO 10	±15, 5

NOTES: NS = NOT SPECIFIED.
NA = NOT APPLICABLE.

POWER DISSIPATION (mW)	INTERNAL S/H	DYNAMICALLY SPECIFIED	PARALLEL I/O	SERIAL I/O	PACKAGE	PRICE (100)
645			•	•	28-PIN HYBRID	$74-$179
280.0 (WITH S/H)		• (WITH COMPANION S/H)	•		40-PIN METAL AND CERAMIC HYBRID	$563-$653
525		•	•	•	32-PIN CERAMIC HYBRID	$93.18-$106.03
575		•		•	28-PIN PLASTIC MONOLITHIC	$32.50
600	NA	•	•	•	48-PIN MONO DIP, 40-PIN DIP	$130 (SET)
280	•	•		•	28-PIN MONOLITHIC DIP OR PLCC	$57.60
40	•	•		•	28-PIN MONOLITHIC DIP OR PLCC	$39.80
220	NA	•		•	18-PIN MONOLITHIC DIP AND SOIC	$29.40
450	NA	•		•	28-PIN MONOLITHIC DIP	$70.60
25	NA			•	20-PIN MONOLITHIC DIP AND SOIC	$18
25	NA			•	20-PIN MONOLITHIC DIP AND SOIC	$27.70
20			•	•	40-PIN MONOLITHIC DIP	$24.75
8400			•		6×4× 0.375-IN. MODULE	$899 (50)
1300				•	2×3.25× 0.4-IN. MODULE	$199
9			•		40-PIN MONOLITHIC OR PLCC	$11
1400			•		32-PIN HYBRID DIP	$169/$187

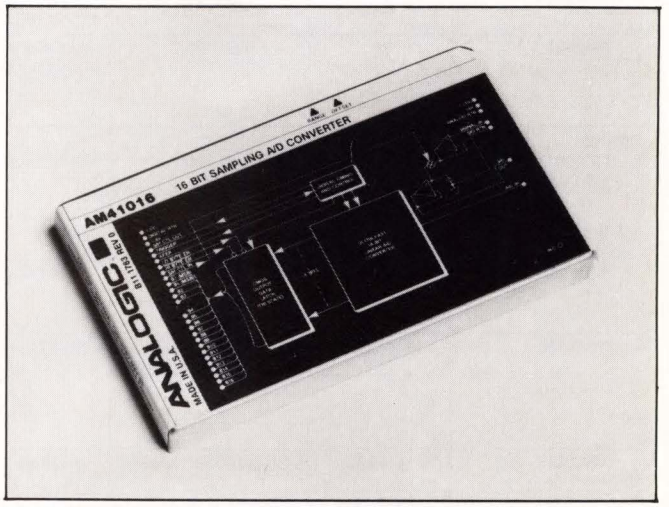
front end is completely isolated from the rest of the system. This isolation guarantees that the ADC is free of ground loops and digital noise in the analog section, two absolute requirements if the system is to achieve sensitivities of 10 μV or better.

500-kHz conversion rates are possible

These high-accuracy, high-resolution parts represent only a segment of the marketplace. There are plenty of applications that require the highest speed available. High speed, however, is relative. You won't find any high-resolution converters with megahertz conversion rates. The current state-of-the-art high-speed plus high-resolution converters have conversion rates of 500 kHz. But you'll pay a lot for this speed. Analogic's, Analog Solutions', Burr-Brown's, and Datel's high-speed products cost between $500 to $900. Both Analogic and Burr-Brown introduced 500-kHz converters at the beginning of 1989.

Analogic's AM40016/40116 and AM41016/41116/41216 modular 16-bit converters are based on a multipass flash architecture that includes internal S/H amplifiers. The AM40016 is tailored for the digitization of several multiplexed channels, such as in automatic test equipment. The AM41016 series features low distortion and was designed for frequency domain applications. Both converter families have an input impedance of $10^8\Omega$ and guarantee no missing codes from 0 to 60°C.

Because the AM41016 series is designed to digitize fast, time-varying signals, its data sheets include com-



Modular packaging lets ADC designers *put the highest-performance subcomponents into one converter. Analogic's AM41016 sampling converter features a 500-kHz conversion rate and includes full dynamic specifications.*

TABLE 1—REPRESENTATIVE HIGH-RESOLUTION CONVERTERS (CONTINUED)

MANUFACTURER AND MODEL	RESOLUTION (BITS)	THROUGHPUT OR CONVERSION RATE	ARCHITECTURE	DIFFERENTIAL NONLINEARITY (NMC = NO MISSING CODES)	INTEGRAL NONLINEARITY	INPUT VOLTAGE RANGE	POWER SUPPLY (V)
MN5284 SERIES	16	50 μSEC	SUCCESSIVE APPROXIMATION	NMC TO 15 BITS	±0.003% FSR	0 TO −20, 0 TO −16.38, 0 TO −10, 0 TO −8.19, ±10, ±8.19, ±5, ±4.09	±15, 5
MN5290/91	16	40 μSEC	SUCCESSIVE APPROXIMATION	NMC TO 14 BITS/13 BITS OVER TEMP	±0.003% FSR/ ±0.006% FSR	±2.5, ±5, ±10, 0 TO 5, 0 TO 10, 0 TO 20	±15, 5
MN5295/96	16	17 μSEC	SUCCESSIVE APPROXIMATION	NMC TO 14 BITS/13 BITS OVER TEMP	±0.003% FSR/ ±0.006% FSR	±2.5, ±5, ±10, 0 TO 5, 0 TO 10, 0 TO 20	±15, 5
MN6290/91	16	20 kHz	SUCCESSIVE APPROXIMATION	NMC TO 14 BITS/13 BITS OVER TEMP	±0.003% FSR/ ±0.006% FSR	±5, ±10, 0 TO 10	±15, 5
MN6295/96	16	50 kHz	SUCCESSIVE APPROXIMATION	NMC TO 14 BITS/13 BITS OVER TEMP	±0.003% FSR/ ±0.006% FSR	±5, ±10, 0 TO 10	±15, 5
MN5420	20	320 kHz	FLOATING POINT	NS	NS	±5	±15, 5
MOTOROLA DSP56ADC16	16	100 kHz	SIGMA-DELTA	±½ LSB	±2 LSB	0.5-4.5	5
PREMA PRECISION ELECTRONICS ADC 5601	25	20 SEC	INTEGRATING	±½ LSB (TYP)	±0.0001% FSR	±2.5, 0 TO −5	±15, 5
SIPEX HS9476	25	15 μSEC	SUCCESSIVE APPROXIMATION	NMC TO 14 BITS	±0.003% FSR	±5, ±10, 0 TO 10, 0 TO 20	±15, +5
HS9516	25	100 μSEC	SUCCESSIVE APPROXIMATION	NMC TO 16 BITS	±0.0015% FSR	±2.5, ±5, ±10, 0 TO 5, 0 TO 10, 0 TO 20	±15, +5
HS9576	25	15 μSEC	SUCCESSIVE APPROXIMATION	NMC TO 14 BITS	±0.003% FSR	±2.5, ±5, ±10, 0 TO 5, 0 TO 10, 0 TO 20	±15, +5
SP9480	25	15 μSEC	SUCCESSIVE APPROXIMATION	NMC TO 14 BITS	±0.003% FSR	±10, 0 TO 10	±15, +5
SP9488	25	16 μSEC	SUCCESSIVE APPROXIMATION	NMC TO 15 BITS	±0.002% FSR	±2.5, ±5, ±10, 0 TO 2.5, 0 TO 5, 0 TO 10	±15, +5
SONY CX20018/ CXA1144S	25	44 kHz	INTEGRATING	NS	NS	NS	±5
TELEDYNE SEMICONDUCTOR TSC 500 A	25	USER PROGRAMMABLE	INTEGRATING	0.0025% FSR	0.01% FSR	±4.2	±5
TSC 800	15 + SIGN	2.5 CONVERSIONS/SEC	INTEGRATING	±0.5 LSB	2.8 LSB (TYP)	±4	±5
TSC 835	±19,999 COUNTS (15.3 BITS)	5 CONVERSIONS/SEC	INTEGRATING	±0.01 LSB (TYP)	±1 COUNT	±4V	±5

NOTES: NS = NOT SPECIFIED.
NA = NOT APPLICABLE.

POWER DISSIPATION (mW)	INTERNAL S/H	DYNAMICALLY SPECIFIED	PARALLEL I/O	SERIAL I/O	PACKAGE	PRICE (100)
255			●	●	32-PIN HYBRID DIP	$249
810 TYP			●	●	32-PIN HYBRID DIP	$175-$225
946 TYP			●	●	32-PIN HYBRID DIP	$162-$261.50
1500	●	●	●	●	32-PIN HYBRID DIP	$180-$270
1300	●	●	●	●	32-PIN HYBRID DIP	$187-$296
6700			●		3×4× 0.625-IN. HYBRID	$1295
400	NA	●		●	20-PIN MONOLITHIC DIP, SOIC	$25 (1000)
600				●	6×6× 0.5-IN. MODULE	$290
1520	●	●	●		32-PIN HYBRID DIP	$195, $355
1200			●		32-PIN HYBRID DIP	$256, $499
1100			●	●	32-PIN HYBRID DIP	$120, $340
1200	●	●	●		32-PIN HYBRID DIP	$240, $395
1400 MAX	●	●	●	●	32-PIN HYBRID DIP	$430, $549
1700/1200				●	28-PIN MONOLITHIC DIP	$19/$22.70
10				●	16-PIN MONOLITHIC DIP	$3.90
20			●	●	40-PIN MONOLITHIC DIP, 60-PIN FLAT PACKAGE	$18.35
30 (MAX)			●		28-PIN MONOLITHIC DIP, PLCC, FLAT PACKAGE	$4.94

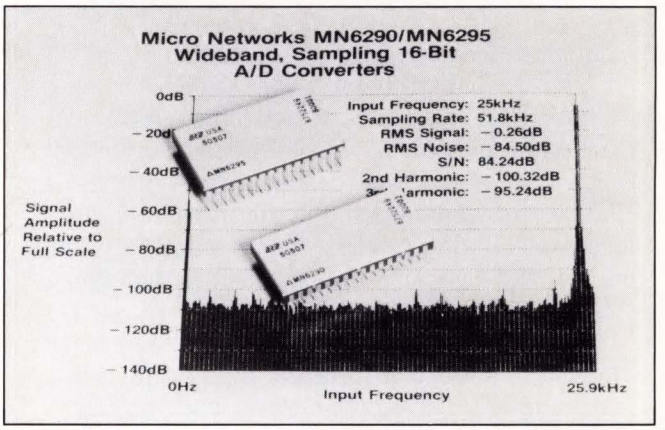
plete dynamic specifications. The S/N ratio with an input of 10 kHz is 88 dB; the peak distortion at 10 kHz is −93 dB; the total harmonic distortion at 10 kHz is −89 dB. Analogic provides dynamic testing on most of their products, and it publishes a technical note to explain the procedure.

Burr-Brown hopes to capture the market for those high-speed, high-resolution applications where small size and low power consumption are especially important. Burr-Brown's ADC 701 and companion SHC702 S/H amplifier ($168) are both hybrid designs characterized as a ADC-S/H pair. Together, the ADC and S/H pair consume 2.8W. The S/H timing is provided directly by the ADC. No other timing circuitry is necessary. Only two connections are required between the SHC702 and the ADC701: the SHC702 analog output to the ADC701 input and the digital hold command from the ADC701 input.

Like Analogic's converters, the ADC701 is based on a 3-step architecture, and Burr-Brown provides dynamic specs for the ADC/SHC pair. The S/N ratio with an input frequency of 5 kHz is 93 dB. Total harmonic distortion at 20 kHz is 0.00068%. The spurious-free dynamic range with a 20-kHz input is 107 dB. Two temperature ranges are available: 15 to 55°C and 0 to 70°C.

Oversampling technology grows rapidly

Although these high-accuracy and high-speed converters have advanced the state of the art, there has been a tremendous amount of activity in the oversampling converter marketplace. This trend is likely to continue. Because of their monolithic construction,



Extended temperature ranges and military screening *are available for many of Micro Networks' converters, including their 6290/6295 series.*

Integrating converters dominate the high-precision marketplace; 3-pass subranging architectures suit high-speed requirements.

TABLE 1—REPRESENTATIVE HIGH-RESOLUTION CONVERTERS (CONTINUED)

MANUFACTURER AND MODEL	RESOLUTION (BITS)	THROUGHPUT OR CONVERSION RATE	ARCHITECTURE	DIFFERENTIAL NONLINEARITY (NMC = NO MISSING CODES)	INTEGRAL NONLINEARITY	INPUT VOLTAGE RANGE	POWER SUPPLY (V)
TSC850	15 + SIGN	40 CONVERSIONS/SEC	INTEGRATING	±½ LSB	±2 LSB	±3.5	±5
THALER ADC100CA	22	320 mSEC	INTEGRATING	FULLY MONOTONIC	3 PPM	±10	±15, +5

NOTES: NS = NOT SPECIFIED.
NA = NOT APPLICABLE.

these converters are an extremely low-cost, high-resolution alternative. Although they can't compete with integrating converters for absolute accuracy, they're ideal for high-resolution, mid-range accuracy and signal-processing applications.

Crystal Semiconductor, a pioneer in 16-bit oversampling converters, has a variety of new products targeted for specific applications. Motorola introduced its first oversampling converter recently, and Carillon Technology, a manufacturer of professional audio equipment, has also announced a 3-chip set based on the sigma-delta architecture.

One of Crystal Semiconductor's three new delta-sigma parts is an upgrade of its CS5501. Designated the CS5503, it's the first 20-bit monolithic A/D converter designed for precision measurement applications. The CS5503's ±0.0003% typical linearity error and its offset and full-scale errors of ±4 LSB max make this converter, priced at $27.70, an extremely low-cost alternative. The CS5503 continuously samples at a rate set by a CMOS clock or a crystal.

The other new products from Crystal, the CS5317 and CS5326, are aimed at the telecommunications and audio markets, respectively. The CS5317 is suitable for high-end voice-band applications such as V.32 modems, speech-recognition systems, telephone-system line cards, and high-resolution sonar. This converter features an internal PLL, which simplifies clock synchronization in complex data systems. The internal PLL makes recovering the master clock transparent to the user. The CS5317 has a total harmonic distortion of 80 dB across its 10-kHz bandwidth, and intermodulation distortion is less than 84 dB. The CS5326 is a stereo 16-bit ADC with a 25-kHz bandwidth. Its output word rate is adjustable from 30 to 50 kHz. It has an S/N ratio of 92 dB and a total harmonic distortion of 0.0015%.

These products from Crystal illustrate the application-specific nature of this marketplace. Motorola is taking a different approach. Its new 56ADC is a versatile converter, aimed at general signal-processing users. The 56ADC provides a complete set of analog-to-digital conversion functions on one chip. It requires a single 5V supply. No glue logic is needed to interface the 56ADC to Motorola's, TI's, NEC's, or AT&T's DSPs. Its dynamic specs include a 90-dB S/N ratio and a 90-dB signal-to-THD ratio for input signals of 0 to 45.5 kHz.

The 56ADC's versatility stems from the implementa-

Follow advice to control noise

Many manufacturers strongly recommend that you avoid using switching power supplies in your system. The frequencies of switching supplies directly overlap many of the high-speed converters' conversion rates. Other design suggestions include extensive power-supply filtering, separate analog and digital grounds that are tied together only at the ADC, and timing schemes that synchronize the converter with other switching circuitry. Certain conversion architectures are more immune to noise. For instance, integrating converters tend to have high CMRR, and you can choose the integration time to improve 50- and 60-Hz rejection.

POWER DISSIPATION (mW)	INTERNAL S/H	DYNAMICALLY SPECIFIED	PARALLEL I/O	SERIAL I/O	PACKAGE	PRICE (100)
20			•		40-PIN MONOLITHIC DIP, 44-PIN PLCC	$14.13
1660			•		40-PIN HYBRID DIP	$360

tion of its internal digital filtering. The decimation process is split between a comb filter and a FIR filter. The outputs of both filters are accessible. Depending on which output you choose, the part performs as either a 12-bit, 400-kHz converter or a 16-bit, 100-kHz converter. This 2-stage design removes the multiplexing restriction.

Oversampling and muxing seldom mix

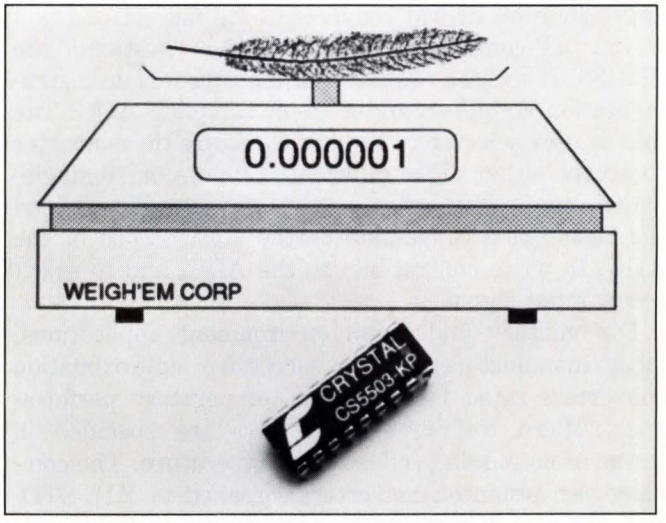
There are some applications for which oversampling converters are not well suited. Systems that have only one ADC to measure a variety of transducer outputs and, therefore, require signal muxing before the ADC, can't take advantage of these converters. The oversampling technique involves a long pipeline delay, which makes multiplexing between channels impractical. Depending on the cost of your system this lack of multiplexing capability may not be a significant disadvantage. You could replace an expensive ADC and mux with individual oversampling converters.

Motorola's 56ADC is not suited for a multiplexed situation when you need 16 bits of resolution. The pipeline delay through the second digital filter is approximately 325 μsec. However, if 12 bits of resolution is enough for your system, you can use the comb-filter output. The pipeline delay between the input and the comb-filter output is approximately 15 μsec. This conversion time is competitive with that of other 12-bit products, so you can use the comb-filter output in the same multiplexing situations.

Integrating, subranging, and sigma-delta converters are usually targeted for either precision dc or signal-processing applications. The rest of the high-resolution market is rounded out by a variety of 16-bit successive-approximation converters. Successive approximation is the workhorse architecture because it provides moderate speed coupled with moderate accuracy. These converters serve the majority of standard data-acquistion systems. The many successive-approximation types listed in **Table 1** feature variations in cost, speed, size, power consumption, and internal functions.

Many of the newer successive-approximation converters, the so-called sampling converters, include internal S/H amplifiers that are designed for compatibility with their companion ADC. The advantages of choosing a sampling ADC are straightforward: you won't have to do as much front-end analog design; the joint performance of the ADC and S/H amplifier is guaranteed by the manufacturer; and internal S/H amplifiers save board space. If your system requires external S/H amplifiers—for example, if you're muxing between different amplifiers—it's important to choose an S/H amplifier that is compatible with your ADC and your system objectives (**Ref 2**).

Many successive-approximation converters feature self- or autocalibration circuitry. The standard calibration approach uses laser-trimmed resistors for the internal DAC. However, Crystal's CS5101 and CS5102 DACs are composed of an array of binary-weighted capacitors. To ensure accuracy, these capacitors are calibrated on chip with digital logic upon reset or power-up. This calibration enables the converter to guarantee 16-bit no missing codes and provides an inherent S/H function—the analog input's value is always



Designed for measuring low frequency signals, *Crystal Semiconductor's CS5503 20-bit delta-sigma converter features 18 bits of accuracy.*

Manufacturers of high-resolution ADCs

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

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(800) 548-6132
FAX 602-889-1510
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FAX 512-445-7581
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FAX 408-720-0624
Circle No 655

Datel
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FAX 617-729-1639
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Microprocessor Products Group
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Austin, TX 78735
(512) 440-2039
Circle No 659

Prema Precision Electronics Inc
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FAX 508-667-3973
Circle No 661

Sony Corp
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FAX 714-229-4271
Circle No 662

Thaler Corp
10940 N Stallard Pl
Tucson, AZ 85737
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FAX 602-742-9826
Circle No 663

held by at least one capacitor.

Successive-approximation converters have the highest number of internal features, including references, clocks, S/H amplifiers, multiplexers, and serial and parallel ports. Some newer converters are also microprocessor compatible and feature short-cycle capability. You can decrease the conversion time if you only require a 14-bit-accurate result.

Burr-Brown's ADC700 includes a reference, a clock, and an 8-bit microprocessor interface. Sipex Corp's Hybrid Systems Div has a variety of 16-bit successive approximation hybrid converters. Its newest one is a 16-bit μP-controlled data-acquistion system, the SP9488. It includes an internal multiplexer, an instrumentation amplifier, and a 16-bit sampling ADC. The mux is user selectable. You can configure the converter to accept either eight differential inputs or 16 single-ended inputs. You can use the 16-bit data bus to read the result of a conversion or the status word of the ADC, to write control bits to the ADC, and to select a new input signal.

For military and harsh environment applications, most manufacturers offer successive approximation converters rated for extended temperature performance. Micro Networks' converters are specified in terms of no missing codes over temperature. The company also produces converters screened to MIL-STD-883. Its new MN6295/6296 ADC family includes converters rated at four electrical performance grades and two operating temperature ranges. The MN6295T/6296T guarantees 14 bits of resolution with no missing codes from −55 to +125°C and is fully specified for dynamic performance. The S/N ratio is 82 dB over temperature; the harmonics and spurious noise spec is −85 dB. This dynamic performance is guaranteed with an input frequency as high as 25 kHz—the Nyquist frequency of the converter.

There's no doubt that the high-resolution ADC market will continue to grow. Future 16-bit converter designs will focus on increasing speed and lowering costs. More products will feature 16 to 20 bits of resolution, and oversampling converters will continue to provide low-cost solutions. The ties between DSP and A/D converters will become even stronger, and devices that integrate A/D and DSP functions may not be far in the future. EDN

References

1. Application Note 4, "Improving system accuracy," Thaler Corp, September 1988.
2. Little, Al, and Bob Burnett, "S/H amp-ADC matrimony provides accurate sampling," *EDN*, February 4, 1988, pg 153.

Acknowledgment

The author wishes to thank the many ADC manufacturers who contributed information and ideas to this article.

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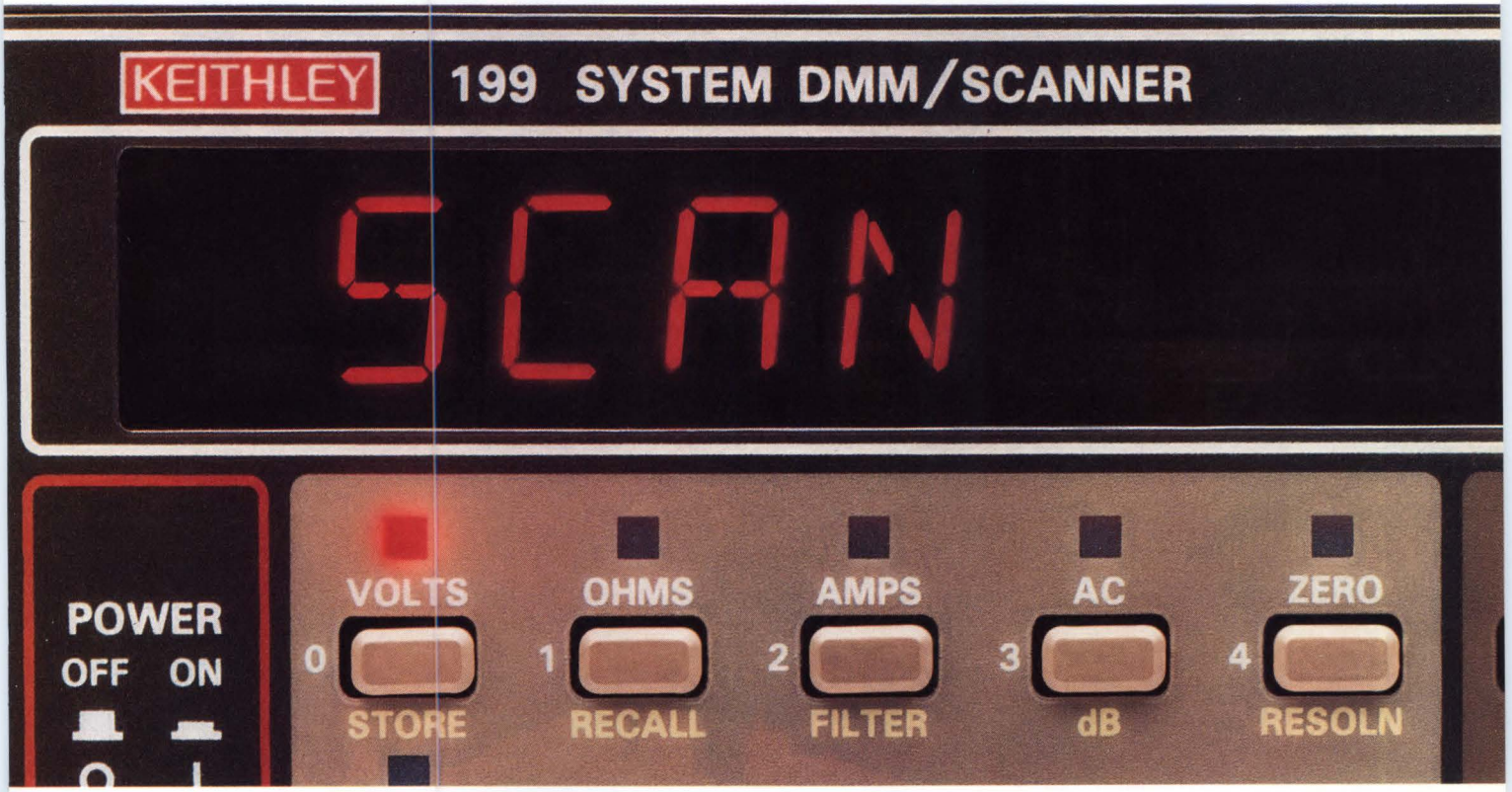

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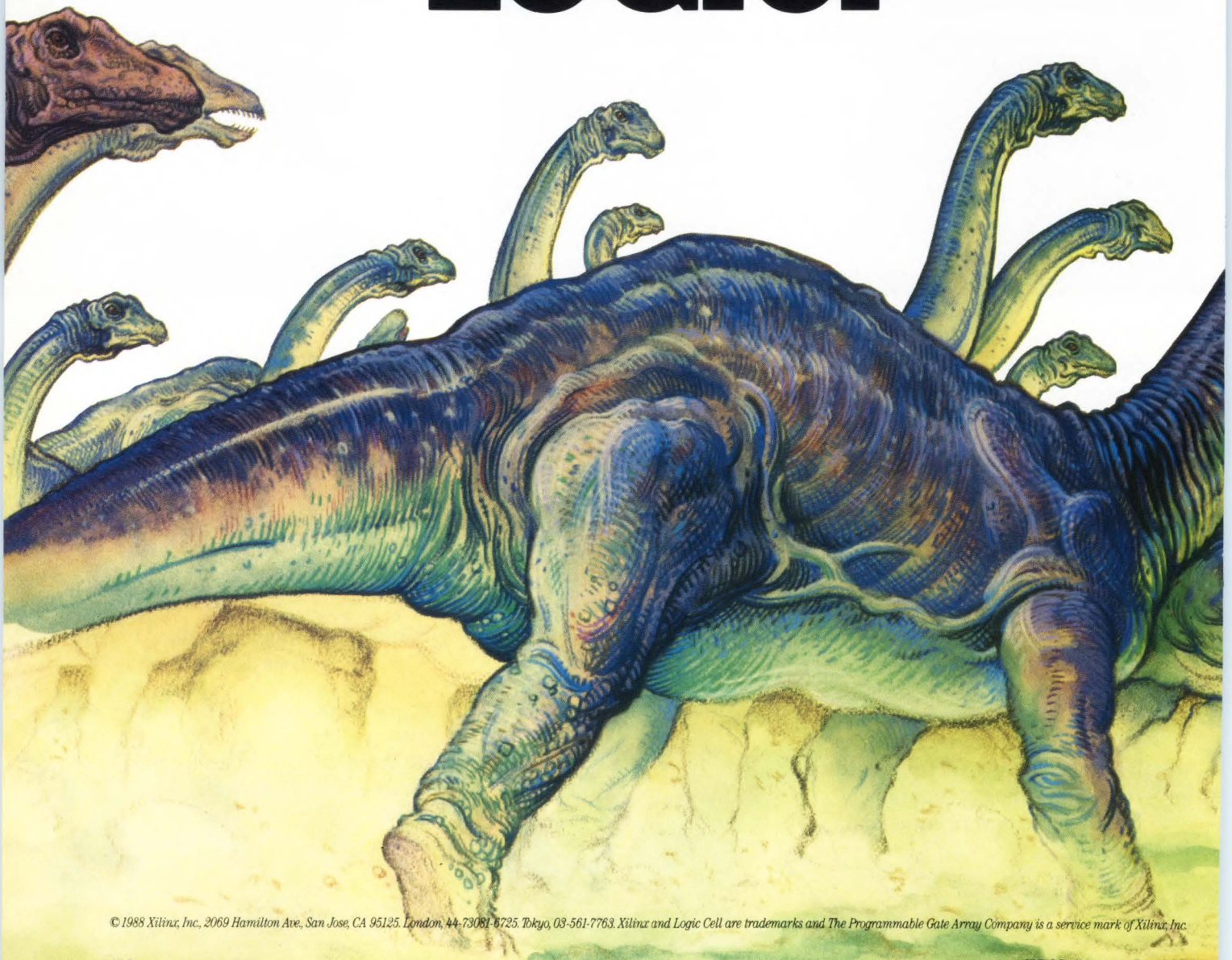

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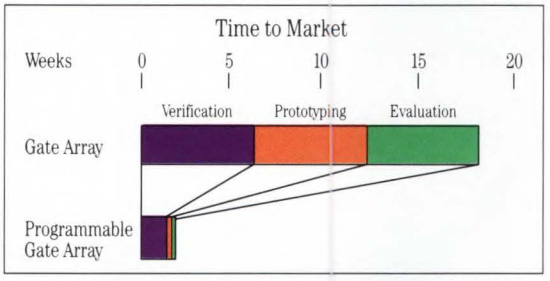

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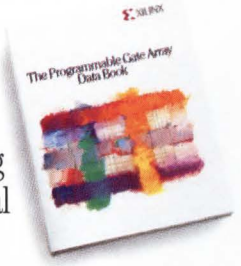

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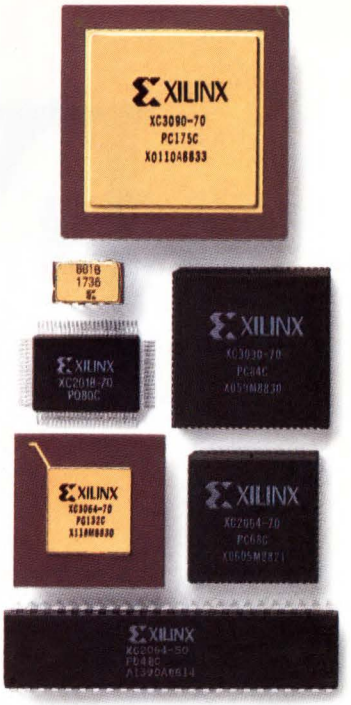

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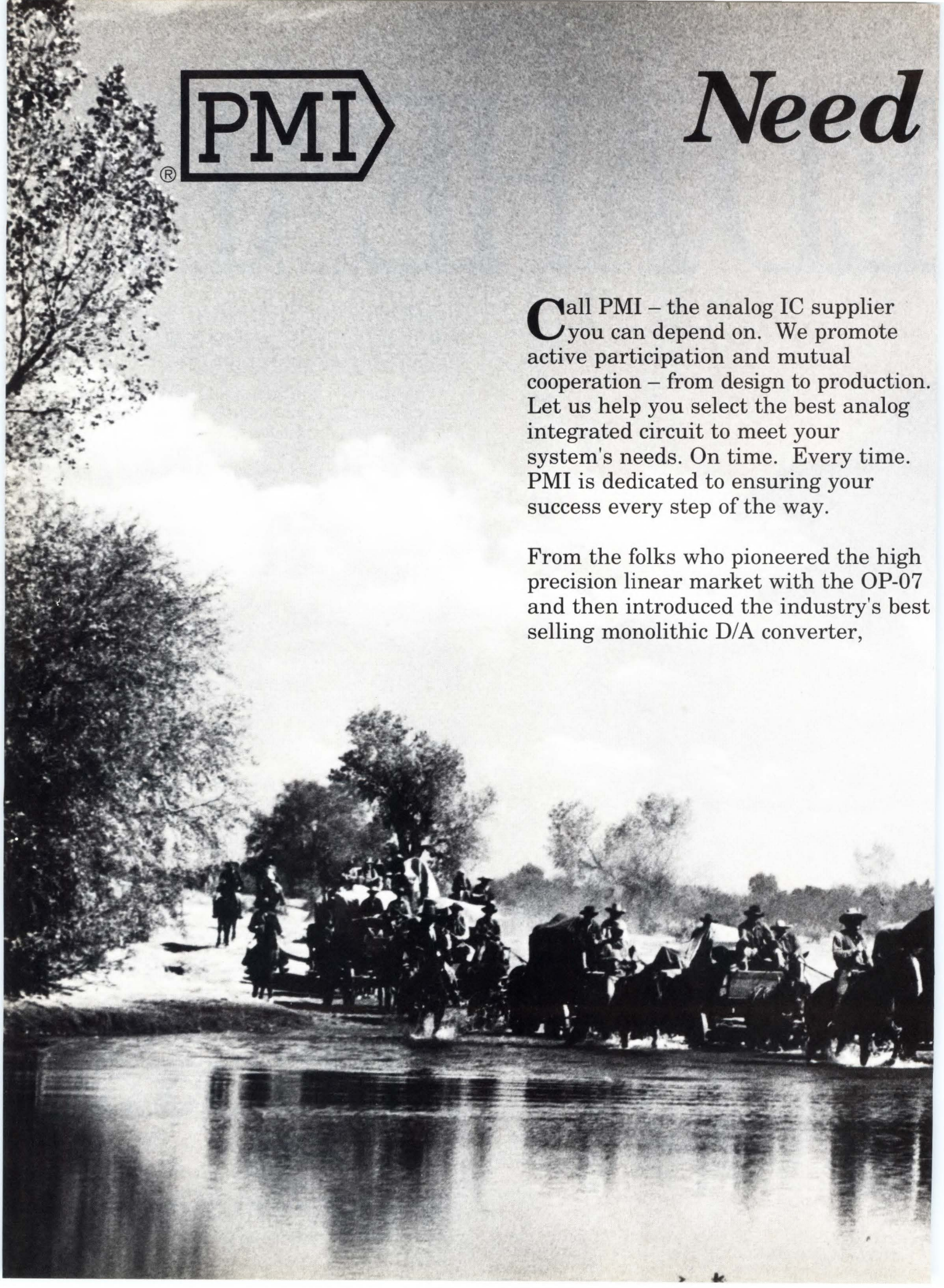

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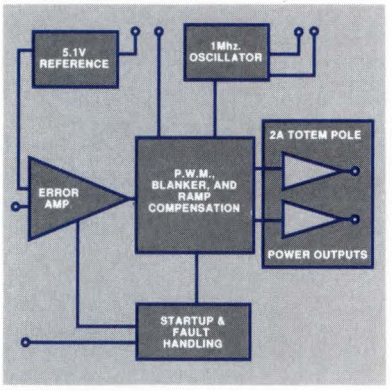
PART TYPE	SOFT START RESET	UNDER-VOLTAGE OUTPUT STATE	COMPARATOR TO OUTPUT DELAY
ML4823-5	COMPLETE	LOW	40 nS
UC1823-5	PARTIAL	FLOAT	50 nS

Micro Linear/Unitrode Comparison



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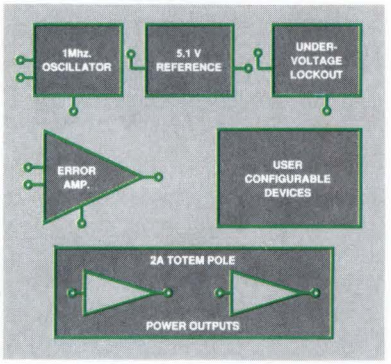

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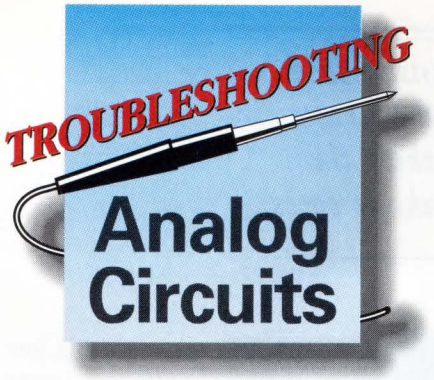


PART 6

Active-component problems yield to painstaking probing

Continuing the previous 5-part series on troubleshooting passive parts, this article from the prolific pen of Bob Pease presents the opening salvo of a 7-part series on troubleshooting active components. Bob begins with the simple stuff: diodes and rectifiers, optically coupled devices, solar cells, and batteries. Subsequent articles will expose the mysteries of more complex active devices.

