A CAHNERS PUBLICATION

AUGUST 18, 1988

EDN®

SPECIAL ISSUE:
Military electronics

Circuit simulation for rad-hard designs

Peer-to-peer protocol eases real-time communications

DRAM-controller ICs

ELECTRONIC TECHNOLOGY FOR ENGINEERS AND ENGINEERING MANAGERS

Breakthroughs move flat-panel displays into a new phase

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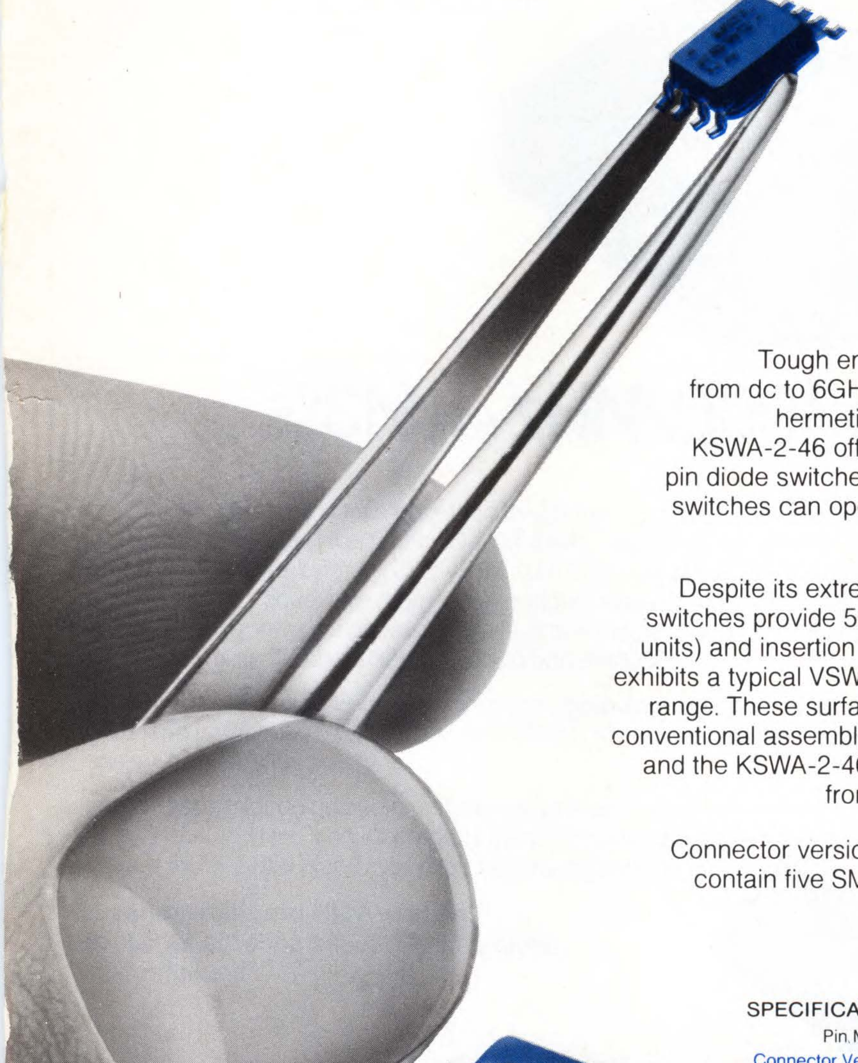
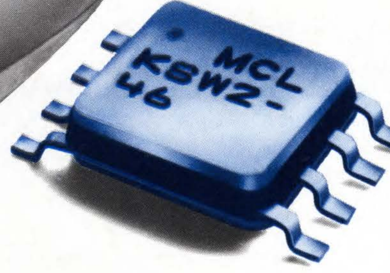
The next

tiny SPDT switches

absorptive... reflective





dc to 4.6 GHz from $32.95 (1-24)

Tough enough to pass stringent MIL-STD-883 tests, useable from dc to 6GHz and smaller than most RF switches, Mini-Circuits' hermetically-sealed (reflective) KSW-2-46 and (absorptive) KSWA-2-46 offer a new, unexplored horizon of applications. Unlike pin diode switches that become ineffective below 1MHz, these GaAs switches can operate down to dc with control voltage as low as -5V, at a blinding 2ns switching speed.

Despite its extremely tiny size, only 0.185 by 0.185 by 0.06 in., these switches provide 50dB isolation (considerably higher than many larger units) and insertion loss of only 1dB. The absorptive model KSWA-2-46 exhibits a typical VSWR of 1.5 in its "OFF" state over the entire frequency range. These surface-mount units can be soldered to pc boards using conventional assembly techniques. The KSW-2-46, priced at only $32.95, and the KSWA-2-46, at $48.95, are the latest examples of components from Mini-Circuits with unbeatable price/performance.

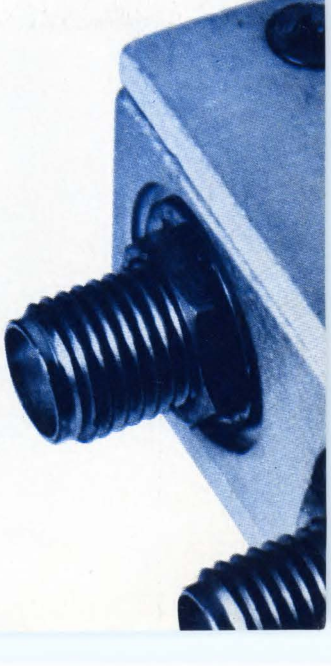
Connector versions, packaged in a 1.25 x 1.25 x 0.75 in. metal case, contain five SMA connectors, including one at each control port to maintain 3ns switching speed.

Switch fast... to Mini-Circuits' GaAs switches.

SPECIFICATIONS

Pin Model	**KSW-2-46**		**KSWA-2-46**	
Connector Version	**ZFSW-2-46**		**ZFSWA-2-46**	
FREQ. RANGE	dc-4.6 GHz		dc-4.6 GHz	
INSERT. LOSS (db)	typ	max	typ	max
dc-200MHz	0.9	1.1	0.8	1.1
200-1000MHz	1.0	1.3	0.9	1.3
1-4.6GHz	1.3	1.7	1.5	2.6
ISOLATION (dB)	typ	min	typ	min
dc-200MHz	60	50	60	50
200-1000MHz	45	40	50	40
1-4.6GHz	30	23	30	25
VSWR (typ) ON	1.3:1		1.3	
OFF	—		1.4	
SW. SPEED (nsec) rise or fall time	2(typ)		3(typ)	
MAX RF INPUT (bBm)				
up to 500MHz	+17		+17	
above 500MHz	+27		+27	
CONTROL VOLT.	**-5V** on, OV off		**-5V** on, OV off	
OPER/STOR TEMP.	-55° to +125°C		-55° to +125°C	
PRICE (1-24)	**$32.95**		**$48.95**	
	$72.95		**$88.95**	

C 117 REV. D



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CIRCLE NO 11

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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. (5-24)
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

††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.

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CIRCLE NO 12

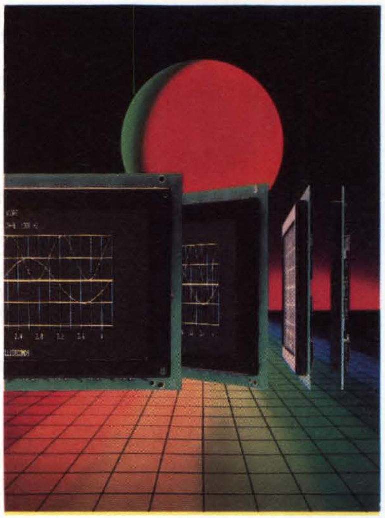
C118 REV. B

Volume 33, Number 17

EDN

August 18, 1988

ELECTRONIC TECHNOLOGY FOR ENGINEERS AND ENGINEERING MANAGERS



On the cover: *Manufacturers are working to make flat-panel displays that are suitable for more and more complex applications, while improving performance levels and lowering their cost. See pg 138. (Photo courtesy Cherry Electrical Products)*

SPECIAL ISSUE: MILITARY ELECTRONICS

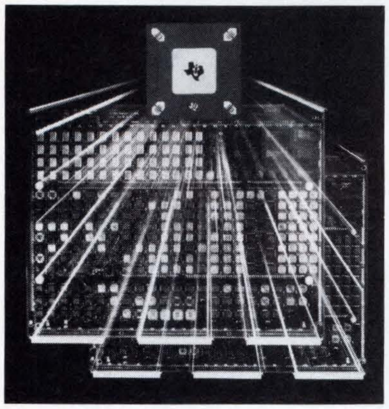
SPECIAL REPORT

DESIGN FEATURES

Continued on page 7

EDN®(ISSN 0012-7515) is published 40 times a year (biweekly with 1 additional issue a month, except for July which has 3 additional issues) by Cahners Publishing Company, A Division of Reed Publishing USA, 275 Washington Street, Newton, MA 02158-1630. Terrence M McDermott, President; Frank Sibley, Electronics/Computer Group Vice President; Jerry D Neth, Vice President/Publishing Operations; J J Walsh, Financial Vice President/Magazine Division; Thomas J Dellamaria, Vice President/Production and Manufacturing. Circulation records are maintained at Cahners Publishing Company, 44 Cook Street, Denver, CO 80206-5800. Telephone: (303) 388-4511. Second-class postage paid at Denver, CO 80206-5800 and additional mailing offices. POSTMASTER: Send address corrections to EDN® at the Denver address. Saul Goldweitz, Chairman; Ronald G Segel, President and Chief Executive Officer; Robert L Krakoff, Executive Vice President; William M Platt, Senior Vice President. Annual subscription rates for nonqualified people: USA, $100/year; Canada/Mexico, $115/year; Europe air mail, $135/year; all other nations, $135/year for surface mail and $210/year for air mail. Except for special issues where price changes are indicated, single copies of regular issues are available for $6, $8, and $10 (USA, Canada/Mexico, and foreign). Please address all subscription mail to Eric Schmierer, 44 Cook Street, Denver, CO 80206-5800.

Continued from page 5



***You no longer** need a supercomputer to run AI-related programs: many such programs will run on modest machines such as the IBM PC/AT and compatibles (pg 71).*

TECHNOLOGY UPDATE

PRODUCT UPDATE

DESIGN IDEAS

Continued on page 9

EDN magazine now offers Express Request, a convenient way to retrieve product information by phone. See the Reader Service Card in the front for details on how to use this free service.

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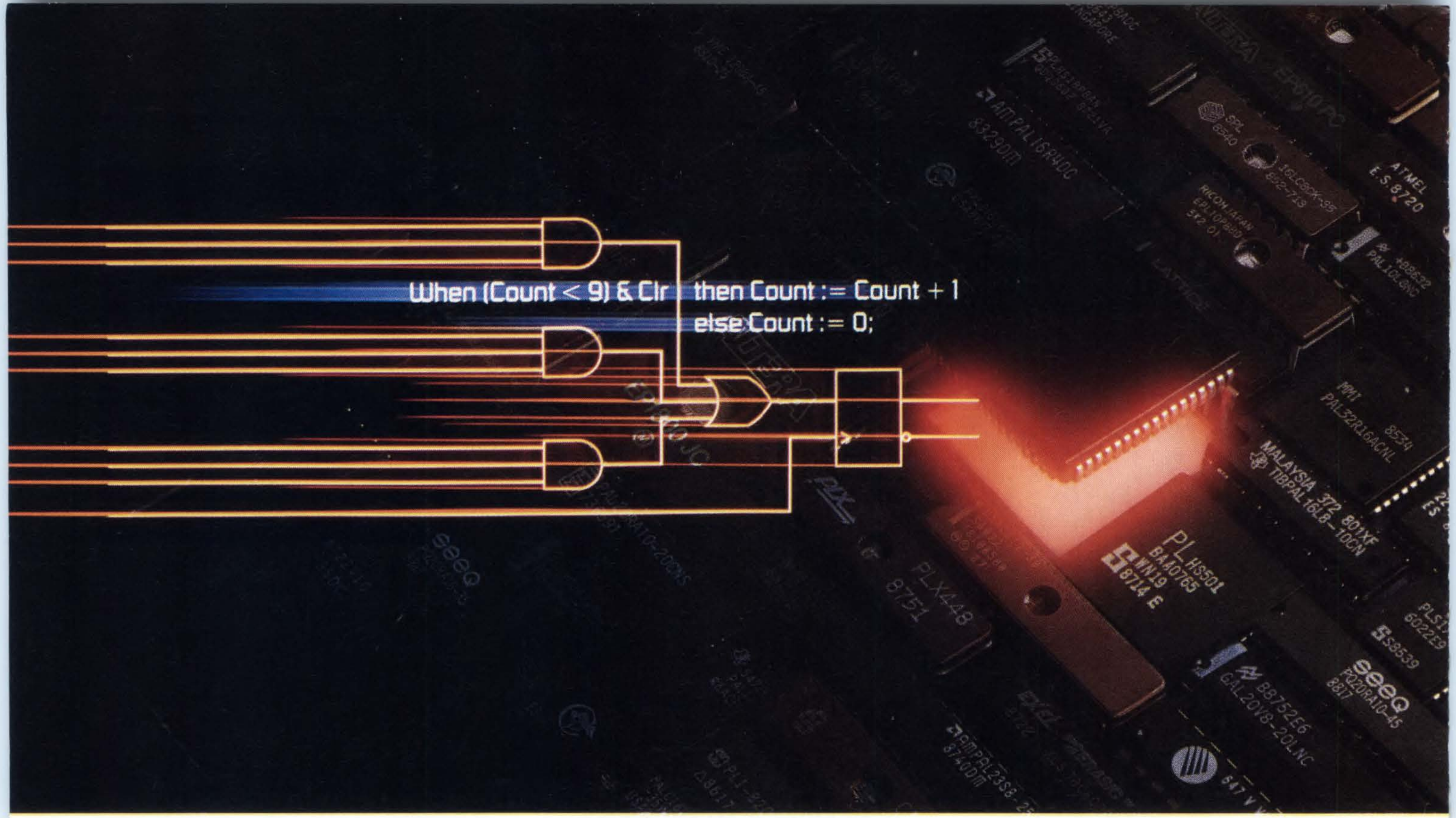

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CIRCLE NO 267

Continued from page 7

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International trade problems may force us to give our Asian trade partners a taste of their own medicine.

NEW PRODUCTS

PROFESSIONAL ISSUES 323

Design firms: A little bit of engineering heaven.—*Deborah Asbrand, Associate Editor*

LOOKING AHEAD 355

Manufacturers praise JIT logistics. . . $20B market predicted for smart network equipment.

DEPARTMENTS

IN DSP.