Robert A Pease, *National Semiconductor Corp*

Even the simplest active devices harbor the potential for causing baffling troubleshooting problems. Consider the lowly diode. The task of a diode sounds simple: to conduct current when forward biased and to block current when reverse biased while allowing negligible leakage. That task sounds easy, but no diode is perfect, and their imperfections are fascinating.

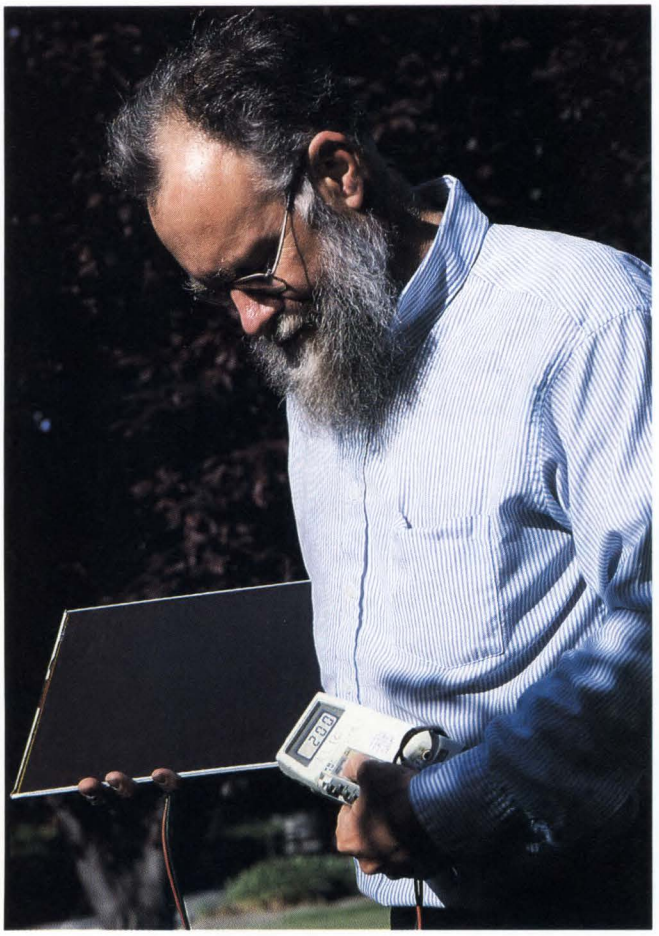
All diodes start conducting current exponentially at low, microampere levels, and the slope of their I/V curves is given by the equation: $g \approx (38.6\ mS/mA) \times I_F$, where mS = millisiemens = millimhos and I_F = forward current. But as the current levels increase, most diodes tail off to $g = (19\ mS/mA) \times I_F$ and then the conductance per milliampere gets even lower due to ohmic and other nonlinear factors. Therefore, at a large forward current, a diode's forward voltage, V_F, will be considerably larger than predicted by simple theory—and larger than desired. Of course, some rectifiers—depending on their ratings—*can* handle large currents from amperes to kiloamperes; but the V_Fs of all diodes, no matter what their ratings, err from the theoretical at high current levels.

These days, Schottky diodes have smaller V_Fs than ordinary pn diodes. However, even germanium diodes and rectifiers still have their following because their low V_Fs are similar to the Schottky's.

High-speed and ultrahigh-speed (sometimes also called high-efficiency) silicon rectifiers that are designed for switching-regulator and other high-frequency applications are also available. They don't have quite as low V_Fs as Schottky diodes and are not quite as fast, but they are available with high reverse-voltage ratings and thus are useful for certain voltage and power levels and certain circuit topologies that impress large flyback voltages on diodes.

When you reverse bias these various diodes, ah, that is where you start to see wild dissimilarities. For example, the reverse-current specification, I_{REV}, for many types of diodes is 25 nA max at 25°C. When you measure them, many of these devices actually have merely 50 or 100 pA of leakage. But the popular 1N914 and its close cousin, the 1N4148, actually *do* have about 10 or 15 nA of leakage at room temperature because of their gold doping. So although these diodes are inex-

Although 1N914s are inexpensive and popular, don't use them in low-leakage circuits because they're much leakier than other diodes with the same leakage specs.



Photographs by Peggi Willis

***With a solar-cell array, you** can make electricity when the sun shines.*

pensive and popular, it's wrong to use them in low-leakage circuits since they're much leakier than other diodes with the same leakage specs.

Why, then, do some low-leakage diodes have the same mediocre 25-nA leakage spec as the 1N914? Diode manufacturers set the test and price at the level most people want to pay because automatic test equipment can test at the 25-nA level—but no lower—without slowing down. If you want a diode characterized and tested for 100 pA, you have to pay extra for the slow-speed testing. Of course, high-conductance diodes such as Schottkys, germaniums, and large rectifiers have much larger reverse leakage currents than do signal diodes.

If you want a very low-leakage diode, use a transistor's collector-base junction instead of a discrete diode (**Ref 1**). You can easily find such "diodes" having less than 1-pA leakage even at 7V or 10 pA at 50V. Although this low leakage is not guaranteed, it's usually quite consistent. However, this diode generally doesn't turn ON or OFF very quickly.

Another source of ultralow-leakage diodes are the 2N4117A and the PN4117A, -18A, and -19A. These devices are JFETS with very small junctions, so leakages well below 0.1 pA are standard—1.0 pA max, guaranteed, for a $0.40 part.

"Computer diodes" like the 1N914 are popular because they turn OFF quickly—in just a few nanoseconds—much faster than low-leakage diodes. What isn't well known is that the faster diodes not only turn OFF fast, they *usually* turn ON fast. For example, when you feed a current of 1.0 mA toward the anode of a 1N914 in parallel with a 40-pF capacitance (20 pF of stray capacitance plus a scope probe or something similar), the 1N914 usually turns ON in less than 1 nsec. Thus, the V_F has only a few millivolts of overshoot.

But with some diodes—even 1N914s or 1N4148s from some manufacturers—the forward voltage may continue to ramp up past the expected dc level for 10 to 20 nsec before the diode turns ON; this overshoot of 50 to 200 mV is quite surprising (**Fig 1**). Even more astonishing, the V_F overshoot may get worse at low repetition rates but can disappear at high repetition rates (**Fig 1b** through **d**).

I spent several hours once discovering this particular peculiarity when a frequency-to-voltage converter suddenly developed a puzzling nonlinearity. The trickiest part of the problem with the circuit's diodes was that diodes from an earlier batch had not exhibited any slow-turn-on behavior. Further, some diodes in a batch of 100 from one manufacturer were as bad as the diodes in **Figs 1b** and **1c.** Other parts in that batch and other manufacturers' parts had substantially no overshoot.

When I confronted the manufacturers of the faulty diodes, they at first tried to deny any differences but at length admitted that they had changed some diffusions to "improve" the product. One man's "improvement" is another man's poison. Thus, you must always be alert for production changes that may cause problems. When manufacturers change the diffusions or the process or the masks, they may think that the changes are minor, but these changes could have a major effect on your circuit.

Many circuits, obviously, require a diode that can turn ON and catch, or clamp, a voltage moving much faster than 20V/μsec. Therefore, if you want any consistency in, for example, a circuit with pulse detectors,

you'll need to qualify and approve only manufacturers whose diodes turn ON consistently. So, as with any other unspecified characteristic, be sure to protect yourself against bad parts by first evaluating and testing and then specifying the performance you need.

One "diode" that does turn ON and OFF quickly is a diode-connected transistor. A typical 2N3904's emitter-collector diode can turn ON or OFF in 0.1 nsec with negligible overshoot and less than 1 pA of leakage at 1V, or less than 10 pA at 4V. However, this diode can only withstand 5 or 6V of reverse voltage, and most emitter-base junctions start to break down at 6 or 8V. Still, if you can arrange your circuits for just a few volts, these diode-connected transistors make nice, fast, low-leakage diodes. Their capacitance is somewhat more than the 1N914's 1 pF.

If you keep LEDs in the dark, they make an impressive, low-leakage diode because of the high bandgap voltage of their materials. Such LEDs can exhibit less than 0.1 pA of leakage when forward-biased by 100 mV or reverse-biased by 1V.

Of course, you don't have to reverse bias a diode a lot to get a leakage problem. One time I was designing a hybrid op amp, and I specified that the diodes be connected in the normal parallel-opposing connection across the input of the second stage to avoid severe overdrive (**Fig 2**). I thought nothing more of these diodes until we had the circuit running—the op amp's

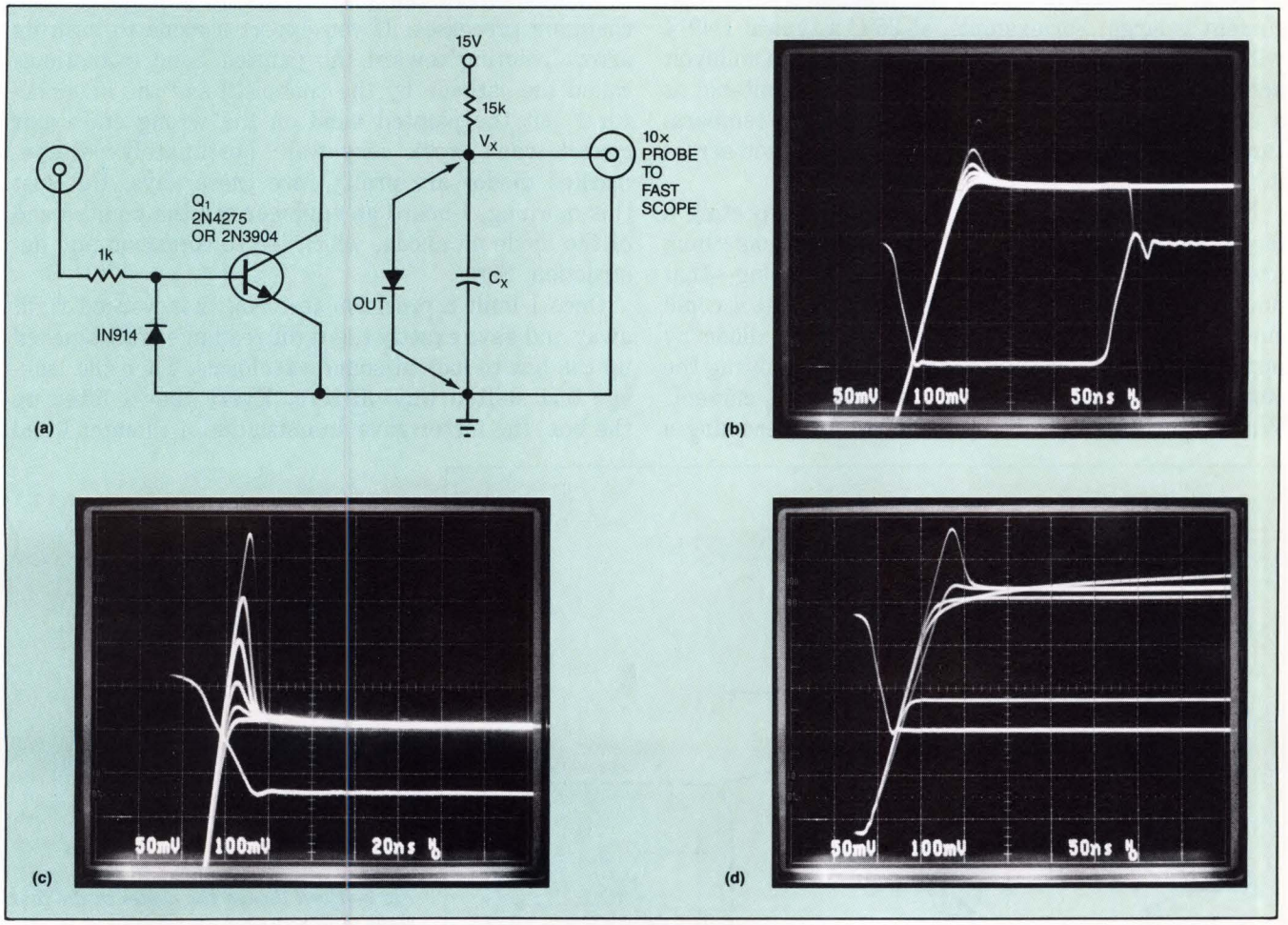


Fig 1—In this diode-evaluation circuit (a), *transistor Q_1 simply resets V_X to ground periodically. When the transistor turns OFF, V_X rises to about 0.6V until the diode starts conducting. In* **b,** *when dV_X/dt is 8V/μsec, this 1N4148 overshoots as much as 140 mV at input frequencies below 10 kHz before it turns ON. At higher frequencies—120, 240, 480, 960, and 1920 kHz—as the repetition rate increases, the overshoot shrinks and disappears. Maximum overshoot occurs when $f_{IN} \leq 7$ kHz. In* **c,** *when dV_X/dt increases to 20V/μsec, this same 1N4148 overshoots as much as 450 mV at 7 kHz but only 90 mV at 480 kHz and negligible amounts at frequencies above 2 MHz. In* **d,** *various diode types have different turn-on characteristics. The superimposed, 120-kHz waveforms are all invariant with frequency, except for the bad 1N4148.*

Always be alert for production changes that may cause problems.

voltage gain was falling badly at 125°C. Why? Because the diodes were 1N914s, and their leakage currents were increasing from 10 nA at room temperature to about 5 μA at the high temperature. And—remember that the conductance of a diode at zero voltage is approximately (30 to 40 mS/mA)×$I_{LEAKAGE}$. That means each of the two diodes really measured only 6 kΩ.

Because the impedance at each input was only 6 kΩ, the op amp's gain fell by a factor of four, even though the diodes may have only been forward or reverse biased by a millivolt. When we substituted collector-base junctions of transistors for the diodes, the gain went back up where it belonged.

You cannot safely assume that the impedance of a diode at zero bias is high if the junction's saturation current is large. For example, at 25°C a typical 1N914 will leak 200 to 400 pA even with only one millivolt across it. Therefore, a 1N914 can prove unsuitable as a clamp or protection diode—even at room temperature—despite having virtually no voltage biased across it.

How can diodes fail? Well, if you were expecting a diode to turn ON and OFF, but it does something unexpected—of the sort I have been mentioning—that unexpected behavior may not be a failure, but it could sure cause *trouble*. Further, you can kill a diode by applying excessive reverse voltage without limiting the current or by feeding it excessive forward current. When a diode fails, it tends to short out, becoming a small blob of muddy silicon rather than an open circuit. I did once see a batch of 1N4148s that acted like thermostats and went open circuit at 85°C, but such cases are rare.

One of the best ways to kill a diode is to ask it to charge up too big a capacitor during circuit turn on. Most rectifiers have maximum ratings for how much current they can pass on a repetitive and on a nonrecurring basis. I've always been favorably impressed by the big Motorola (Phoenix, AZ) books with all the curves of safe areas for forward current as a function of time and repetition rate. These curves aren't easy to figure out at first, but after a while they're fairly handy tools.

Manufacturers can play tricks on you other than changing processes. If you expect a diode to have its arrow pointing toward the painted band (sometimes called the cathode by the snobbish) and the manufacturer put the painted band on the wrong end, your circuit won't work very well. Fortunately reverse-marked diodes are pretty rare these days. But just this morning, I heard an engineer call the pointed end of the diode an anode, which led to confusion and destruction. Sigh . . .

Once I built a precision test box that worked right away and gave exactly the right readings until I picked up the box to look at some waveforms. Then the leakage test shifted way off zero. Every time I lifted up the box, the meter gave an indication; I thought I had

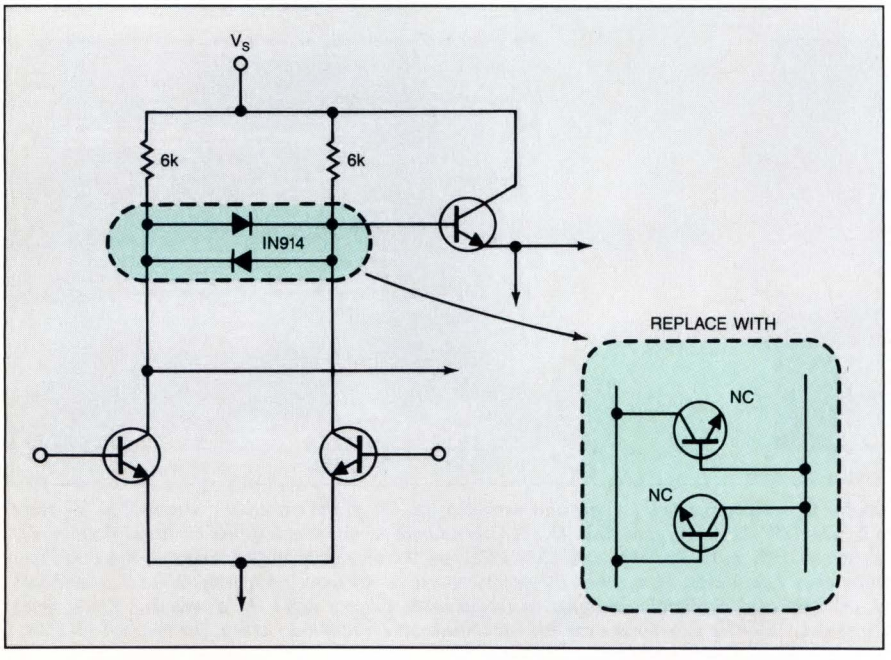


***Fig 2—Even though the diodes in the first stage** of this op amp are forward or reverse biased by only a millivolt, the impedance of these diodes is much lower than the output impedance of the first stage or the input impedance of the second stage at high temperatures. Thus, the op amp's gain drops disastrously.*

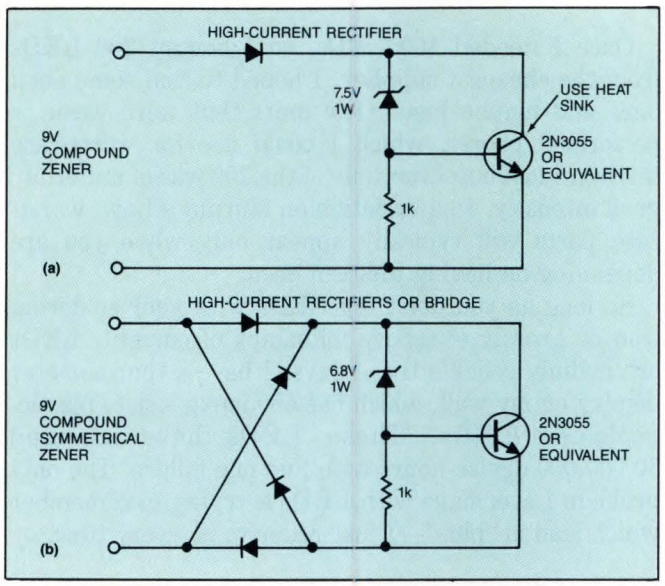


Fig 3—The power rating of this compound Zener (a) *is that of the power transistor. The second compound Zener,* ***(b),*** *is almost the same as* ***a*** *but acts as a symmetrical, matched, double-ended compound Zener.*

designed an altimeter. After some study, I localized the problem to an FD300, whose body is a clear glass DO-35 package covered with black paint. This particular diode's paint had been scratched a little bit, so when I picked up the test box, the light shone under the fixture and onto the diode. Most of these diodes didn't exhibit this behavior; the paint wasn't scratched on most of them.

To minimize such problems, I recommend the following strategies:

- Have each manufacturer's components specifically qualified for critical applications. This is usually a full-time job for a components engineer, with help and advice from the design engineer and consultation with manufacturing engineers.
- Establish a good relationship with each manufacturer.
- Require that manufacturers notify you when, or preferably before, they make changes in their products.
- Keep an alternate source qualified and running in production whenever possible.

My boss may gripe if I say this too loudly, but it is well known that having two good sources is better than having one. The argument that "One source is better than two" falls hollow on my ears. Two may be better than seven or eight, but one is *not* better than two.

Just about all diodes will break down if you apply too much reverse voltage, but Zener diodes are *designed* to break down in a predictable and well-behaved way. The most common way to have problems with a Zener is to starve it. If you pass too little current through a Zener, it may get too noisy. Many Zeners have a clean and crisp knee at a small reverse-bias current, but this sharp knee is not guaranteed below the rated knee current.

Some Zeners won't perform well no matter how carefully you apply them. In contrast to high-voltage Zeners, low-voltage (3.3 to 4.7V) Zeners are poor performers and have poor noise and impedance specs and bad temperature coefficients—even if you feed them a lot of current to get above the knee, which is very soft. This is because "Zeners" at voltages above 6V are really avalanche-mode devices and employ a mechanism quite different from and superior to the low-voltage ones, which are real Zener diodes. At low-voltage levels, band-gap references, such as LM336s and LM385s, are popular because their performance is good compared with low-voltage Zeners.

Zener references with low temperature coefficients, such as the 1N825, are only guaranteed to have low temperature coefficients when operated at their rated current, such as 7.5 mA. If you adjust the bias current up or down, you can sometimes tweak the temperature coefficient, but some Zeners aren't happy if operated off bias. Also, don't test your 1N825 to see what its "forward-conduction voltage" is because in the "forward" direction, the device's temperature-compensating diode may break down at 70 or 80V. This breakdown damages the device's junction, degrades the device's performance and stability, and increases its noise.

And before you subject a Zener to a surge of current, check its derating curves for current vs time, which are similar to the rectifiers' curves mentioned earlier. These curves will tell you that you can't bang an ampere into a 10V, 1W Zener for very long.

If you do need a Zener to conduct a surge of current, check out the specially designed surge-rated Zener devices—also called transient-voltage suppressors—from General Semiconductor Industries Inc (Tempe, AZ). You'll find that their 1W devices, such as the 1N5629 through 1N5665A, can handle a surge of current better than most 10 or 50W Zeners. If you need a *really* high-current Zener, a power transistor can help out **(Fig 3)**.

As mentioned earlier, a diode tends to fail by becom-

If you want a really low-leakage diode, use a transistor's collector-base junction instead of a discrete diode.

ing a short circuit when overpowered, and Zeners cannot absorb as much power as you would expect from short pulses. How dreadful; but, can IC designers serendipitously take advantage of this situation? Yes!

The V_{OS} of an op amp usually depends on the ratio of its first-stage load resistors. IC designers can connect several Zeners across various small fractions of the load resistor. When they measure the V_{OS}, they can decide which Zener to short out—or zap—with a 5-msec, 0.3-to-1.8A pulse. The Zener quickly turns into a low-impedance (~1Ω) short, part of the resistive network shorts out, and the V_{OS} improves.

In its LM108, National Semiconductor (Santa Clara, CA) first used Zener zapping, although Precision Monolithics (Santa Clara, CA) *talked* about Zener zapping first and used it extensively later on. Although Zener zapping is a useful technique, you have to be sure that nobody discharges a large electrostatic charge into any of the pins that are connected to the Zener zaps. If you like to Zap Zeners for fun and profit, they really do make a cute lightning flash in the dark when you zap them. Otherwise, be careful *not* to zap them.

These Zener zaps are also becoming popular in digital ICs under the name of "vertical fuses" or "antifuses." If an IC designer uses platinum silicide instead of aluminum metallization for internal connections, the diode resists zapping.

Once I needed 100 LEDs, so I bought 200 LEDs from the cheapest supplier. I hoped to find some good ones and maybe just a few units that were weak or performed poorly, which I could use for worst-case testing. I lost out; every one of the 200 was of uniformly good intensity. In a variation on Murphy's Law, worst-case parts will typically appear only when you are depending on having uniform ones.

So long as you don't fry LEDs with your soldering iron or grossly excessive milliamps of current, LEDs are awfully reliable these days. I have a thermometer display on my wall, which has 650 inexpensive, plastic-packaged LEDs. These LEDs have amassed 30,000,000 device-hours with just one failure. The only problem I ever have with LEDs is trying to remember which lead is "plus"—I just rederive it, every time.

Optoisolators

An optoisolator usually consists of an LED and a sensitive phototransistor to detect the LED's radiation. In the course of working with the cheaper 4N28s, I've found it necessary to add circuitry to achieve moderate speeds. For example, if you tailor the biases per **Fig 4,** you can usually get a 4N28's response up toward 50 kHz; otherwise the devices can't make even 4 kHz reliably. The trick is decreasing the phototransistor's turn-off time by using a resistor from pin 4 to pin 6.

I've evaluated many different makes and lots of

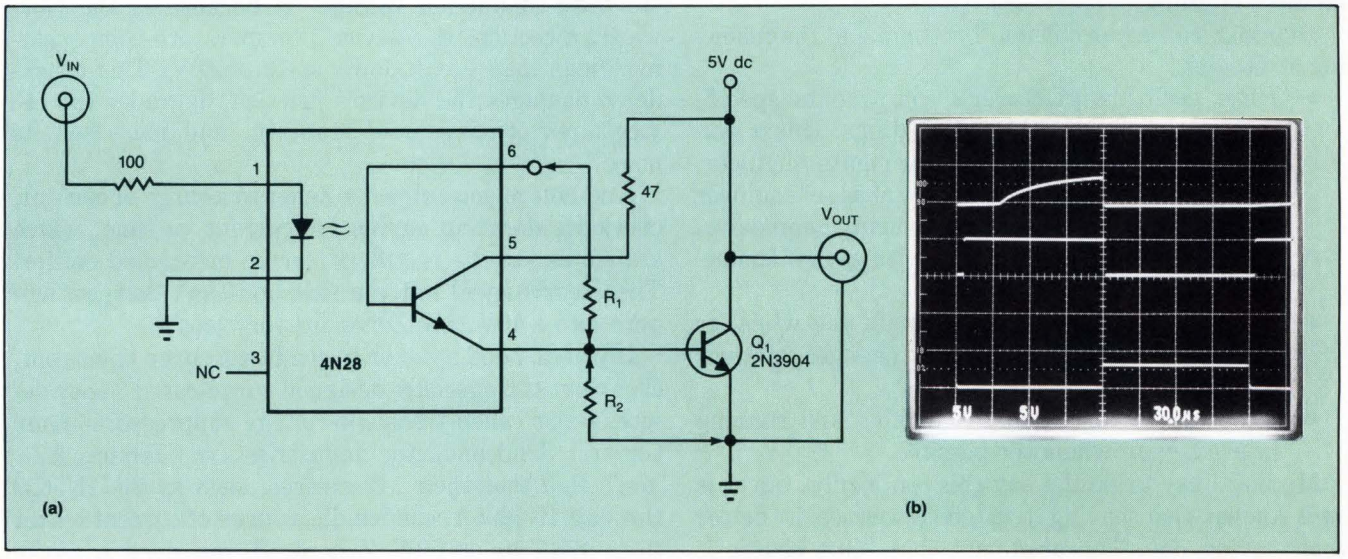
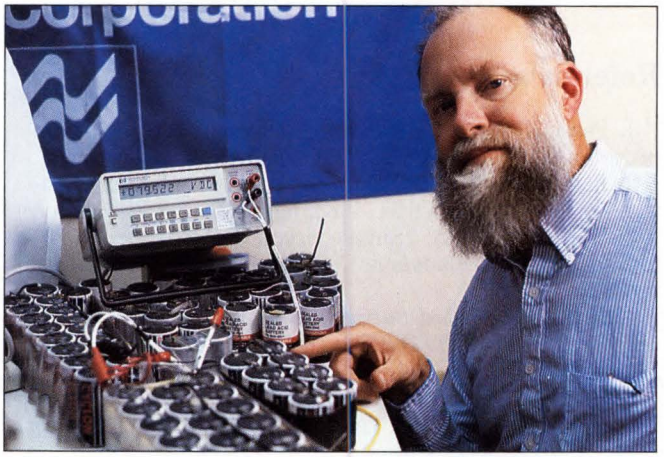


***Fig 4—Adding R_1 and R_2 to the** inexpensive 4N28 optoisolator lets it handle faster signals with less delay—5 µsec vs 60 µsec. The scope photo's bottom trace is an input waveform, the top trace is the circuit's output without R_1 and R_2, and the center trace is the output with R_1=2 MΩ and R_2=1 kΩ.*



Maintaining a healthy battery *involves careful attention to charging, discharging, and temperature.*

4N28s and have found widely divergent responses. For example, the overall current gain at 8 mA can vary from 15 to 104%, even though the spec is simply 10% min. Further, the transfer efficiency from the LED to the photodiode varies over a range wider than 10:1, and the β of the transistor varies from 300 to 3000. Consequently, the transistor's speed of response, which is of course related to β and $f_{-3\ dB}$, would vary over a 10:1 range.

If your circuit doesn't allow for gains and frequency responses that vary so wildly and widely, expect trouble. For example, two circuits, one an optoisolated switching regulator (**Ref 2**) and the other a detector for 4- to 20-mA currents (**Ref 3**), have enough degeneration so that any 4N28 you can buy will work. I used to have a group of several "worst-case" 4N28s from various manufacturers that I would try out in prototypes and problem circuits. Unfortunately, I don't have the marginal devices anymore, but they were pretty useful.

Also, the data sheets for optoelectronic components often don't have a clear V_F curve or list any typical values; the sheets list only the worst-case values. Therefore, you may not realize that the V_F of an LED in an optoisolator is a couple hundred millivolts smaller than that of discrete red or infrared LEDs. Conversely, the V_F of high-intensity, or high-efficiency, red LEDs tends to be 150 mV larger than that of ordinary red LEDs. And the V_F of DEADs (a DEAD is a Darkness Emitting Arsenide Diode; that is, a defunct LED) is not even defined.

Once I was troubleshooting some interruptor modules. In these modules, a gap separated an infrared LED and a phototransistor. An interruptor—say a gear tooth—in the gap can thus block the light. I tested one module with a piece of paper and nothing happened—the transistor stayed ON. What was that again? It turned out that the paper could diffuse the infrared light but not completely attenuate it. A thin sheet of cardboard or two sheets of paper would indeed block the light.

Solar cells

Extraneous, unwanted light impinging on the pn junction of a semiconductor is only one of many tricky problems you can encounter when you try to design and operate precision amplifiers—especially high-impedance amplifiers. Just like a diode's pn junction, a transistor's collector-base junction makes a good photodiode, but a transistor's plastic or epoxy normally does a very good job of blocking out the light.

When light falls onto the pn junction of any diode, the light's energy is converted to electricity and the diode forward biases itself. If you connect a load across the diode's terminals, you can draw useful amounts of voltage and current from it. For example, you could stack a large number of large-area diodes in series and use them for recharging a battery. The most unreliable part of this system is the battery. Even if you never abuse them, batteries don't like to be discharged a large number of cycles, and your battery will eventually refuse to take a charge.

So much for the charms of solar energy. It's much better to use a solar-powered night-light. Remember that one? A solar-powered night-light doesn't need a battery; it simply needs a 12,000-mile extension cord. To be serious, the most critical problem with solar cells is their packaging; most semiconductors don't have to sit out in the sun and the rain as solar cells do. And it's hard to make a reliable package when low cost is—as it is for solar cells—a major requirement.

In addition to packaging, another major trouble area with solar cells is their temperature coefficients. Just like every other diode, the V_F of a solar cell tends to *decrease* at 2 mV/°C of temperature rise. Therefore, as more and more sunlight shines on the solar cell, it puts out more and more current, but its voltage could eventually drop below the battery's voltage whereupon charging stops. Using a reflector to get even more light onto the cell contributes to this temperature-coefficient problem. Cooling would help, but the attendant compli-

A diode tends to short out when overpowered, and Zeners cannot absorb as much power from short pulses as you would expect.

cations rapidly overpower the original advantage of solar cells' simplicity.

Lastly, I want to say a few things about batteries. The only thing that batteries have in common with diodes is that they are both 2-terminal devices. Batteries are complicated electrochemical systems, and large books have been written about the characteristics of each type (**Refs 4 through 9**). I couldn't possibly give batteries a full and fair treatment here, but I will outline the basics of troubleshooting them.

First, always refer to the manufacturer's data sheet for advice on which loads will yield optimal battery life. When you recharge a nickel-cadmium battery, charge it with a constant current, not constant voltage. And be sure that the poor little thing doesn't heat up after it is nearly fully charged. If you're subjecting your battery to deep-discharge cycles, refer to the data sheet or the manufacturer's specifications and usage manual for advice. Some authorities recommend that you do an occasional deep discharge, all the way to zero; others say that when you do a deep discharge, some cells in the battery discharge before the others and then get reversed, which is not good for them. I cannot tell you who's correct.

Sometimes a NiCd cell will short out. If this happens during a state of low charge, the cell may stay shorted until you zap it with a brief burst of high current. I find that discharging a 470-μF capacitor charged to 12V into a battery does a good job of opening up a shorted cell.

When you recharge a lead-acid battery, charge it to a float voltage of 2.33V per cell. At elevated temperatures, you should decrease this float voltage by about 6 mV/°C; again, refer to the manufacturer's recommendations. When a lead-acid battery is deeply discharged (below 1.8V per cell), it should be recharged right away or its longevity will suffer due to sulfation.

Be careful when you draw excessive current from a lead-acid battery; the good strong ones can overheat or explode. Also be careful when charging them; beware of the accumulation of hydrogen or other gases that are potentially dangerous or explosive.

And, please dispose of all dead batteries in an environmentally sound way. Call your local solid-waste-disposal agency for their advice on when and where to dispose of batteries. Perhaps some can be recycled.

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Author's Biography

For information about Bob Pease, see the box, "Who is Bob Pease, anyway?" in the January 5, 1989, edition of EDN.

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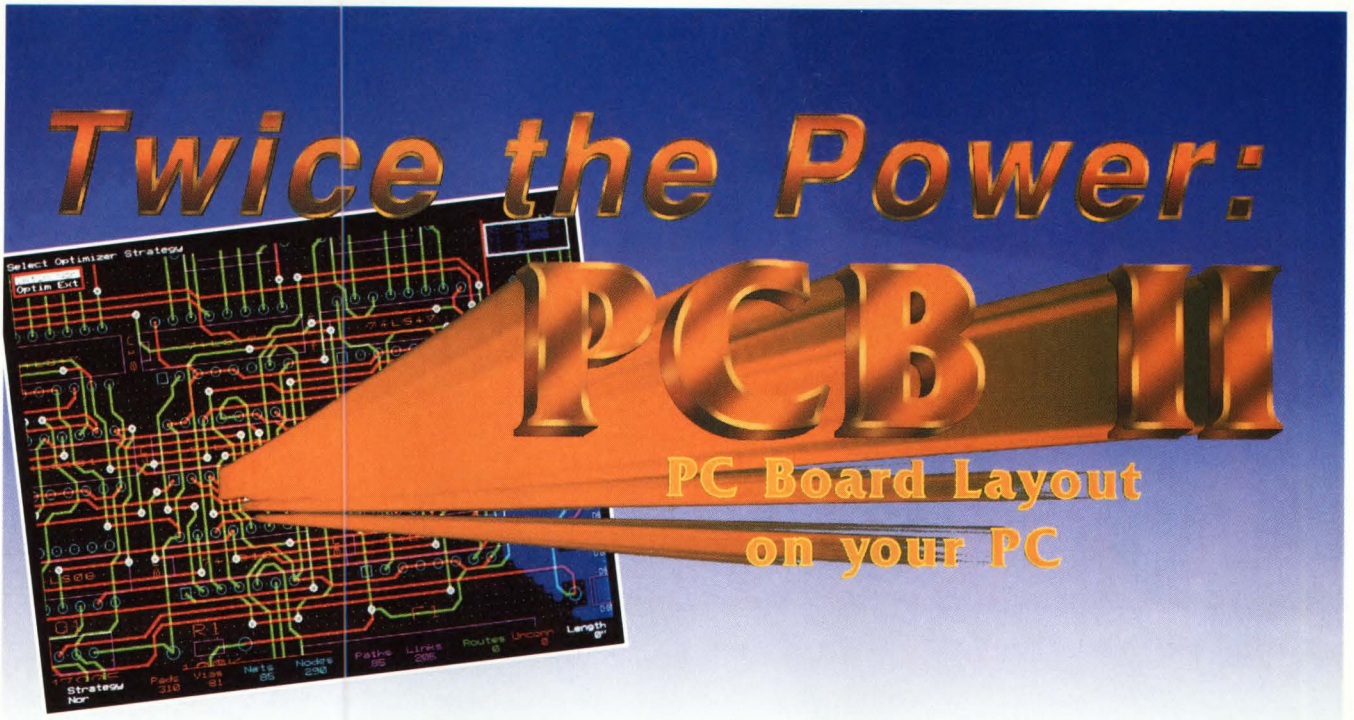

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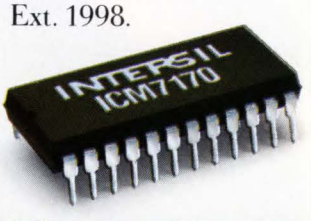

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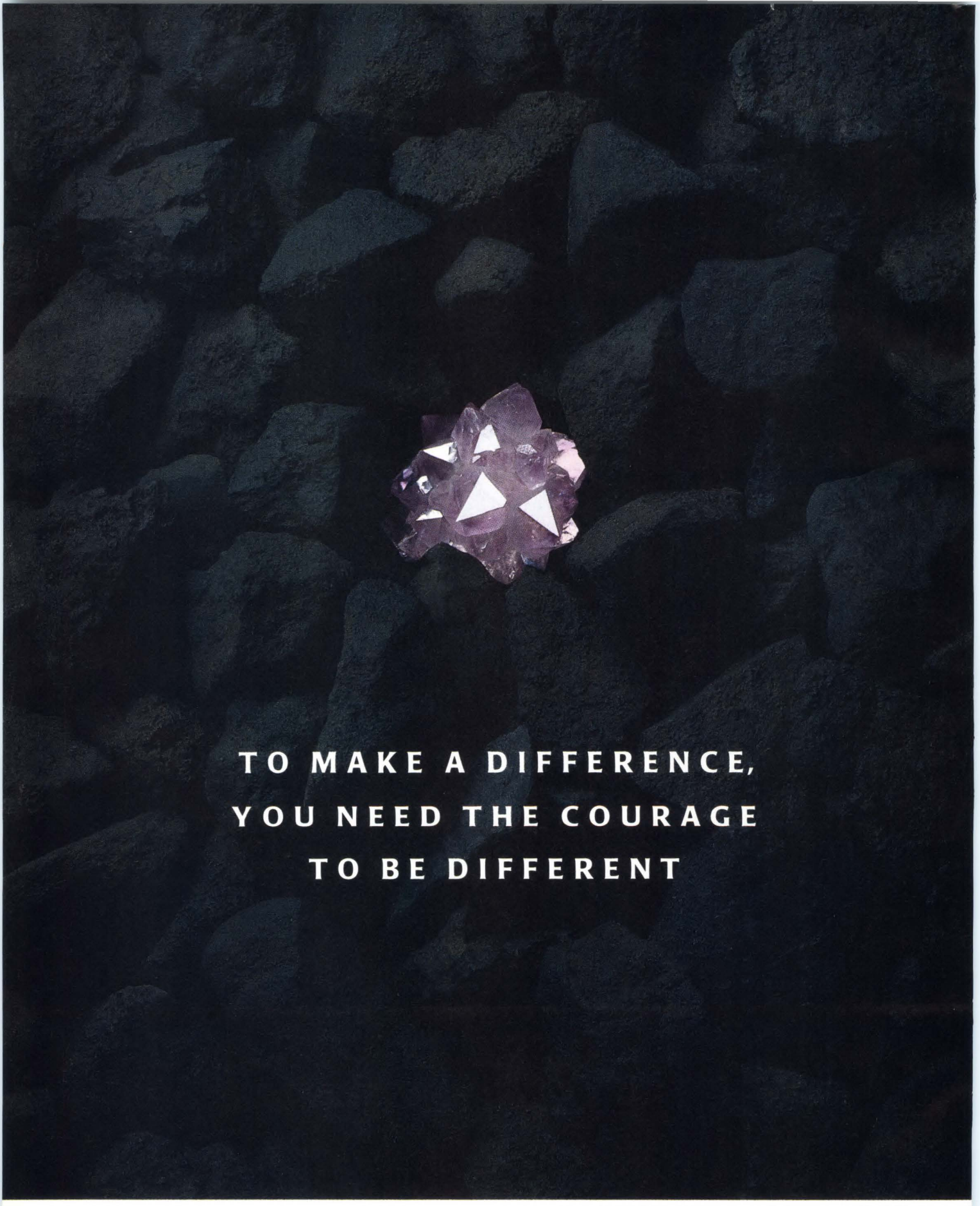

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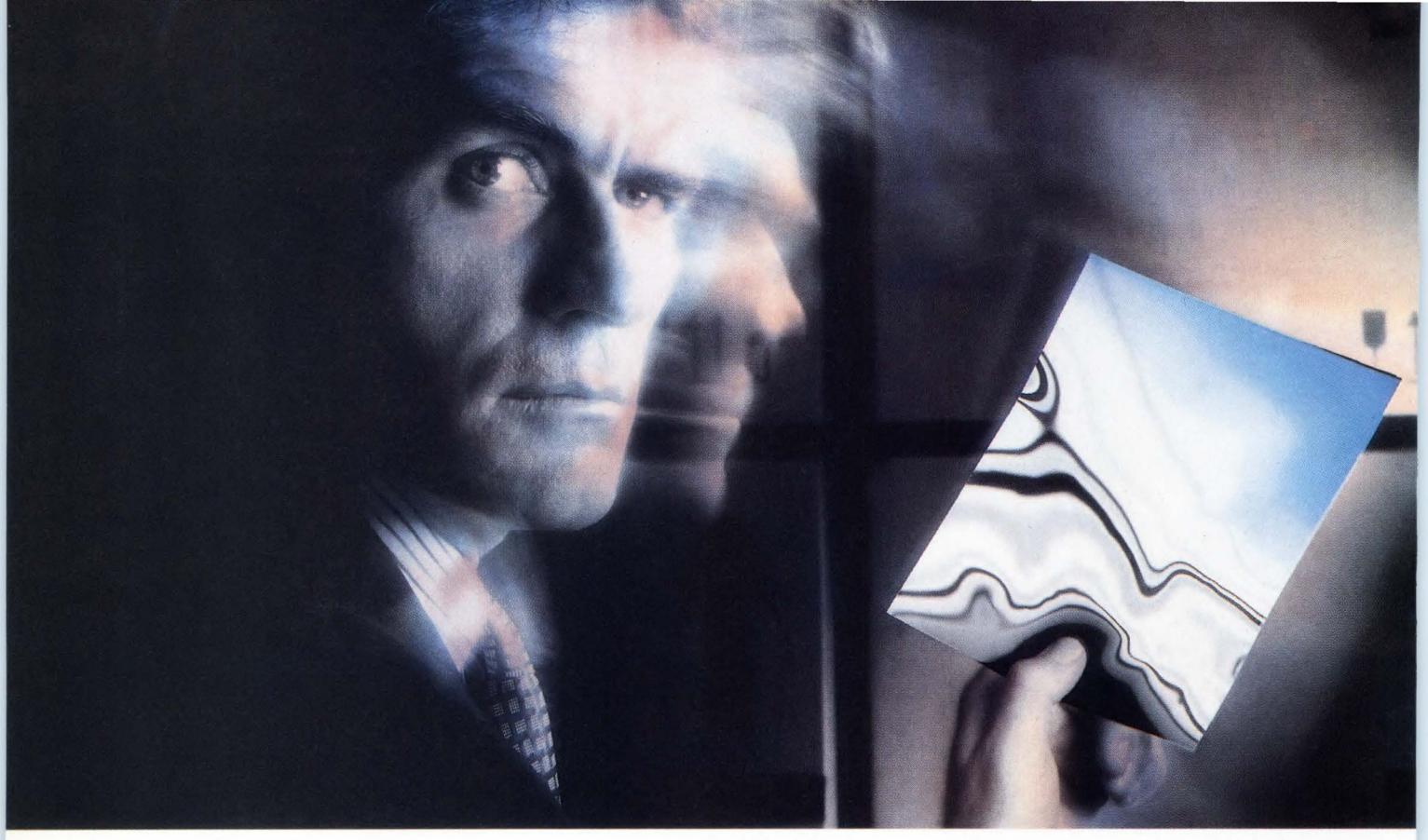

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ICI's research budget of $2.5 million per day has also created a separate technology that can print those stored color images.

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Icon lets software tools perform special tasks

The Icon language has many features that let you quickly build special-purpose tools for manipulating lists, sets, and tables.

Sandra L Wightman, *Allied Signals Companies*

If you must analyze numeric data that's already organized as tables or sets, or analyze textual data that entails unusual kinds of pattern matching, positional analysis, or sorting, you'll have a difficult time finding any off-the-shelf software tool that does exactly what you want. You may want to do different tasks than the very specific tasks performed by off-the-shelf programs. In that case, you can use the Icon language to build your own special-purpose tool.

Icon is a very high-level programming language developed by Ralph Griswold (the creator of Snobol) and his colleagues at the University of Arizona. The language lets you quickly write ad hoc programs for manipulating strings, lists, tables, and complex data sets. In particular, Icon has built-in facilities for string scanning and for coexpressions (a way of suspending the operation of expressions, which resume where they left off when reactivated). Icon is extensible: You can combine the simpler concepts in the language to create more complex commands or functions. And for most computers, the package includes an interpreter for easy development and a compiler, which speeds the execution of your finished programs.

You may well ask, "Why should I learn yet another programming language? Why shouldn't I write the tool in Basic or C, which I already know?" You certainly could do so—you can do almost any job in either of those languages if you have the expertise and plenty of time. But Icon has special features that are specifically designed for processing lists, tables, and sets, and these features make it easy for you to write programs quickly. Further, you won't have to spend a lot of money to sample Icon, because it's in the public domain; the **box** "Icon materials" tells you how to obtain Icon inexpensively.

Icon has nontraditional features

Icon has some unusual and powerful features. For example, it performs runtime data typing and provides a feature called "generators," which allows nonuniform control of iteration. Also, the language makes no provision for Boolean values; instead of returning a Boolean value, every expression either "succeeds" or "fails." An expression that succeeds generally returns the right-hand side of that expression; an expression that fails does not return anything. The left-hand side of the expression remains unchanged. One advantage of this success/failure feature is that, instead of writing a complex series of if . . . then . . . else conditional statements, you can write deeply nested expressions,

Icon has features that make it easy to manipulate strings, lists, tables, and complex data sets.

each depending on the success of the preceding expressions.

Nested success/failure expressions can appear cryptic to the novice, but for readability you can place the various expressions on separate lines. As you become more familiar with the language, however, you can write a single line of code that performs multiple functions and behaves differently under different conditions.

The simplest example of a success/failure statement is the following:

```
line := ''
write(line := read(input_file))
```

Line 1 creates an empty string variable called 'line.' In line 2, if the system fails to read a line from the input file, the left side of the expression remains unchanged and the variable 'line' remains empty. If the system reads a line from the input file, then the whole expression 'line := read(Input_file)' succeeds, with the result that the program first stores the input line in the string variable 'line' and then writes the contents of 'line' to the standard output stream.

Nesting allows you to extend the functions of this simple statement as follows:

```
line := ''
if (line := read(input_file)) then
  write(line[find("The",line) :0])
```

Now, if the program can read a line from the input file, it searches the new contents of string variable 'line' for the word "The." If the search fails, nothing is sent to the output; if the search succeeds, the program sends the remaining portion of 'line' (starting at the word "The") to the standard output stream.

Generators control program flow

A "generator" is an operator that manages the flow of control to permit iteration through a series of operations. The generator lets you evaluate the result of each operation, and then proceed to the next operation or break out of the loop. You can use a generator to iterate through a series of patterns—a procedure that could be difficult when the loop index must increment or decrement uniformly (as in Basic's FOR . . . NEXT construct).

For example, you might need to quickly create a set of all the variables having a 3-character prefix (such as VA_ or FL_) that are used in the program modules of a large project. You also might need to create a similar set of such variables already present in the project data dictionary. The generators feature makes it very easy to write a program to perform these tasks. The program then performs a set-subtraction operation to discover the differences between the two lists and to ensure that all development changes are reflected in the dictionary.

Icon has a number of built-in generators such as "upto" and "find," each tailored to a specific application, such as string parsing. Also, to meet more specific demands, the language lets you define your own generators; such definitions are easy to write and seldom require more than a few lines of code.

To see how a generator works in the context of the code for the success/failure examples above, suppose you want to verify that at least one space exists within the first 40 characters of the line read from the file. The following line of code searches the string; it returns nothing if there are no spaces, and it returns the value 40 (the right side of the expression) as soon as the search encounters a space.

```
write((i := upto(' ', line)) < 40)
```

If you want to know the actual position of the first blank, swap the left and right sides of the expression inside the Write statement and put the returned index into the variable 'i,' as follows:

```
write(40 > (i: = upto(" ", line)))
```

You might also want to know the position of every blank that has an index greater than 40. To find these positions, combine the "upto" generator with the control structure 'every . . . do . . . ':

```
every (40 < (i := upto(" ", line)))
  do write("Found a blank at position ", i)
```

The above code ignores blanks that have an index of less than 40, but it either writes the position of all blanks with indices greater than 40, or does nothing. This is an example of "goal-directed evaluation"; the generator iterates repeatedly in an attempt to make the condition succeed. Generation halts upon success or exhaustion of all the possibilities.

You're not restricted to searching for blanks or other single characters, however. Combining the 'find' gen-

erator with the 'every . . . do' control structure allows you to find the index of every instance of a pattern within a string. The code shown below tells you the position of every instance of "ado" in the given phrase—in this case, the code would return two values: 6 and 36. And, of course, if you want to search a whole file for the pattern, you could add a read operation and substitute the variable 'line' for the quoted string.

```
every i := find("ado", "Much ado about
  nothing is too much ado.") do
  write("The value is ", i)
```

Another important feature of Icon is the use of alternation, which is activated by the operator "|". Alternation allows you to specify a set of prioritized statements and to execute the first one that succeeds. To see how this works, you can once more use the example of searching a string for blanks. If you want the program to inform you if it finds no blanks, write a simple conditional statement:

```
if not write(40 < (i := upto(" ", line))) then
  write("Failed to find desired blank.")
```

You can simplify this statement somewhat (and extend the operations, if necessary) by using the alternation operator instead:

```
write(40 < (i := upto(" ", line))) |
  write("Failed to find desired blank.")
```

Alternation somewhat resembles C's conditional operator (?:), which acts like an if . . . then . . . else construct. The C conditional operator is less flexible than Icon's alternation operator because it works only with expressions that return a Boolean, numeric, or character value. The conditional operator requires exactly three operands; the first operand takes the value of the second operand if the condition is true, or the value of the third operand if the condition is false. In contrast, Icon's alternation operator lets you select and execute very complex procedures, depending on whether the conditional expression succeeds or fails, and you can nest multiple conditions.

In Icon, variables are not associated with any specific data type until runtime. Instead, every value is associated with a data type. For example, the digit 2 is numeric unless it's enclosed within quotes ("2"), when it becomes a string. As far as possible, the compiler or interpreter coerces any specific value to the data type required by the expression in which the value appears. Of course, a data structure such as a table cannot masquerade as a number in an equation, but the language allows for very flexible data typing, and many people use this feature to their advantage when writing in C.

Runtime data typing makes most variable declarations and memory allocations unnecessary. However, Icon does require type declarations for structures such as tables, sets, and lists. Runtime data typing makes it very easy to manipulate structures and strings, because you're not restricted to any predefined total size; you can dynamically concatenate or reduce these elements as needed.

Another strength of Icon is that it has many built-in

Icon materials

Icon is available for Unix and VMS computers and for most PCs. The cost is that of duplicating and shipping.

Unix versions come in a variety of formats and cost $25 to $50. The VMS version is available only on 1600- or 6250-bpi tape and costs $25.

Icon is currently available for the following personal computers: Atari ST, Macintosh/MPW, and machines that run MS-DOS, Unix PC, and Xenix. Prices range from $15 to $20.

You can obtain Icon disk or tape versions from Icon Project, Dept of Computer Sciences, Gould-Simpson Bldg, University of Arizona, Tucson, AZ 85721. Request an order form by mail, or obtain ordering information by calling (602) 621-2018. You can order the Icon Newsletter from the University of Arizona by calling (602) 621-6613; back issues cost $0.50 each, and a complete set (no. 1-27) costs $6. The University of Arizona also supplies *The Icon Programming Language* ($30) and *The Implementation of the Icon Programming Language* and update ($40).

You can obtain several versions of Icon electronically, at no cost, from the Icon Project's bulletin board system at (602) 621-2283.

Alternation lets you specify a set of prioritized expressions and execute the first one that succeeds.

facilities for processing structures such as lists, sets, and tables. These structures are all predeclared as to type, but they may change size dynamically. Some of the built-in operators associated with them are Push, Pop, Insert, Delete, and Sort. An Icon set conforms to the classical definition of a set insofar as it has no duplicate elements. Therefore, union, intersection, and other set operators all behave precisely as a mathematician would expect them to. Tables consist of a number of keys that are dynamically expandable, and each key is associated with a second field, which may be of any type you wish. To assign a field in a table, you need only write:

```
table_name[key_name]  :=  desired_data
```

Icon does have a few disadvantages, however. The principal one is that Icon is relatively unsupported, because it's public-domain software. Although members of the Icon project at the University of Arizona are always willing to hear about any bugs that you might find, and they are equally willing to consider proposed solutions (provided that these are coded in C), they don't guarantee that bugs will be resolved and corrected immediately. Also, they have no facilities for supporting individual users. On the other hand, the documentation includes a thorough, well-organized book by the Griswolds (**Ref 1**), an implementation manual, and a newsletter.

Another potential disadvantage is that, on certain systems, it's difficult to integrate system and library routines into your programs. Integrating modules written in other languages is also a challenge. On the bright side, C source code for Icon is readily available, and you can modify the existing source code or add new procedures to improve the interface between Icon and your system or other languages; most compilers let you recompile and relink the results of your modifications. Despite these minor inconveniences, you'll find Icon to be extremely valuable as a tool builder in many different situations. EDN

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1. Griswold, R E and M T Griswold, *The Icon Programming Language*, Prentice-Hall Inc, Englewood Cliffs, NJ, 1983.
2. *The Implementation of the Icon Programming Language*, Princeton University Press, Princeton, NJ, 1986.

Author's biography

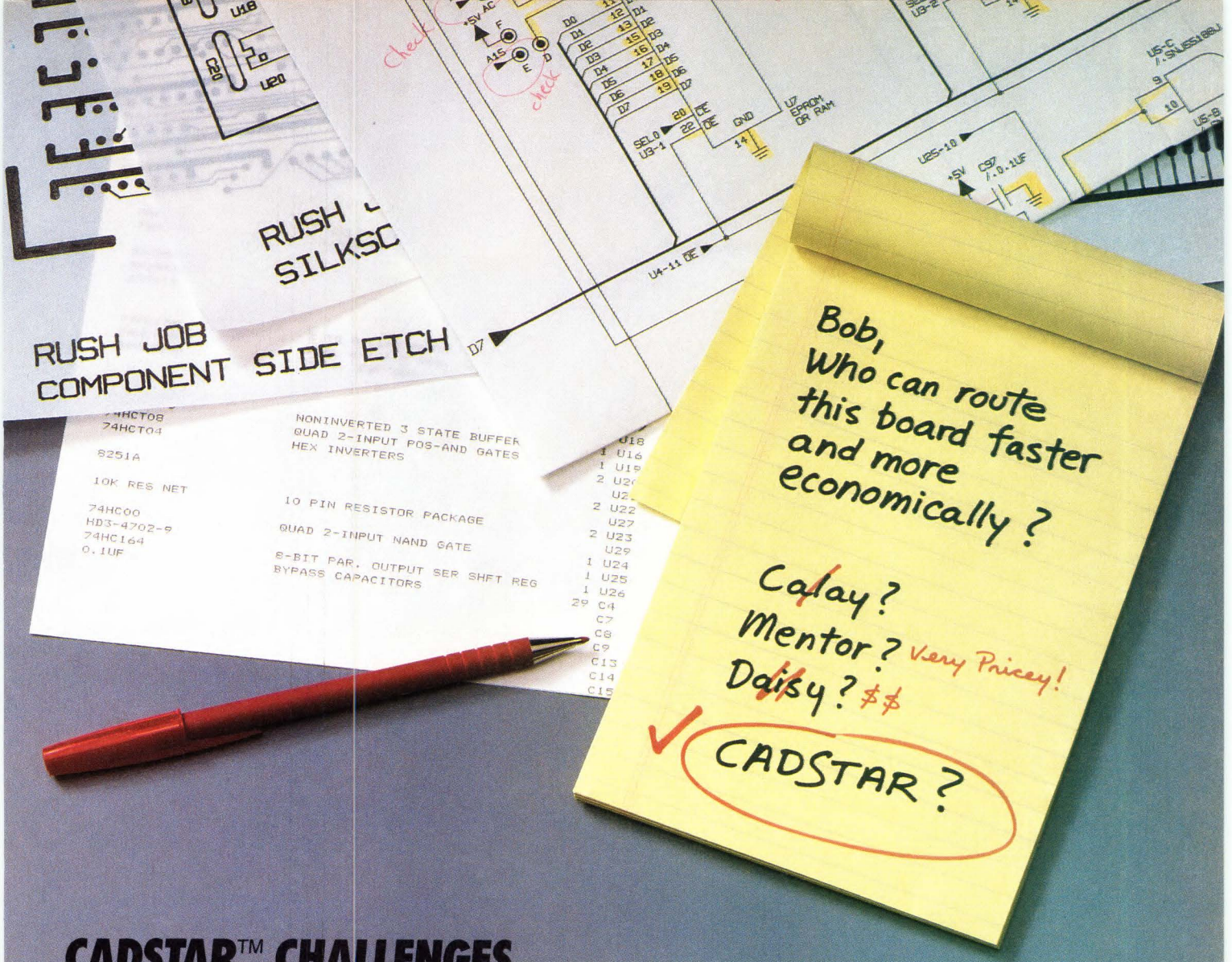
Sandra Wightman is a software engineer with the AiResearch Tucson Div of Allied Signals Companies, where she leads a project on the design and development of the C-17 cabin-pressure-control system software. Sandra has studied at the University of Washington, holds a Bachelor of Music degree from the University of Arizona, and is doing graduate work in computer science at the University of Arizona. She is active in the Society of Women Engineers, and in her leisure time she enjoys listening to classical music, playing the violin, racquetball, badminton, and hiking.

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

WHAT'S COMING IN EDN

EDN's August 17 edition is our annual military special issue. The staff-written Special Report will be devoted to the Ada language and real-time Ada development systems. This article will provide an in-depth look at this language, and how you can use it to solve problems in both commercial and military software projects. Other staff-written military articles will cover ECL-programmable gate arrays and PLDs, and relays for military aircraft. This issue will also include nonmilitary articles, such as part 7 of Bob Pease's troubleshooting analog circuits series, and our regular departments.

In September, look for reports on nonvolatile memories, signal conditioners, and 8- and 16-bit microcontrollers.



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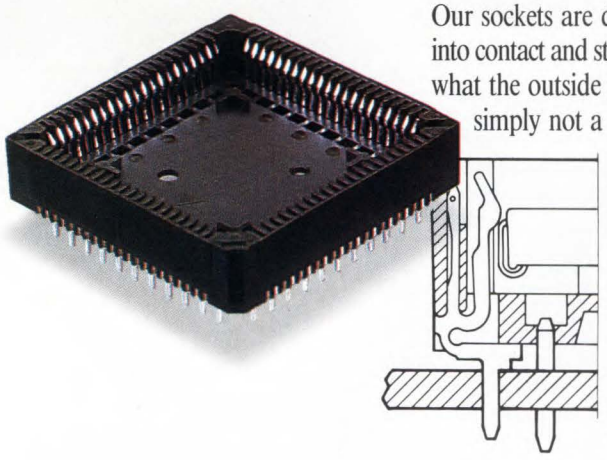

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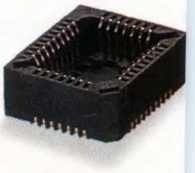

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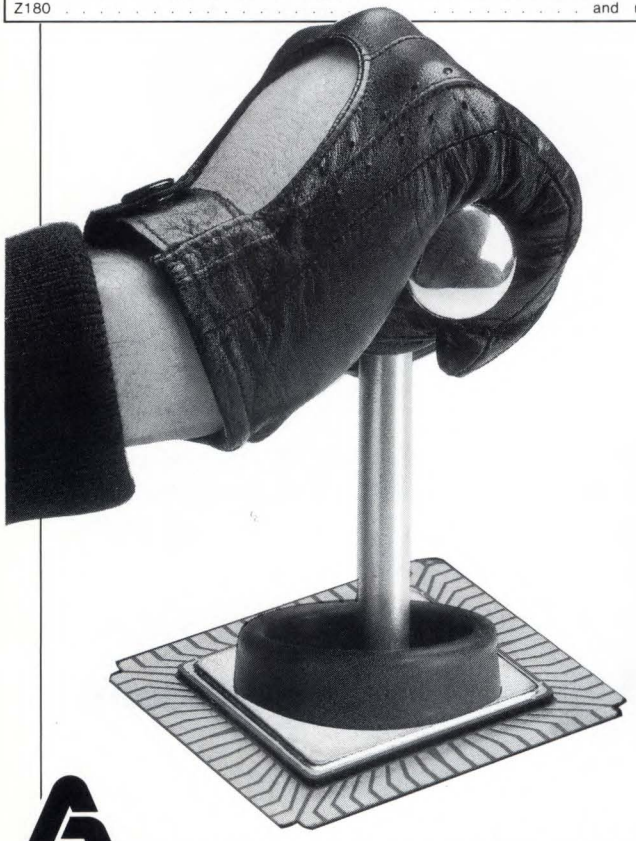

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EDITED BY CHARLES H SMALL

Quadrature oscillator locks to reference

John Quinlan
Biddle Instruments, Blue Bell, PA

The oscillator in **Fig 1** can phase lock to a reference over a frequency range of 30 to 1600 Hz. Its output level is 8V. You can use potentiometer R_7 to adjust the phase relationship between the oscillator's output and the reference by a constant amount within the range of ±85°. This constant phase difference is independent of frequency.