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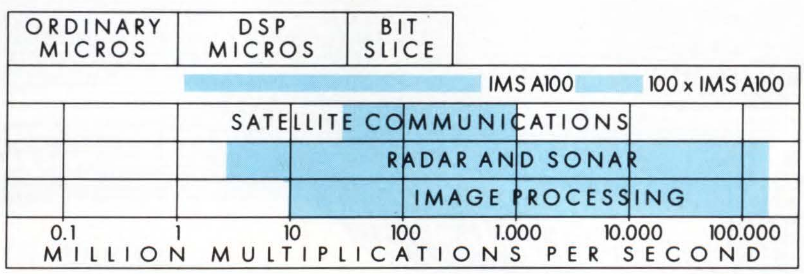

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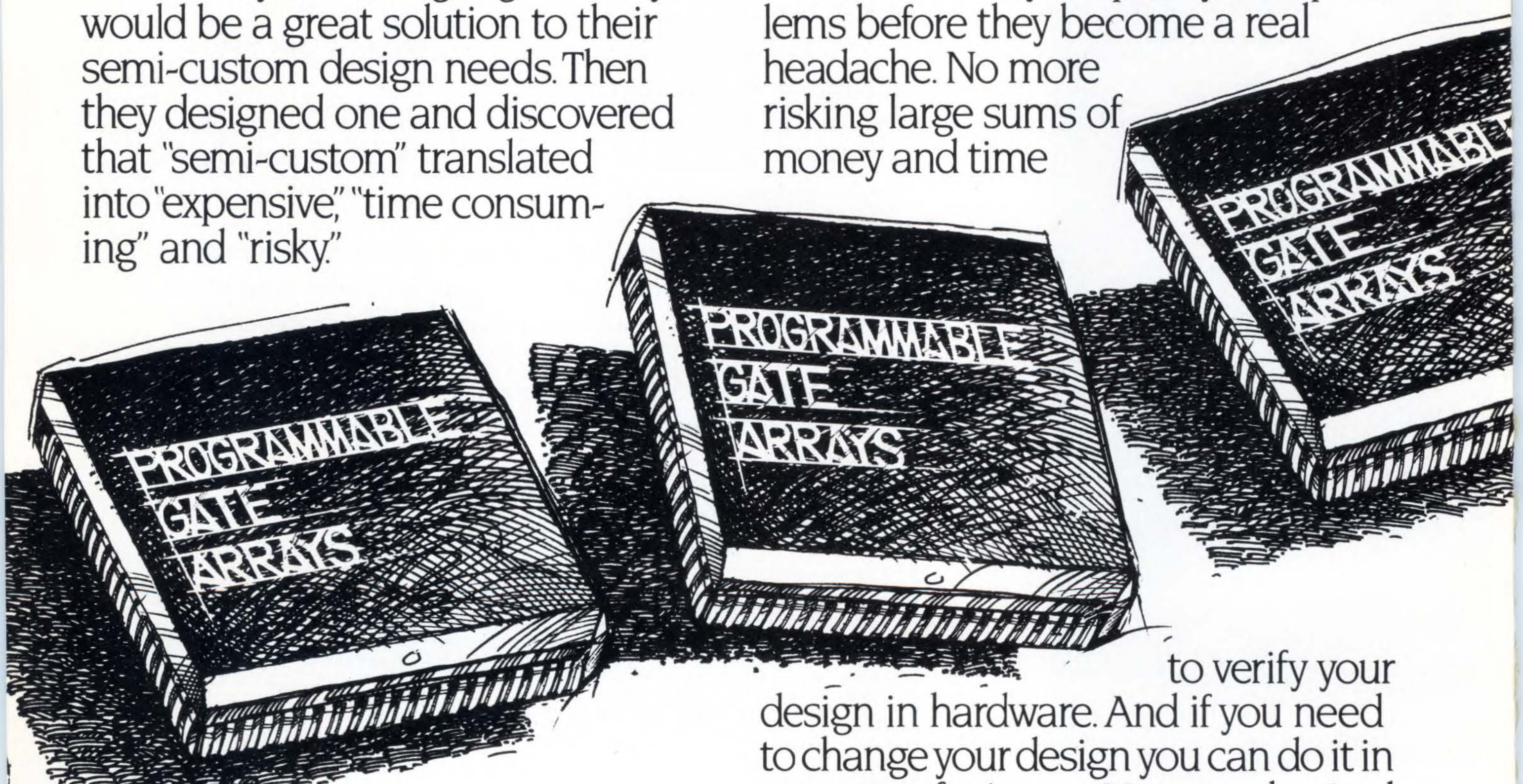

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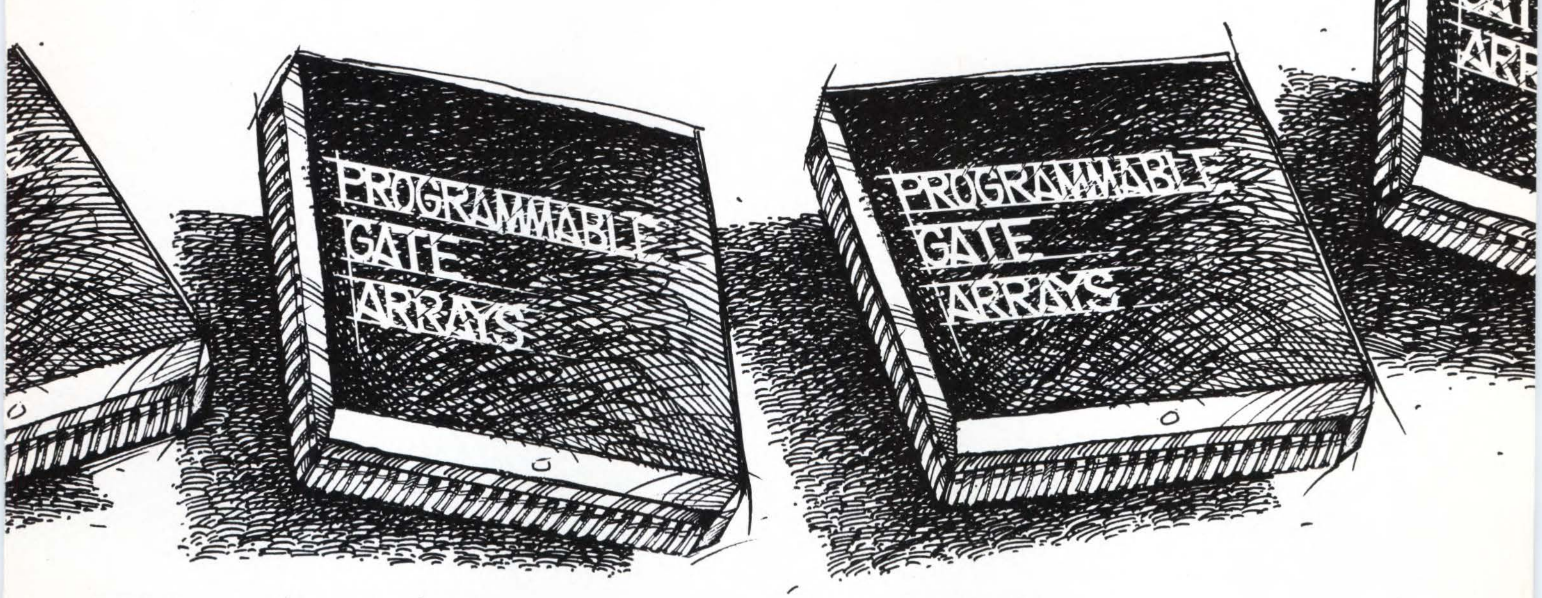

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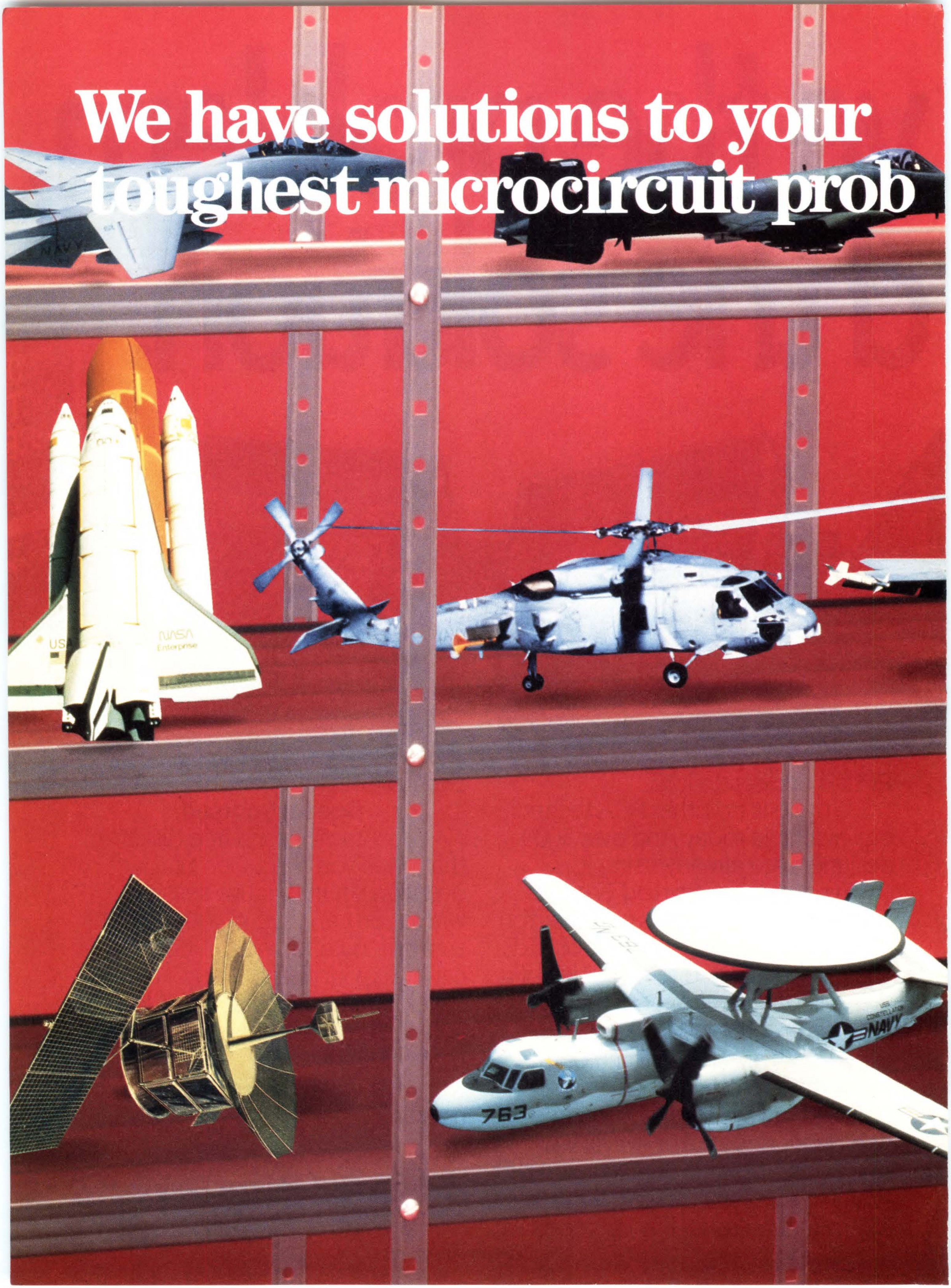
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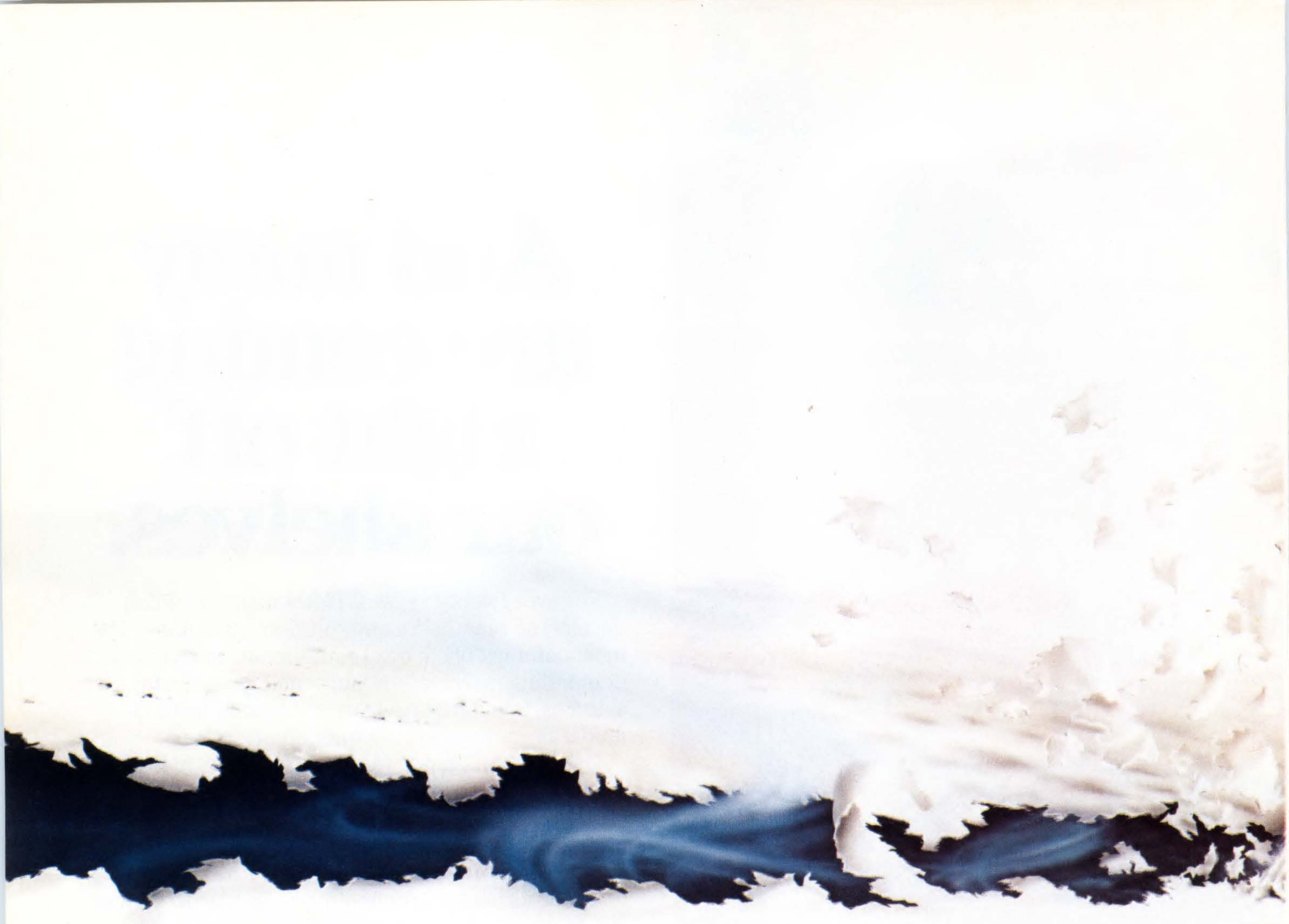

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*Sometimes called Rocky Mountain BASIC or BASIC 5.0.

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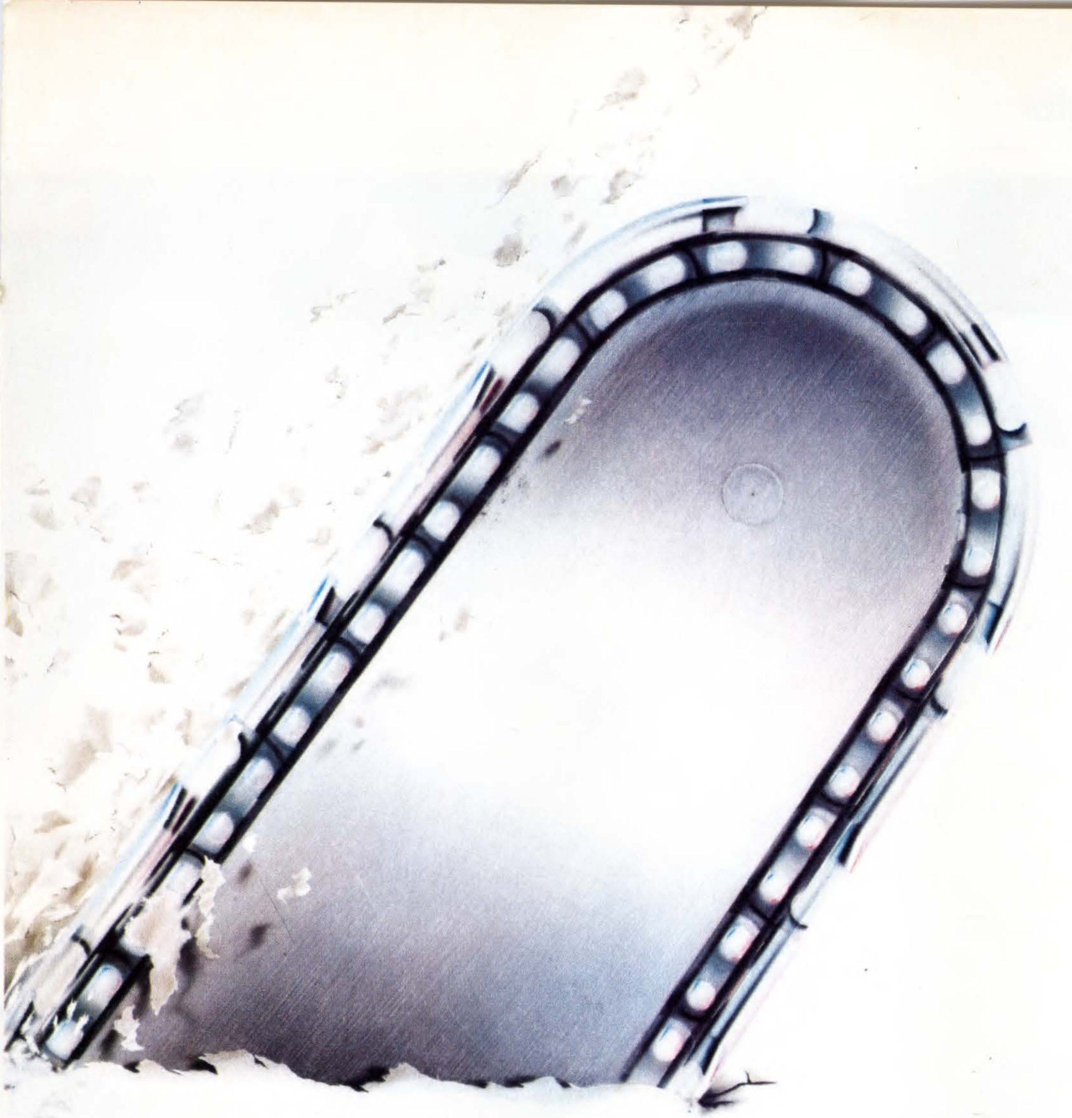