The circuit comprises two sections: the oscillator and the phase shifter. You can find details of the voltage-controlled, dual-integrator, quadrature-oscillator portion of the circuit in many standard texts and applications handbooks. R_3 and R_4 provide feedback to ensure oscillation at startup; D_1, R_1, R_2, and the diode bridge limit the oscillation's amplitude. IC_1 and IC_2's Y1 pins are the VCO inputs.

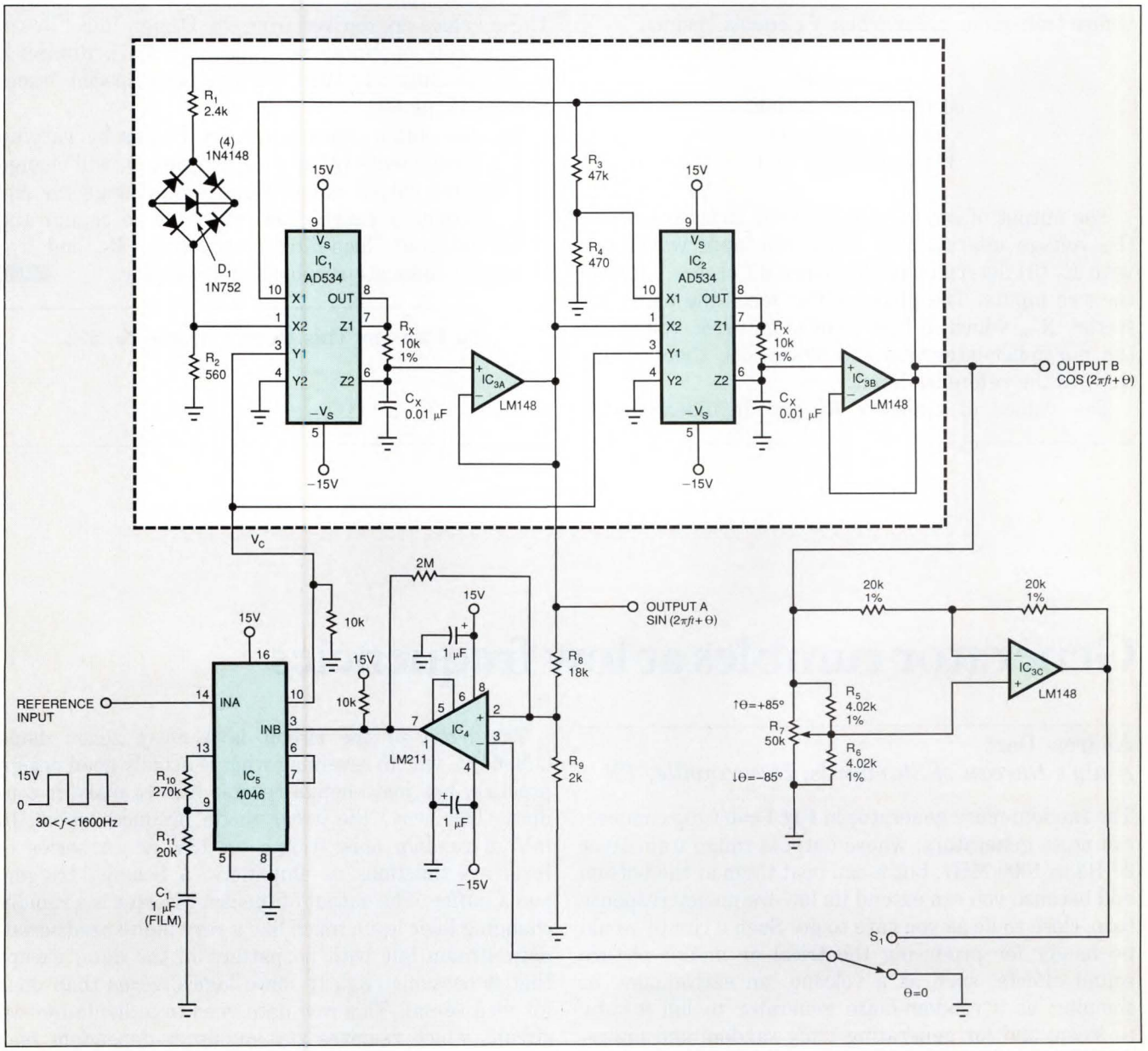

Fig 1—This quadrature oscillator not only can phase *lock to an input reference signal, but it can also set the phase difference between its output and input.*

Op amp IC_{3C} and comparator IC_4 form the sign changer. The sign changer first multiplies IC_{3B}'s output, OUTPUT B, by a constant, β, which you set between −1 and +1 with potentiometer R_7. Comparator IC_4 compares this signal with the oscillator's other, orthogonal output, output A. Note that resistors R_8 and R_9 attenuate output A by a factor of 10.

Fig 2 shows a simplified schematic of the sign changer. If the changer's input is cosΘ and β is the attenuation factor of R_7, then IC_{3C}'s output, V_A, is

$$V_A = \cos\Theta(2\beta - 1),$$

where $0 \le \beta \le 1$.

IC_4 is a comparator that produces a square wave whose transitions occur when V_A equals $\frac{1}{10}\sin\Theta$:

$$V_A = \tfrac{1}{10}\sin\Theta$$
$$\cos\Theta(2\beta - 1) = \tfrac{1}{10}\sin\Theta$$
$$\tan\Theta = 10(2\beta - 1)$$
$$\Theta = \tan^{-1}(10(2\beta - 1))$$

The output of comparator IC_4 thus changes state at the voltage intersections of its two input waveforms with R_7 (β) determining the phase difference between the two inputs. The phase shifter feeds the phase detector, IC_5, which in turn applies an error voltage to the multiplier-integrators to phase lock their oscillations to the reference input.

The values of resistors R_5 and R_6 linearize the arctangent function inherent in the phase shifter. These values are derived from the Design Idea "Resistors provide nonlinear pot taper" by Mark Rumreich in EDN's July 21, 1988, Design Idea Special Issue, Volume II, pg 69.

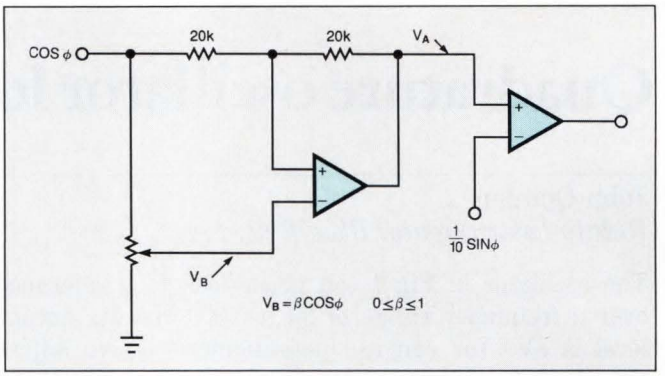

Fig 2—This phase shifter can vary *its output over a ±85° range.*

You can obtain other frequency ranges by varying timing components R_X and V_X; varying D_1 will change the circuit's output amplitude. If you change the circuit's frequency range, you may have to change the phase detector's loop-filter components, R_{10} and R_{11}, to ensure adequate response and stability. EDN

To Vote For This Design, Circle No 522

Generator rumbles at low frequencies

Andrew Dart
Andy's Bureau of Standards, Duncanville, TX

The random-noise generator in **Fig 1** can't top commercial noise generators, whose outputs range from 10 or 20 Hz to 1000 MHz, but it can beat them at the bottom end because you can extend its low-frequency response to as close to dc as you care to go. Such a circuit would be handy for producing theatrical or motion-picture sound effects, such as a volcano, an earthquake, or thunder; as a random-noise generator to lull a baby to sleep; and for generating truly random and unpredictable mechanical vibrations or electrical noise for electronic countermeasures, simulation, or testing.

The heart of the circuit is a noisy zener diode (1N964B), which, reversing what is usually good design practice, has just enough reverse bias to make it conduct. This way, the zener diode produces about 10 mV of random noise riding on 13V dc. A series of inverters functions as amplifiers, a Schmitt trigger, and a buffer. The output of the last inverter is a rapidly changing logic level, much like a very high-speed serial-data stream but with no pattern in the data, except that it contains slightly more logical zeros than ones (or vice versa). This raw data goes to a divide-by-two circuit, which removes any amplitude-dependent bias in the data stream, thus assuring a 50/50 mix of highs and lows.

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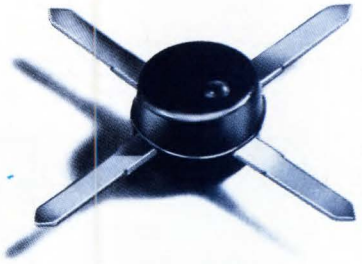

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MAR-6	DC-2000	20	16	11	9	0	2.8	1.29	(25)
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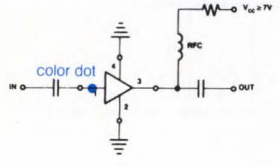

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C113-Rev. D

Because of a specific application, this circuit has a crystal-controlled oscillator; you could use any oscillator circuit you like. The master-clock signal goes to IC_4, which generates a 4-phase clock. The 4-phase clock eliminates glitches and races in following circuitry.

The first phase clocks a random high or low into IC_{5A}. The second phase enables this random high or low to the $\overline{UP}$ input of counter IC_7 via IC_{6A}. The counter either counts up or does nothing, depending the previously latched state of the random data stream. The two remaining pulses of the 4-phase clock perform a similar function for the counter's $\overline{DOWN}$ input. Thus, counter IC_7 counts up, down, or not at all, in a random fashion.

Finally, an 8-bit A/D converter translates the random output of the counter into a random analog signal. Note that because the 8-bit counter may increment, decrement, or remain unchanged for each succeeding clock cycle, the count stays unchanged, on the average, half the time. This situation produces a much more interesting output signal than if the counter had to increment or decrement on every clock cycle.

In order to prevent abrupt jumps in the analog output, the counter cannot overflow or underflow. You prevent overflow by simply connecting the $\overline{CARRY}$ output of the most significant counter stage to the $\overline{LOAD}$ inputs of both stages and leaving all eight preset input lines tied high. To prevent underflow, you can't simply connect the BORROW line of the most significant counter through an inverter to the $\overline{RESET}$ inputs of both stages. You must hold the $\overline{RESET}$ line high from the occurrence of the $\overline{BORROW}$ output until the next UP clock pulse. Left-over gates IC_{6C} and IC_{6D} configured as an SR latch do this job. EDN

To Vote For This Design, Circle No 523

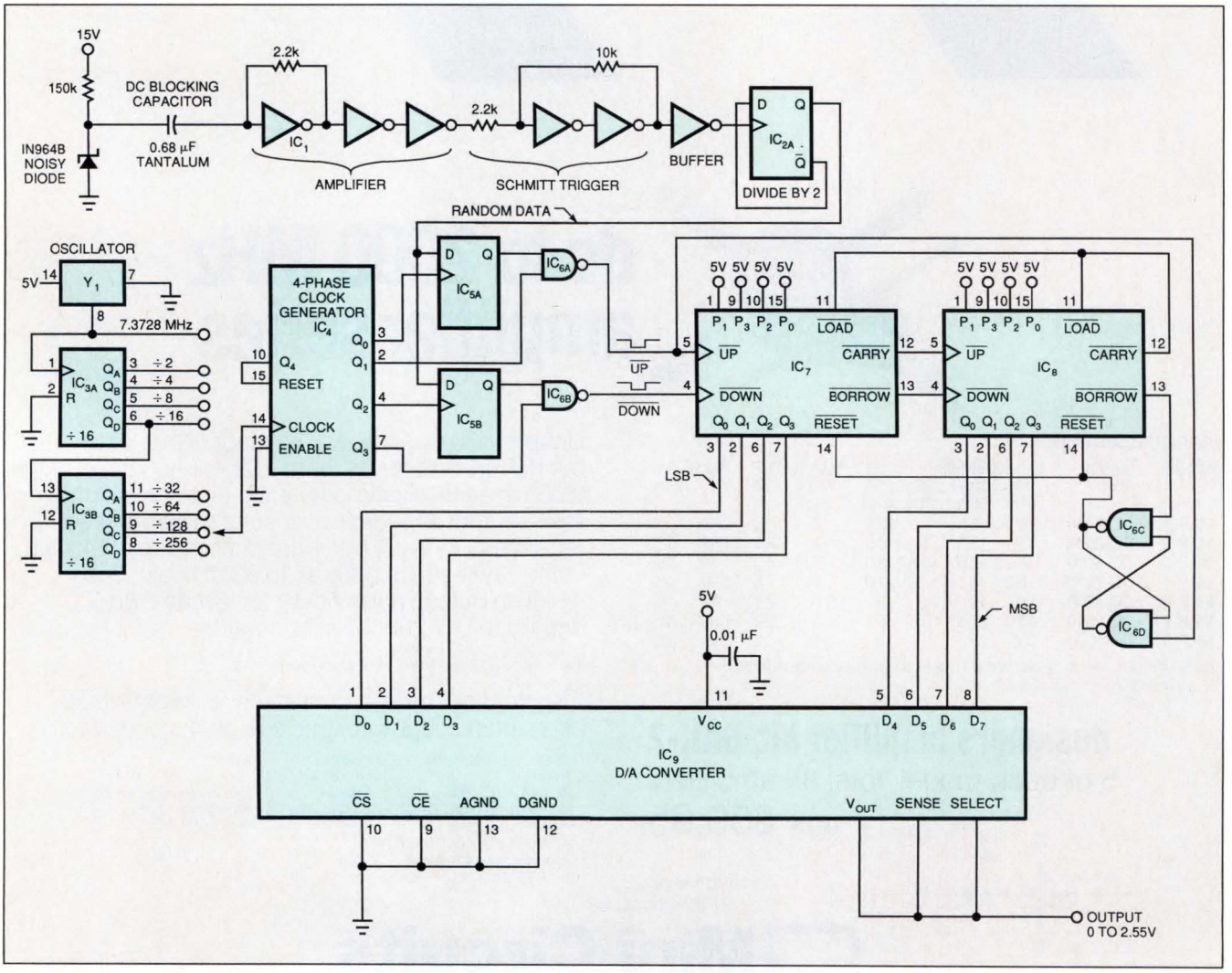


Fig 1—This low-frequency random-noise *generator uses the conditioned output of a noisy zener diode to randomly drive an up/down counter. An inexpensive A/D converter transforms the counter's random output into an audio signal.*

LINEAR TECHNOLOGY

DESIGN NOTES

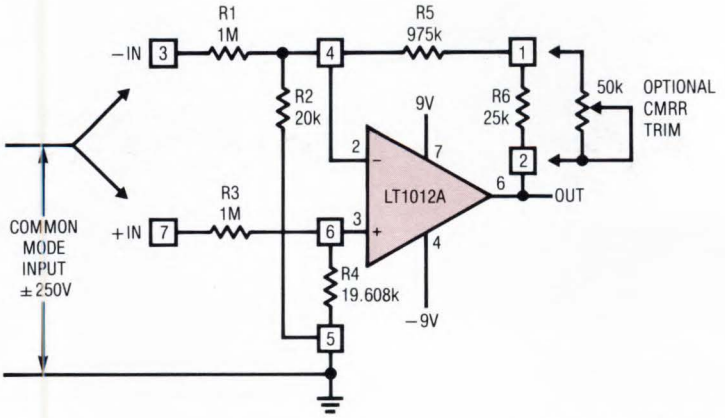
Number 25 in a series from Linear Technology Corporation *August, 1989*

A Single Amplifier, Precision High Voltage Instrument Amp

Walt Jung
George Erdi

Instrumentation amplifier (IA) circuits abound in analog systems, in fact virtually any linear applications handbook will show many useful variations on the concept[1]. While this may be somewhat bewildering to a newcomer, all the variations have uses which are differentiated and valuable. A good working knowledge of the alternate forms can be a powerful tool towards designing cost-effective high performance linear circuits.

A case in point is a single amplifier *precision qualified* high voltage IA. This circuit must withstand very high common mode voltages at the input, yet it should still be relatively simple, while at the same time capable of high performance. Whereas dual summing amplifier setups can provide high input-voltage qualifications, a more simple single amp solution is often sought. An IA topology which achieves all the above objectives is shown in Figure 1, the "Precision High Voltage IA." The circuit employs the virtues of two key parts in performing its function; the resistor array and the op amp used with it.



TYPICAL PERFORMANCE:
COMMON MODE REJECTION RATIO = 74dB (RESISTOR LIMITED)
WITH OPTIONAL TRIM = 130dB
OUTPUT OFFSET (TRIMMABLE TO ZERO) = 500μV
OUTPUT OFFSET DRIFT = 10μV/°C
INPUT RESISTANCE = 1M (CM)
2M (DIFF)
BANDWIDTH = 13kHz
BATTERY CURRENT = 370μA

R1–R6: VISHAY 444 ACCUTRACT THIN-FILM SIP NETWORK
[X] : VISHAY 444 PIN NUMBERS

VISHAY INTERTECHNOLOGY, INC.
63 LINCOLN HIGHWAY
MALVERN, PA 19355

Figure 1. ±250V Common Mode Range Instrumentation Amplifier (A_V = 1)

Here, the resistor network is a precision high-voltage design thin-film system, comprised of R1 through R6. This array, a Vishay type 444, is a thin-film SIP with a 250V/100mW input rating for R1–R3. This high voltage rating allows direct connection to AC or DC line shunts for current monitoring, level shifting from high voltage DC rails, and other such interfacing feats normally uncommon to low voltage IC circuits. The 444 network has a basic common-mode attenuation of 50 times, thus an op amp with an input voltage range of ±10V would allow a theoretical range at input pins 3–7 of ±500V. So, devices with standard ±15V supplies are basically compatible with the network operating parameters. While the network has a CM attenuation of 50 times, the differential signal scaling is nominally unity, with an error of ±0.1%. Functionally then, the differential mode input signal between pins 3–7 is referred at the output of this circuit to the local ground (pin 5 of the network), with unity gain scaling.

A second keen application point which is a large determining factor towards the overall success of this type of IA is the relative precision of the op amp A1. Indeed, this amplifier is the second "key ingredient" towards high overall performance. Because the circuit basically amplifies the input offset voltage of A1 by the same factor as the CM attenuation, both the initial offset and the drift of A1 can become limitations, as can the CMRR of the device. Here an LT1012A op amp is used, a device with a 25μV(max) input offset voltage; the output offset will then be 1.25mV or less, worst case. The overall CMRR of the circuit has two primary sources for errors, the basic ratio match of the network halves, and to a lesser degree, the CMRR of A1. The LT1012A has a minimum CMRR of 114dB, while the network is factory trimmed to a 0.02% match, corresponding to a 74dB CMRR. For 120dB or more CMRR, a 50k trimmer can be substituted for R6.

While A1 is shown operating from ±9V battery supplies (a feature possible by virtue of the 370μA quiescent current) the LT1012 device family can also be used on standard ±15V supplies, or on lower voltage supplies down to ±1.2V (with reduced CM range, of course). With the 9V supplies shown, input ranges of ±250V or more to the circuit will not tax the network.

For single battery applications (i.e. when pin 4 is grounded), the LT1012A should be replaced by a single supply op amp such as the LT1006 or the LT1077. These devices can handle about −250mV of negative common mode voltage, while maintaining accuracy. Therefore, the 250V positive common mode range is unchanged, but the negative common mode range is reduced to −12V.

Using an LT1006, bandwidth and battery current are basically unchanged. With the LT1077 micropower op amp, battery current is reduced to 45μA but at the expense of bandwidth (=4.5kHz). Offset voltage and drift specifications are degraded by approximately a factor of two using the LT1006 or the LT1077 compared to the LT1012A.

References

1. Jung, W.G. *IC Op Amp Cookbook, 3d Ed.,* Ch 7, "Amplifier Techniques," Howard W. Sams, Indianapolis, IN 1986.

Linear Technology Corporation
1630 McCarthy Blvd., Milpitas, CA 95035-7487 • (408) 432-1900
FAX: (408) 434-0507 • TELEX: 499-3977

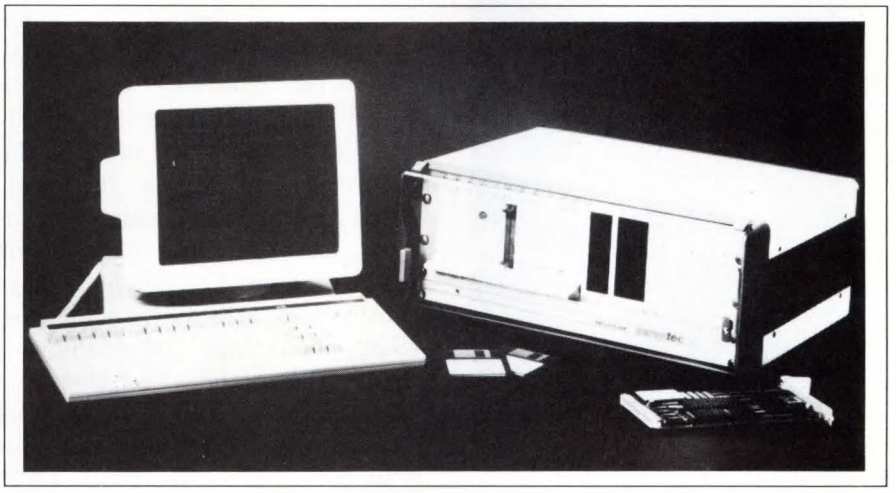
IM/GP 789 165K

NEW PRODUCTS

COMPUTERS & PERIPHERALS

PARALLEL PROCESSOR

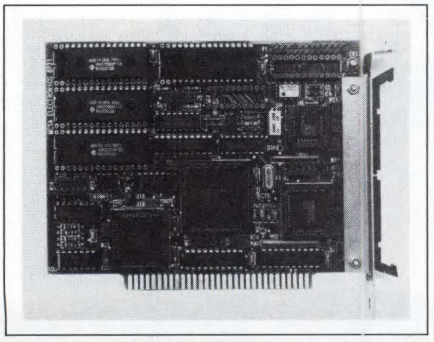
- *Matrix of jumpers for connecting Transputer serial links*
- *Consists of system unit and expansion chassis*



The Multicluster Transputer-based parallel-processing system consists of two enclosures—a stand-alone system unit and an expansion chassis. The system unit comes in a 19-in. rack-mountable enclosure with 10 card slots. It accepts any combination of the company's busless module family. Its configuration matrix at the back of the enclosure lets you jumper the serial links between any of the Transputers' 20M-bps channels. The links have RS-422 differential buffers that permit data transmission at 20M bps as far as 30 ft or at 10M bps as far as 100 ft. The links separate the ReSetIn and the ReSetOut lines that allow you to reset Transputers individually. The system unit can hold as many as 30 32-bit CPUs or 40 16-bit CPUs. Also included are a mass-storage controller; a terminal interface; a 720k-byte, 3½-in. floppy-disk drive; and a 66M-byte SCSI hard-disk drive. System unit, $8450; expansion chassis, $4750. Delivery, four to six weeks ARO.

Paracom Inc, Bldg 9, Unit 60, 245 W Roosevelt Rd, West Chicago, IL 60185. Phone (312) 293-9500. FAX 312-231-0345. TLX 4974811.

Circle No 389



I/O COPROCESSOR

- *Has a 10-MHz V40 μP*
- *Occupies 2k bytes of host memory space and 1 interrupt line*

Measuring 4.2×5.5 in., the 6P21 I/O coprocessor board for the IBM PC/XT bus contains a 10-MHz V40 μP that acts as a slave processor for I/O-intensive applications. It communicates with the host through a 1k-byte dual-port RAM. Multiple boards can coexist in a single host. Each board occupies 2k bytes of the host memory space and one interrupt line. The interrupt line can be shared by several boards. The supplied BIOS provides full DOS emulation. The I/O resources include 8k to 512k bytes of RAM, an RS-232C port, 24 digital I/O lines, six 16-bit counters, a 400-kHz 8-bit ADC with four inputs, and two analog outputs with 8-bit resolution. Board with 96k bytes of RAM, $335.

Mesa Electronics, 1329-D 61st St, Emeryville, CA 94608. Phone (415) 547-0837.

Circle No 390

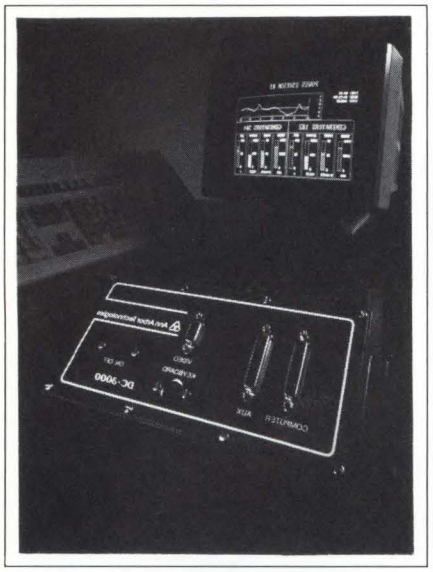
ETHERNET BOARDS

- *Use video DRAMs as global data memory*
- *Boards' CPUs use dedicated memory for Ethernet control*

Using full throughput (FXP) architecture, which implements separate program and data memory, the CMC-130 and CMC-135 are Ethernet adapter boards for the VMEbus. The boards' CPUs execute instructions from a dedicated private memory, which eliminates any arbitration time with network or bus controllers. The FXP architecture incorporates video dynamic RAM as global memory. Video DRAM offers a parallel DRAM port and a sequential access port, thereby eliminating competition for data memory between the CPU, the network, and the bus controllers. The 32-bit parallel-access rate is 800M bytes/sec. The CMC-130 supports the company's TCP/IP and OSI networking protocols. The CMC-135 includes a link-level software driver, which facilitates the use of customer-developed software. Both boards achieve transfer rates of 34M bytes/sec on the VMEbus and 10 bps on the Ethernet network. CMC-130, $3195; CMC-135, $2695.

CMC Inc, 125 Cremona Dr, Santa Barbara, CA 93117. Phone (805) 968-4262. FAX 805-968-6478. TLX 240876.

Circle No 391



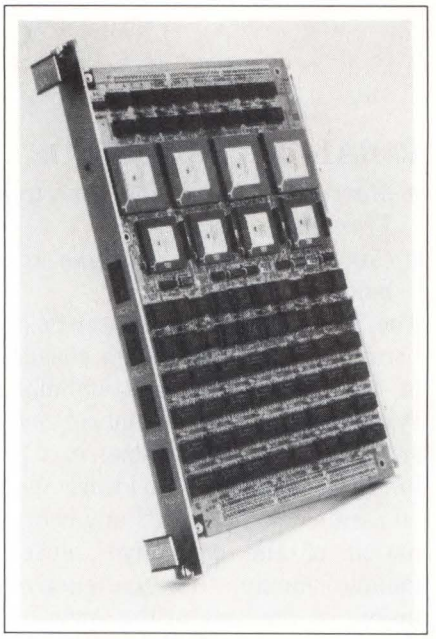
DISPLAY CONTROLLER

- *Provides 640×350-pixel resolution and 16 colors*
- *Contains μP that offloads tasks from the host*

The DC3EGA color-graphics display controller in a stand-alone enclosure communicates with a host via an RS-232C port at baud rates ranging from 110 to 38.4k baud. It also has an IBM PC/AT-compatible keyboard port and a TTL video monitor port for IBM EGA displays. The controller provides a screen resolution of 640×350 pixels with 16 colors. A μP offloads the controller tasks from the host. ANSI 3.64 terminal-emulation firmware has graphics routines for drawing lines, rectangles, polygons, circles, arcs, fills, and double-wide, double-high, or double-size text. The enclosure measures 4.25×9.25×1.75 in. and operates from 0 to 65°C with a humidity of 0 to 95% (non-condensing). DC3-EGA only, $895.

Ann Arbor Technologies Corp, Box 3083, Ann Arbor, MI 48106. Phone (313) 995-1360. FAX 313-662-3707.

Circle No 392



MULTIPROCESSOR

- *Contains four 20-MHz 68020 μPs for VMEbus*
- *Has 256k bytes of private RAM and a 68882 FPU*

The MPU-2 multiprocessor board for VMEbus systems contains four 20-MHz 68020 μPs. Each μP has its own 68882 floating-point unit and 256k bytes of private RAM. In addition, each processor has 512k bytes of RAM for interprocessor communication. The board uses the company's HyperFlo data-flow architecture for multiprocessor operation. Each processor can act as a private, local, or global master. Because no processor maintains a superior position, there is a high degree of fault tolerance. Its operating system can automatically redistribute both system- and application-level software if a processor fails. The 6U board consumes 30W from a 5V supply. $6870.

PC/M Corp, 6805 Sierra Ct, Dublin, CA 94568. Phone (415) 829-8700. FAX 415-829-9796. TWX 910-389-6890.

Circle No 393

PRINTER

- *Creates typeset-quality symbols on adhesive strip*
- *High-resolution print mode produces 240,000 dots/in²*

The 460PC printer for PC users can create typeset-quality letters and symbols on adhesive-backed tape. In a high-resolution print mode, the device prints with 400-dpi vertical and 600-dpi horizontal resolution, producing 240,000 dots/in². The standard print mode produces 160,000 dots/in². You can rotate images and condense or expand letters vertically and horizontally to fill the available space. In addition, you can generate special font variations such as outlines, italics, bold fill patterns, and superscripts. The printer doesn't require a toner. A drop-in supply cartridge contains a black-print ribbon and clear output tape for 80 or 150 ft of lettering. The thermal printer weighs 10 lbs and has a footprint of $15 \times 11\frac{1}{4}$ in. Printer and software, $2295. Software only, $595.

Kroy Inc, Box C-12279, Scottsdale, AZ 85267. Phone (602) 948-2222.

Circle No 394

INDUSTRIAL PCS

- *Contain a 20-MHz 80386 and a 16-MHz 80386SX, respectively*
- *Have passive backplanes with 13 IBM PC/AT-compatible slots*

The IS/386 family consists of two industrial IBM PC/AT-compatible

computers. The Model 60 contains a 20-MHz 80386 CPU, and the Model 40 has a 16-MHz 80386SX CPU. Both models have passive backplanes with 13 16-bit IBM PC/AT-compatible expansion slots. Configurations for both units include a 1.2M-byte floppy-disk drive and controller; a SCSI hard-disk drive with capacities of 40M or 80M bytes; and a LynxOS, a Unix-compatible, real-time operating system. Other features include a Booster II board, containing hardware for fast context switching, a SCSI controller, two RS-232C ports, and 128k bytes of battery-backed disk-caching RAM; as much as 8M bytes of RAM; and a keyboard. The model 60 also comes with an 80387 coprocessor. Options include disk-drive capacities as large as 600M bytes and an Ethernet controller with TCP/IP software. You can mount the computers' steel chassis in a 19-in. rack. Model 60 with 1M byte of RAM and a 40M-byte hard disk, $11,995; Model 40 with same configuration, $6995.

Lynx Real-Time Systems Inc, 550 Division St, Campbell, CA 95008. Phone (408) 370-2233.

Circle No 395

DISK EMULATOR

- *Provides as much as 8M bytes in SIMMs for IBM PC buses*
- *Host can move data every memory cycle using DMA*

Using SIMMs which are upgradable by the user, the Drive 8000 semiconductor disk emulator for the IBM PC, PC/XT, PC/AT, and compatible computers provides from 1M to 8M bytes of solid-state memory. A host system can move data every memory cycle using DMA. An Auto Format firmware utility configures the board in <1 minute with little effort by the user. The board requires no special drivers or programs. Boot firmware allows you to boot a system directly from the board. You can install system boot files using DOS commands, SYS or FORMAT. Two levels of hardware support ensure that the data is nonvolatile. An AC power adapter, which is separate from the host power source, maintains the data when the computer is off. In addition, onboard batteries supply power for at least 4 hours if an AC power failure occurs. You can physically transfer the board from one system to another without loss of data. Without SIMMs, $375.

Kapak Design, 12280 Saratoga-Sunnyvale Rd, Saratoga, CA 95070. Phone (408) 253-5000.

Circle No 396

DSP BOARD

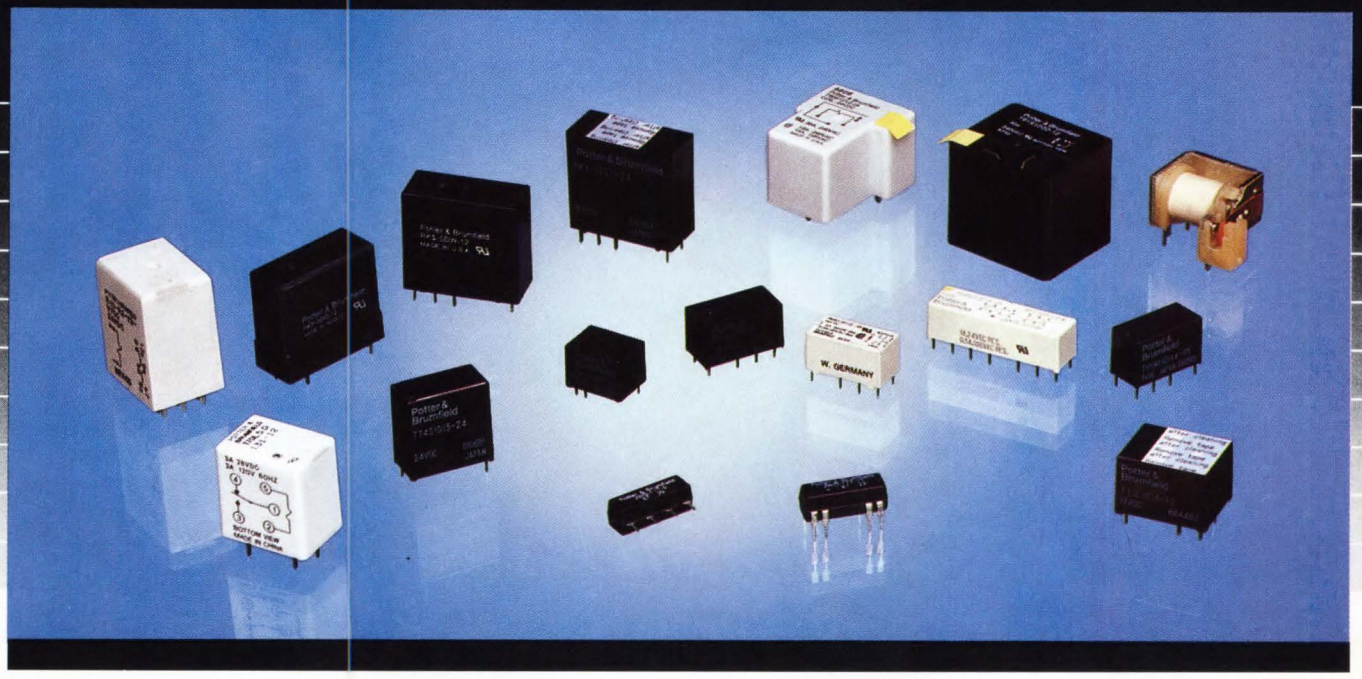
- *Places AT&T DSP32 chip on IBM PC/XT half card*
- *Comes with C language and Forth development software*

The DSP32-8 development system on an IBM PC/XT-compatible plug-in board uses an AT&T DSP32 chip operating at 16 MHz to deliver 8M flops. The system includes 128k bytes of 70-nsec static RAM and a buffered serial I/O port that connects to optional external modules. Available modules have either a codec, such as AT&T's T7500 and T7522, or 12-bit ADCs or DACs. C language and Forth development software is available for the board. An interactive debugger provides breakpoint, single-step, and trace functions. The debugger also has a host server that allows programs running on the DSP chip to communicate with the host. The debugger uses several pop-up windows to display the processor and stack status. DSP32-8, $795; C development system, including compiler, linker, assembler, and simulator, $1500; Forth operating system including debugger, $400; debugger separately, $250.

Micro K Systems, 15874 E Hamilton Pl, Aurora, CO 80013. Phone (303) 693-3413.

Circle No 397

Specify P&B for dry circuit to 30A load switching on your P.C. board.



New Models Expand Offering

Potter & Brumfield's expanded line of printed circuit board relays provides the features you need – whether you're switching dry circuits or 30A loads. New products, traditional P&B quality and unbeatable service combine to help solve your toughest relay design-in problems in telecommunications, appliance, industrial control and other applications.

Miniature Relays Switch 1mA to 10A

New T73 and T74 series miniature P.C. board relays join the T70 series as Potter & Brumfield's low-cost SPDT units for general purpose applications. Various contact materials permit these immersion cleanable relays to switch from 1 mA through 10A. Sensitive coil models are available.

Expanded Line of 4,000V Isolation Relays

Extensions to the line of RK series relays feature 8mm coil-to-contact spacing for 4,000V isolation. SPDT models switch loads to 20A, while DPDT models switch up to 5A. Both sealed and unsealed types are now offered with either AC or DC coils.

T90 & T91 – 30A Workhorses

T90/T91 series relays have SPDT contacts for loads to 30A. The DC coil T90 is offered as an open-style or sealed relay. The T91 is available with a DC coil, and it's offered with quick connect terminals for load connections. An AC coil T91 will be available soon.

More Models for Low Signal Switching

The growing line of P&B low-signal relays features units with single or multiple contacts to provide dependable switching of 2A and under loads. Both polarized and non-polarized units are offered in various coil sensitivities. Included are immersion cleanable DIP and SIP types.

Stock Availability

Many models are available off-the-shelf from your authorized P&B distributor. Of course, distributor stock is backed by Potter & Brumfield's extensive factory inventory.

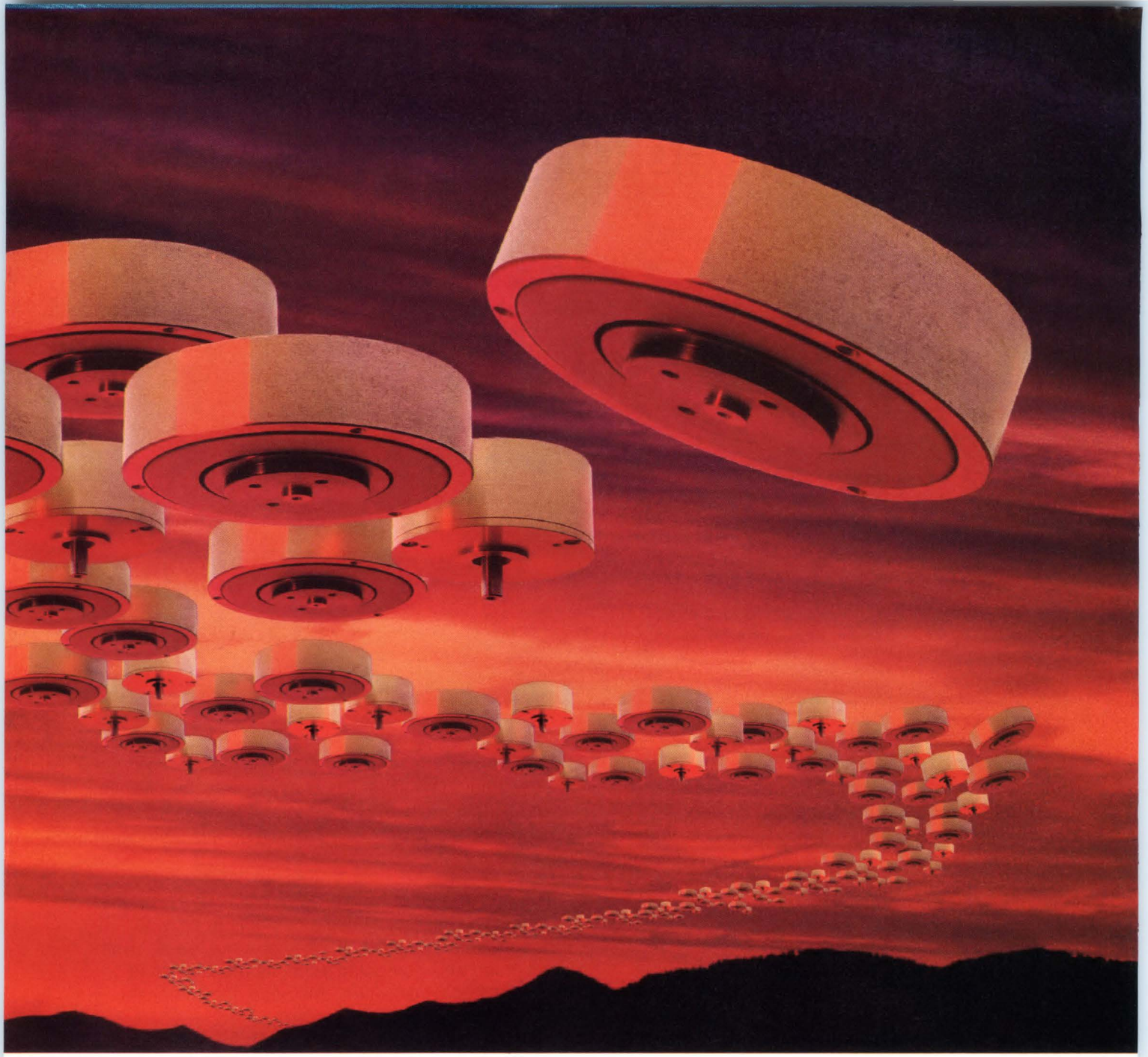
Find Out More

Contact us today for information on our complete line of P.C. board relays. Potter & Brumfield, A Siemens Company, 200 S. Richland Creek Drive, Princeton, Indiana 47671-0001.

Call toll-free 1-800-255-2550 for the P&B authorized distributor, sales representative or regional sales office serving your area.

Potter & Brumfield A Siemens Company

8905



Brushless DC motors from Lamb have arrived

The performance and endurance of Lamb® motors will take you just about anywhere.

Lamb motors utilize electronic commutation to give you a motor that "flies" a lot further in a more compact housing.

These brushless DC motors have been engineered by Lamb with a high torque to inertia ratio for the superior stop/start capability required by many of today's high tech applications. They also minimize the problems of ripple torque, cogging effects, or demagnetization by high currents by utilizing cost effective rare earth magnets.

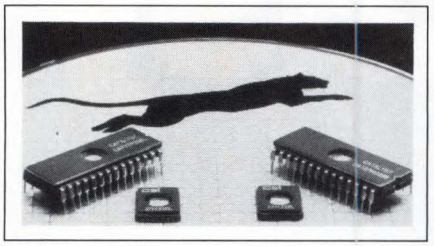
Only 2" or 3.2" in diameter, these motors have stall torque ratings up to 84 oz. in., which makes them perfect for a wide variety of applications, including tape cartridge drives, medical instruments, robots, pumps, compressors, or machine tools.

For technical data, contact AMETEK, Lamb Electric Division, 627 Lake Street, Kent, OH 44240. Tel: 216-673-3451. Fax: 216-673-8994.

AMETEK
LAMB ELECTRIC DIVISION

NEW PRODUCTS

INTEGRATED CIRCUITS



CMOS EPROMs

- *Have 256k-bit density*
- *Speed ratings from 70 to 120 nsec*

Organized in a 32,768-word × 8-bit configuration, the CAT27HC256 and the low-power-version CAT-27HC256L EPROMs feature high-speed operation. The 256k-bit devices are available in speed ratings of 55, 70 and 90 nsec for commercial versions, and 70, 90, and 120 nsec for industrial and military versions. Typical current requirements are 60 mA max in the active mode and 500 μA in the standby mode. The programming speed for these EPROMs, which use a special algorithm to reduce programming time, is 100 μsec/byte. The devices are available in 28-pin DIPs and 32-pin LCC packages. 55-nsec commercial version, $79.50; 70-nsec military version, $149.32 (100).

Catalyst Semiconductor Inc, 2231 Calle De Luna, Santa Clara, CA 95054. Phone (408) 748-7700. FAX 408-980-8209. TWX 510-601-7631.

Circle No 376

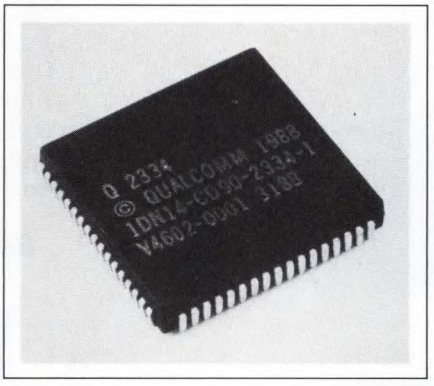
GaAs GATE ARRAYS

- *3000 to 16,000 gates*
- *Toggle rates to 1 GHz*

The Fury family of GaAs gate arrays features D flip-flop toggle rates to 1 GHz and power dissipation that is one-third that of comparable ECL gates. The largest member of the family, the VSC15K, has 16,896 2-input NOR gates and is optimized to contain 1408 D-type flip flops. Packaged in a 256-pin leaded chip carrier, the VSC15K can support 196 TTL, CMOS, ECL, or GaAs I/Os. Other members of the family include the VSC3K with 3480 gates and 92 I/Os, the VSC5K with 6400 gates and 120 I/Os, and the VSC10K with 13,376 gates and 196 I/Os. The speed-power product of the 2-input NOR gate is 0.025 pJ typ, and the delay is 90 psec typ. Nonrecurring engineering charges, $35,000 to $100,000; commercial-grade products, $0.01 to $0.04/gate (OEM qty).

Vitesse Semiconductor Corp, 741 Calle Plano, Camarillo, CA 93010. Phone (805) 388-3700.

Circle No 377



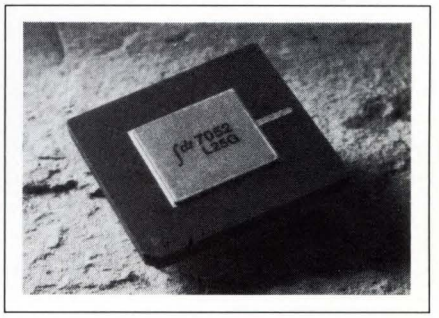
DIGITAL SYNTHESIZER

- *Provides direct digital synthesis*
- *Dual unit operates at 20 MHz*

The Q2334I-20 dual Direct Digital Synthesizer (DDS) generates high-resolution digitized sine waves, using phase-accumulation techniques combined with on-chip sine lookup. The single-chip CMOS device provides two independent DDS functions for use in applications such as quadrature oscillators and full-duplex systems. A μP interface controls the frequency and mode of operation, and synchronous inputs provide phase and frequency modulation of the synthesized waveform. The Q2334I-20 operates at a maximum sampling rate of 20 MHz, which allows the synthesis of waveforms from dc to 10 MHz with a resolution of more than 0.005 Hz. Available in a 68-pin PLCC, the device operates over the temperature range of −40 to +85°C. $69 (100).

Qualcomm Inc, 10555 Sorrento Valley Rd, San Diego, CA 92121. Phone (619) 587-1121. FAX 619-452-9096.

Circle No 378



4-PORT SRAMs

- *Have 25-nsec speed*
- *8k- and 16k-bit versions*

The IDT7050 1k × 8-bit and IDT7052 2k × 8-bit, 4-port static RAMs feature access times of 25 nsec and provide substantial improvements in system speed. For example, using four IDT7052s to interface with a 32-bit μP or DMA devices results in an effective bus bandwidth of 640M bytes/sec, which is 10× faster than other interprocessor communications methods. Featuring independent asynchronous-address data and control lines, each of the four ports communicates via a standard SRAM interface that can access any location in memory simultaneously and asynchronously. The 4-port chips are expandable in depth and width to fit a variety of word sizes and memory needs. In 108-pin ceramic packages, IDT7050, $212.50; IDT7052, $297.50 (100).

Integrated Device Technology Inc, 3236 Scott Blvd, Santa Clara, CA 95052. Phone (408) 727-6116. FAX 408-988-3029.

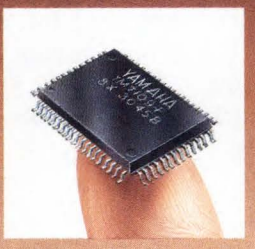
Circle No 379

FAX'n Easy

Designing Group 3 FAX capabilities into a laptop or other portable device has just been made faster and easier. All it takes is the new YM7109, a true single-chip 9600bps FAX MODEM, and FAXSIM™ (FAX Software Integration Module) by Yamaha LSI.

It's in there.

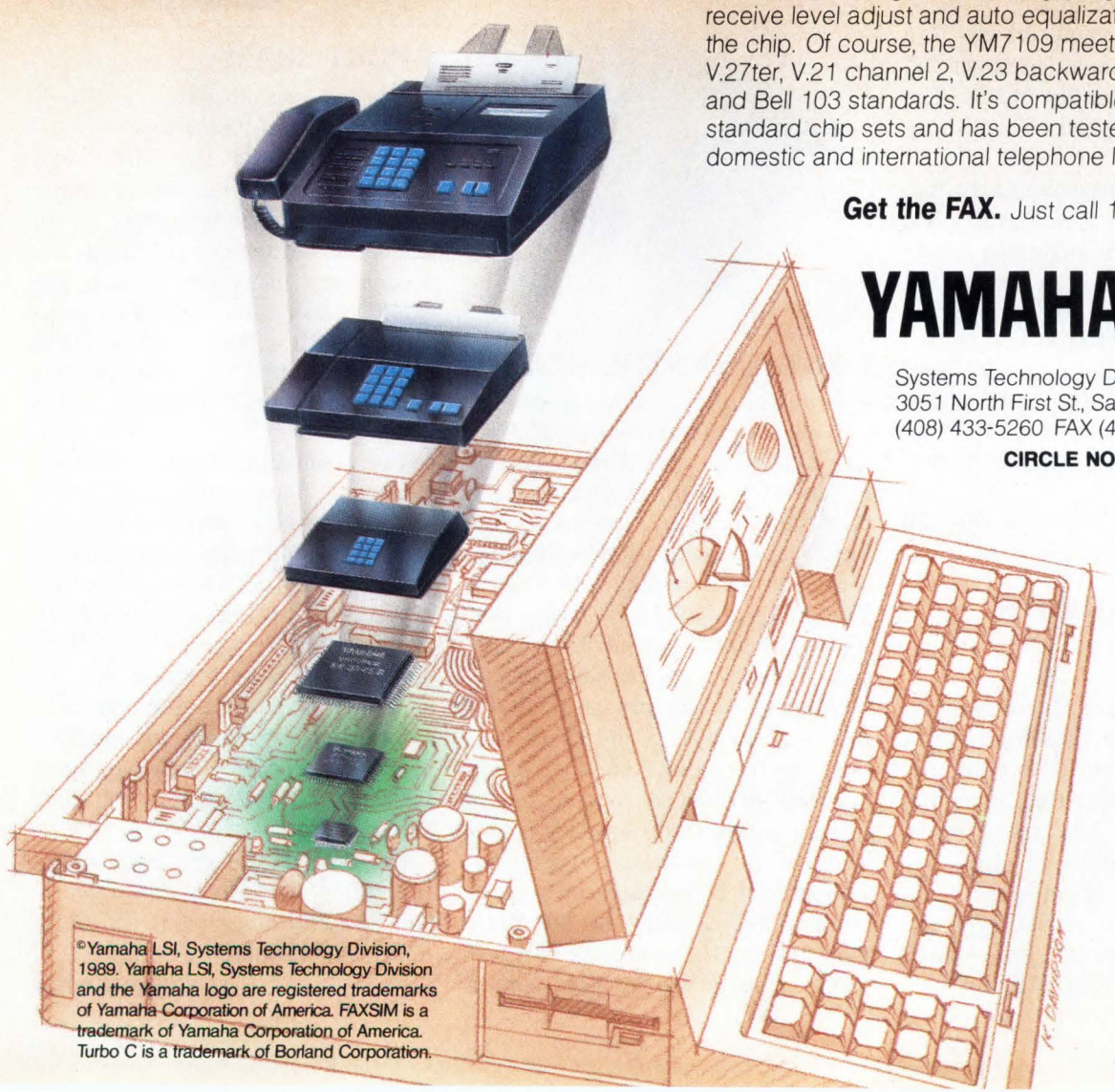
With the YM7109, the solution to your Group 3 FAX design is suddenly no bigger than a 40-pin DIP or 64-pin QFP. And, FAXSIM can cut weeks, even months off your design time. Because FAXSIM allows you to sidestep thick manuals and detailed T.4 or T.30 documentation. There's no need to interpret chip specs and study the idiosyncrasies of communication protocol or training sequences because we make the source code (developed in Borland Turbo C) available. FAXSIM gives you what you need to beat the competition — a head start.



It takes so little power.

The YM7109 typically consumes only 200mW ± 25mW, so batteries will last longer. And, the YM7109 needs only one +5V supply. DTMF detect for remote control or security, flag pattern detect, selectable cable equalization, receive signal monitoring, programmable receive level adjust and auto equalization are all in the chip. Of course, the YM7109 meets CCITT V.29, V.27ter, V.21 channel 2, V.23 backward channel, V.21 and Bell 103 standards. It's compatible with industry-standard chip sets and has been tested on both domestic and international telephone lines.

Get the FAX. Just call 1-800-543-7457



YAMAHA® LSI

Systems Technology Division
3051 North First St., San Jose, CA 95134
(408) 433-5260 FAX (408) 433-5230

CIRCLE NO 70

805-A-004-89

SENSOR INTERFACE

- *Has eight inputs*
- *Eliminates contact bounce*

The 74HC10490 sensor-interface IC merges sensor-signal debounce circuitry with interrupt masking and generation. Because of its built-in power-on initialization circuitry, you can use the 74HC10490 in both μP-based and non-μP-based monitoring and control systems. The IC, which is 8-bit bus oriented and can monitor as many as eight sensor inputs, provides the usual bus-control input signals such as RESET, R/W, CS, as well as an INT output signal that you can connect to other similar interrupt signals. An input clock signal sets up the debounce period for the eight sensor inputs and an internal clock input divider can fine tune the debounce characteristics of individual sensor input groups. 24-pin DIP, $4.72 (1000).

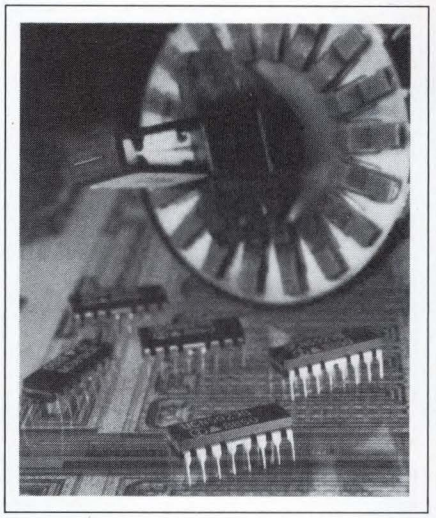
Corporation SONEET, Box 4612, Huntsville, AL 35815. Phone (205) 883-5411. FAX 205-883-5436.

Circle No 380

LATCHED SINK DRIVER

- *Drives dot-matrix print heads*
- *Has 3-bit serial input*

The UCN5929B uses BiMOS technology to merge low-power CMOS logic with high-voltage, high-current bipolar output drivers on a single chip. The IC has three diode-clamped, open-collector npn bipolar output drivers, each capable of sinking 1.7A continuous (2A peak) and sustaining load voltages to 80V. The CMOS logic includes an externally clocked, serial-input 3-bit shift register and an externally strobed data latch for each driver. This combination supports both serial and parallel data output and allows operation with most μP- and LSI-based systems. This flexible interface allows cascaded operation when driving 9-, 18-, and 24-wire print heads as well as 66- and 132-wire line printers at rates to 2.6 MHz. On-chip protection includes



high-current clamp diodes for each output driver and internal shutdown circuitry. 16-pin DIP with a copper lead frame, $2.21 (1000). Delivery, 12 to 14 weeks ARO.

Sprague Semiconductor Group, Box 15036, Worcester, MA 01615. Phone (508) 853-5000. FAX 508-853-5049.

Circle No 381

MOTOR DRIVERS

- *For use with stepper motors*
- *Feature PWM current control*

Suitable for full-step, half-step and microstep applications, the UC3770A and UC3770B offer higher maximum current (1.8A) and lower saturation voltage (1.3V at 1A) than do the previous UC3717 and UC3770 types. Featuring an H-bridge power-output stage, the UC3770A/3770B offer LSTTL-compatible logic inputs, current sense, a monostable circuit, and thermal shutdown. The 3770A/3770B are identical except for the current-sense thresholds. The thresholds for the 3770A are identical to the older 3717, permitting drop-in replacement where high-side diodes are not needed. The thresholds for the 3770B are tailored for microstepping applications where current levels of 50%, 71%, and 100% are desirable. Both devices operate from a motor-supply voltage of 10 to 45V and feature PWM current

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FEATURES	222	223
Audible Readout		•
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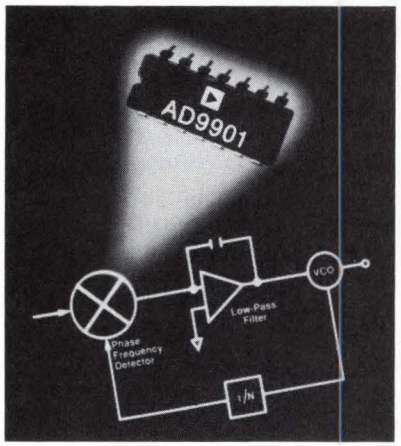
CIRCLE NO 74

control. 16-pin DIP, $1.98; 28-pin PLCC, $2.85 (1000).

Unitrode Integrated Circuits Corp, 7 Continental Blvd, Merrimack, NH 03054. Phone (603) 424-2410.

Circle No 382



PHASE DETECTOR

- *Compares signals to 200 MHz*
- *TTL, CMOS, or ECL logic*

The AD9901 phase/frequency detector can compare signals as high as 200 MHz and can operate with either TTL, CMOS, or ECL logic levels. Unlike similar ICs, the AD9901 exhibits no "dead zone" in the middle of its phase-detection range, thereby eliminating excessive phase noise. Useful in phase-locked-loop applications, the AD9901 produces a variable pulse-width output signal, which varies in width according to the phase/frequency difference between two input signals. Key specifications include a linear phase-detection range of 360, 320, and 270° at 40 kHz, 30 MHz, and 70 MHz, respectively. Output current is from 1 to 10 mA with a programmable voltage swing to 1.8V p-p. The AD9901 is available in a choice of two temperature grades and two packages. From $8 (100).

Analog Devices, 7910 Triad Center Dr, Greensboro, NC 27409. Phone (919) 668-9511.

Circle No 383

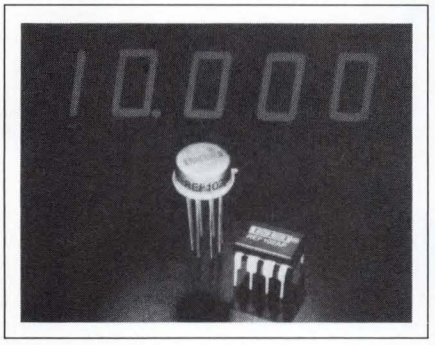
GaAs MMIC

- *Operates from 2 to 16 GHz*
- *Has 14-dB gain at 4 GHz*

Designed for use as a wide-band gain stage in the 2- to 16-GHz range, the MGA-62100 high-performance, monolithic-microwave IC amplifier comes in unpackaged chip form for use in thin- or thick-film hybrids. Typical characteristics include a gain of 14 dB, a noise figure of 2.5 dB, and linear output power of 12.5 dBm at 1-dB gain compression at 4 GHz. The amplifier combines a 2-FET cascade with feedback around the output stage to provide an output that is matched to 50Ω. The user must provide the input match externally. An internal resistive network and ac-grounded sources allow biasing from a single positive power supply. The source grounding-capacitor for the input stage is an external element that allows extended low-frequency performance. $34 (100).

Avantek Inc, 481 Cottonwood Dr, MS M82, Milpitas, CA 95035. Phone (408) 943-3038.

Circle No 384

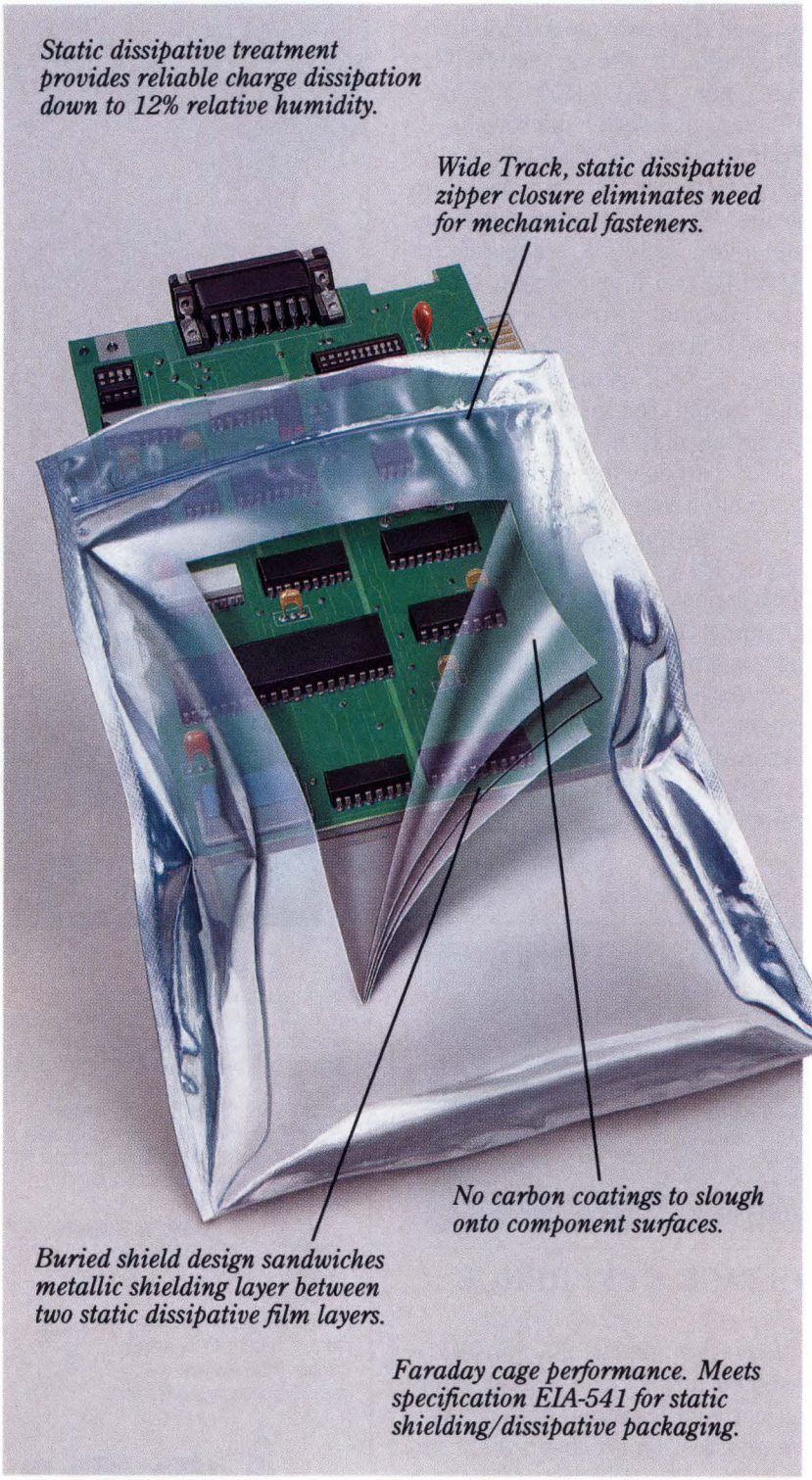


VOLTAGE REFERENCE

- *Has 10V ±0.0025V output*
- *Maximum drift is 2.5 ppm/°C*

Designed for use as a master reference in multichannel data-acquisition and test-and-measurement applications, the REF102 provides a precision 10.000V output. The drift is laser trimmed to 2.5 ppm/°C over the −25 to +85°C temperature range. The REF102, which achieves an accuracy of ±2.5 mV

How to cut the cost of ESD control without cutting any corners



New CHIPLOC CT electrostatic shielding and dissipative packaging gives you top-quality protection for less

Compared to the cost of *not* guarding against ESD-related damage, what you spend on ESD control might seem like a bargain. But it's no bargain if you're paying for more protection than you need.

That's why we've developed the new CHIPLOC* CT protective bag. Now you can choose economical—yet truly static shielding—protection for static sensitive components and assemblies.

Quality features at a competitive price

We've taken features that make our reusable CHIPLOC ES bag so popular in demanding military and aerospace applications, and put them in a bag especially designed for storing and shipping static sensitive parts in applications where extensive reusability and total humidity independence aren't required.

The result? A top-quality shielding bag that provides all the static protection you may need, and all the features you want, for less than you're probably paying for your current bag.

Find out more about CHIPLOC CT and the family of CHIPLOC products

For more information about how the family of CHIPLOC products can help you cut the cost of ESD control, and the name of an authorized distributor near you, call toll-free 1-800-258-2436.

The family of CHIPLOC packaging includes shielding bags—the ES, ESP, and CT products—as well as static dissipative bags, CHIPLOC DP. Each bag is available in a variety of sizes.

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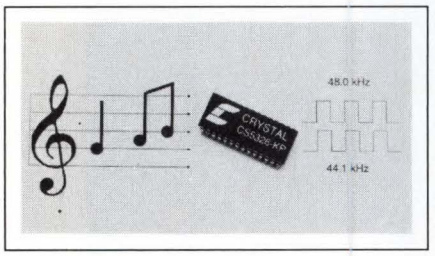
without the use of a heater, has a maximum quiescent current of only 1.4 mA. Other key specs include low noise of 5 μV p-p from 0.1 to 10 Hz, and line and load regulation of 1 ppm/V and 10 ppm/mA, respectively. The REF102 operates from a single supply over a range of 11.4 to 36V dc. The REF102 comes in a TO-99 package and an 8-pin DIP. From $2.75 (100).

Burr-Brown Corp, Box 11400, Tucson, AZ 85734. Phone (602) 746-1111. TWX 910-952-1111. FAX 602-889-1510.