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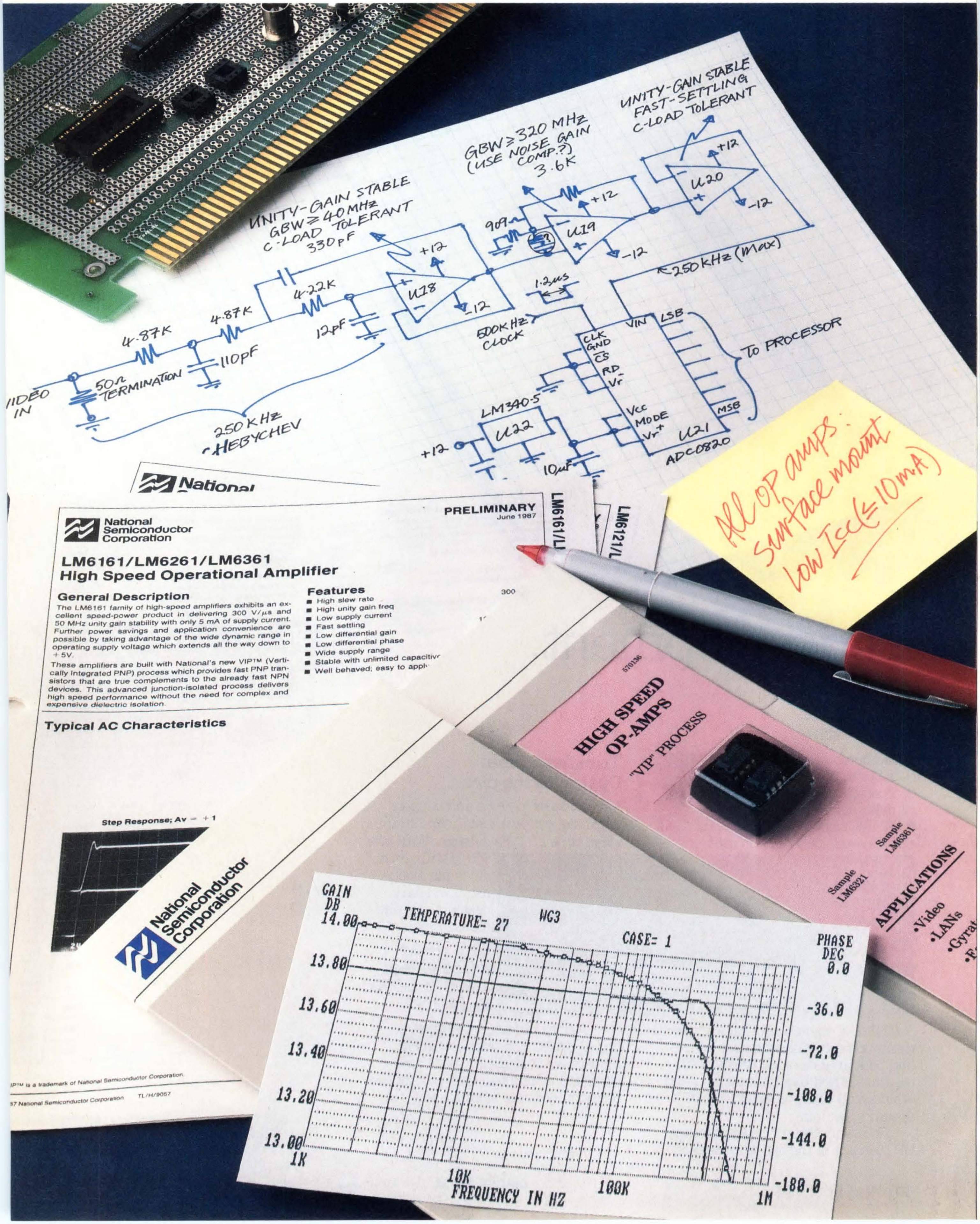

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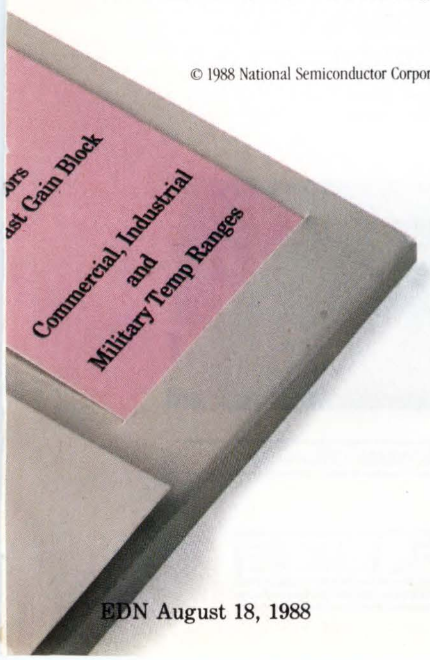

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CIRCLE NO 34

NEWS BREAKS

EDITED BY JOANNE CLAY

MOSFET COMBINES HIGH POWER WITH LOW DRIVE REQUIREMENTS

The APT5010FN, a 500V power MOSFET from Advanced Power Technology (Bend, OR, (503) 382-8028), delivers 50A of usable current and features input capacitance of 6000 pF—about half the drive requirement of conventional MOSFETs configured for comparable currents, according to the manufacturer. Designed for power-supply and motor-control circuits in military and commercial systems, the device features 0.1Ω on-resistance. The MOSFET is fabricated on a 338×588-mil die and is available in a hermetically sealed package and in a die version (APT5010DN). The units are available with full military screening. The packaged and die versions cost $149.88 (1000) and $66.20, respectively. Delivery is four to six weeks.—Tom Ormond

POWER RECTIFIERS FEATURE 50-NSEC RECOVERY TIME

The 5A USC130X power rectifier from Semtech (Newbury Park, CA, (805) 498-2111) features a 50-nsec reverse recovery time at 200V, 300V, and 400V. (The X in the part number can be 4, 5, or 6, designating 200V, 300V, or 400V, respectively.) The hermetically sealed, subminiature, axially leaded parts are also available in a 2A version, the USC110X. Prices start at $4 (OEM qty).—Margery S Conner

RF GENERATOR SENDS LONG-WAVE SIGNALS THROUGH UHF

Priced at only $195 and providing an output range from 100 kHz to 150 MHz, the Model 2005 RF Signal Generator from B&K Precision (Chicago, IL, (312) 889-1448) offers you six fundamental bands and 450 MHz on harmonics. You can modulate the amplitude of the generator's output via an internal 1-kHz source, or you can do it externally by using any audio frequency. The 2005 can perform step and variable output attenuation to 40 dB, as well as variable amplitude modulation from 0 to 100%. The unit has a separate output for an external frequency counter and an RF connection. An antibacklash vernier dial gives you output-frequency control to within 3%.—J D Mosley

JFET OP-AMP FAMILY YIELDS HIGH SPEED AND LOW POWER

Texas Instruments' (Dallas, TX, (800) 232-3200) TL050 Enhanced-JFET op amps reduce input-offset voltage (V_{IO}) shifts to 60 μV (typ) without resorting to metal packaging. They provide higher slew rates and lower input-bias-current requirements than do standard bipolar devices. The devices are pin-compatible with industry-standard JFET op amps, and you can choose a 15 or 2V/μsec minimum slew rate with a maximum V_{IO} ranging from 0.8 to 4.0 mV.—J D Mosley

8-BIT HALF-FLASH ADC INCLUDES TRUE SAMPLE/HOLD AMPLIFIER

The LTC1099 from Linear Technology Corp (Milpitas, CA, (800) 637-5545) is a half-flash 8-bit A/D converter that converts in 2.5 μsec. A true sample/hold amplifier is included on the chip; it allows the ADC to convert 5V p-p signals at as much as 167 kHz, or signals with slew rates as high as 20V/μsec. The LTC1099 is pin compatible with the AD7820 and the ADC0820; these older devices can complete the A/D conversion in 1.5 μsec, but have pseudo-S/H amplifiers that can accept signals with a maximum slew rate of 0.1V/μsec or a bandwidth limit of 7 kHz. (To acquire signals with higher frequencies, these older devices require an external S/H amplifier, which is usually expensive.) The LTC1099 costs $8 (100).—David Shear

NEWS BREAKS

VME BUS SINGLE-BOARD COMPUTER INTEGRATES PERIPHERAL CONTROL

The Liberator-SBC single-board VME Bus computer is the only one to include so many functions on a single board, claims its vendor, Integrated Solutions (San Jose, CA, (408) 943-1902). Other products require as many as five boards to implement the same functions. The board includes a 16- or 20-MHz 68020 coupled with a 68851 paged memory-management unit and a 68881 floating-point unit. Its memory comprises 4M bytes of 1-wait-state RAM, 64k bytes of 2-wait-state EPROM, and 32 bytes of EEPROM. The board also includes an Ethernet interface, two synchronous/asynchronous serial ports, a synchronous or asynchronous SCSI port, 1024×768-pixel graphics with 16 colors, an 8-bit DAC with a 20-kHz bandwidth, and a battery-backed clock/calendar function. The board costs $5995.—Doug Conner

STANDARD CREATES SET OF COMMON CALLS FOR 88000 OPERATING SYSTEMS

A trial-use binary compatibility standard (BCS) published by the 88open Consortium Ltd (Stratham, NH, (603) 778-3001) establishes a common set of basic, system-level calls for executable and binary programs written for systems based on Motorola's 88000 μP. The 66 BCS calls define standard services an operating system can provide to an application program, including file I/O, process creation, and interprocess communications. The consortium's BCS defines a subset of calls taken from AT&T's proposed Unix application binary interface (ABI); AT&T has informally indicated to the 88open BCS committee that it intends to use the BCS as the basis for an 88000-μP Unix ABI. Copies of 88open's BCS publication cost $100.—Steven H Leibson

FLOATING-POINT MATH CHIP HELPS BREAK I/O BOTTLENECKS

The ADSP-3264 64-bit floating-point math chip from Analog Devices (Norwood, MA, (617) 329-4700) will incorporate an architecture that permits either eight 32-bit or four 64-bit internal data transfers per cycle. The transfers involve moving data to and from an internal register file, an arithmetic-logic unit (ALU), and a multiplier-divider unit. Packaged in a 280-pin ceramic pin-grid array (PGA), the chip will run at 15.6 MHz. That clock frequency translates into a 31M-flops rate—one floating-point operation per clock cycle in the ALU and one operation in the chip's multiplier. A 64-bit double-precision division operation requires 768 μsec.

The chip performs standard IEEE-754 single- and double-precision floating-point math operations as well as 32-bit 2's-complement and 32-bit unsigned fixed-point manipulations. Samples are $545 (1000); they should be available in October. The manufacturer expects to offer production quantities during the second quarter of 1989.—Jon Titus

PLD-DEVELOPMENT TOOL GETS NEW PRIMARY SOURCE

CUPL, the PLD-development software heretofore marketed by Personal CAD Systems, is now a product of Logical Devices Inc (LDI) (Fort Lauderdale, FL, (305) 974-0975). LDI will assume all of P-CAD's existing CUPL maintenance agreements. CUPL, which lists for $1250, runs under MS-DOS, Unix, and VMS.—Dan Strassberg

DIGITAL ENCODERS PROVIDE DIRECT μP INTERFACE

Available in 2-, 4-, or 5-bit versions, the EV and EH Series encoders from Allen-Bradley (El Paso, TX, (800) 592-4888 or (800) 292-4888) may eliminate the need for A/D conversion in your design application. The devices offer panel potentiometer capabilities, continuous rotation, and as many as 36 electrical positions per revolution; they range in price from $1.39 to $1.51 (1000).—J D Mosley

NEWS BREAKS: INTERNATIONAL

RF MOS POWER TRANSISTORS OUTPERFORM BIPOLAR TYPES

Offering significant performance advantages in comparison with high-frequency bipolar power transistors, the BLF series of MOS power transistors from Philips Components Div (Eindhoven, The Netherlands, TLX 51573) is suitable for use in the output stages of HF and VHF transmitters. In the near future, the company plans to extend the range with power transistors that can operate at UHF.

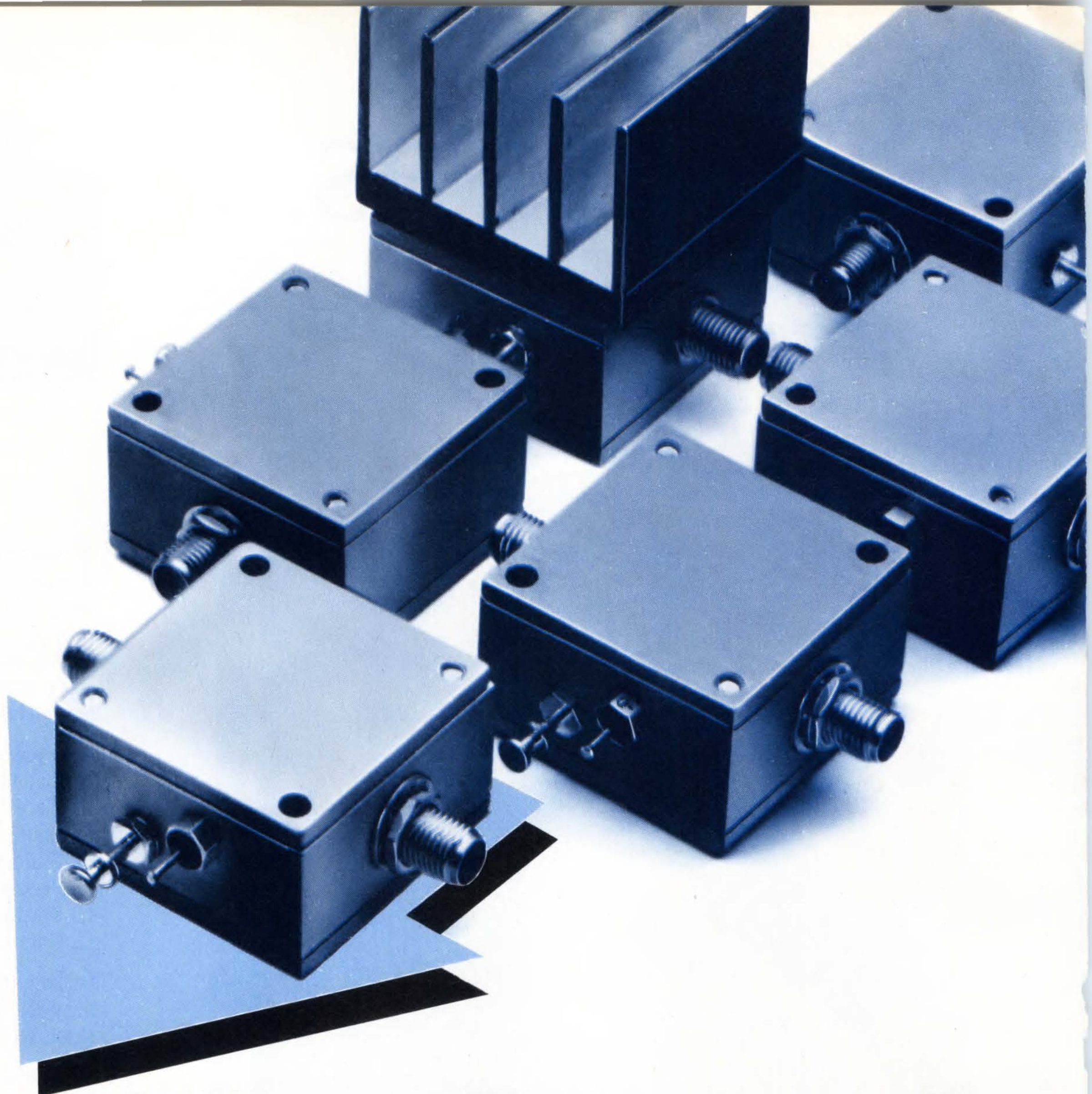
Among the currently available transistors are devices with power ratings of between 2 and 300W. These transistors feature noise figures in duplex mode that are typically 7 dB less than those of bipolar types, and they offer power gains that are as much as 4 dB higher than bipolar types. In addition, it's easier to control the power level of a MOS transistor because you can do so simply by altering the device's gate bias voltage. MOS transistors are also more reliable than bipolar types. Their negative drain-current temperature coefficient eliminates thermal runaway problems and allows you to parallel devices without incurring current-sharing problems. In addition, the MOS devices have greater tolerance of load mismatch (lower-power devices withstand an all-phases VSWR as high as 50:1 at full rated power without damage), and they have less of a tendency toward parasitic oscillation. The BLF145, an 8W, 28-MHz device in a SOT-123 package, sells for around gld 60 (100).
—Peter Harold

DEMAND FOR DRAMs EXPECTED TO SHIFT FROM 256k- TO 1M-BIT PARTS

The Japanese Ministry of International Trade and Industry (MITI) has reportedly predicted a decline in the demand for 256k-bit dynamic RAMs for the third quarter of 1988. The demand is expected to drop 1% from the second-quarter figure. Meanwhile, MITI also predicted a big increase in the demand for 1M-bit dynamic RAMs. The 40-million-part demand projected for the second quarter is expected to swell to almost 53 million pieces in the third quarter. The ministry expects another 35% increase in demand for the 1M-bit parts and another 3.3% drop in demand for the 256k-bit DRAMs in the fourth quarter. MITI also projected that DRAMs will remain in short supply even though vendors are increasing production.—Joanne Clay

32-BIT FLOATING-POINT COPROCESSOR REACHES 6.7M FLOPS

The MuPD72691 32-bit floating-point math coprocessor from NEC can perform 6.7M flops. The chip, which is fabricated in a 1.2-μm, double-layer-aluminum CMOS process, operates with the company's V Series 32-bit microprocessors. The device can perform high-speed arithmetic floating-point operations and matrix operations in one command, a capability that's essential for 3-dimensional-image display and manipulation. Samples of the 16-MHz device cost approximately $615; for the 20-MHz part, the sample price is about $769.—Joanne Clay



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MODEL	FREQUENCY MHz	GAIN, dB (min.)	MAX. POWER OUTPUT dBm(typ)	NF dB(typ)	PRICE $ Ea.	Qty.
ZFL-500	0.05-500	20	+9	5.3	69.95	1-24
ZFL-500LN	0.1-500	24	+5	2.9	79.95	1-24
ZFL-750	0.2-750	18	+9	6.0	74.95	1-24
ZFL-1000	0.1-1000	17	+9	6.0	79.95	1-24
ZFL-1000G*	10-1000	17	+3	12.0	199.00	1-9
ZFL-1000H	10-1000	28	+20	5.0	219.00	1-9
ZFL-500HLN	10-500	19	+16	3.8	99.95	1-24
ZFL-1000LN	0.1-1000	20	+3	2.9	89.95	1-24
ZFL-1000VH	10-1000	20	+25	4.5	229.00	1-9
ZFL-2000	10-2000	20	+17**	7.0	219.00	1-9

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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

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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

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

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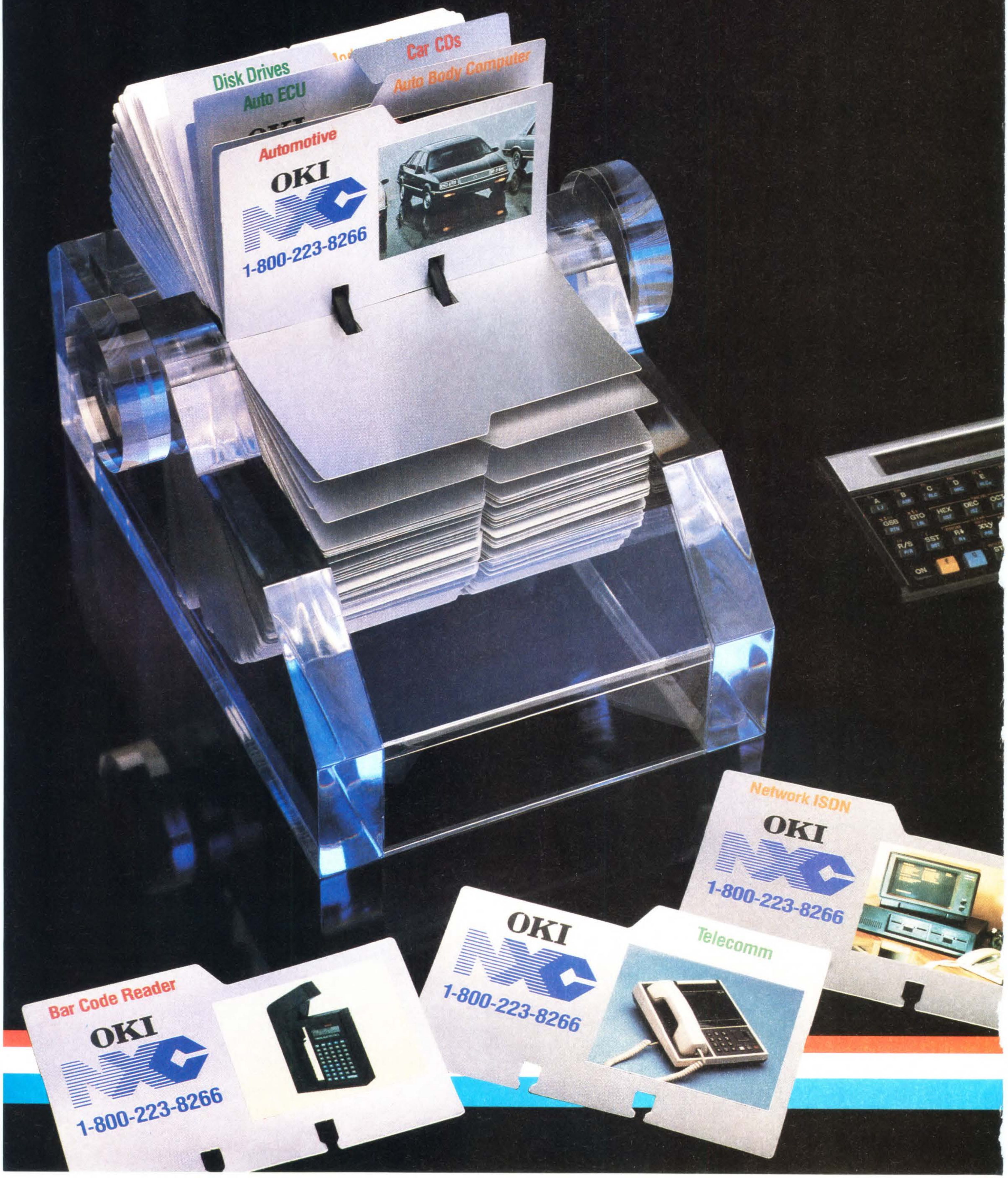

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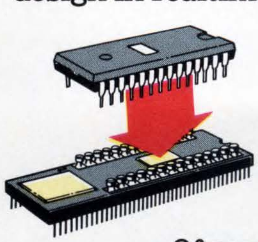
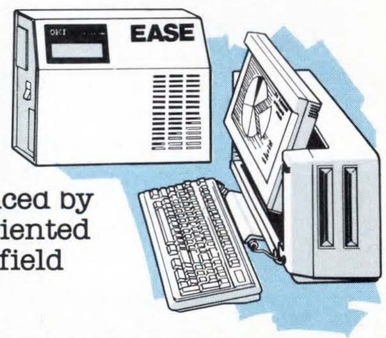


Of course, OKI's 66301 MCU is solidly backed with a full-scale development system. For realtime in-circuit emulation (ICE), use the **NXC** EASE system. The portable EASE package includes your ICE hardware, user's manual, plus complete assembler and debugger software for both MSDOS and VMS. With a compatible high-efficiency C-Compiler option as well. All available from OKI. All part of the **NXC** solution to high-end multitasking applications, produced by the most system-oriented technologies in the field today.



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EDN081888

Swap amplifier leads to make thermocouple work

I'd like to correct some errors in the schematic I submitted with the Design Idea "Electronic thermometer has 10-mV/°F output" (EDN, April 28, 1988, pg 237). To make the thermocouple thermometer work correctly, you must swap the leads to the amplifier: You hook the thermocouple lead to pin 3 and connect the other wire from the bridge circuit to ground. The accompanying **figure** shows a corrected version of the circuit.

If you reduce the gain of the amplifier to 100 (by changing R_2 from 1 MΩ to 100 kΩ), the output of the thermometer will be 1 mV/°F, so the thermometer will be able to read temperatures as high as 1800°F. Note, however, that there will be a 2% error in the temperature readings above 660°F.

Bill Donofrio
Moore Research Center
Grand Island, NY

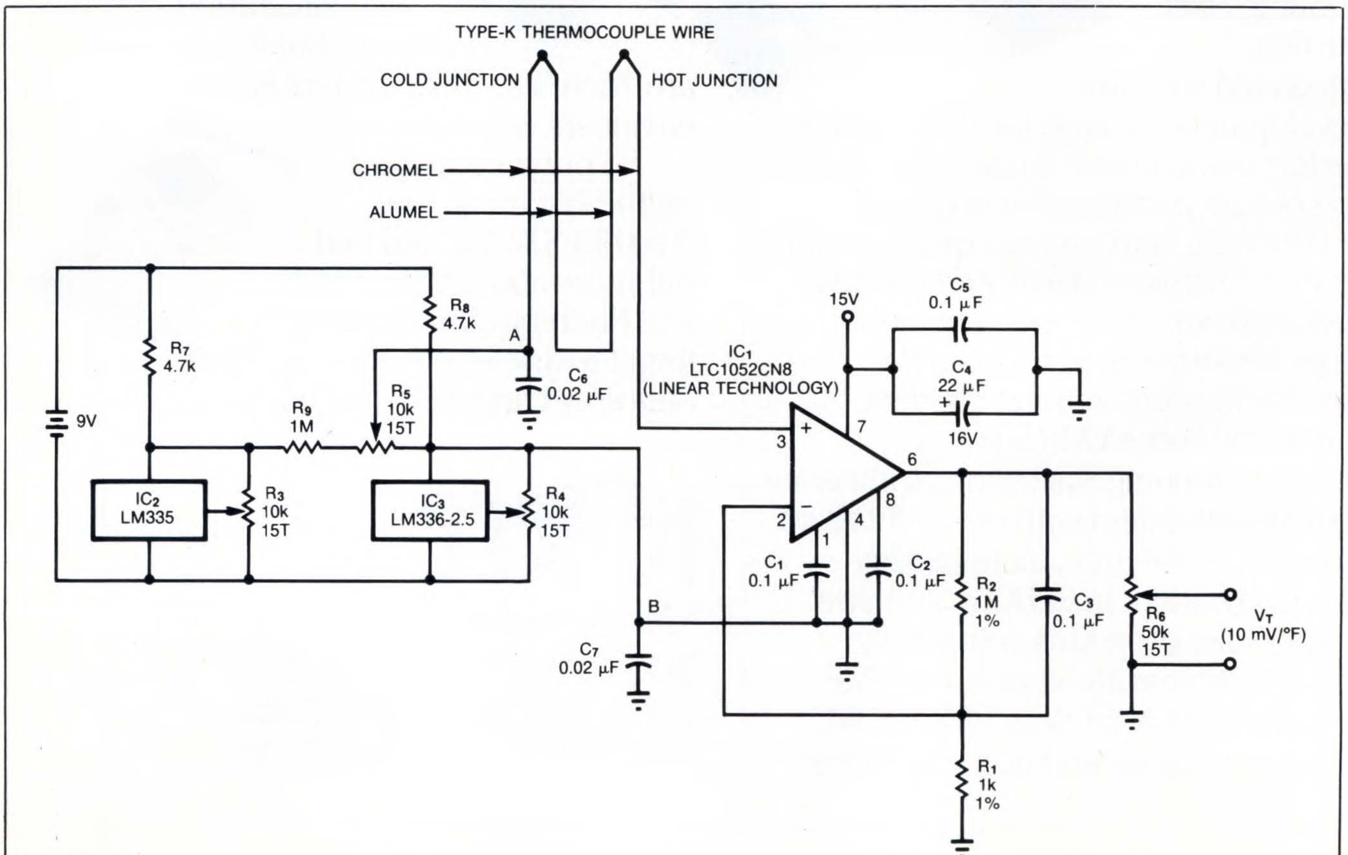
Self-modifying code poses unacceptable risk

I am writing to express my shock at the Design Idea "Alterable code enhances instructions" by Noor Singh Khalsa (EDN, May 12, 1988, pg 210). I hope that Mr Khalsa takes what follows as criticism of his assumptions and ideas rather than as criticism of him as a person or as a professional engineer. In fact, my criticism is most sharply pointed to the editors of EDN for admitting the design to the magazine's pages.

The very heart of Mr Khalsa's Design Idea is self-modifying code —on a microprocessor that seems to be designed to prevent just that. Do engineers who attempt this practice realize that code and data have been separated by the designers of the 8031 because they are two entirely different kinds of things? Code acts and data is acted upon. To confuse the two by executing data or by modifying code as it runs is to commit an error so grave as to destroy the very possibility of software design.

What automated design tool, what paper-and-pencil formal design could possibly have been used to generate this kind of code? Do engineers who add that little OR gate in Mr Khalsa's design realize what horrors lie behind the door they've just opened? Are they certain that the next line of code, or the next, or the next will not, under some untested machine state, unintentionally clobber some other line of code?

And to what effect? Will I be a passenger on an aircraft whose avionics software incorporates this design? Are missiles now being prevented from destroying my family by this kind of software? In fact, outside of school, is there any software these days that does not have a serious intent? And if there isn't, should we not simply and firmly state that this design poses an unacceptable risk?



SIGNALS & NOISE

Let me ask another question from a purely selfish standpoint. As a software designer whose job sometimes requires me to interface assembly code to a high-order language, what kind of questions am I likely to get from my customer now that you've revealed self-modifying code as the latest state of the art?

I can't help thinking that our customer, on reading this Design Idea, not realizing the profound sense of outrage it causes for professional software designers, will use it as a justification for making life more difficult for us.

Self-modifying code indeed! EDN should realize that the third digit of this year is an 8 and not a 6.

Bob Crispen
Decatur, AL

Design Idea corrections

I'd like to thank you for your acceptance of my Design Idea "Signal-powered switch connects devices" (EDN, April 14, 1988, pg 227) and point out a few errors in the published schematic:

- The signal ground on the DTE side should be labeled pin 7;
- V^+ of the MBR2045CT is pin 2;
- Pin 8 of the Si7661 should be connected to V^+.

In response to inquiries I've received, I'd like to mention that the DG509s are bidirectional analog switches, so it's possible to operate the circuit in the opposite direction (that is, to connect one printer to four PCs) if you make appropriate changes to the diode connections. Also, the diode packs are Motorola parts, and the voltage inverter is from Siliconix.

James Dean
Herzberg Institute of Astrophysics
National Research Council
Canada
Ottawa, Ontario, Canada

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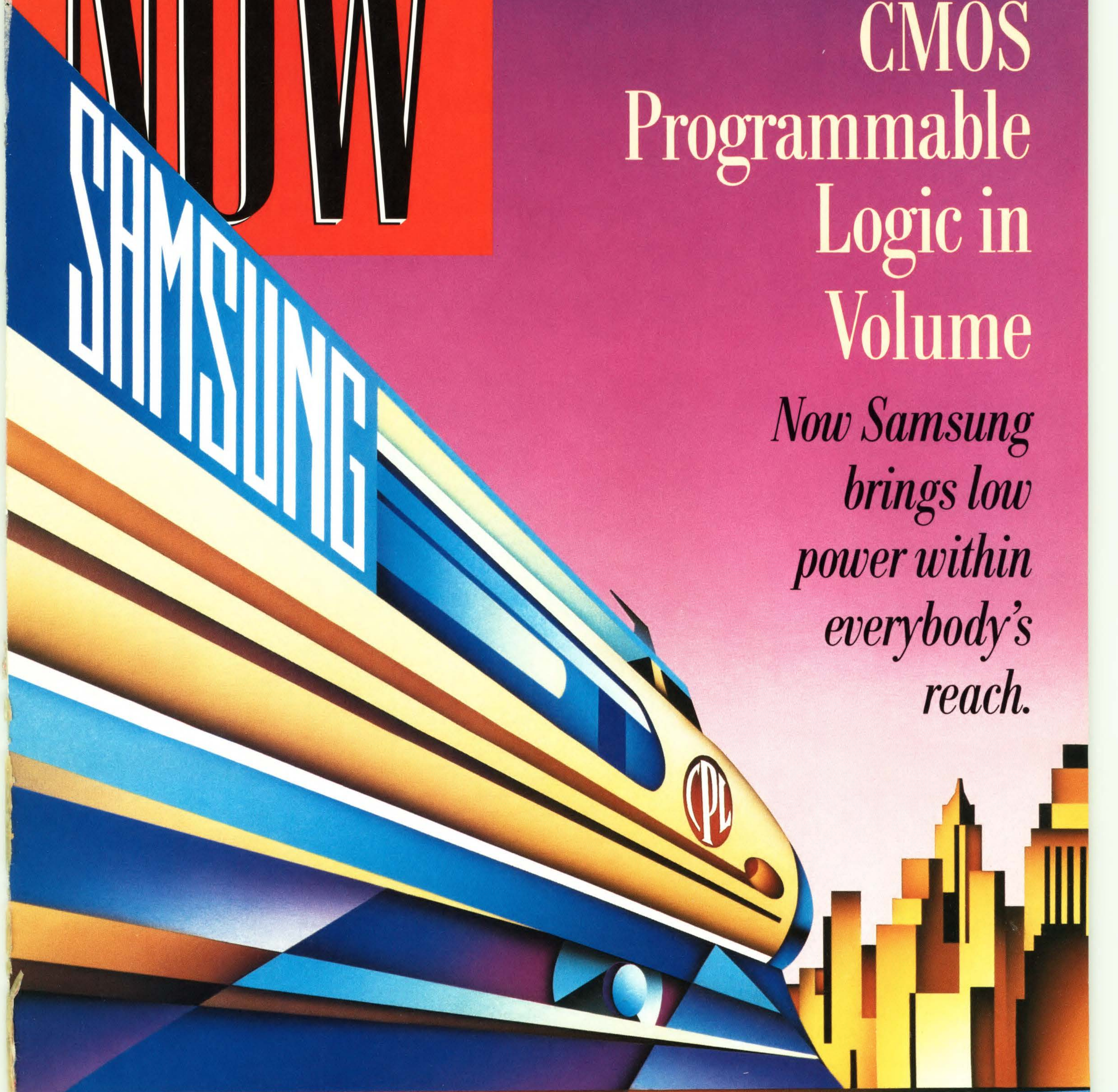