Circle No 385



STEREO 16-BIT ADC

- *Uses delta-sigma conversion*
- *Features 64× oversampling*

Designed for digital-audio applications, the CS5326 high-performance, stereo 16-bit ADC uses delta-sigma conversion over a 25-kHz bandwidth. The device incorporates on-chip dual ADCs, digital antialiasing filters, digital decimation, a voltage reference, and sample-and-hold circuits. The IC has two completely independent channels and achieves a dynamic range of more than 94 dB. Harmonic distortion is <0.0015%, and the S/N ratio is more than 92 dB over a 10-Hz to 22-kHz bandwidth. The CS5326's delta-sigma design uses an oversampling ratio of 64×, and the antialiasing filter exhibits <0.001-dB passband ripple and more than 86-dB stopband rejection. 28-pin plastic DIP, $48 (1000).

Crystal Semiconductor Corp, Box 17847, Austin, TX 78744. Phone (512) 445-7222. TWX 910-874-1352. FAX 542-445-7581.

Circle No 386

ADC SUBSYSTEM

- *12-bit resolution*
- *Subranging architecture*

Designed for high-performance applications, the CLC926 features 12-bit resolution (one part in 4096), an update rate of 10M samples/sec, and a spurious-free signal range of 75.8 dB at 404 kHz and 67.2 dB at 4.996 MHz. The hybrid A/D converter subsystem includes an input amplifier, a 2V reference, a low-jitter track-and-hold circuit, a 12-bit quantizer with error correction, and output latches. Other features include an S/N ratio of 67.5 dB at 404 kHz and 66.7 dB at 4.996 MHz; a bipolar/unipolar input range of 2V p-p; and TTL outputs. The complete converter is packaged in a 40-pin, 2.8-in^2 side-brazed ceramic DIP. Power dissipation is 5.1W. Industrial-temperature-range version, $925 (100).

Comlinear Corp, 4800 Wheaton Dr, Fort Collins, CO 80525. Phone (303) 226-0500. TLX 450881. FAX 303-226-0564.

Circle No 387

14-BIT ADC

- *Has 2.4-μsec speed*
- *Features low-power operation*

The ADC-914 hybrid, 14-bit A/D converter has a conversion time of 2.4 μsec and a power dissipation of 925 mW. Based on a digitally corrected subranging architecture, the ADC-914 contains an internal clock and an internal reference that can supply 10V at 1.5 mA externally. All digital inputs and 3-state outputs are CMOS/TTL compatible. A pin-programmable feature allows analog-input selection of either 0 to 10V unipolar or ±5V bipolar inputs. The ADC-914 comes in a 24-pin double DIP and operates from 15 and 5V supplies. From $219.

Datel Inc, 11 Cabot Blvd, Mansfield, MA 02048. Phone (508) 339-3000. FAX 508-339-6356. TLX 174388.

Circle No 388

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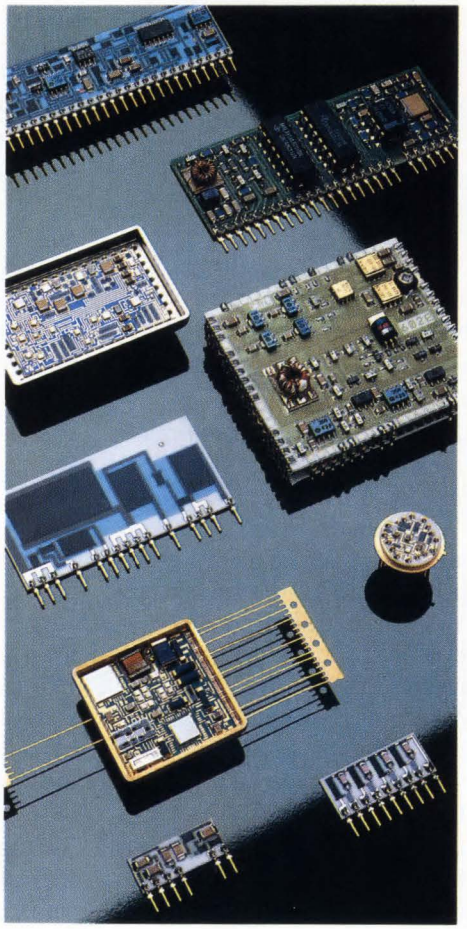

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COMPONENTS & POWER SUPPLIES

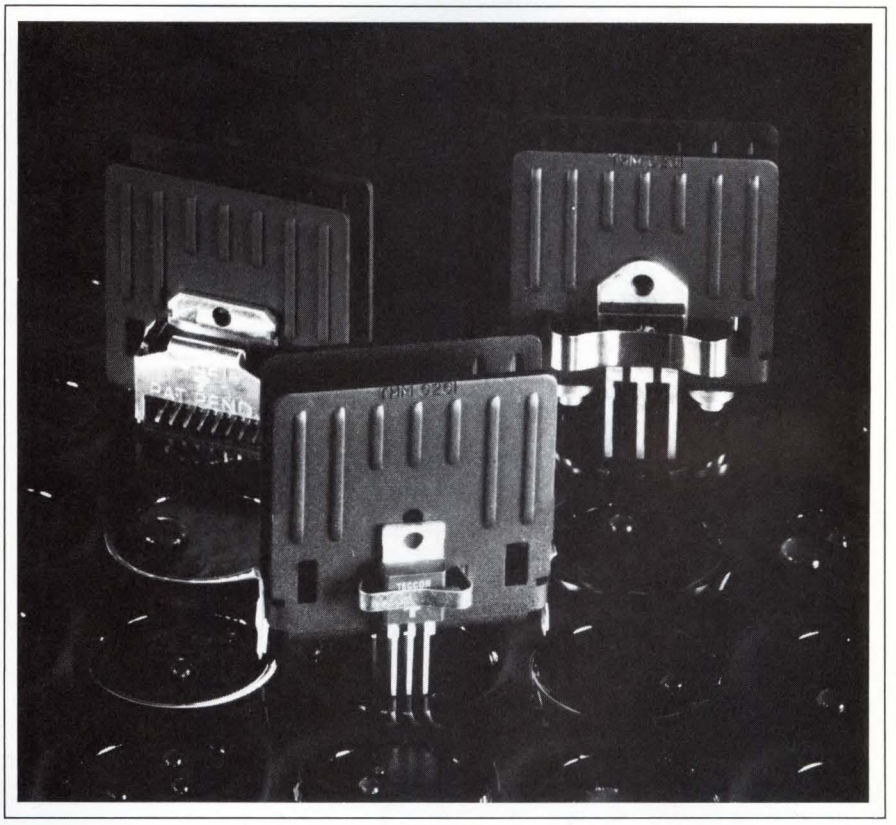
HEAT SINKS

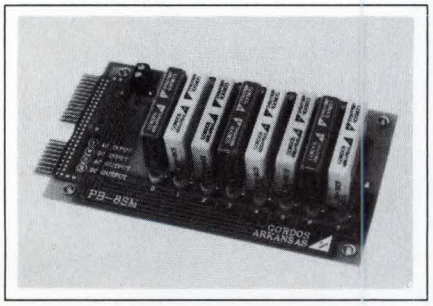
- *Hold two devices*
- *Designed for plastic devices*

Model 6260B and 6261B heat sinks are designed to cool plastic devices. Each will handle two devices—one on each side. Thermal resistance is 8.5°C/W for the 6260B and 7.5°C/W for the 6261B at 75°C temperature rise above that of the mounting surface. The 6261B is available with solderable studs to ensure secure retention in the pc board. Alternatively, you can obtain positive pc-board retention by mounting the heat sinks, using solderable bifurcated mounting tabs. Spring clips are available to help you save time assembling the transistor and heat sink. Model 6260B, $0.41 (1000).

Thermalloy Inc, Box 810839, Dallas, TX 75381. Phone (214) 243-4321. FAX 214-241-4656. TLX 203965.

Circle No 357





I/O BOARD

- *Conserves space*
- *Accepts as many as eight I/O modules*

The Model PB-8SM digital I/O board measures only 3.5×6.4 in. and occupies 20% less area than standard PB-8 racks. The board can accommodate as many as eight Gordos SM Series I/O modules and includes LED indicators, 3.3 kΩ pull-up resistors, load fuses, field wiring, power-supply barriers, and a gold-plated card-edge connector. Available options include detachable barriers, vertical or horizontal header connectors, and a hold-down bar to accommodate harsh environments. $40.

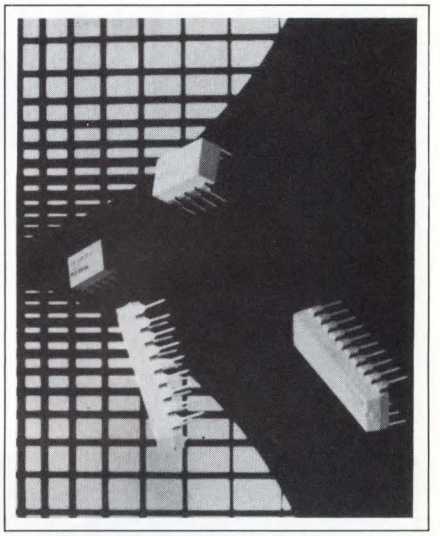
Gordos, 1000 N Second St, Rogers, AR 72756. Phone (800) 643-3500.

Circle No 358

RESISTOR NETWORK

- *Compatible with automated insertion equipment*
- *In bused, isolated, or dual-terminator circuits*

The Model 4120R resistor network is housed in a 20-pin molded DIP that's compatible with all popular automated insertion equipment. The network is available in bused, isolated, or dual-terminator configurations. Standard resistance values range from 10Ω to 10 MΩ, and resistor tolerance equals 2%. Per-resistor power rating equals 250 mW at 70°C, and the temperature coefficient of resistance is 100 ppm/°C. From $0.50 (1000). Delivery, stock to eight weeks ARO.



Bourns Inc, 1200 Columbia Ave, Riverside, CA 92507. Phone (714) 781-5500. TWX 910-332-1252.

Circle No 359

COMPONENTS & POWER SUPPLIES

DC/DC CONVERTERS

- *Have a 100W output*
- *Operate at 82% efficiency*

UWT Series triple-output dc/dc converters develop a 100W output and operate at 82% efficiency. The units operate from inputs of 18 to 36V or 36 to 72V, and output 5 and ±12 or ±15V. The converters feature a 100-kHz switching frequency. Voltage accuracy is more than 1%, and ripple and noise equals 100 mV p-p. Additional standard features include reverse-voltage, short-circuit, and overvoltage protection; remote sensing; and thermal shutdown. The converters are housed in 6-sided shielded cases to reduce noise-radiation problems. $200 (100).

International Power Devices Inc, 155 N Beacon St, Brighton, MA 02135. Phone (617) 782-3331. FAX 617-782-7416. TLX 989752.

Circle No 360

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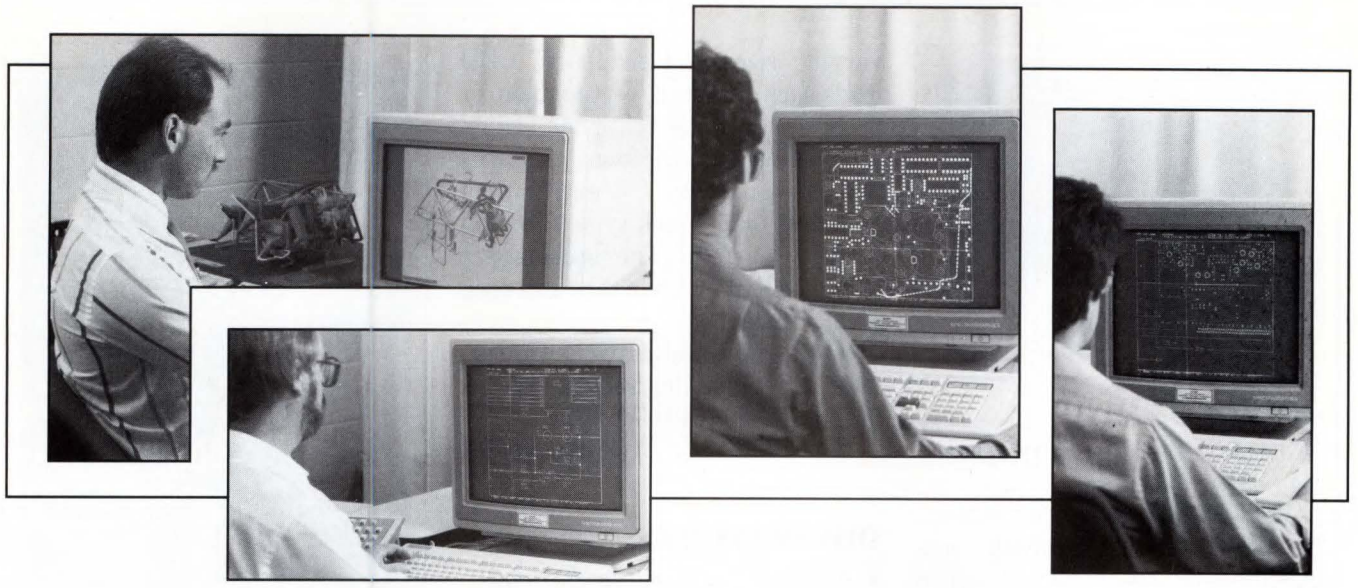

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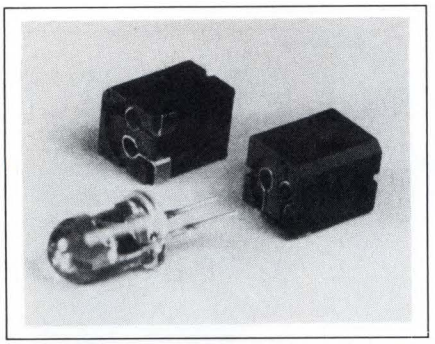


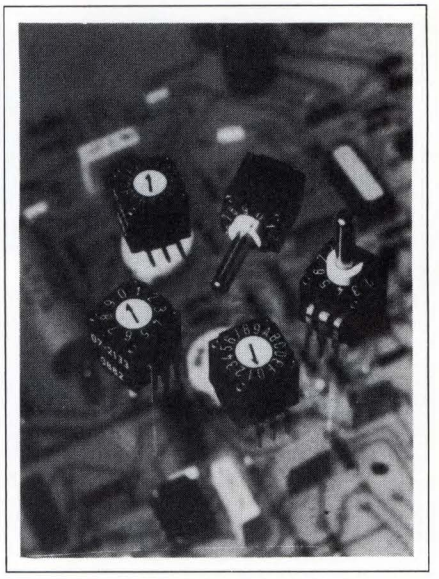
LED SOCKET

- *Compatible with surface assembly operations*
- *Accepts a variety of lead styles*

The SMD 330 is a horizontally configured socket specifically designed for the solderless installation of an LED in surface-mount assemblies. It features a UL-rated plastic body and tin-plated phospher-bronze contacts. You can mount the LED from either end of the socket. The sockets feature specially formed contacts, which automatically adjust to varying sizes and shapes of LED leads such as round, rectangular, or square as long as the leads are on 0.1-in. centers. Additional features include polarity identification, standoffs, and a lock-type vibration security system. The sockets are available in bulk or on tape and reel. $0.25 (10,000).

Visual Communications Co Inc, 7920-G Arjons Dr, San Diego, CA 92126. Phone (619) 549-6900.

Circle No 361



DIP SWITCHES

- *Available in shorting and nonshorting versions*
- *Switch 10W loads*

Series 07 DIP switches are available in BCD, hexadecimal, and Gray code versions. Featuring shorting or nonshorting operation, the switches come with screwdriver or shaft-type controls. The switches accommodate loads of 0.2A at 50V max. Contact resistance measures 50Ω max, and insulation resistance equals $10^{11}\Omega$. The units have a 10,000 cycle-switching life expectancy and operate over a −40 to +85°C range. The switches are

fully sealed to withstand board-washing operations. From $3.50 (100).

Elma Electronic Inc, 41440 Christy St, Fremont, CA 94538. Phone (415) 656-3400. FAX 415-656-3783.

Circle No 362

RECTIFIER CHIPS

- *Designed for high-speed applications*
- *Have 10-nA leakage current*

Process JZA and JPA full-wave rectifier bridge chips employ dielectric-isolation processing to achieve typical parasitic leakage of only 1 nA. The JZA chip features a 50-nsec switching response. Reverse leakage for the JPA equals only 10 nA max. Key JZA specs include a 1.5V forward voltage at 100 mA, 5-nA reverse current at a reverse voltage of 40V, and an 85V breakdown at a reverse current of 100 μA. The JPA chip figures are a forward voltage of 0.9V at 20 mA, a reverse current of 3 nA at a reverse voltage of 50V, and a reverse breakdown voltage of 80V at 100 μA. Mechanically identical, the chips measure 0.03×0.03 in. and share the same isothermal thermal layout for temperature-stable operation. $0.77 (1000). Delivery, four to six weeks ARO.

Sprague, 70 Pembroke Rd, Concord, NH 03301. Phone (603) 224-1961.

Circle No 363

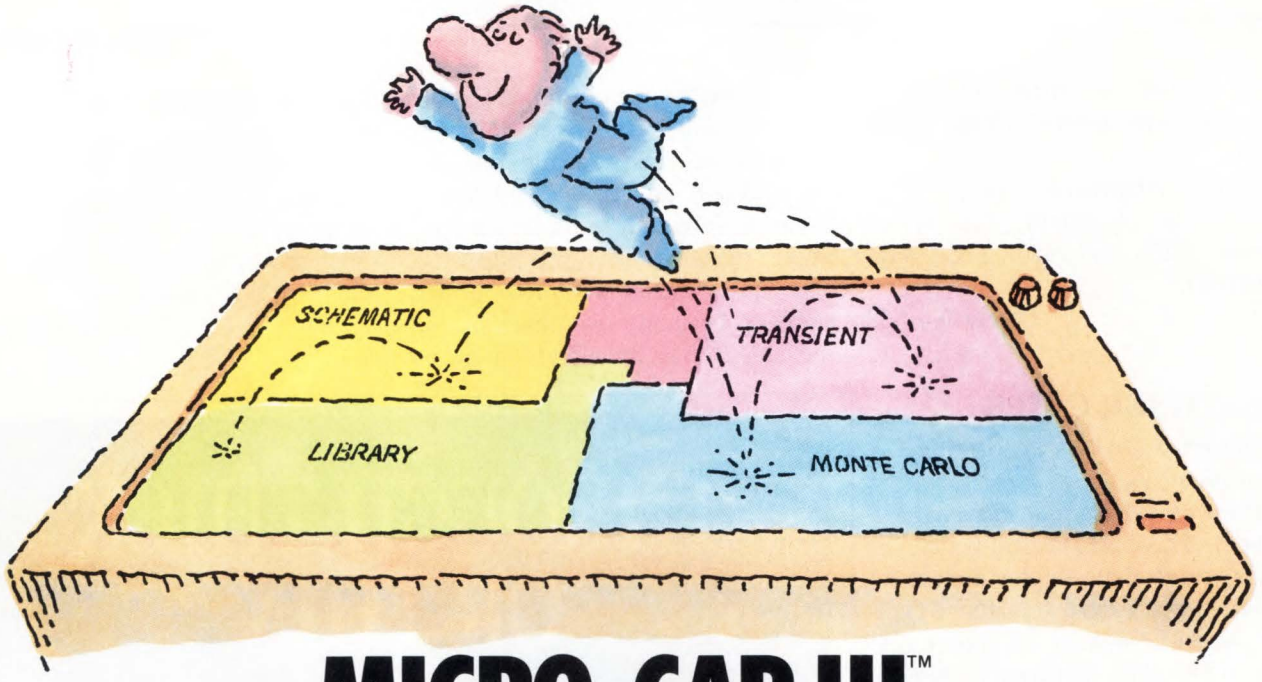
POSITION SENSORS

- *Triangulation scheme yields consistent measurements*
- *Have 500-operation/sec switching speed*

This line of photoelectric sensors has range-detection capabilities ranging from 0.5 in. to 7 ft. They employ an optical triangulation range-measurement principle to provide consistent range measurements regardless of the color, material, or surface condition of the object under detection. The measurement techniques also minimize the degradation effect of soiled lenses because detection is based on light angle rather than light intensity. The units work within a preset sensing region so background movement has no effect on measurement accuracy. The sensors have a maximum switching speed of 500 operations/sec. $100 (100).

Aromat Corp, 629 Central Ave, New Providence, NJ 07974. Phone (800) 228-2350; in NJ, (201) 464-3550. FAX 201-464-8513.

Circle No 364



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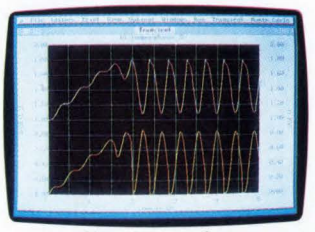
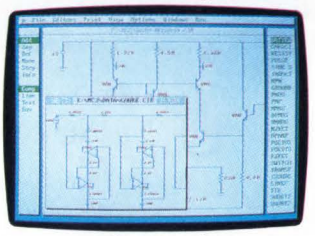
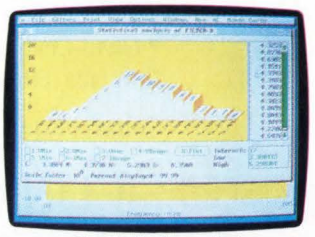


Transient analysis



Schematic editor



Monte Carlo analysis

Modeling power leaps upward as well, to Gummel-Poon BJT and Level 3 MOS — supported, of course, by a built-in Parameter Estimation Program and extended standard parts library.

There's support for Hercules,® CGA, MCGA, EGA and VGA displays. Output for laser plotters and printers. And a lot more.

The cost? Just $1495. Evaluation versions are only $150.

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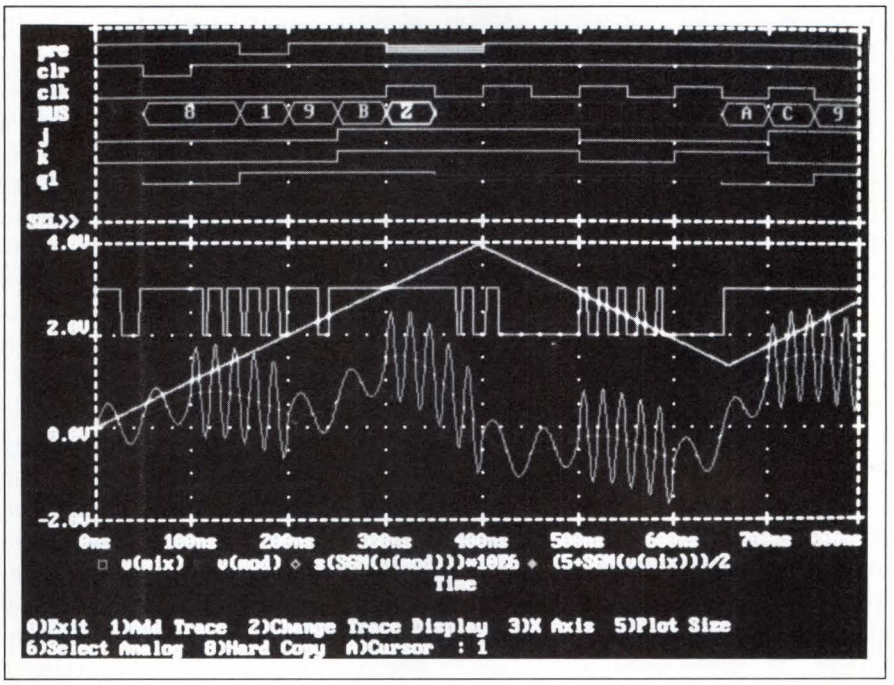
NEW PRODUCTS

CAE & SOFTWARE DEVELOPMENT TOOLS

PSPICE FOR 80386

- *Provides combined analog/digital simulation*
- *Uses extended memory for simulation software and circuit data*

PSpice-DOS/16M is a new version of the vendor's PSpice that runs in protected mode on Intel 80286- and 80386-based machines (and will eventually run on 80486-based machines), using extended memory with the aid of the DOS/16M memory extender from Rational Systems Inc (Natick, MA). In addition to allowing much larger analog circuits than the original PC-DOS version of PSpice, the new version lets you use the Digital Simulation Extension (DSE) that was previously available only for OS/2 machines, workstations, and VAX machines. This new version also lets you suspend the simulation by a keyboard command and, with the aid of the Probe viewer, view all the waveforms generated up to that point. You can use the pause as often as you wish, and can continue the simulation or abort it after you've analyzed the waveforms. This feature can substantially reduce the time needed to explore "what if . . . ?" design changes. PSpice-DOS/16M, $1450; the optional tools Probe, Parts, Monte Carlo, Analog Behavioral Modeling, and Digital Simulator cost $750, $750, $550, $550, and $1950, respectively.



MicroSim Corp, 20 Fairbanks, Irvine, CA 92718. Phone (714) 770-3022. TLX 265154.

Circle No 351

SIMULATION BUS

- *Allows multiple simulators to work on parts of the same design*
- *Common user interface controls tools within design framework*

The MultiSim modular software package lets you select the most suitable tools to simulate specific portions of your design and integrate these tools with existing tools and libraries of simulation models. The package also provides links to CAD tools, such as schematic-capture and layout programs, as well as to databases and software for automatic test equipment (ATE). MultiSim currently runs on Sun workstations, and it works with the Aida and Vanguard design systems and the Lasar simulation system. Other versions will become available for a variety of workstations, design tools, and simulators. Pricing depends on system configuration and optional tool selection; prices for the user interface and simulation bus start at $10,000.

Teradyne EDA, 5155 Old Ironsides Dr, Santa Clara, CA 95054. Phone (408) 980-5200. FAX 408-748-7761.

Circle No 352

TIMING TOOL

- *Lets you create stimuli and display simulation results*
- *Closely integrated with the vendor's digital-IC-timing simulator*

TimeView is a graphical tool set that works with the vendor's Timemill digital-IC-timing simulator. TimeView consists of a stimulus tool, a hierarchy manager, and an output tool. The stimulus tool provides a window that lets you create and analyze waveform-simulation stimuli for the rapid development of test vectors. You can combine existing test vectors with those you create graphically with aid of TimeView; when you've completed the task of stimulus creation, you can run the simulation from within the tool set. The hierarchy manager ensures design integrity by recognizing changes you've made to the schematic and automatically updating the simulation net list. The output tool lets you display and analyze the simulation results. You can view, swap, search, and zoom in on particular areas of the waveform to obtain a comprehensive and detailed picture of the results. To make analysis easier, the tool lets you display input waveforms next to the corresponding simulation results for detailed comparison. The tool set runs on Sun-3 and Sun-4 workstations, and also on VAXstations and DECsta-

tions. Timemill+, which includes TimeView and Timemill, costs $35,000; current users of Timemill can obtain TimeView separately for $7500.

Valid Logic Systems Inc, 2820 Orchard Pkwy, San Jose, CA 95134. Phone (408) 432-9400. FAX 408-432-9430.

Circle No 353

TRANSPUTER OS

- *Provides multitasking, multiuser facilities*
- *Allows reduced operation rate after a μP failure*

Helios is a multiuser, multitasking operating system (OS) for Transputer-based processing structures. The OS is based on a client/server model, in which application tasks request services from server tasks. These server tasks may reside on any number of available processors, although each processor must run at least a name server that identifies the location of other services. Such servers include file handlers, window managers, data servers, spoolers, and other system-resource managers. All servers respond to a general server protocol, which is designed so that servers are stateless and hence unaffected by crashes and losses of communications. Helios is a true distributed operating system that has no central services upon which the whole system must rely. The failure of any one processor will not cause the whole system to crash; the system will continue to operate at somewhat reduced efficiency. Application programs do not need to know the location of a particular service, because each processor contains a processor manager that creates, runs, and dismantles tasks. If a local manager has insufficient resources to satisfy a request, the request is passed up the tree of managers to the next immediate supervisor until the request can be satisfied. Helios supports XWindows, C, Fortran, Modula-2, and Pascal. Occam will also be available soon. From $1680 for a single-user PC version.

Paracom Inc, Bldg 9, Unit 60, 245 W Roosevelt Rd, West Chicago, IL 60185. Phone (312) 293-9500. FAX 312-231-0345.

Circle No 354

IC DESIGN TOOL

- *Automatically places and routes standard cells and custom blocks*
- *Handles analog and mixed analog/digital designs*

Compose 2.0 is an IC-design tool that automatically places and routes both standard cells and custom blocks simultaneously. The auto-

matic routing features accommodate variable-height standard cells, mixed blocks and cells, and rectilinear blocks. An interactive routing feature lets you make incremental engineering changes without having to rip up and reroute the entire design. Interactive editing commands let you closely control cell-to-cell and signal-to-signal spacing in a manner that minimizes noise and crosstalk. Interactive floorplanning features let you specify a group of analog cells that the program will automatically place together in a designated area of the chip; for example, you can designate separate areas near the periphery of the chip that the automatic-placement routines will use for analog components. The tool handles a variety of IC technologies, including high-speed ECL and gallium arsenide devices. Compose runs on Sun-3 and Sun-4 workstations. The base price of $50,000 includes the block placer, block router, compactor, interactive editor, footprint generator, and foreign-net-list translator. The $15,000 option package consists of the standard-cell placer and global router.

Valid Logic Systems, 2820 Orchard Pkwy, San Jose, CA 95134. Phone (408) 432-9400. FAX 408-432-9430.

Circle No 355

ASIC DESIGN TOOLS

- *Let you evaluate floorplans before implementing them*
- *Verify routability, density, and performance of a floorplan*

Gate Assistant generates floorplans for the vendor's large channelless gate arrays, such as the 1-µm VGT300 and 1.5-µm VGT200 devices. Chip Assistant creates floorplans for cell-based designs in the high-performance VSC300 1-µm family and high-density VSC120 1.5-µm family. The timing criteria supplied to the floorplanners are documented in the schematic or net list. You can then generate a capacitance file that will verify the timing of acceptable floorplans before you commit them to silicon. After physical implementation of the floorplan, the system extracts RC tree information for back annotation; the output from the Assistants and from the RC tree extraction can be used by the vendor's Timing Verifier or Simulator. The Assistants run on VAX, Apollo, HP9000 Series 320, and Sun computers. Each tool costs $20,000.

VLSI Technology Inc (GC-TOOL), 565 Sinclair Frontage Rd, Milpitas, CA 95053. Phone (408) 434-3000. FAX 408-263-2511.

Circle No 356

NEW MICROLITHIUM™ BATTERY SERIES JOINS THE DURACELL® XL™ POWER FAMILY!

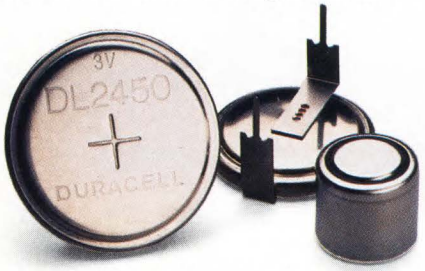
Today Duracell is your best source for all your lithium battery needs.

First with high-power consumer-replaceable lithium batteries, Duracell now introduces the MicroLithium Battery Series for long-life, low-drain applications. These new lithium/manganese dioxide cells have the same quality and dependability as our popular High Power Series, but have been optimized for micropower equipment. UL recognized, they're available in a wide-range of coin and cylindrical sizes, with or without pin terminations.

DL123A – First 3-volt, high-power consumer-replaceable lithium batteries.

Our sales engineers listen to your engineers.

World-wide, you can count on our field sales engineers for

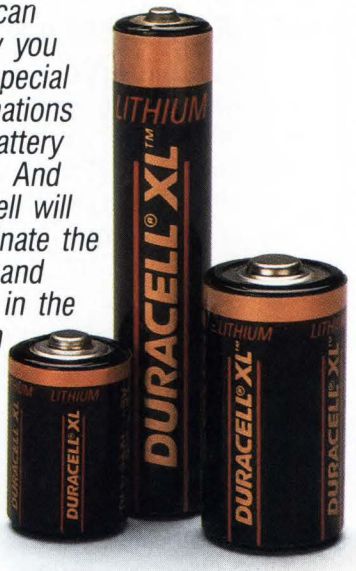


Assorted cell sizes and PCB pin types. Shown are DL2450; DL2032 with chip-straddle pins; DL1/3N.

expert applications assistance, battery samples, and test information, when you need it. From form-fit evaluation to component sourcing, we can help match the optimum lithium cell to your requirements.

Custom assemblies. . . standard solutions.

Our national network of Authorized Value-Added Assemblers can supply you with special terminations and battery packs. And Duracell will coordinate the effort and assist in the design work too!



Popular-size cylindrical configurations: DL1/2AAL; DL2NSE; and DL2/3AL.

SPECIAL 10% INTRODUCTORY DISCOUNT!

We want you to try the new DURACELL XL MicroLithium Series of batteries. That's why we're offering a special discount on all orders placed and shipped before September 30, 1989.*

DL2/3AL with single pins (polarized pins available).

Velcro-mountable DL223AR computer clock battery.

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*Discount applies to cells with and without PCB pins purchased directly from Duracell: DL2450; DL2430; DL2032; DL2025; DL2016; DLAAL; DL2/3AL; DL1/2AAL.