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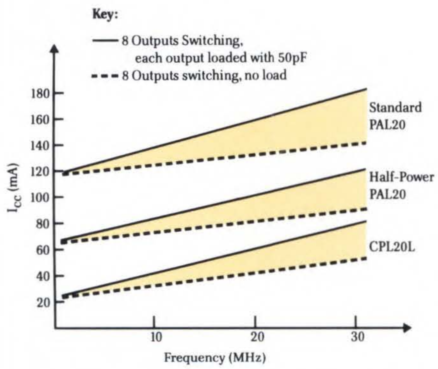

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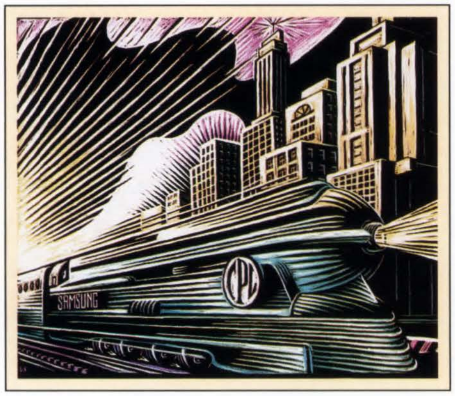

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CPL16L8	CPL20L10
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CPL16R6	CPL20R4
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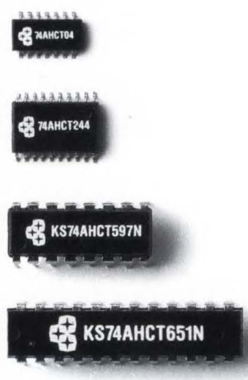

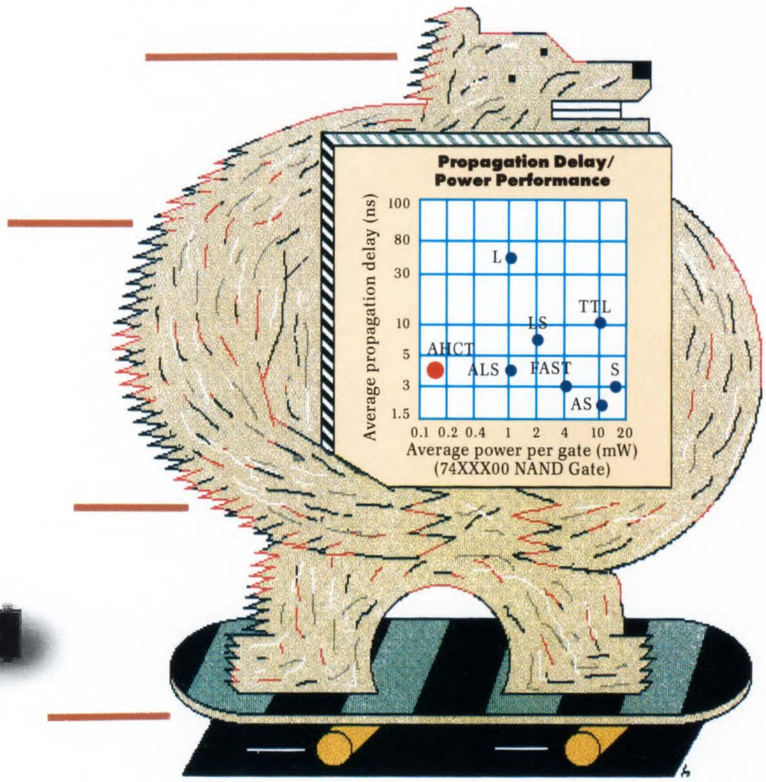

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00	08	20	51
01	09	21	58
02	10	22	86
03	11	27	132
04	12	30	133
05	14	32	266

Buffers and Line Drivers

125	241	367	467
126	244	368	468*
210	365	465*	540
240	366	466	541

Flip-Flops

73	173	534	823
74	174	564	824*
76	175	574	825*
78	273	670	826*
107	374	794	
109	377	821*	
112	399	822*	

Latches

75*	533	841*	845
77*	563	842*	846
259	573	843*	
373	793	844*	

Transceivers/ Registered Transceivers

242*	643	651	664
243*	645	652	665*
245	646	658*	
640	648	659*	

Counters

160	168	192	590*
161	169	193	591*
162	190	390*	592
163	191	393	593*

Decoders/Encoders

42	139	154	238
138	148	155	239

Multivibrators

121* 123* 423*

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4049 4050*

Multiplexers

151	158	257	353
153	251	258	
157	253	352	

Shift Registers

164	194	299	596*
165	195	595	597
166			

Arithmetic Circuits

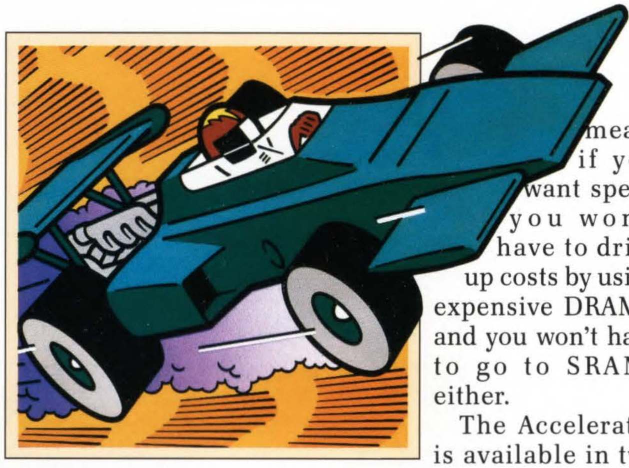
181	518	522	684*
182*	519	679	686*
183	520*	680	688
280	521	682	689*

All parts are available in plastic DIP. For SOIC availability, contact the factory.
**Available by end of 1988.*

DRAM CONTROLLER

Our new 1- and 4-meg DRAM Controller is also a system accelerator. It can give you

80ns *Performance* *from* 120ns *DRAMs.*



Our new 1- and 4-meg DRAM Controller does so much for system speed that we've named it *The Accelerator.*

If you're a designer attracted to speed, you're going to want to design it in.

The KS84C21/22 DRAM Controller supports interleaving, and it supports the fastest access modes of the newest DRAMs.

It radically reduces parts count and engineering effort compared to PAL-based designs and interfaces to all major microprocessors.

But above all, it effectively increases the speed of your memory array–giving you performance exceeding 80ns from 120ns DRAMs.* Which means if you want speed, you won't have to drive up costs by using expensive DRAMs, and you won't have to go to SRAMs either.

The Accelerator is available in two versions. One has an externally programmable register, for prototyping and moderate-volume applications. The other version is the first and only mask-programmed DRAM controller ever developed anywhere, and it eliminates still more logic parts.

To make it easier to get started with The Accelerator, we've made up a sample kit.

Request yours today and start designing-in speed! NOW

Samsung's DRAM Controller.

Part	RAMs Supported	Package
KS84C21-25CL	256K, 1 MB	68-pin PLCC
KS84C22-25CL	256K, 1 MB, 4 MB	84-pin PLCC

*System dependent.

TURN *to coupon on back page to request free DRAM controller sample kit and specifications.*

Samsung: Building on our leadership in DRAMs

As one of the world's leading producers of DRAMs, Samsung Semiconductor has been able to compete in one of the most demanding technologies of all. And we will continue to do so as our 4- and even 16-megabit products emerge. We're making additional use of this manufacturing know-how to deliver an extremely broad range of semiconductor products that are remarkable for their high performance, their cost-effectiveness, and their reliability.

EEPROMS

Our CMOS 64K EEPROM Is an Entirely New Breed.

Feature by feature it's as good or better. But besides using less power, it also consumes less money.

When you stack it up against the leading competitors, our new CMOS 64K EEPROM is, in a word, better.

It uses less power (100 μA vs. 150 μA standby current, 30 mA vs. 50 mA active current). It's exceptionally fast.

And it's available at much lower cost.

The part is available in volume right now.

In reliability, it's superb–far more reliable than requirements call for. In 1000 hours of testing in the key areas of endurance, WHTS, HOPL, and WHOPL–with industry-standard testing procedures–there were *zero* failures experienced.

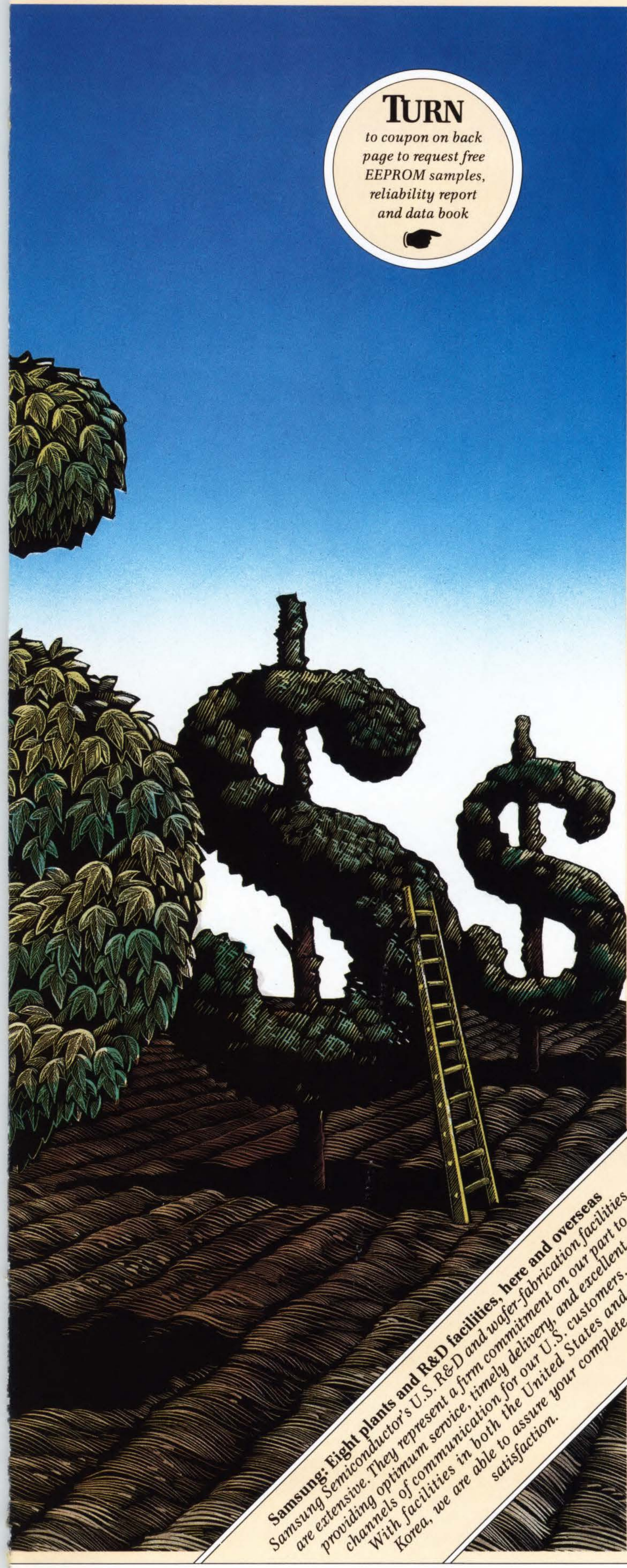
We think what all this means is that our new CMOS 64K EEPROM is simply the most sensible choice on the market.

But don't take our word for it. Request our reliability report, data sheet, and samples today. Then compare it for yourself. NOW

Product Specification	Samsung 28C64 8K x 8 CMOS EEPROM	Leading Competitor's 64K CMOS EEPROM
ISB (standby current)	100 μA	150 μA
ICC (active current)	30 mA	50 mA
TAA (address access time)	200 ns	200 ns
TRC (read cycle time)	200 ns	200 ns
TWC (write cycle time)	2-5 ms/byte	2-5 ms/byte
VCC	5V ± 10%	5V ± 10%
Page mode	Yes	Yes
Endurance (write cycle)	10,000	10,000
Data retention	10 years	10 years
Packaging	DIP, PLCC	DIP, PLCC

The KM28C64/65 at a glance.

8K x 8 CMOS EEPROM ■ 28-pin JEDEC byte-wide memory pinout (DIP, PLCC) ■ Single 5V ± 10% Vcc supply ■ Performance: 200/250ns ■ Current: standby (max) 100μA; active (max) 30mA ■ 32 byte page write: 5ms ■ 4-cell bridge for enhanced reliability ■ Write completion indicator: Data polling, Rdy/busy (for KM28C65) ■ Endurance 10,000 cycles ■ Data retention 10 years



The Most Reliable Battery-Backed SRAMs Aren't SRAMs at All.

They're EEPROMs from Samsung.

Since EEPROMs don't require batteries to retain data during power loss, they are, of course, inherently more reliable than devices that do–such as SRAMs.

Because of the relative costs, however, it wouldn't occur to most designers to use an EEPROM where conventional thinking calls for an SRAM–even *with* the improvement in reliability that there'd be.

But those relative costs are changing.

Today, SRAMs cost more than they once did. And Samsung's EEPROMs, in fact, now compare favorably in price.

Which means that if you want reliability, there's every reason to start using these EEPROMs–and making your next battery-backed SRAMs, Samsung EEPROMs.

There are, of course, additional applications at which we excel. Our entire EEPROM family–including our new 64K CMOS part–is also superbly suited to rugged applications such as communications, instrumentation, robotics, and industrial control.

All Samsung EEPROMs are guaranteed to provide endurance in excess of 10,000 write cycles and data retention of 10 years. And they meet or surpass all other industry standards for performance, reliability, and quality.

Most important of all, our EEPROMs are available in large quantities *from stock*–so you avoid escalating lead times as well as high prices.

EEPROM performance, reliability, and availability–all at low cost. To start taking advantage of them, request samples, a data sheet, and a reliability report today. NOW

Samsung CMOS and NMOS EEPROMs.

Part Type	Organization	Speed	Features	Technology	Pinout	Availability
KM28C64P	8K x 8	200,250	Data Polling, 32-byte Page Mode, Low Power, 5ms (max) write time	CMOS	28 pin	From Stock
KM28C65P	8K x 8	200,250	Data Polling, 32-byte Page Mode, Low Power, 5ms (max) write time	CMOS	28 pin	From Stock
KM2816AP	2K x 8	250,300,350	10ms (max) write time	NMOS	24 pin	From Stock
KM2817AP	2K x 8	250,300,350	Ready/Busy, 10ms (max) write time	NMOS	28 pin	From Stock

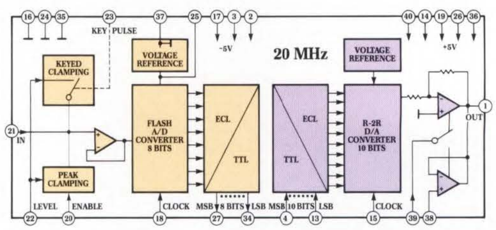
In linear, what Samsung gives you can be stated easily.

MORE.

A DATA CONVERTER THAT DOES MORE.

Samsung's new KSV3110 data converter is a technological feat that we're rather proud of.

On a single chip, it offers independent 8-bit flash A/D and 10-bit D/A functions. And with an operating range of DC to 20MHz, it's faster than any other part available that does both. Also unique, it gives you an auxiliary circuit, which can be used to do impedance matching within the chip.



What's good about having all this on one chip, of course, is that it saves you real estate and money–and also cuts power drain. And, at the same time, boosts system reliability.

In short, the KSV3110 doesn't just do more. It does *way* more.

TURN
to coupon on back page to request linear data books and specifications.

Samsung's 3110 Series Combination A/D-D/A Converters.

Part Type	Resolution		Linearity		Conversion Speed	Industry Part
	A/D	D/A	A/D	D/A		
KSV3110N-10	8 bits	10 bits	±1/2 LSB	±1/2 LSB	20 MSPS	
KSV3110N-9	8 bits	10 bits	±1/2 LSB	±1 LSB	20 MSPS	
KSV3110N-8	8 bits	10 bits	±1/2 LSB	±2 LSB	20 MSPS	
KSV3110N-7	8 bits	10 bits	±1/2 LSB	±4 LSB	20 MSPS	
KSV3100AN-8	8 bits	10 bits	±1/2 LSB	±2 LSB	20 MSPS	UVC3101
KSV3100AN-7	8 bits	10 bits	±1/2 LSB	±4 LSB	20 MSPS	UVC3101

VOLUME LEADERSHIP IN CONVENTIONAL A/D AND D/A...

As a company that does remarkable things in the manufacturing arena, Samsung is in a superb position to produce high-quality conventional data converters cost effectively and in volume.