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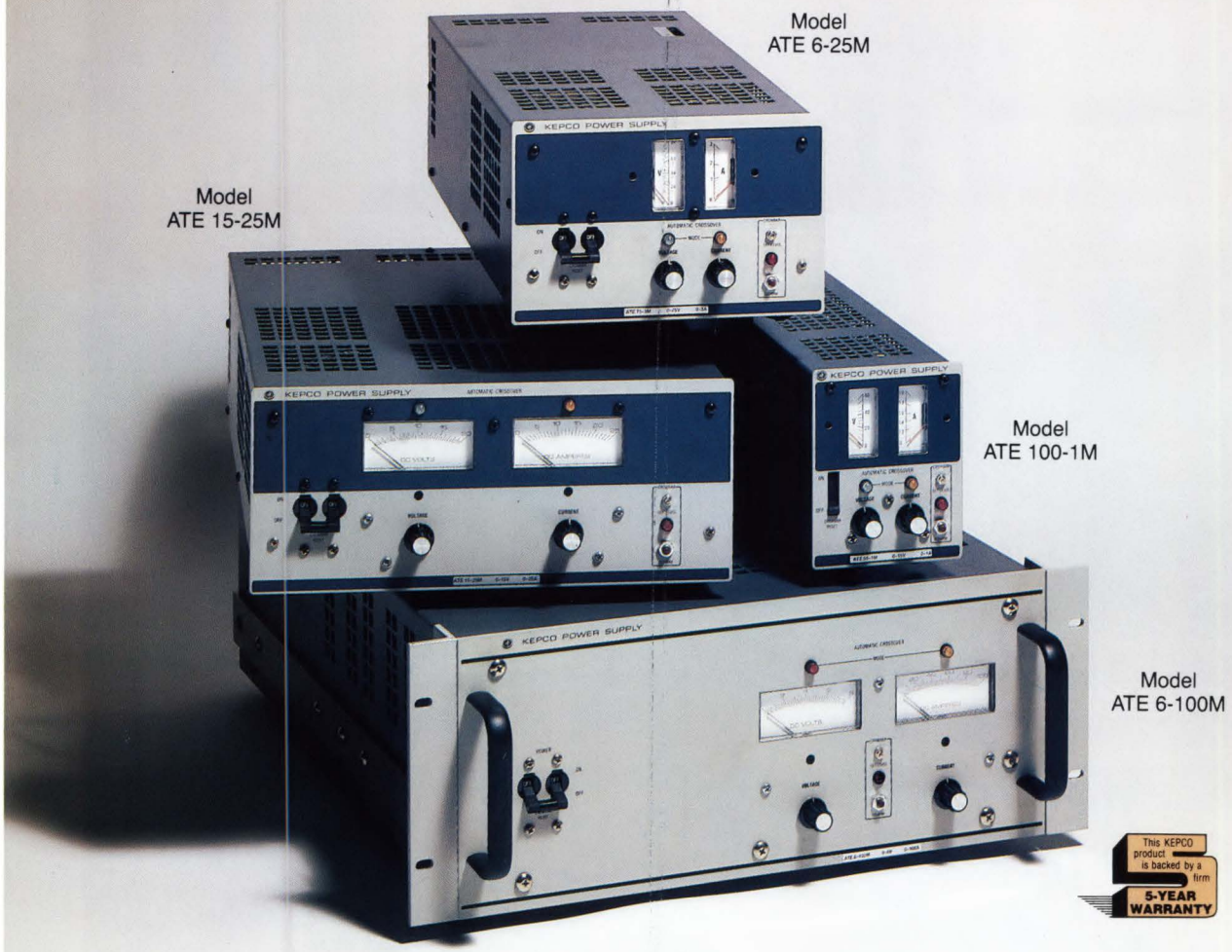
TEAR ON DOTTED LINE TO REMOVE AND SAVE.



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Kepco unipolar linear programmable power supplies

Kepco ATE Power Managers are unipolar linear programmable power supplies; offering full external control over both voltage and current, with automatic crossover. Panel-mounted meters monitor both channels. Front panel LEDs (and optically isolated flags accessible through the user port) show which channel is in charge. Local control is by panel-mounted 10-turn rheostats.

High Gain, Fast Programmable, Very Low Noise, Excellent Stability

INFLUENCE QUANTITY	OUTPUT EFFECTS VOLTAGE MODE Typ.	Max.	OUTPUT EFFECTS CURRENT MODE Typ.	Max.	OFFSETS (4) ΔE_{io}	ΔI_{io}
SOURCE VOLTAGE (min.–max.):	<0.0005% E_o max.	0.001% E_o max.	<0.002% I_o max.	0.005% I_o max.	<1 μV	<1 nA
LOAD (no load–full load):	<0.001% E_o max.	0.002% E_o max.	<0.5 mA (1)	1 mA (1)	—	—
TIME (8-hour drift):	<0.005% E_o max.	0.01% E_o max.	<0.01% I_o max.	0.02% I_o max.	<20 μV	<1 nA
TEMPERATURE, per °C:	<0.005% E_o max.	0.01% E_o max.	<0.01% I_o max.	0.02% I_o max.	<20 μV	<2 nA
RIPPLE and NOISE (2) rms:	<0.1 mV	0.3 mV	<0.01% I_o max.	0.03% I_o max.	—	—
(Slow Mode) p–p: (3)	<1 mV	3 mV	<0.1% I_o max.	0.3% I_o max.	—	—
RIPPLE and NOISE (2) rms:	<1 mV	3 mV	<0.01% I_o max.	0.03% I_o max.	—	—
(Fast Mode) p–p: (3)	<10 mV	30 mV	<0.1% I_o max.	0.3% I_o max.	—	—
INPUT:	User Selectable 104, 115, 208, 250V a-c 47-65Hz single phase					

(1) For models with output current rating of 50A and higher, the load effect is 2 mA typical and 5 mA maximum. In slow mode, the leakage current through the output capacitor adds approximately 0-6 mA to the current mode load effect.
(2) One terminal must be grounded for this measurement, or connected so that common mode current does not flow through the load or, in current mode, through the current-sensing resistor.
(3) Peak-to-peak ripple is measured over a 20 Hz to 10 MHz bandwidth.
(4) Uncommitted amplifier offsets.

KEPCO®
THE POWER SUPPLIER™

ATE MODELS • QUARTER • HALF • THREE-QUARTER • FULL RACK

ACCESSORY FOR RACK MOUNTING: RA 37

50 WATTS
0-55°C No Derating
QUARTER RACK SIZE A

MODEL	D-C OUTPUT RANGE VOLTS	AMPS	OUTPUT IMPEDANCE VOLTAGE MODE SERIES RESISTANCE	SERIES INDUCTANCE(3) SLOW	FAST	OUTPUT IMPEDANCE CURRENT MODE SHUNT(2) RESISTANCE	SHUNT CAPACITANCE (4) SLOW	FAST
ATE 6-5M	0-6	0-5	24 μΩ	0.5 μH	5 μH	12 kΩ	1,000 μF	1 μF
ATE 15-3M	0-15	0-3	100 μΩ	0.5 μH	5 μH	30 kΩ	450 μF	0.4 μF
ATE 25-2M	0-25	0-2	250 μΩ	1 μH	10 μH	50 kΩ	250 μF	0.25 μF
ATE 36-1.5M	0-36	0-1.5	480 μΩ	1 μH	10 μH	72 kΩ	200 μF	0.2 μF
ATE 55-1M	0-55	0-1	1.1 mΩ	2 μH	20 μH	110 kΩ	150 μF	0.15 μF
ATE 75-0.7M	0-75	0-0.7	2.15 mΩ	2 μH	20 μH	150 kΩ	110 μF	0.1 μF
ATE 100-0.5M	0-100	0-0.5	4 mΩ	4 μH	40 μH	200 kΩ	50 μF	0.05 μF
ATE 150-0.3M	0-150	0-0.3	10 mΩ	4 μH	40 μH	300 kΩ	55 μF	0.02 μF

Size: 5 7/32" H x 4 5/32" W x 17 1/8" D (132.6mm H x 105.6mm W x 435.0mm D)(1) **Net Weight:** 14 lbs. (6.4 kg.)

100 WATTS
0-55°C No Derating
QUARTER RACK SIZE B

MODEL	D-C OUTPUT RANGE VOLTS	AMPS	OUTPUT IMPEDANCE VOLTAGE MODE SERIES RESISTANCE	SERIES INDUCTANCE SLOW	FAST	OUTPUT IMPEDANCE CURRENT MODE SHUNT (2) RESISTANCE	SHUNT CAPACITANCE SLOW	FAST
ATE 6-10M	0-6	0-10	12 μΩ	0.5 μH	5 μH	12 kΩ	1,800 μF	2 μF
ATE 15-6M	0-15	0-6	50 μΩ	0.5 μH	5 μH	30 kΩ	1000 μF	0.8 μF
ATE 25-4M	0-25	0-4	125 μΩ	1 μH	10 μH	50 kΩ	500 μF	0.5 μF
ATE 36-3M	0-36	0-3	240 μΩ	1 μH	10 μH	72 kΩ	350 μF	0.4 μF
ATE 55-2M	0-55	0-2	0.55 mΩ	2 μH	20 μH	110 kΩ	200 μF	0.3 μF
ATE 75-1.5M	0-75	0-1.5	1 mΩ	2 μH	20 μH	150 kΩ	110 μF	0.2 μF
ATE 100-1M	0-100	0-1	2 mΩ	4 μH	40 μH	200 kΩ	80 μF	0.1 μF
ATE 150-0.7M	0-150	0-0.7	4 mΩ	4 μH	40 μH	300 kΩ	55 μF	0.04 μF

Size: 5 7/32" H x 4 5/32" W x 17 1/8" D (132.6mm H x 105.6mm W x 435.0mm D)(1) **Net Weight:** 17 lbs. (7.7 kg.)

ACCESSORY FOR RACK MOUNTING: RA 37

250 WATTS
0-55°C No Derating
HALF RACK SIZE C

MODEL	D-C OUTPUT RANGE VOLTS	AMPS	OUTPUT IMPEDANCE VOLTAGE MODE SERIES RESISTANCE	SERIES INDUCTANCE SLOW	FAST	OUTPUT IMPEDANCE CURRENT MODE SHUNT (2) RESISTANCE	SHUNT CAPACITANCE SLOW	FAST
ATE 6-25M	0-6	0-25	4.8 μΩ	0.5 μH	5 μH	12 kΩ	11,000 μF	5 μF
ATE 15-15M	0-15	0-15	20 μΩ	0.5 μH	5 μH	30 kΩ	5,800 μF	2 μF
ATE 25-10M	0-25	0-10	50 μΩ	1 μH	10 μH	50 kΩ	2,900 μF	1.25 μF
ATE 36-8M	0-36	0-8	90 μΩ	1 μH	10 μH	72 kΩ	2,400 μF	1 μF
ATE 55-5M	0-55	0-5	0.22 mΩ	2 μH	20 μH	110 kΩ	1,400 μF	0.75 μF
ATE 75-3M	0-75	0-3	0.5 mΩ	2 μH	20 μH	150 kΩ	850 μF	0.5 μF
ATE 100-2.5M	0-100	0-2.5	0.8 mΩ	4 μH	40 μH	200 kΩ	375 μF	0.25 μF
ATE 150-1.5M	0-150	0-1.5	2 mΩ	4 μH	40 μH	300 kΩ	275 μF	0.1 μF
ATE 325-0.8M	0-325	0-0.8	8.1 mΩ	100 μH	1 mH	650 kΩ	180 μF	0.01 μF

Size: 5 7/32" H x 8 11/32" W x 17 9/64" D (132.6mm H x 211.9mm W x 435.4mm D)(1) **Net Weight:** 35 lbs. (15.9 kg.)

ACCESSORY FOR RACK MOUNTING: RA 37

500 WATTS
0-55°C No Derating
THREE-QUARTER RACK SIZE D

MODEL	D-C OUTPUT RANGE VOLTS	AMPS	OUTPUT IMPEDANCE VOLTAGE MODE SERIES RESISTANCE	SERIES INDUCTANCE SLOW	FAST	OUTPUT IMPEDANCE CURRENT MODE SHUNT (2) RESISTANCE	SHUNT CAPACITANCE SLOW	FAST
ATE 6-50M	0-6	0-50	2.4 μΩ	0.5 μH	5 μH	12 kΩ	12,000 μF	10 μF
ATE 15-25M	0-15	0-25	12 μΩ	0.5 μH	5 μH	30 kΩ	8,000 μF	4 μF
ATE 25-20M	0-25	0-20	25 μΩ	1 μH	10 μH	50 kΩ	5,800 μF	2.5 μF
ATE 36-15M	0-36	0-15	48 μΩ	1 μH	10 μH	72 kΩ	4,900 μF	2 μF
ATE 55-10M	0-55	0-10	0.11 mΩ	2 μH	20 μH	110 kΩ	2,900 μF	1.5 μF
ATE 75-8M	0-75	0-8	0.19 mΩ	2 μH	20 μH	150 kΩ	1,200 μF	1 μF
ATE 100-5M	0-100	0-5	0.4 mΩ	4 μH	40 μH	200 kΩ	600 μF	0.5 μF
ATE 150-3.5M	0-150	0-3.5	0.86 mΩ	4 μH	40 μH	300 kΩ	440 μF	0.2 μF

Size: 5 7/32" H x 12 17/32" W x 17 9/64" D (132.6mm H x 318.3mm W x 435.4mm D)(1) **Net Weight:** 43 lbs. (19.5 kg.)

The full rack model is supplied with brackets for direct mounting in a standard 19-inch rack.

1000 WATTS
0-55°C No Derating
FULL RACK SIZE E

MODEL	D-C OUTPUT RANGE VOLTS	AMPS	OUTPUT IMPEDANCE VOLTAGE MODE SERIES RESISTANCE	SERIES INDUCTANCE SLOW	FAST	OUTPUT IMPEDANCE CURRENT MODE SHUNT (2) RESISTANCE	SHUNT CAPACITANCE SLOW	FAST
ATE 6-100M	0-6	0-100	1.2 μΩ	0.5 μH	5 μH	12 kΩ	22,000 μF	15 μF
ATE 15-50M	0-15	0-50	6 μΩ	0.5 μH	5 μH	30 kΩ	12,000 μF	6 μF
ATE 25-40M	0-25	0-40	12.5 μΩ	1 μH	10 μH	50 kΩ	11,000 μF	4 μF
ATE 36-30M	0-36	0-30	24 μΩ	1 μH	10 μH	72 kΩ	9,500 μF	3 μF
ATE 55-20M	0-55	0-20	55 μΩ	2 μH	20 μH	110 kΩ	5,200 μF	2.25 μF
ATE 75-15M	0-75	0-15	0.1 mΩ	2 μH	20 μH	150 kΩ	3,400 μF	1.5 μF
ATE 100-10M	0-100	0-10	0.2 mΩ	4 μH	40 μH	200 kΩ	1,200 μF	0.75 μF
ATE 150-7M	0-150	0-7	0.42 mΩ	4 μH	40 μH	300 kΩ	1,050 μF	0.3 μF

Size: 6 31/32" H x 16 1/2" W x 20 1/64" D (177.0mm H x 419.1mm W x 508.4mm D)(1) **Net Weight:** 87 lbs. (39.5 kg.)

(1)Add 2 1/2" (63.5mm) for connector protrusion. (2)Based on 0.5 mA load effect in FAST mode.
(3)For determining dynamic impedance in voltage mode. (4) For determining dynamic impedance in current mode.

For complete specifications send for Power Manager Catalog 146-1570 Data subject to change without notice.

KEPCO, INC. • 131-38 SANFORD AVENUE • FLUSHING, NY 11352 USA • (718) 461-7000 • FAX: (718) 767-1102 • Easylink (TWX): 710-582-2631

NEW PRODUCTS

TEST & MEASUREMENT INSTRUMENTS

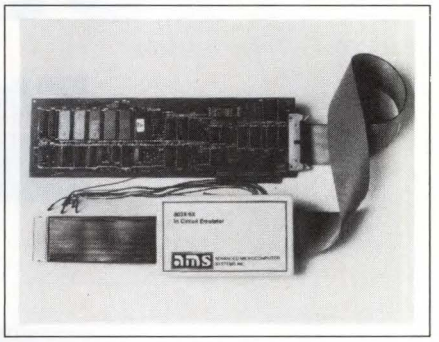
V40/V50 EMULATOR

- *Supports both V40 and V50 without extra pods or modules*
- *Dequeues prefetched instructions during trace*

The V40/50 Icealyzer is an in-circuit emulator for NEC's V40 and V50 μPs. It supports both chips without extra pods or personality modules. During trace operation, the emulator decodes prefetched instructions, and by simulating the processor's operation, places only those instructions actually executed into the trace buffer. As a result, the unit correctly disassembles trace data. Breakpoints operate to 12.5 MHz without the addition of wait states, and a pass counter lets you delay program breaks for as many as 2^{16} cycles. The unit includes 64k bytes of overlay RAM, which you can expand to 256k bytes and map anywhere in the CPU's address space. A real-time performance analyzer monitors the μP's address bus and provides histograms of the portion of time spent executing code resident in various regions of memory. $4995.

Softaid Inc, 8930 Rte 108, Columbia, MD 21045. Phone (800) 433-8812; in MD, (301) 964-8455. FAX 301-596-1852. TWX 650-265-2092.

Circle No 365



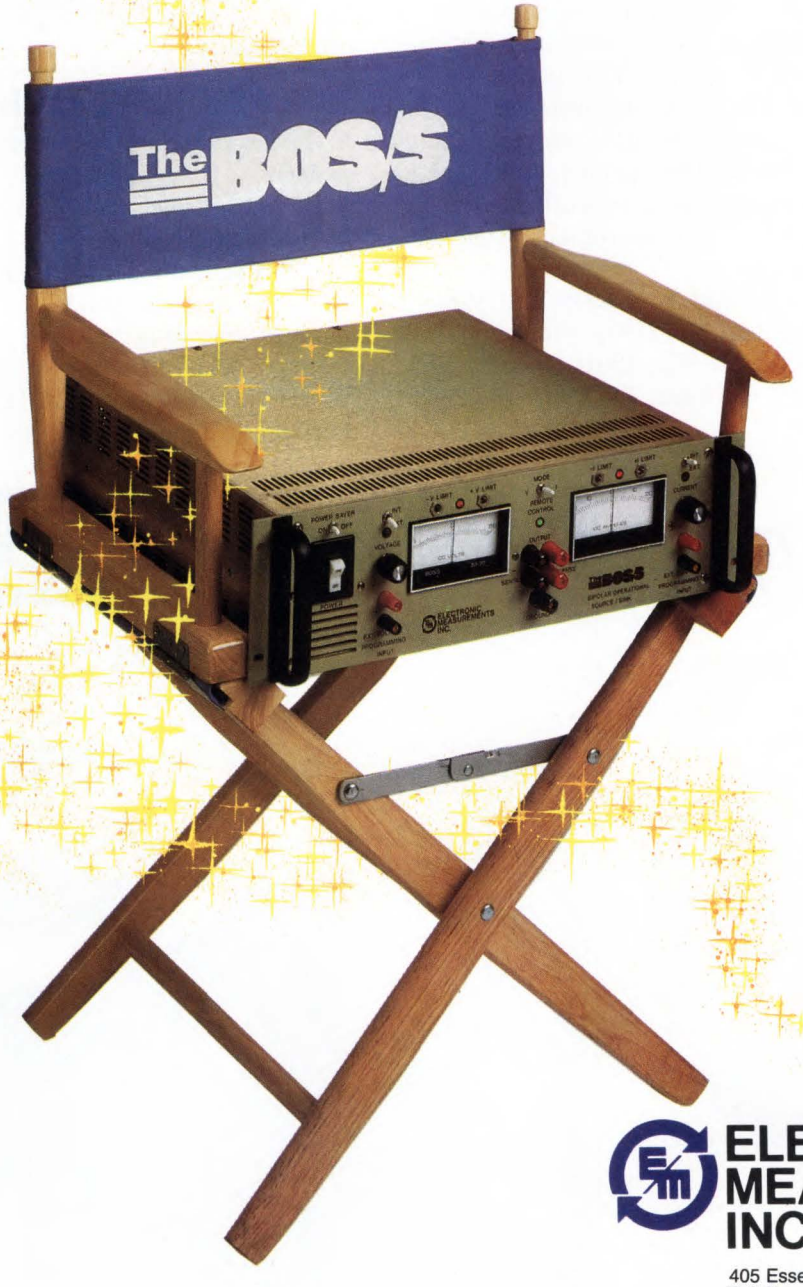
803X/805X EMULATOR

- *Allows programs to run at 12 MHz*
- *Includes 48-channel logic analyzer*

The Pro-32 is an in-circuit emulator for μPs from the 803X and 805X families operating in the external-memory mode. The unit consists of a card that plugs into the IBM PC bus and an emulator pod that plugs

A STAR IS BORN

The BOS/S™



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- Current Source
- Power Function Generator
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- Variable Gain Amplifier
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- AC Power Supply
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The BOS/S is a star in a variety of standard or custom configurations. For information, call TOLL FREE 1-800-631-4298.

ELECTRONIC MEASUREMENTS INC.

405 Essex Road, Neptune, New Jersey 07753
Toll Free: 1-800-631-4298
(In NJ, HI, AL and Canada—201-922-9300)
FAX: 201-922-9334

CIRCLE NO 86

into the target system. The unit includes 8k, 32k, or 64k bytes of writeable control store (WCS) memory that you can use to store instructions or data. A 2k-frame trace buffer stores addresses, instructions, and I/O data from ports 1 and 3. You can insert as many as 64k breakpoints anywhere in the target processor's address range. Pro-32 with WCS: 8k-byte version, $495; 32k-byte version, $595; 64k-byte version, $695.

Advanced Microcomputer Systems Inc, 1321 NW 65th Pl, Fort Lauderdale, FL 33309. Phone (800) 972-3733; in FL, (305) 975-9515. FAX 305-975-9698. TWX 910-250-4806.

Circle No 366

DMMs

- *Offer basic dc accuracy to 0.3%*
- *Two of three models measure temperature*

The HP E2373A, E2377A, and E2378A are 3½-digit (3200-count) handheld DMMs that offer basic dc accuracy of 0.7, 0.3, and 0.3%, respectively. The HP E2378A case is gasketed and water resistant. All units offer audible continuity verification and maximum input levels of 1000V dc, 750V ac, and 10A ac or dc. The ac measurements use the average ac/dc conversion technique and have a basic accuracy of 2% to 500 Hz on the HP E2373A and 1% to 1 kHz on the other two models. All units carry a 3-year warranty. HP E2373A, $99; HP E2377A, $169; HP E2378A, $189.

Hewlett-Packard Co, 19310 Pruneridge Ave, Cupertino, CA 95014. Phone local office.

Circle No 367

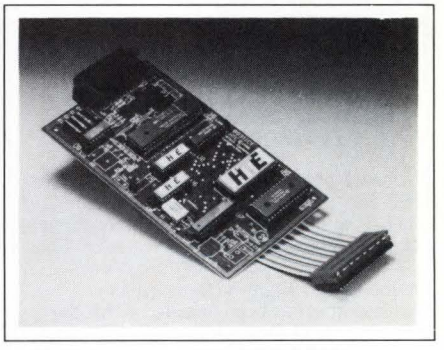
JITTER DEBUGGER

- *Presents timing and voltage histograms*
- *Runs on graphics-capable IBM PCs and compatible computers*

To assist in analyzing noise and jitter, a software package called i-Pattern works with the vendor's digital-storage oscilloscopes and waveform digitizers. The unit runs on IBM PCs, PS/2s, and 100% compatible machines equipped with at least 512k bytes of RAM and any common type of graphics adapter. The software stores waveform data in computer memory and allows you to select regions of interest for detailed display and analysis. You can display data as an X-Y plot and use color to denote intensity, or present data in three dimensions as a "waterfall" or solid-fill waterfall. You can also view as many as 40 acquired waveforms in a variable-persistence mode. The software also calculates many waveform statistics and indicates the number of samples that fall within a value region that you can specify. $850.

Tektronix Inc, Box 1700, Beaverton, OR 97077. Phone (800) 835-9433, ext 170.

Circle No 368



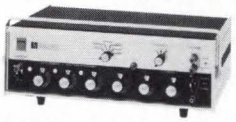
8031/8051 EMULATOR

- *Supports expanded-memory mode*
- *Downloads program via independent serial link*

The DryIce in-circuit emulator for 8031 and 8051 μPs works at clock speeds to 12 MHz with target systems that utilize the μPs' external memory mode. The product is housed on a 3.5×6-in. pc card and receives power from your 5V supply (500 mA for the standard version; 100 mA for the CMOS version). The emulator interfaces to a

New Instruments

DC Current and Voltage Calibrator — Model CR-103/J



Model CR-103/J is comprised of two complete instruments. DC voltage section is an ultra-stable, chopper stabilized amplifier with selectable precision resistors in the feed-back loop. The temperature compensated, aged zener diode is the reference. DC current section is the same configuration plus a precision, reference resistor. HIGH STABILITY-LOW NOISE

Features Current Mode
Variable Constant: Two Ranges ± 10nA to ± 100mAdC
High Resolution: ± 0.0001% (1 PPM)
Minimum selectable setting 10 nAmps
High Accuracy (1 Mode): ± 0.005% of setting + 0.005% of range)
Compliance (Power): ± 100 volts
Noise: 2 u Amps
Calibration cycle: 12 months

Features Voltage Mode
Variable Constant: Three Ranges: ± 100nV to ± 10 Vdc
High Resolution: 0.0001% (1 PPM)
Compliance (Power): 50 mAmps
Noise: 5 uV
"Crowbar" (Zero) Ref.

Price: $2,095
Engineering Contact: **Bob Ross**
Tel: (617) 268-9696 • FAX: 268-6754

CIRCLE NO 88

µP-based Programmable E/I dc Calibrator — Model 521

The new Model is a micro-processor based, IEEE-488 (GP-IB) controlled, Voltage and Current DC Calibrator. One of its important applications is an imbedded standard as used in Data Acquisition and Process Control Systems.

An important feature of the new microprocessor that has been installed is that the programming of this instrument is transparent with respect to the programs written for the earlier 520, 520/A and even the older 501/J (GP-IB version).

The height is only 3½", and features current mode outputs from 10 nanoamperes (nA) to 110 milliamperes (mA), in two ranges, with extraordinary compliance of 100 Vdc. Even with this power, ideal for transducer instrument testing (4-20 and 10-50 mA), the accuracy is ± 0.005% of setting.

The voltage has three ranges with outputs from 100 nV to 100 Vdc and optional to 1100 Vdc. Compliance current is 100 mA. The one-year accuracy is ± 0.002% of setting.

All ranges and both modes resolve to 1 ppm. A crowbar zero provides a reference for this essential value.

Price: $3,150.
Engineering Contact: **Bob Ross**
Tel: (617) 268-9696 • FAX: 268-6754

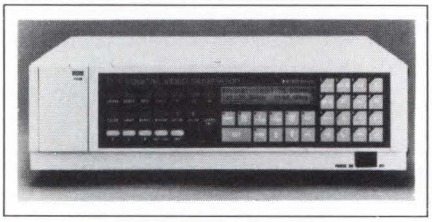
ELECTRONIC DEVELOPMENT CORP.
11 Hamlin St., Boston, MA 02127

CIRCLE NO 89

terminal or PC using a dedicated RS-232C link, which automatically selects its data rate from 75 to 19.2k bps. An 8k-byte static overlay memory is standard; it expands to 32k bytes. You download your program code in Intel hexadecimal format; optional nonvolatile RAM stores the program even when you remove power. $199.

HiTech Equipment Corp, 9400 Activity Rd, San Diego, CA 92126. Phone (619) 566-1892. FAX 619-530-1458.

Circle No 369



HDTV GENERATOR

- *Has variable-aspect ratio and resolution*
- *Is programmable to adapt to a wide range of proposed standards*

The Astro VG-814 programmable video generator can simulate a wide variety of Japanese, US, and European HDTV (high-definition television) standards. The unit produces analog and TTL RGB (red/green/blue) output with virtually any proposed resolution, aspect ratio, frame rate, and bandwidth. Pixel-by-pixel control over the 2048 × 1280-pixel graphics plane allows creation of special test patterns. You can create as many as 40 tests with different picture content, color balance, and average level, store them, and quickly recall them from the front panel or via an RS-232C interface. If you define 15 such patterns at the time of order, the factory will install them prior to shipping your unit. $5650.

Team Systems, 2934 Corvin Dr, Santa Clara, CA 95051. Phone (800) 338-1981; in CA, (408) 720-8877. FAX 408-720-9643. TLX 297584.

Circle No 370

SCSI Analyzer/ Emulator

- **POWERFUL**
- **EASY TO USE**
- **AFFORDABLE**

Features:
- 50 ns Time Stamp
- Sync and Async Tracing
- 32K Event Trace Memory
- Initiator and Target Emulation
- Custom Routines Programmable In C
- Easily Readable "SCSI English" Display

```
> Display trace memory   [in structured format]
Enter starting addr(Hex): 0

0001:    Arbitration /80
0003:    Select w.ATN /C0
0006:       Message-Out/C0(Identify)
0007:       Command /12(Inquiry) 00 00 00 30 00
000D:          Data-In /00 00 01 01 29 00 00 00 43 4F 4E 4E 45 52 20 20
                       43 70 33 34 30 20 28 34 30 6D 62 20 33 2E 35 29
002D:                  2D 30 34 20 42 30 31 33 54 42 20 20 20 20
003B:       Status  /00
003C:       Message-In /00
003D: Bus free
003F:    Arbitration w.ATN /80
0041:    Select w.ATN /C0
0044:       Message-Out/C0(Identify)
0045:       Command /08(Read) 00 00 10 01 00
0048:       Message-In /04(Disconnect)
004C: Bus free
004E:    Arbitration /40
0050:    Reselect /C0
0052:       Message-In /80(Identify)
0053:          Data-In /00 00 00 00 12 34 56 79 12 34 56 7A 12 34 56 7B
0063:                  12 34 56 7C 12 34 56 7D 12 34 56 7E 12 34 56 7F
```

```
> Display trace memory   [in BINARY format]
Enter starting addr(Hex): 0

TRMA: BSY SEL ATN RST MSG I/O C/D   DATA  ParErr  Exp  Time Diff (ns)
0000:  .   A   .   .   .   .   .   01 (.)   .    00          0 000
0001:  A   A   .   .   .   .   .   01 (.)   .    00         21 750
0002:  A   .   .   .   .   .   .   00 (.)   A    00         11 250
0003:  A   .   .   .   .   .   A   00 (.)   .    00        269 250
0004:  A   .   .   .   .   .   A   00 (.)   .    00        145 500
0005:  A   .   .   .   .   .   A   00 (.)   .    00        129 000
0006:  A   .   .   .   .   .   A   00 (.)   .    00        129 000
0007:  A   .   .   .   .   .   A   00 (.)   .    00        129 000
0008:  A   .   .   .   .   .   A   00 (.)   .    00        138 750
0009:  A   .   .   .   .   A   A   00 (.)   .    00        180 000
000A:  A   .   .   .   A   A   A   00 (.)   .    00        173 000
0008:  .   .   .   .   .   .   .   00 (.)   .    00         72 250
000C:  .   A   .   .   .   .   .   01 (.)   .    00      5 455 100
000D:  A   A   .   .   .   .   .   01 (.)   .    00         29 950
000E:  A   .   .   .   .   .   .   00 (.)   A    00         13 250
000F:  A   .   .   .   .   .   A   0A (.)   .    00        269 250
0010:  A   .   .   .   .   .   A   00 (.)   .    00        155 250
0011:  A   .   .   .   .   .   A   00 (.)   .    00        138 750
0012:  A   .   .   .   .   .   A   20 (.)   .    00        138 750
0013:  A   .   .   .   .   .   A   01 (.)   .    00        138 750
0014:  A   .   .   .   .   .   A   00 (.)   .    00        138 750
0015:  A   .   .   .   .   .   .   AD (-)   .    00        431 350
```

[415] 363-0667

ANCOT CORPORATION

1755 E. Bayshore Road, 18A
Redwood City, CA 94063

CIRCLE NO 90

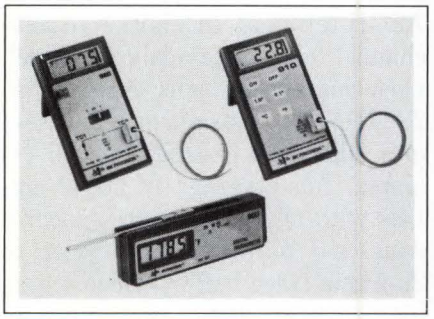
WAVE SYNTHESIZER

- *Includes 16k points of waveform memory*
- *Produces predefined or arbitrary waves to 10 MHz*

The R4000 arbitrary waveform synthesizer and function generator works in conjunction with an IBM PC or compatible computer. It can generate a wide variety of standard waveforms in continuous, sweep, and burst modes. The standard repertoire includes sine, square, and triangular waves; ramps; pulses; dc levels; and white noise. It can also download ASCII files describing arbitrary waveforms into its 16k-point waveform memory. The vendor supplies software drivers that work with C and Turbo Pascal. $2495.

Rapid Systems Inc, 433 N 34th St, Seattle, WA 98103. Phone (206) 547-8311. FAX 206-548-0322.

Circle No 371



THERMOMETERS

- *Use K-type thermocouples*
- *One model includes integral probe*

The Model 900 thermometer is a compact digital temperature meter with an integral probe. The 910 is a single-input, handheld temperature meter, and the 920 is a dual-input, handheld unit that lets you read the temperature at either of its probes and lets you select either 0.1 or 1° resolution. The 900 reads from −58 to +302°F with its integral probe and from −58 to 1500°F with an optional external probe. The other two models read from −58 to +1999°F. All units use type

K thermocouples or probes based on type K thermocouples. 900, $55; 910, $80; 920, $110.

B&K Precision, 6470 W Cortland St, Chicago, IL 60635. Phone (312) 899-9087.

Circle No 372

E-BEAM ANALYZER

- *Adds logic analysis to vendor's electron-beam probers*
- *Provides a standard logic-analyzer interface*

The Logic Analyzer Tool is a hardware and software product that adds logic-analysis capability to the vendor's IDS 4000/5000 electron-beam probers, which enable noncontact probing of internal nodes on complex IC chips. The tool employs multiple beam pulses for each test-pattern repetition, and a pipelined memory and signal-processing architecture to permit the use of test patterns two orders of magnitude longer than the previous patterns. It increases data-acquisition speed and lets you interactively manipulate large volumes of data. These capabilities permit diagnosis of intermittent failures. The tool's user interface is similar to that of conventional logic analyzers. $45,000; retrofitted onto an existing system, $50,000. Available in October 1989.

Schlumberger Technologies, ATE Div, 1601 Technology Dr, San Jose, CA 95110. Phone (408) 437-5000. FAX 408-453-0137.

Circle No 373

WAVEFORM DIGITIZER

- *Acquires data at rates to 200M samples/sec*
- *Stores 512k samples*

The IQ300 system offers plug-in options that permit it to simultaneously acquire signals at rates from 100k to 200M samples/sec on a maximum of 248 channels. Data memory can hold 512k samples, and the unit sports a 9-in. CRT that can display as many as eight channels. To increase waveform storage and to store setup configurations, you can configure the system with a hard drive or an MS-DOS-compatible floppy-disk drive. All units include two RS-232C ports and an IEEE-488 port, as well as a clock to time/date-stamp acquired data. The unit also calibrates itself. $9950; channel electronics from $1400/channel. Delivery, 30 to 45 days ARO.

Hi-Techniques Inc, 152 Owen Rd, Madison, WI 53716. Phone (800) 248-1633; in WI, (608) 221-7500. FAX 608-221-7509.

Circle No 374

PROGRAM ANALYZER

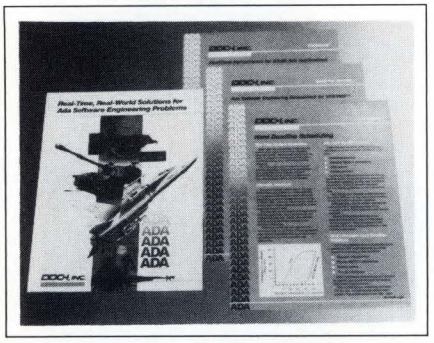
- *Supports 680X0 family*
- *Filters out insignificant information during trace*

The PMA-030 real-time program analyzer supports the 680X0 series of μPs, including the 68030. To operate, the unit requires only an ASCII terminal. In addition to a 92-channel logic state analyzer, which performs synchronous sampling at 25 MHz, the instrument offers several additional capabilities; for example, full coverage of 68030 signals with ability to detect synchronous and burst-memory cycles; a 2k-frame trace buffer, which stores only useful data and permits searches for significant occurrences; time-tagging of trace data; and real-time determination of interrupt-level distributions, event counts, and cache-hit rates. The unit also includes enough battery-backed RAM to store 30 test routines. $6990. Target adapters: 68030, $500; 68020, $400; 68010/000/008, $300.

Vmetro Inc, 2500 Wilcrest, Suite 530, Houston, TX 77042. Phone (713) 266-6430. FAX 713-266-6919.

Circle No 375

LITERATURE



Packet describes Ada solutions

A 5-pg folder and three technical data sheets provide information on Ada software. *Hard Deadline Scheduling in Ada* looks at research conducted at Carnegie-Mellon University and how it will affect the Ada programming language. *Ada Software Engineering Environment for VAX/VMS* examines various development tools to solve Ada software-engineering problems. *Real-Time Performance for 80×86 Ada Applications* analyzes how to enhance hardware performance and minimize software development and cost.

DDC-I Inc, 9630 N 25th St, Suite 118, Phoenix, AZ 85021.

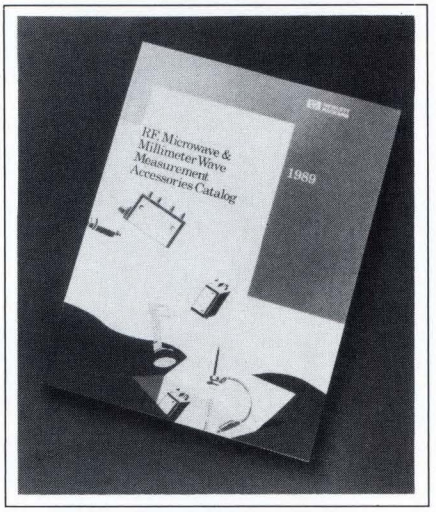
Circle No 398

Guide to buying your CAD/CAM tools

The Engineer's CAD/CAM Purchase Checklist can help you make the best decision when you're in the market for a new system. The guide tells you how to double-check your current setup, talk to vendors, check out a component or a peripheral, and look for new applications. In addition to these and other helpful hints, the book offers checklists on training aids; database management; accounting and cost control; hard-copy and communications needs; system and user environment; vendor experience; N/C mill programming; electronic design; pc-board layout; mold analysis programs; and plant design. $29.95 or free with new $154 1-year subscription to *Computer Aided Design Report.*

CAD/CAM Publishing Inc, 841 Turquoise St, Suite D, San Diego, CA 92109.

INQUIRE DIRECT



Abundant offering of measurement accessories

RF, Microwave & Millimeter Wave Measurement Accessories Catalog (Literature 5953-2346) presents more than 500 products, including an economy spdt coaxial-switch series; 11-, 70-, and 90-dB step attenuators for 40 GHz; and a family of planar-doped-barrier coaxial detectors. Selection guides and 18 product sections cover fixed and step attenuators; adapters, detectors, power sensors, probes, and 75Ω components; and test accessories and calibration kits for scalar and vector network analyzers. You will also find waveguide and flange data, coaxial-connector information, band designations, and applications-literature listings.

Hewlett-Packard Co, 19310 Pruneridge Ave, Cupertino, CA 95014.

Circle No 399

Report discusses effect of logic synthesis

The Impact of Logic Synthesis on Design Automation answers questions such as why logic synthesis is the most popular design technology since design simulation, how logic synthesis differs from silicon compilation, and how much design time logic-synthesis tools can save. The publication forecasts the market for various CAE/CAD tools and projects the impact in dollars that logic synthesizers will have on the 1989-1993 CAE market. It reviews the background of logic synthesizers, as well as currently available products and major companies in today's market. $985.

Electronic Trend Publications, 12930 Saratoga Ave, Suite D1, Saratoga, CA 95070.

INQUIRE DIRECT

Kit features logic-analysis system

The vendor's packet contains two brochures and four data sheets that describe the CLAS 4000 configurable logic-analysis system. The 4-color brochures deal with "perspectives" and "performance." The Perspectives brochure discusses challenges, configurability, the man/machine interface, the crosspoint switch, and graphics selections. The Performance brochure describes the system, pyramid module sampling and pyramid module trace control, the magnifying-glass module, the system controller, and control specifications. The four data sheets summarize information about the four different models of the probe adapter. Photos, diagrams, tables, and figures illustrate the publications.

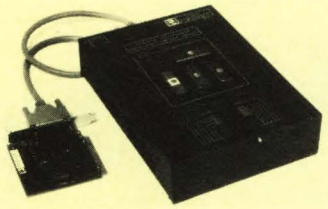
Gould Inc, Test and Measurement, 19050 Pruneridge Ave, Cupertino, CA 95014.

Circle No 400

EDN PRODUCT MART

This advertising is for new and current products.

Please circle Reader Service number for additional information from manufacturers.



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- **Software driven pin drivers. D/A generated** programming voltages.
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- File formats accepted: **Intel Hex 86/88, Tetronix Hex, Motorola S , JEDEC.**
- Customer support via voice line, **dedicated BBS** or fax. **Full 1 year warranty.**
- **Base** price includes Interface card, cable, **Memory** device library and 1 year. free updates. Additional **Device Libraries (Logic, Micros, Bipolars) $95 ea.**
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- Handles **all memory devices to 32 pins.** (Ugradeable up to **8 megabit** parts).
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- Includes PC Interface card, Memory device library and 1 **year free updates.**

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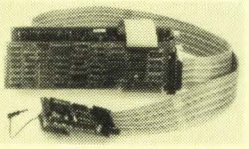
B&C MICROSYSTEMS INC.
355 WEST OLIVE AVE., SUNNYVALE, CA 94086
TEL: (408) 730-5511 FAX: (408) 730-5521

CIRCLE NO 325

68HC11

PC-based emulator for 68HC11



- PC plug-in or RS-232 box.
- Pull-down menus with full window support, combined with command-driven User Interface.
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- No intrusions to the 68HC11's resources.
- 48 bit wide 16K deep trace. All functions usable without disturbing emulation. Time stamping. Two level trigger.
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PRICES: 64K Emulator and pod $2590;* 4K Trace $1995*

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CIRCLE NO 326

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FREE EVALUATION PACKAGE
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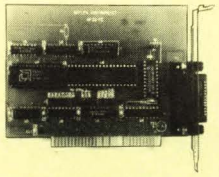
ACCEL Technologies, 6825 Flanders Dr., San Diego, CA 92121

CIRCLE NO 327

IEEE-488
$210



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CIRCLE NO 328

3.5/4.5 Digit LED & LCD Digital Panel Meters

- **Low Power Consumption (1 Watt, typ)**
- **Fast, Unique Mounting Arrangement**
- **User Selectable Decimal Point Placement**
- **Very Low Cost**
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ACCULEX
A METRABYTE COMPANY
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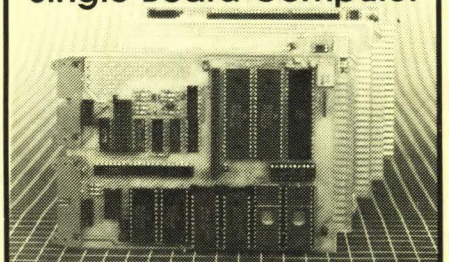
(508) 880-3660 TLX: 503989

CIRCLE NO 329

6809
Single Board Computer



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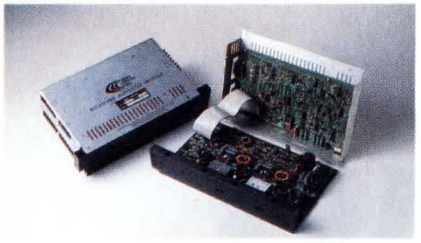
WINTEK
Wintek Corp.
1801 South Street
Lafayette, IN 47904
800-742-6809

CIRCLE NO 330

To advertise in Product Mart, call Joanne Dorian, 212/463-6415



High Power 71kHz Power Amplifiers (Master/Slave System)

Model 220/230

- Highest freq. 71kHz
- Lowest noise...pure DC output
- Performs like a linear amplifier
- Master/slave design...power from 1kW to 30kW at 150 volts
- DC output eliminates RFI

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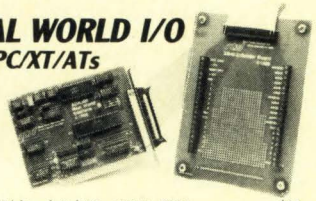

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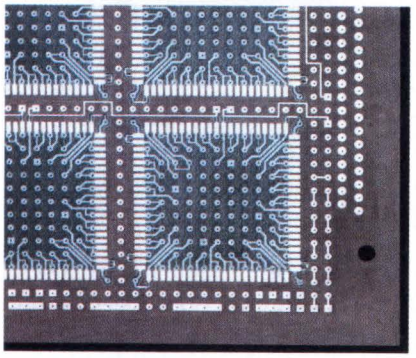

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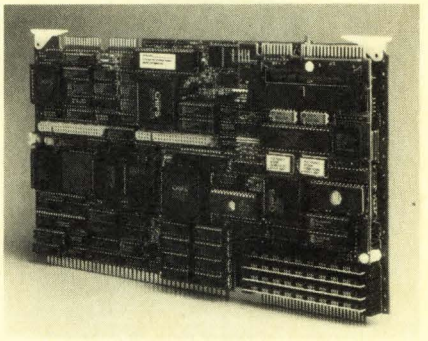

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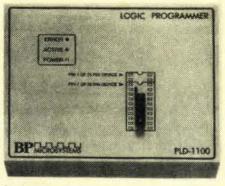

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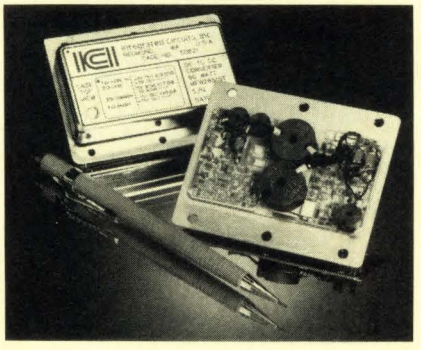

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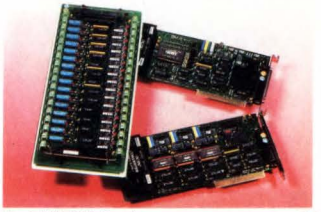

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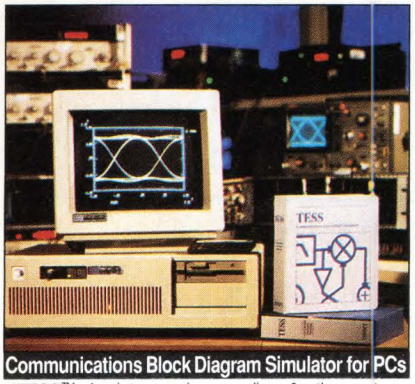

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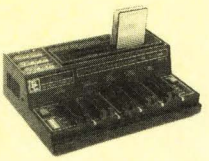

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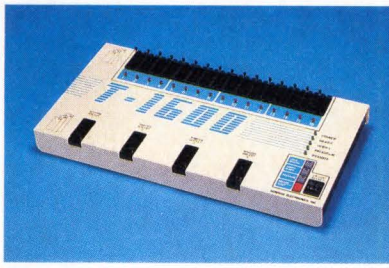

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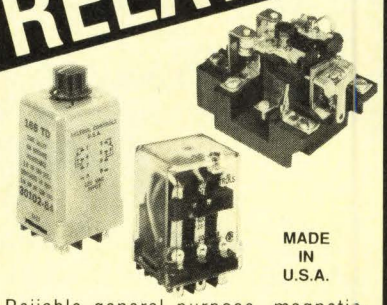

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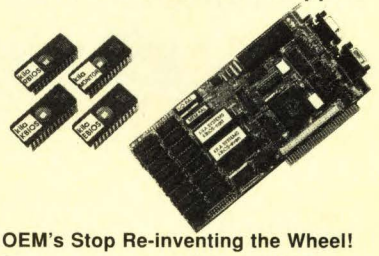

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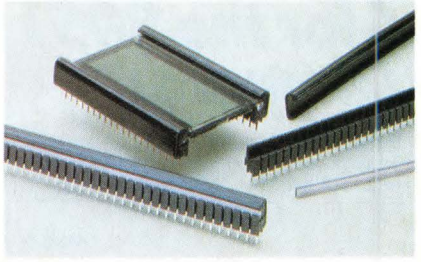

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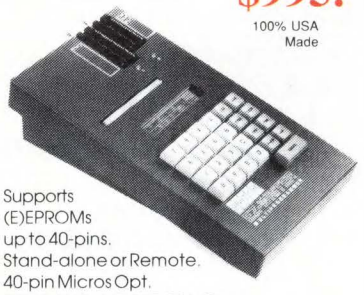

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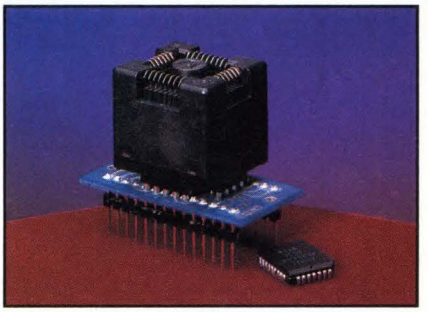

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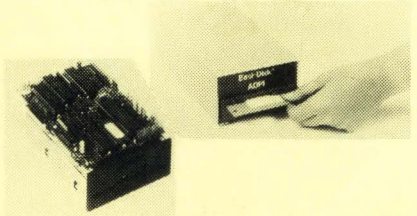

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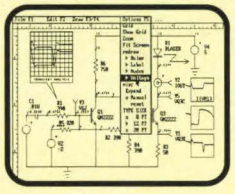

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Issue Date	Recruitment Deadline	Editorial Emphasis	EDN News Edition
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Sept. 14	Aug. 24	Industrial Product Showcase, Digital ICs	Closing: Aug. 30 Mailing: Sept. 21
Sept. 28	Sept. 7	Integrated Circuits, Computer Peripherals	Closing: Sept. 15 Mailing: Oct. 5
Oct. 12	Sept. 21	DSP Chip Directory, Integrated Circuits	Closing: Sept. 28 Mailing: Oct. 19
Oct. 26	Oct. 5	Test & Measurement Special Issue Computers & Peripherals	Closing: Oct. 27 Mailing: Nov. 16
Nov. 9	Oct. 19	CAE, Integrated Circuits	
Nov. 23	Nov. 2	16th Annual μP/μC Directory, Integrated Circuits	Closing: Nov. 9 Mailing: Nov. 30
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For the Texas positions, send your resume to: **Advanced Micro Devices, Department MS-556-EDN, 5204 East Ben White Blvd., Austin, Texas 78741.** You may also call toll free **1-(800) 531-5202, Ext. 5355, or FAX your resume to (512) 462-5108.** For manufacturing line openings, ask for **Pamela May or Ed Moore;** for product line openings, ask for **Paul Maack or John O'Hara.**

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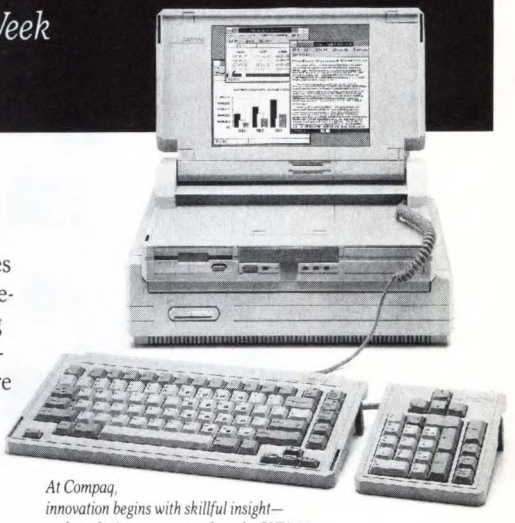

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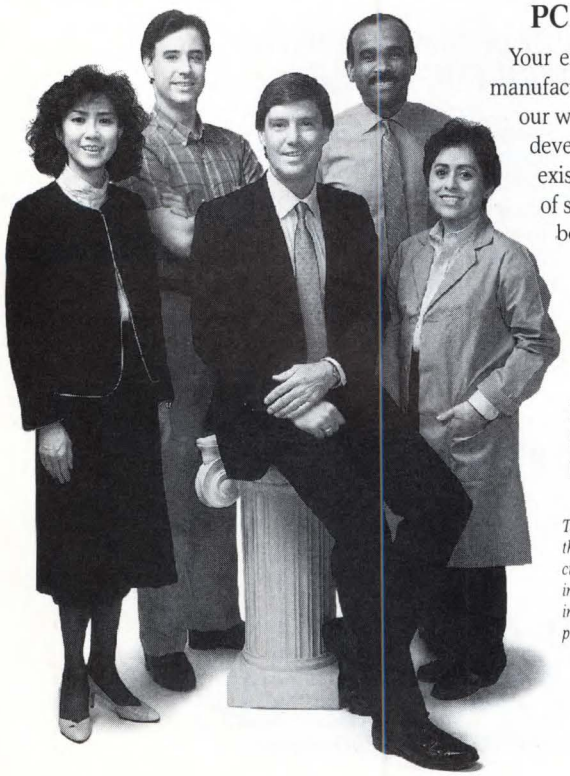

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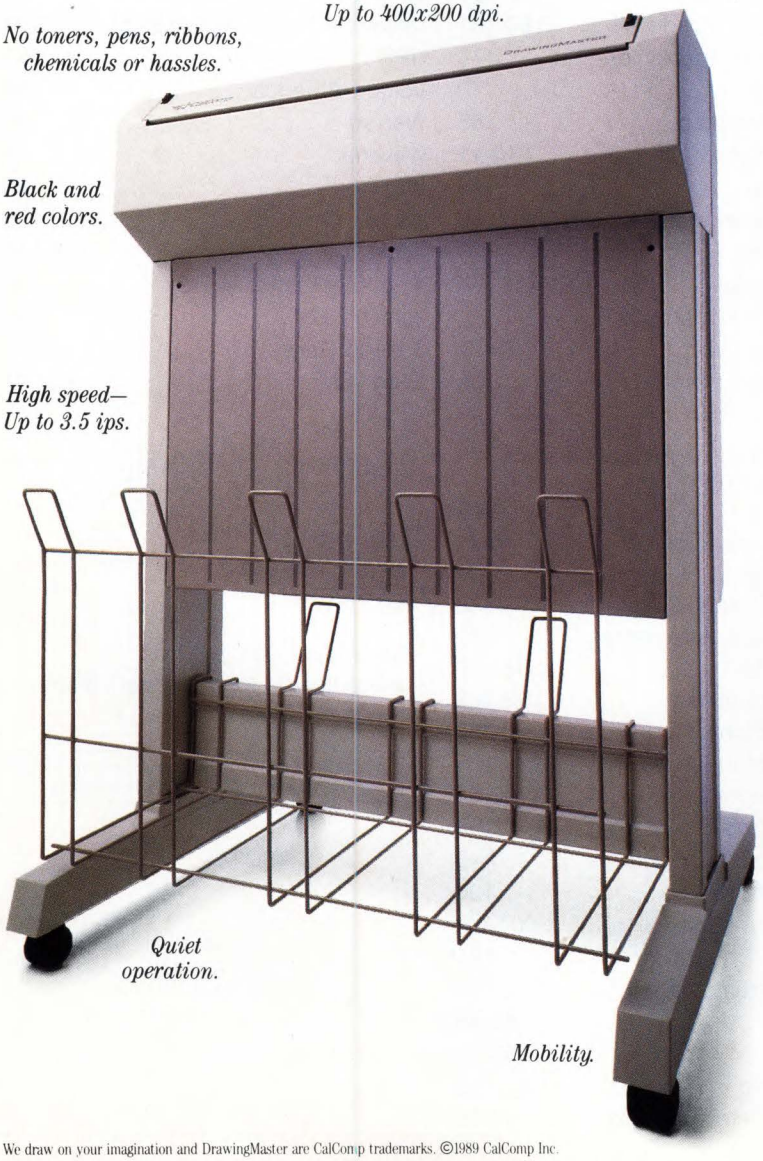

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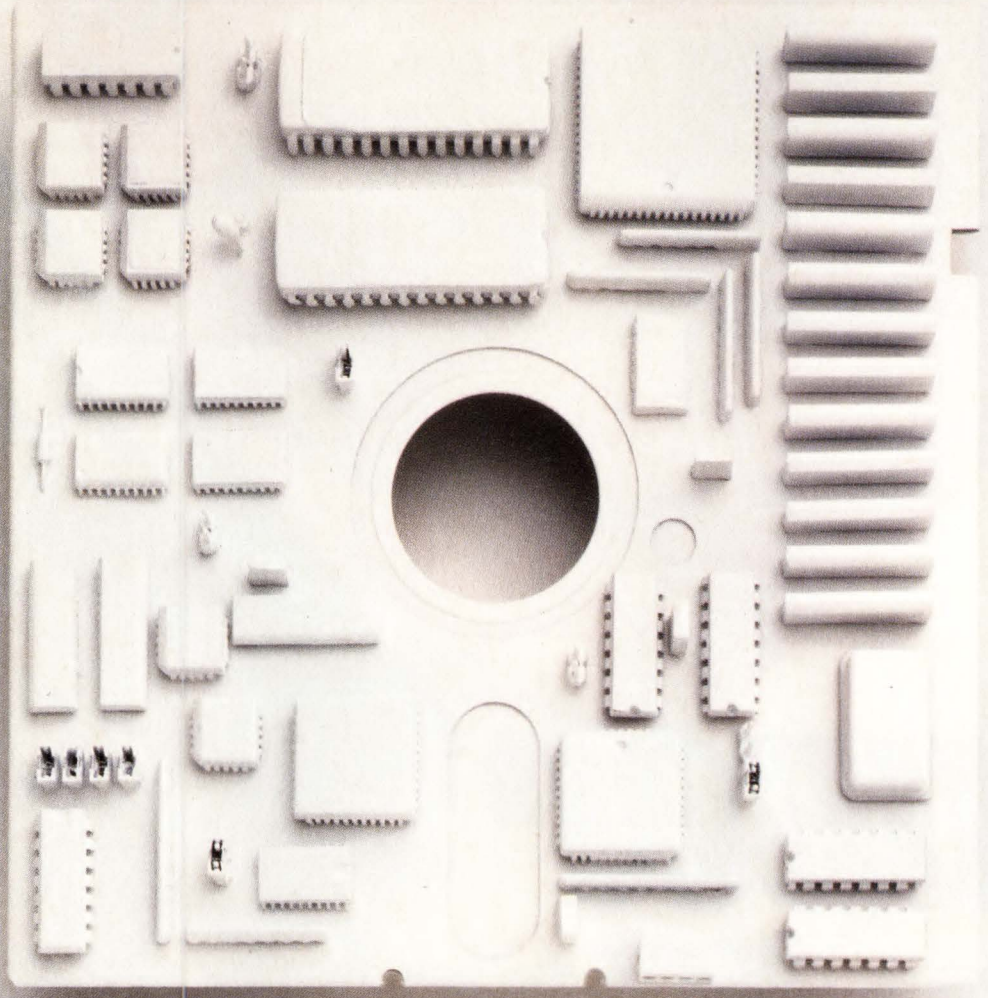

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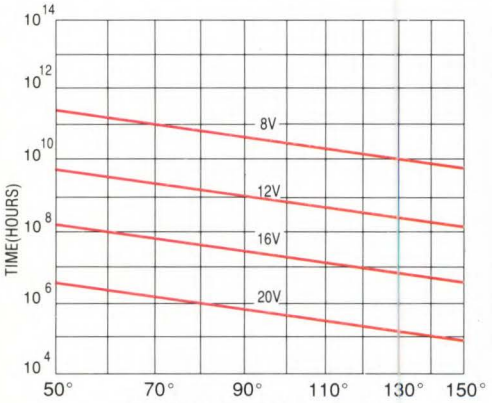
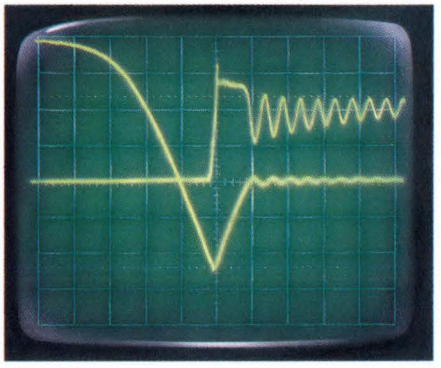
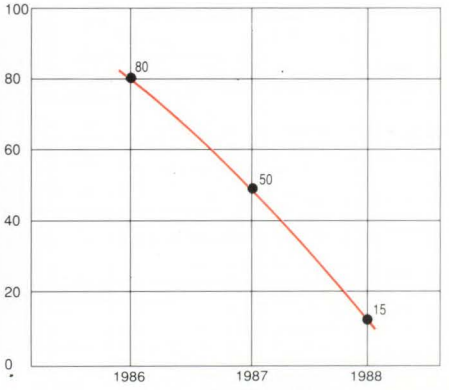


Gate stress TO-220 time to failure


HEXFET IRF530 under avalanche



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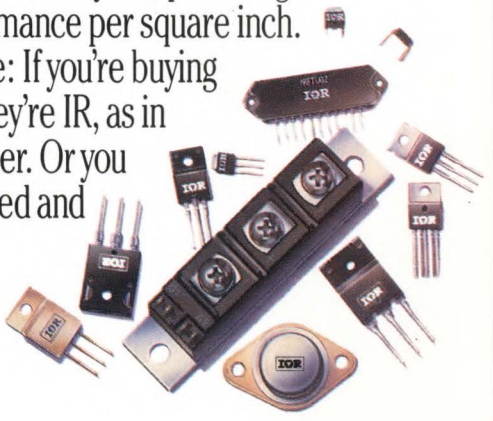

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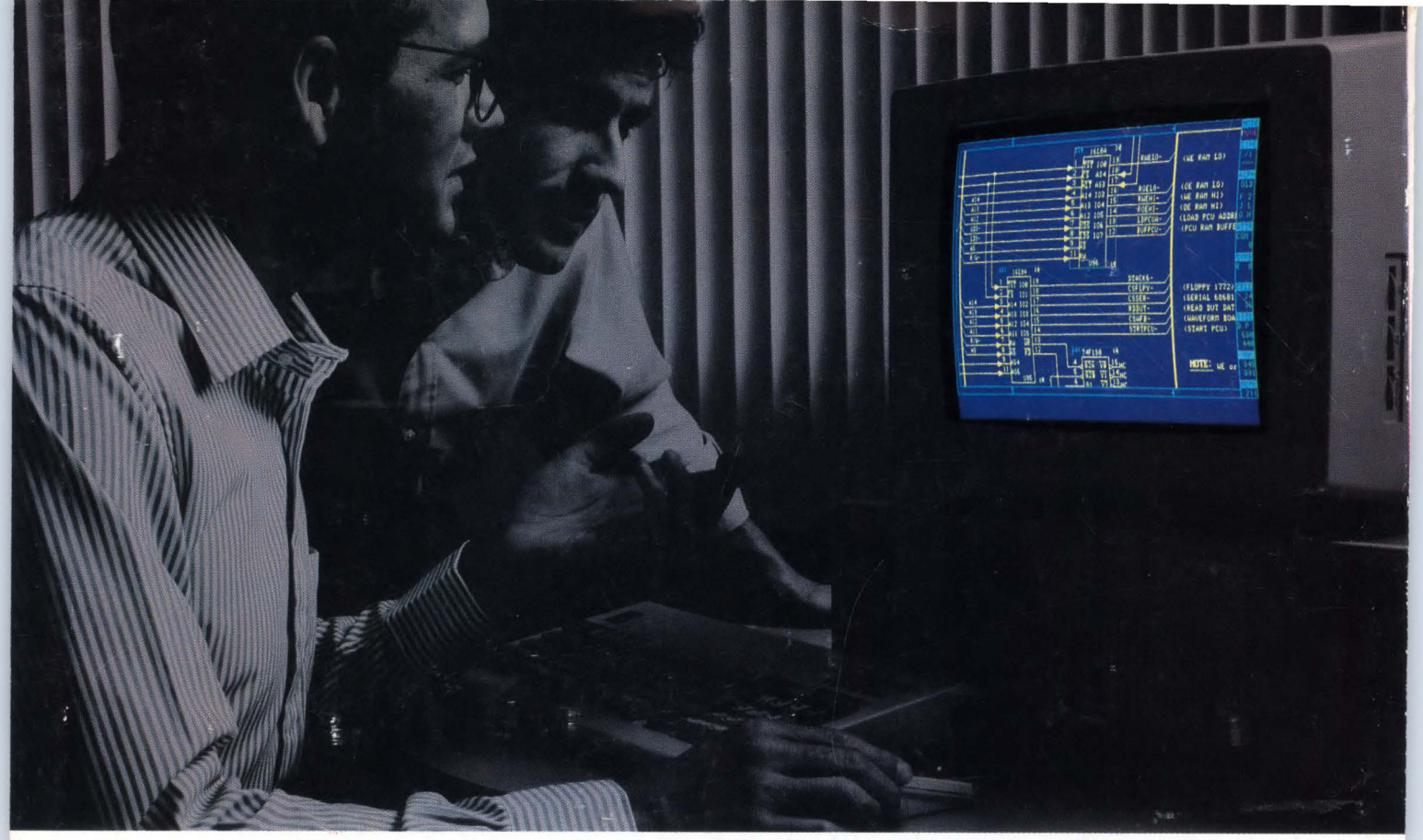

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