And that's just what we do.

Which means that if you use data converters in large quantities, you simply won't find anyone it makes better sense to do business with.

Samsung: Some of the world's most advanced fabrication lines

Among our fabrication lines, a particular showpiece is our new Class 1 6" wafer facility in Kiheung, Korea, dedicated to DRAM technology and set to open in October of this year. It utilizes advanced stepper technology and is among the largest in the world.

The Samsung A/D and D/A Lines.

Part Type	Resolution A/D	Resolution D/A	Linearity A/D	Linearity D/A	Conversion Speed	Industry Part
KSV3208N	8 bits		±1/2 LSB		20 MSPS	
KAD0820ACN	8 bits		±1/2 LSB		1.5 μsec	ADC0820BCN
KAD0820AIN	8 bits		±1/2 LSB		1.5 μsec	ADC0820BCJ
KAD0820BCN	8 bits		±1 LSB		1.5 μsec	ADC0820CCN
KAD0820BIN	8 bits		±1 LSB		1.5 μsec	ADC0820CCJ
KAD0808IN	8 bits		±1/2 LSB		100 μsec	ADC0808CCN
KAD0809IN	8 bits		±1 LSB		100 μsec	ADC0809CCN
KDA0800CN		8 bits		±1/2 LSB	*100 nsec	DAC0800LCN
KDA0801CN		8 bits		±1 LSB	*100 nsec	DAC0801LCN
KDA0802CN		8 bits		±1/4 LSB	*100 nsec	DAC0802LCN
KDA0806CN		8 bits		±2 LSB	*150 nsec	DAC0806LCN
KDA0807CN		8 bits		±1 LSB	*150 nsec	DAC0807LCN
KDA0808CN		8 bits		±1/2 LSB	*150 nsec	DAC0808LCN
KS7126CN	3-1/2 digit		±1/2 LSB		333 msec	TSC7126
KS25C02	CMOS 8-bit successive approx. register					DM2502
KS25C03	CMOS 8-bit successive approx. register					DM2503
KS25C04	CMOS 12-bit successive approx. register					DM2504

**Settling Time*

And In Op Amps, Regulators, Comparators, Timers, And More.

Across the entire spectrum of high-volume linear devices, in fact, Samsung–being a manufacturing leader–offers a combination of reliability and competitiveness in price that has given these devices tremendous acceptance in the marketplace.

It's a market we're strongly committed to, and we have more than 250 industry-standard ICs available for immediate delivery now.

If by chance you *aren't* buying linear devices from Samsung, it will make sense for you to look into us.

Solutions Tailored To Specific High-Volume Needs. For Those Who Simply Need More.

A particular specialty that Samsung offers in linear is in the area of specific, rather simple solutions tailored to certain very high-volume applications.

We have developed devices for use in such high-volume areas as telephones, car stereo, and household appliances–among many others.

If you have a need for a high-volume, tailored linear device on this order, we may have the device you need–and if we don't, we'd like to talk about making it for you.

Our line of simple speech synthesis chips–designed for use primarily in electronic toys and answering machines–is one particular example of the kind of low-cost solution we can offer.

To learn about others, please contact us.

Our Speech Synthesizers.

Part	Function	Application
KS5901A	Voice synthesizer (external ROM)	Sound information answering machines
KS5902XX	Voice synthesizer (internal ROM)	Toys; simple sound generation
KS5911	Voice recording and reproducing (talking back type)	Talk-back answering machines
KS5912XX	Natural sound generation	Toys; natural sound effect

Major Linear ICs

Regulators

3T Positive

KA78TXXCF	3 Amp
KA78TXXCT	3 Amp
LM317T	1.5 Amp
MC78XXCT	1 Amp
MC78MXXCT	0.5 Amp
MC78LXXACZ	0.1 Amp
LM723CN	0.1 Amp

3T Negative

KA337T	1.5 Amp
MC79XXCT	1 Amp
MC79MXXCT	0.5 Amp
MC79LXXACZ	0.1 Amp

Switching

KA78S40CN	KA3524N

REF Voltage

KA431CZ (TL431CLP)	KA336Z-2.5,5
KA431N (TL431CP)	KA385Z-1.2

Comparators

KA319N (LM319N)	LM2903N
KA361N (LM361N)	LM311N*
KA710CN (LM710N)	LM3302N
KS374N (TLC374N)	LM339N/AN*
LM2901N	LM393N/AN*

Op Amplifiers

KA301N/AN (LM301N)*	LM348N*
KA733CN (LM733CN)	LM358N/AN*
KA9256 (POWER AMP)	LM741CN*
KF351N (LF351N)	MC1458N*
LM2902N	MC3303N
LM2904N	MC3403N*
LM324N/AN*	MC4558N*

Telecommunication ICs

KA2410N	Tone Ringer
KA2411N	Tone Ringer
KA2418N	Tone Ringer/bridge diode
KA2412FN	Speech Network
KA2413N	DTMF
KS5808N	DTMF (MK5089)
KS5805AN	Pulse (MK50992)
KS5805BN	Pulse (MK50993)
KS55820N	DTMF/Pulse
KT3040J	CODEC Filter
KT5116J	CODEC
LM567N*	Tone Decoder
LM567LN	Tone Decoder (Low Power)
KS5812N	Quad UART

Timers

KS555N (CMOS)*	NE555CN*
KS555HN (CMOS)*	NE556CN*
KS556N (CMOS)*	NE558CN

RS-232 Interfaces

MC1488N*	MC1489/AN*

Audio ICs

LM386N	0.5 Watt Power Amp
KA2201N	1.2 Watt Power Amp
KA2206	2.3 Watt Dual Power Amp
KA22062	4.6 Watt Dual Power Amp
KA2210	5.8 Watt Dual Power Amp
KA22101	23 Watt Power Amp
KA2243	AM/FM IF & DET
KA22441	FM IF & DET
KA22495	FM Front End
KA2263	FM MPX

45 other audio ICs available

Video ICs

KA2914A	Color TV VIF/SIF
KA2153	NTSC Chroma & Deflection
KA6101	Video R.G.B. Interface
KA6102	Video R.G.B. Interface

40 other video ICs available

Others

KA2580AN	(UDN2580AN)
KA2588AN	(UDN2588AN)
KA2651N	(UCN5815AN)
KA2615	LED/Lamp Driver
KA2616	LED/Lamp Driver
KA2284	5 Dot LED Meter Driver
KA2286	5 Dot LED Meter Driver
KA2288	7 Dot LED Meter Driver
KA2181	Infrared Amp
KA8301	Motor Driver IC
KS5803AN	Infrared Transmitter
MC3361N	FM IF Amp

**Also available in surface mount package (SOIC)*

TRANSISTORS

We Launch a New 1500 volt Power *Transistor*

With over 500 transistors, Samsung is among the world's largest producers. Our 1500-volt parts break ground even for us.

As a producer of transistors, Samsung sits squarely among the very largest in the world.

There is virtually no transistor need we can't fill–with a high-quality part, and at an advantageous price.

Our entire line of more than 500 transistors, in fact, is in full production and available from stock.

You can order anything from our list *now,* and get immediate delivery.

At present, we are introducing state-of-the-art, 1500-volt power transistors–transistors so difficult to produce that only one other company makes them.

We also provide 100 types of SOT-23s, ideal for both hybrid and surface-mount applications, plus TIP Series, MJE Series, and TO-92 transistors.

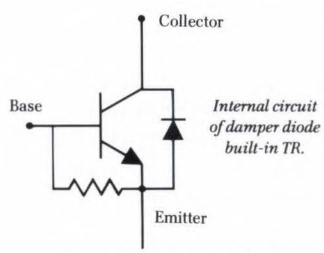
Many are listed here, but for a complete list of Samsung transistors, please turn to the back of this issue and request it.

NOW

Samsung: One of the world's largest corporations

As a unit of one of the world's largest corporations, Samsung Semiconductor is here to stay. Last year, the Samsung Group enjoyed revenues of $24 billion–which would put us in 15th place on the list of the Forbes 500. We have the resources to make things happen technologically, and we have the strength to be a partner in whom you may have absolute confidence.

The new 1500-volt transistors at a glance.



Designed for high-voltage switching systems and industrial motor controls, the eight new Samsung 1500-volt power transistors utilize the TO-3PF fully isolated plastic package.

TURN

to coupon on back page to request complete list of Samsung transistors and data book.

Transistors From Samsung

1500-Volt Power TR

2.5 amps	5 amps	6 amps
KSD5010*	KSD5012*	KSD5013*
KSD5014	KSD5016	KSD5017

3.5 amps
KSD5011*
KSD5015

**Damper diode built-in transistor*

SOT-23

BCX70G	MMBT4403	MMBTA43
BCX71G	MMBT5087	MMBTA55
MMBR5179	MMBT5088	MMBTA56
MMBT2222A	MMBT5089	MMBTA63
MMBT2484	MMBT5401	MMBTA64
MMBT2907A	MMBT5550	MMBTA70
MMBT3904	MMBT6428	MMBTA92
MMBT3906	MMBTA05	MMBTA93
MMBT4123	MMBTA06	MMBTH10
MMBT4124	MMBTA13	MMBTH17
MMBT4125	MMBTA14	MMBTH24
MMBT4126	MMBTA20	
MMBT4401	MMBTA42	

66 other types also available.

TIP SERIES

TIP29 Family	TIP106	TIP140F
TIP30 Family	TIP107	TIP140T
TIP31 Family	TIP110	TIP141F
TIP32 Family	TIP111	TIP141T
TIP41 Family	TIP112	TIP142F
TIP42 Family	TIP115	TIP142T
TIP47	TIP116	TIP145F
TIP48	TIP117	TIP145T
TIP59	TIP120	TIP146F
TIP50	TIP121	TIP146T
TIP100	TIP122	TIP147F
TIP101	TIP125	TIP147T
TIP102	TIP126	
TIP105	TIP127	

MJE SERIES

MJE170	MJE210	MJE800
MJE171	MJE340	MJE801
MJE172	MJE350	MJE802
MJE180	MJE700	MJE803
MJE181	MJE701	MJE2955T
MJE182	MJE702	MJE3055T
MJE200	MJE703	

TO-92

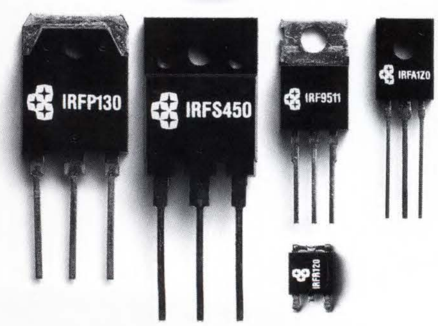
2N3904	2N5210	MPSA42
2N3906	2N5400	MPSA43
2N4123	2N5401	MPSA55
2N4124	2N5550	MPSA56
2N4125	2N5551	MPSA70
2N4126	2N6427	MPSA92
2N4400	2N6428	MPSA93
2N4401	2N6515	MPSH10
2N4402	2N6517	MPSH17
2N4403	2N6520	MPSH20
2N5086	MPSA05	MPSH24
2N5087	MPSA06	PN2222A
2N5088	MPSA14	PN2907A
2N5089	MPSA20	

200 other types also available.

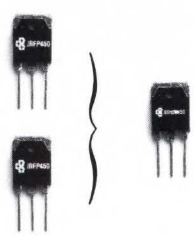
MOSFETS

THE WORD IS Rugged

Power MOSFETs just don't come any more rugged than ours.



The single MOSFET that does the job of two.



Samsung's SSH20N50 - available only from us - improves reliability, simplifies assembly, and minimizes mounting hardware, because it's a direct replacement for two IRFP450's. There's less to go wrong, and less to mount.

Exhaustive testing has proven Samsung's line of over 400 industry-standard power MOSFETs to be unsurpassed anywhere in ruggedness. They've been shown to withstand 2J at 500V, and in addition, each part has been screened to MIL-STD-750 specifications.

Our recently published ruggedness application note thoroughly documents the superior ruggedness of these parts, and we invite you to complete the coupon at the back of this insert to request a copy. We'll rush it to you.

In the past several months, our MOSFETs have been qualified at an exceptionally large number of major accounts. We continue to offer the entire line with competitive pricing.

Samsung MOSFETs directly replace parts from IR and Motorola.® And since they are one of the broadest lines on the market, you can get just about anything you need. Both N and P channel parts are available, as are a variety of packages–including lead-formed TO-220s, state-of-the-art TO-247 FULL PACK and DPAK.

What more could you ask? NOW

TURN

to coupon on back page to request MOSFET samples and ruggedness application note.

Samsung Power MOSFETs

TO-247 Full Pack N-Channel Types

IRFS130 IRFS450
IRFS140 SSS4N70
IRFS150 SSS6N70
IRFS230 SSS10N70
IRFS240 SSS4N60
IRFS250 SSS6N60
IRFS330 SSS8N60
IRFS340 SSS15N60
IRFS350 SSS20N50
IRFS430 SSS25N40
IRFS440

TO-3P Package N-Channel Types

IRFP120 IRFP422
IRFP121 IRFP423
IRFP122 IRFP430
IRFP123 IRFP431
IRFP130 IRFP432
IRFP131 IRFP433
IRFP132 IRFP440
IRFP133 IRFP441
IRFP140 IRFP442
IRFP141 IRFP443
IRFP142 IRFP450
IRFP143 IRFP451
IRFP150 IRFP452
IRFP151 IRFP453
IRFP152 SSH3N70
IRFP153 SSH4N70
IRFP220 SSH6N70
IRFP221 SSH10N70
IRFP222 SSH4N60
IRFP223 SSH6N60
IRFP230 SSH8N60
IRFP231 SSH15N60
IRFP232 SSH4N55
IRFP233 SSH6N55
IRFP240 SSH8N55
IRFP241 SSH15N55
IRFP242 SSH4N50
IRFP243 SSH20N50
IRFP250 SSH4N45
IRFP251 SSH20N45
IRFP252 SSH5N40
IRFP253 SSH25N40
IRFP320 SSH5N35
IRFP321 SSH25N35
IRFP322 SSH7N20
IRFP323 SSH8N20
IRFP330 SSH7N18
IRFP331 SSH8N18
IRFP332 SSH7N15
IRFP333 SSH8N15
IRFP340 SSH7N12
IRFP341 SSH8N12
IRFP342 SSH12N10
IRFP343 SSH10N10
IRFP350 SSH12N08
IRFP351 SSH10N08
IRFP352 SSH12N06
IRFP353 SSH10N06
IRFP420 SSH12N05
IRFP421 SSH10N05

TO-3P Package P-Channel Types

IRFP9120 IRFP9220
IRFP9121 IRFP9221
IRFP9122 IRFP9222
IRFP9123 IRFP9223
IRFP9130 IRFP9230
IRFP9131 IRFP9231
IRFP9132 IRFP9232
IRFP9133 IRFP9233
IRFP9140 IRFP9240
IRFP9141 IRFP9241
IRFP9142 IRFP9242
IRFP9143 IRFP9243

TO-3 Package N-Channel Types

IRF120 IRF242
IRF121 IRF243
IRF122 IRF250
IRF123 IRF251
IRF130 IRF252
IRF131 IRF253
IRF132 IRF320
IRF133 IRF321
IRF140 IRF322
IRF141 IRF323
IRF142 IRF330
IRF143 IRF331
IRF150 IRF332
IRF151 IRF333
IRF152 IRF340
IRF153 IRF341
IRF220 IRF342
IRF221 IRF343
IRF222 IRF350
IRF223 IRF351
IRF230 IRF352
IRF231 IRF353
IRF232 IRF420
IRF233 IRF421
IRF240 IRF422
IRF241 IRF423

IRF430 SSM4N50
IRF431 SSM20N50
IRF432 SSM4N45
IRF433 SSM20N45
IRF440 SSM5N40
IRF441 SSM25N40
IRF442 SSM5N35
IRF443 SSM25N35
IRF450 SSM7N20
IRF451 SSM8N20
IRF452 SSM7N18
IRF453 SSM8N18
SSM3N70 SSM7N15
SSM4N70 SSM8N15
SSM6N70 SSM7N12
SSM10N70 SSM8N12
SSM4N60 SSM12N10
SSM6N60 SSM10N10
SSM8N60 SSM12N08
SSM15N60 SSM10N08
SSM4N55 SSM12N06
SSM6N55 SSM10N06
SSM8N55 SSM12N05
SSM15N55 SSM10N05

TO-3 Package P-Channel Types

IRF9120 IRF9220
IRF9121 IRF9221
IRF9122 IRF9222
IRF9123 IRF9223
IRF9130 IRF9230
IRF9131 IRF9231
IRF9132 IRF9232
IRF9133 IRF9233
IRF9140 IRF9240
IRF9141 IRF9241
IRF9142 IRF9242
IRF9143 IRF9243

TO-220 Package N-Channel Types

IRF510 IRF741
IRF511 IRF742
IRF512 IRF743
IRF513 IRF820
IRF520 IRF821
IRF521 IRF822
IRF522 IRF823
IRF523 IRF830
IRF530 IRF831
IRF531 IRF832
IRF532 IRF833
IRF533 IRF840
IRF540 IRF841
IRF541 IRF842
IRF542 IRF843
IRF543 SSP3N70
IRF610 SSP4N70
IRF611 SSP4N60
IRF612 SSP6N70
IRF613 SSP6N60
IRF620 SSP6N55
IRF621 SSP4N60
IRF622 SSP4N55
IRF623 SSP4N50
IRF630 SSP4N45
IRF631 SSP5N40
IRF632 SSP5N35
IRF633 SSP7N20
IRF640 SSP8N20
IRF641 SSP7N18
IRF642 SSP8N18
IRF643 SSP7N15
IRF710 SSP8N15
IRF711 SSP7N12
IRF712 SSP8N12
IRF713 SSP12N10
IRF720 SSP10N10
IRF721 SSP12N08
IRF722 SSP10N08
IRF723 SSP12N06
IRF730 SSP40N06
IRF731 SSP10N06
IRF732 SSP12N05
IRF733 SSP10N05
IRF740

TO-220 Package P-Channel Types

IRF9510 IRF9610
IRF9511 IRF9611
IRF9512 IRF9612
IRF9513 IRF9613
IRF9520 IRF9620
IRF9521 IRF9621
IRF9522 IRF9622
IRF9523 IRF9623
IRF9530 IRF9630
IRF9531 IRF9631
IRF9532 IRF9632
IRF9533 IRF9633
IRF9540 IRF9640
IRF9541 IRF9641
IRF9542 IRF9642
IRF9543 IRF9643

TO-126 Package N-Channel Types

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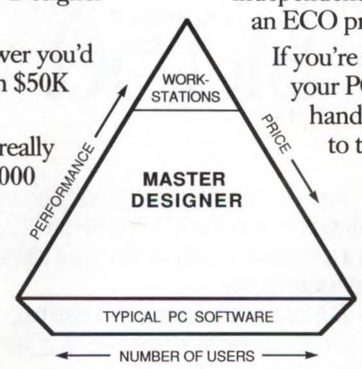

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$10,750.

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8088 8039	68HC11A8 6802	6301Y	6505	CDP6805C4	Z180
80186 8344	68B02	6303R	6506	CDP6805C8	Z8001
80188 8048	68000 146805E2	6305V	6507	CDP6805D2	Z8002
80286 8049	68008 6803	63705	6512	CDP6805E3	
8050	68010 6808	6309	6513		
8051	68B08	6309E	6514		
8085A	6809	64180R0	6515		
8085A2	6809E	64180R1			
8096/97	68B09				
	68B09E				

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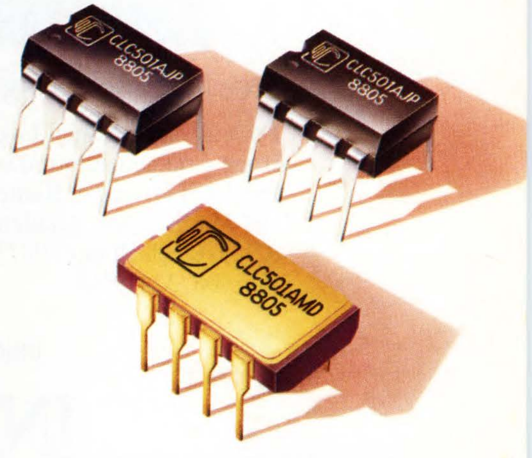

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Midcon, Dallas, TX. Electronic Conventions Management, 8110 Airport Blvd, Los Angeles, CA 90045. (800) 421-6816; in CA, (213) 772-2965. August 30 to September 1.

Surface Mount '88, Marlborough, MA. MG Expositions Group, 1050 Commonwealth Ave, Boston, MA 02215. (800) 223-7126; in MA, (617) 232-3976. August 30 to September 1.

Modern Electronic Packaging (seminar), Santa Clara, CA. Technology Seminars, Box 487, Lutherville, MD 21093. (301) 269-4102. September 7 to 9.

International Test Conference, Washington, DC. Doris Thomas, ITC, Box 264, Mount Freedom, NJ 07970. (201) 267-7120. September 12 to 14.

Worst-Case Circuit Analysis (seminar), Boston, MA. Design and Evaluation, 1000 White Horse Rd, Suite 304, Voorhees, NJ 08043. (609) 770-0800. September 12 to 14.

C Programming Workshop (short course), Seattle, WA. SSC, Box 55549, Seattle, WA 98155. (206) 527-3385. September 12 to 15.

12th International Fiber Optic Communications and Local Area Networks Exposition, Atlanta, GA. Information Gatekeepers, 214 Harvard Ave, Boston, MA 02134. (800) 323-1088; in MA, (617) 232-3111. September 13 to 16.

Unix Hands-on Workshop (short course), Montreal, Canada. Integrated Computer Systems, Box 3614, Culver City, CA 90231. (800) 421-8166; in CA, (213) 417-8888. September 13 to 16.

Troubleshooting Microprocessor-Based Equipment and Digital Devices, Atlanta, GA. Micro Systems Institute, 73 Institute Rd, Garnett, KS 66032. (800) 247-5239; in KS, (913) 898-4695. September 19 to 22.

CIRCLE NO 56

CALENDAR

Unix Hands-on Workshop (short course), Washington, DC. Integrated Computer Systems, Box 3614, Culver City, CA 90231. (800) 421-8166; in CA, (213) 417-8888. September 20 to 23.

34th IEEE Holm Conference on Electrical Contacts, San Francisco, CA. IEEE Holm Conference Registrar, 345 E 47th St, New York, NY 10017. (212) 705-7405. September 26 to 29.

Troubleshooting Microprocessor-Based Equipment and Digital Devices, Chicago, IL. Micro Systems Institute, 73 Institute Rd, Garnett, KS 66032. (800) 247-5239; in KS, (913) 898-4695. September 27 to 30.

Unix Hands-on Workshop (short course), San Diego, CA. Integrated Computer Systems, Box 3614, Culver City, CA 90231. (800) 421-8166; in CA, (213) 417-8888. September 27 to 30.

Connector and Interconnection Technology Symposium, Dallas, TX. Electronic Connector Study Group, 104 Wilmot Rd, Suite 201, Deerfield, IL 60015. (312) 940-8800. October 3 to 5.

IEEE International Conference on Computer Design: VLSI in Computers and Processors, Port Chester, NY. Gail Clanton, IEEE, 1730 Massachusetts Ave NW, Washington, DC 20036. (202) 371-1013. October 3 to 5.

Autotestcon, Minneapolis, MN. Steve Palmer, Unisys, 3333 Pilot Knob Rd, Eagan, MN 55121. (612) 456-2349. October 4 to 6.

Buscon/88 East, New York, NY. Conference Management Corp, 200 Connecticut Ave, Norwalk, CT 06856. (203) 852-0500. October 4 to 6.

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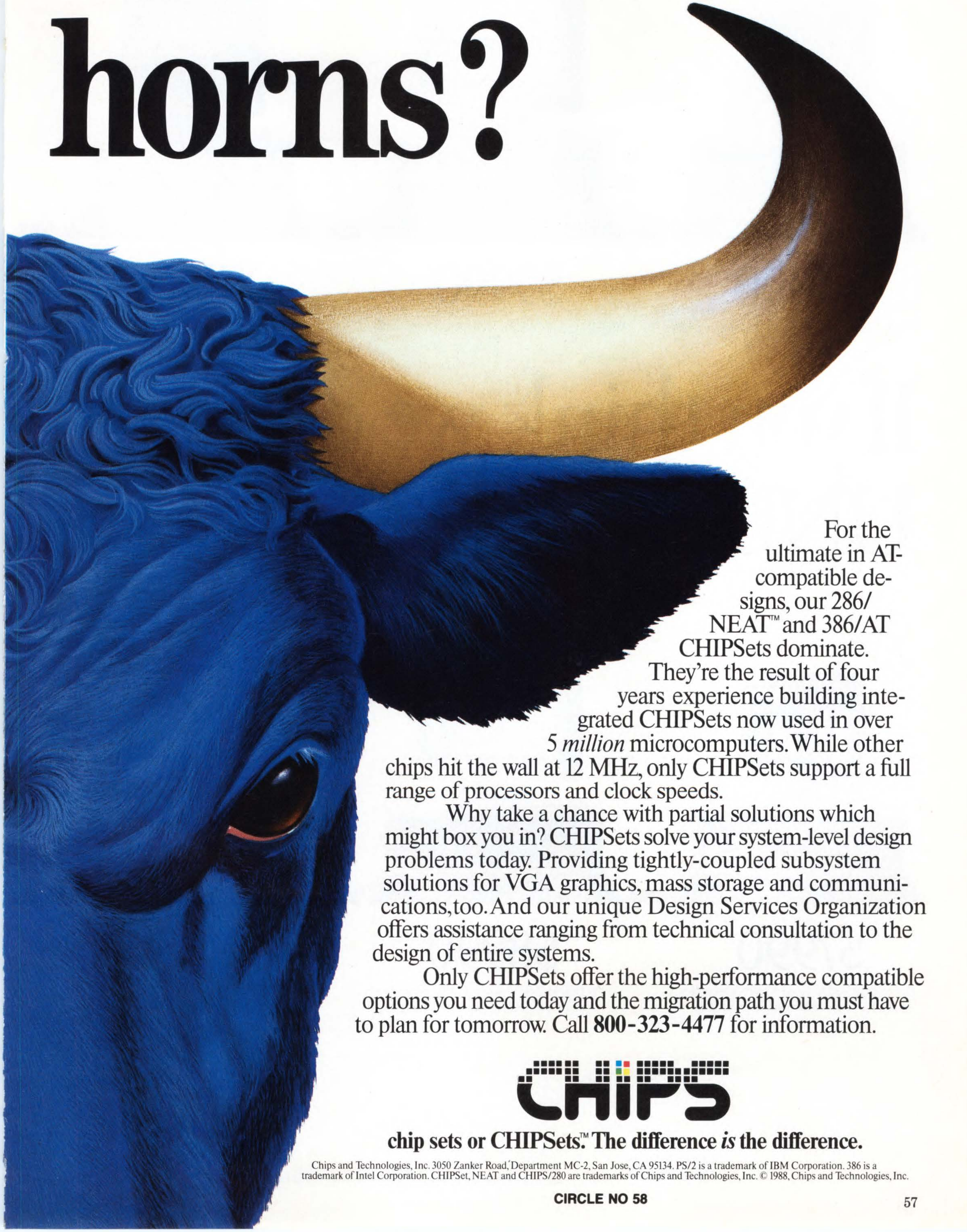

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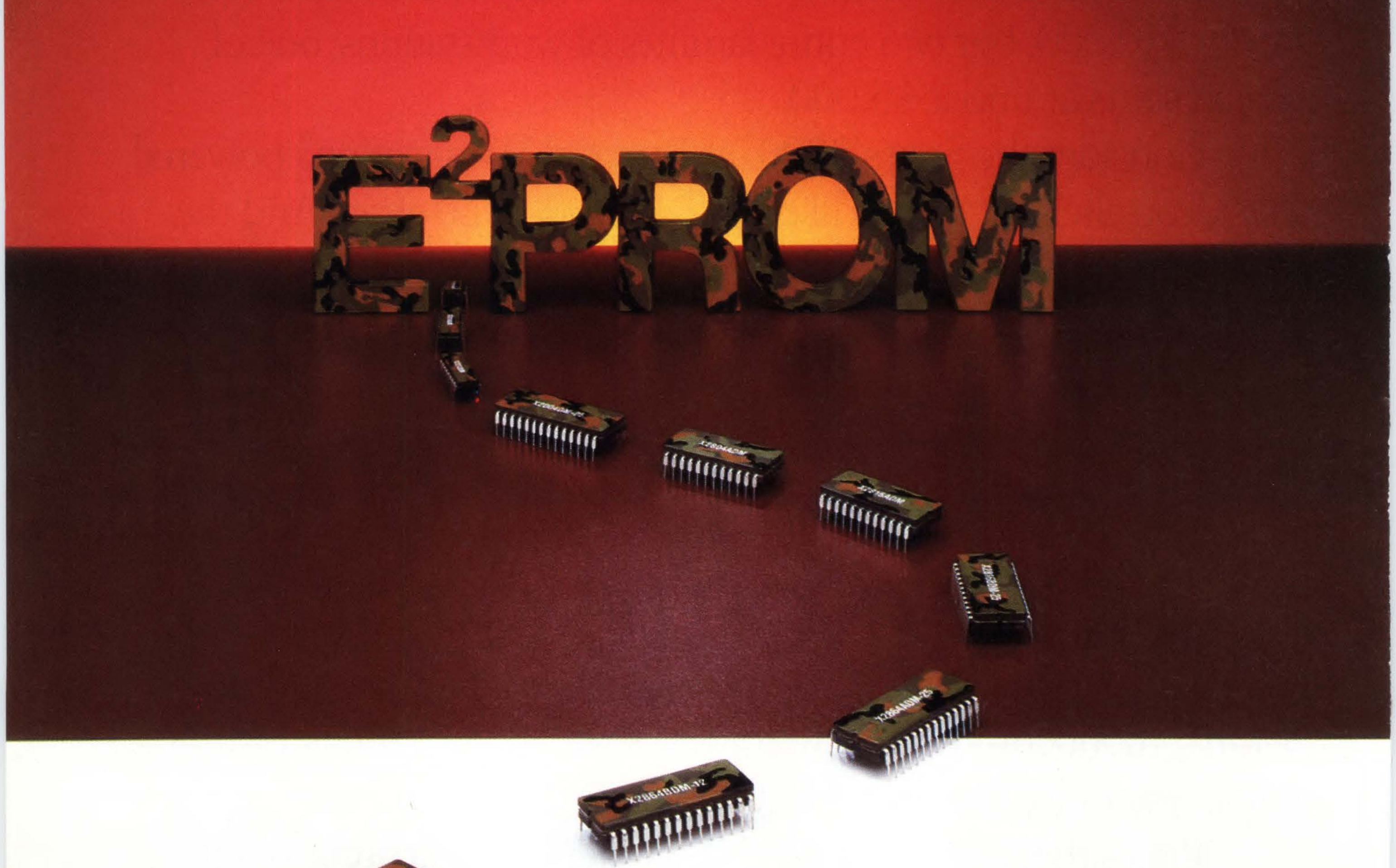

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X2816BM	2048 x 8	16	250, 300
X2864AM	8192 x 8	16	250, 300, 350, 450
X2864BM	8192 x 8	32	120, 150, 180
X2864HM	8192 x 8	32	90
X28256M	32768 x 8	64	250, 300, 350
X28C256M	32768 x 8	64	250, 300, 350
XM28C010M	131072 x 8	64	250, 300

NOVRAM Part No.	Organ.
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X2004M	512 x 8
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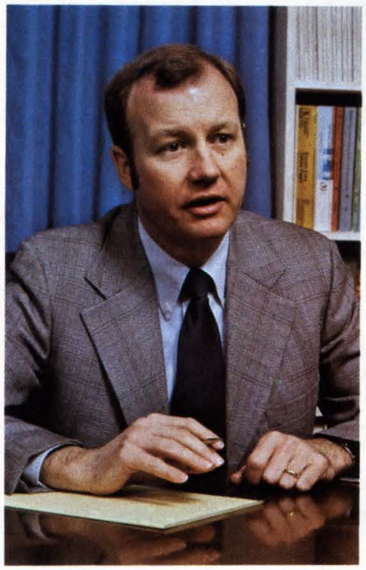
CIRCLE NO 60

EDITORIAL

That's the way the trade problems crumble



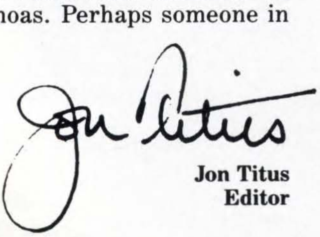
The recent shortage of dynamic-RAM chips has set off a new round of discussions about working with our Asian trading partners. It turns out that there may be a way to help solve some of the semiconductor and trade problems. But before you hear my proposal, you'll need a little background information.

Earlier this year, Federal Express began a new service: It started shipping small packages to Japan at prices lower than the normal shipping costs of Japanese carriers. Because the Japanese have no similar small-package courier service, they decided to stop or slow Federal Express until one of their domestic carriers could offer a competitive service. Instead of levying enough duties and restrictions to shut down Federal Express's new service outright, the Japanese demanded shipping documents for each Federal Express package. The extra paperwork and complex customs processing are making Federal Express shipments uncompetitive with the Japanese shippers, according to *Business Week* (May 30, 1988, pg 116).

At about the same time, the Japanese taught the Girl Scouts of America a lesson about international trade. US Navy personnel stationed in Japan ordered Girl Scout cookies at $2 per box. Unfortunately for the sailors, when the cookies arrived in Japan, the unfathomable customs inspectors placed a $5 duty on each box. After all, cookies are agricultural products which threaten Japanese suppliers' markets. In the end, US Congressional intercession carried the day, and the sailors got their cookies.

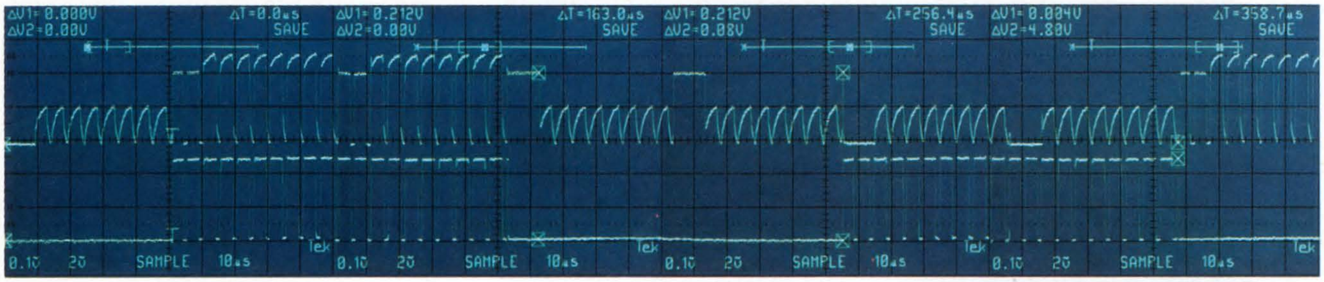
Now we're facing a semiconductor crisis that threatens US computer manufacturers—almost all of whom rely on now-scarce DRAM chips from Asia. According to industry watcher Warren Andrews, there may be a conspiracy among foreign DRAM vendors to keep supplies scarce and thus keep prices high. Andrews thinks that the DRAM shortages are part of a concerted plan by Japanese suppliers who ultimately want to control the computer-board and -systems markets, too.

Well, like it or not, the time has come to retaliate against the Japanese by giving them a taste of their own medicine. Just as we depend on DRAMs, Japanese manufacturers depend on many types of US-made semiconductors. But instead of planning a price-and-supply conspiracy, we'll take another approach. Here's the plan: From now on, whenever US companies ship semiconductor products to Japan, they should send them by Federal Express. Let's set a limit of 12 parts per package, though. Also, to show our good will, we'll throw in a box of Girl Scout cookies with each order—I recommend the sticky chocolate-covered Samoas. Perhaps someone in Japan will get the message.



Jon Titus
Editor

Digital scopes with a



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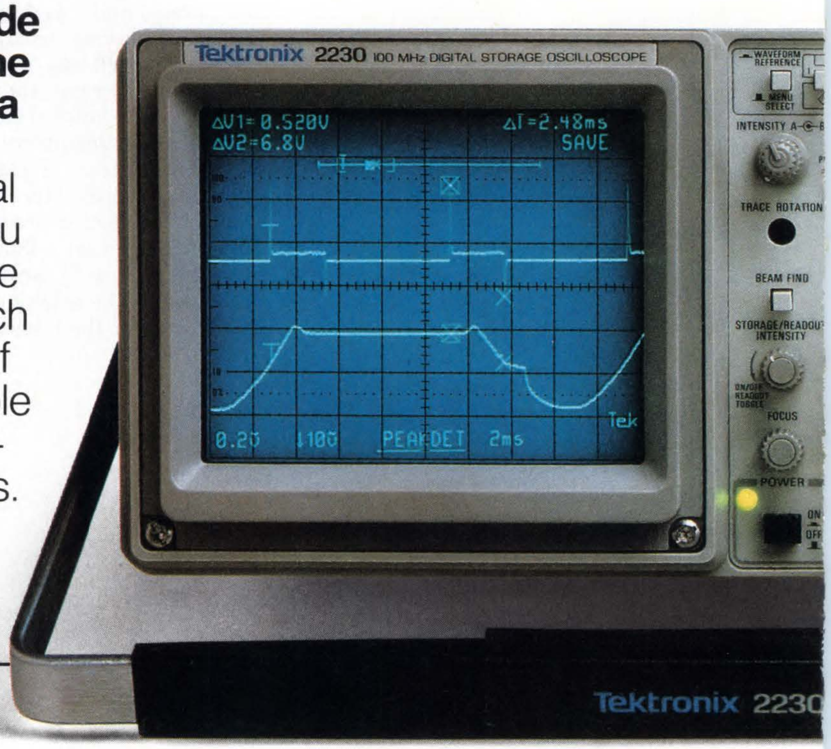

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Record Length	4K	4K	4K	4K
Glitch Capture	100 ns	100 ns	100 ns	No
CRT Readout/ Cursors	Yes	Yes	No	No
GPIB/RS-232-C Options	Yes	Yes	Yes	No
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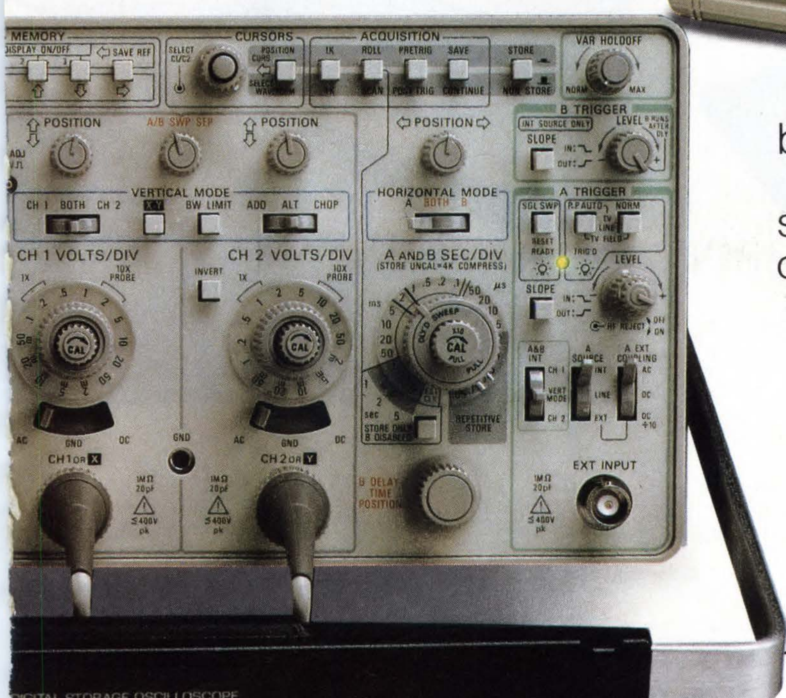

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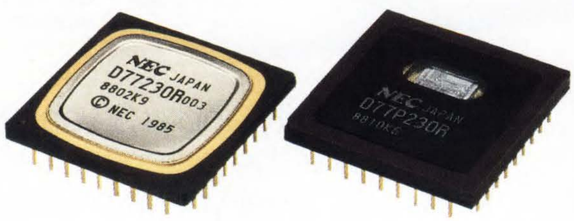

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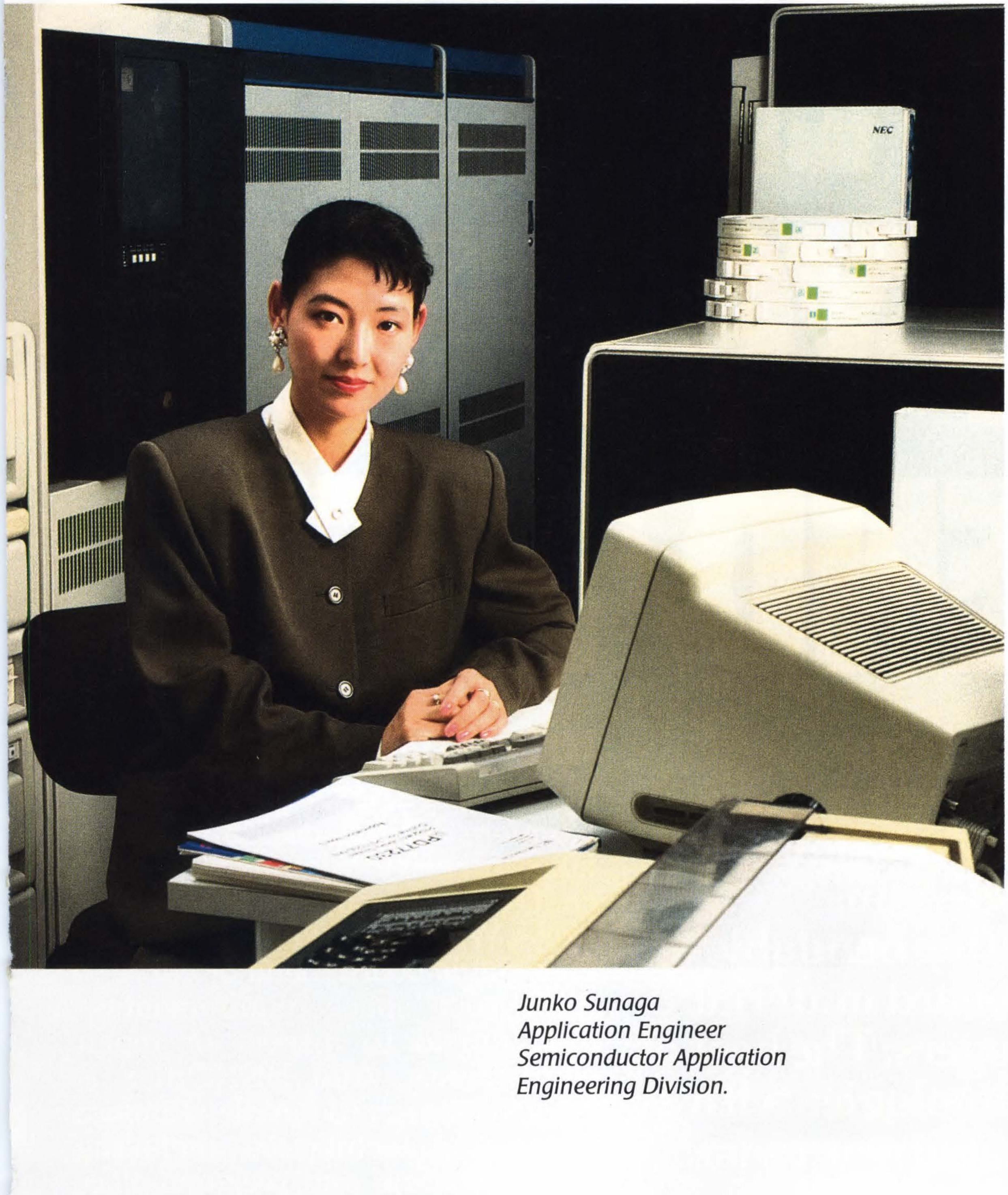

Junko Sunaga
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Semiconductor Application
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CIRCLE NO 63

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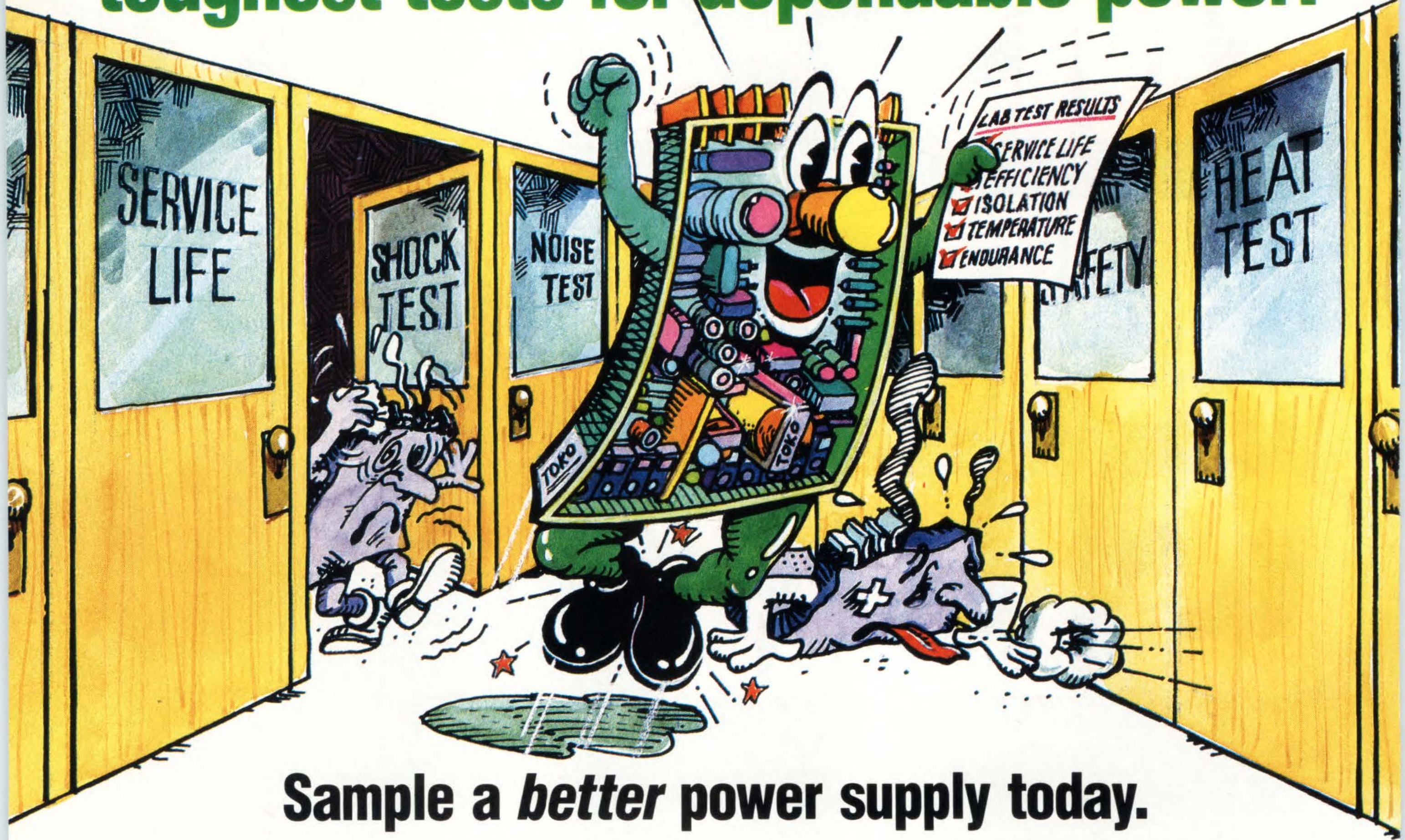

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	85-264	15/30W	3	1.0"	4.3"	2.4"
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EM	170-264	10/15W	3	2.6"	4.5"	1.3"
PS	85-132	10/15/30 50/100W	1	3.8"	3.5"	1.0"
PE	85-132	30/50/100W	1	3.8"	6.3"	1.4"
AS	90-132	75W	1	1.6"	8.0"	4.9"
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PC-based development products move AI out of the classroom, into the workplace

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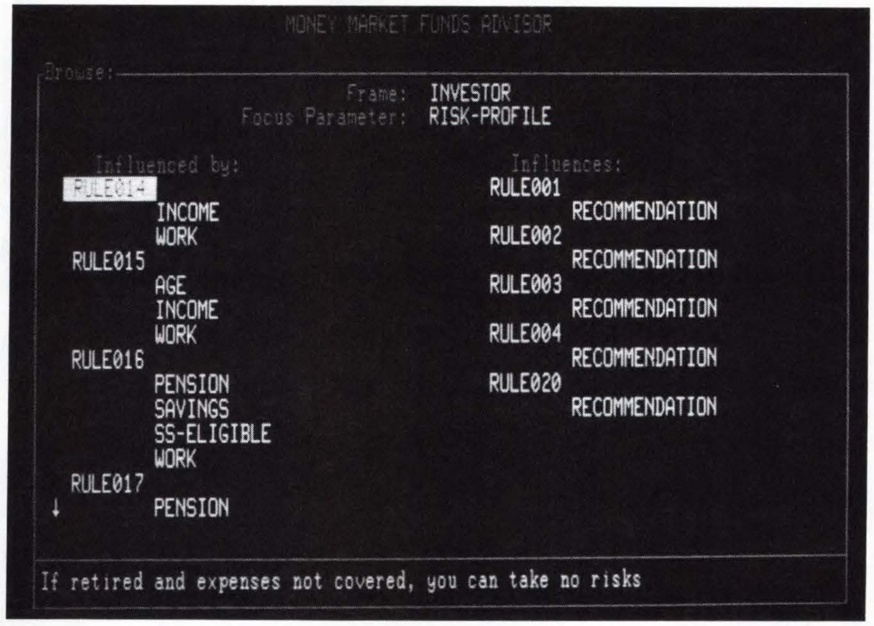

***Most expert systems will show you a list** of the existing rules, as well as the dependencies between them. The Texas Instruments Personal Consultant Plus 3.0, for example, lets you create complex expert-system applications for 80286/80386, DOS-based personal computers.*

Artificial intelligence (AI) was the dreamchild of the 50s—or perhaps it was Aladdin's lamp, which would release a genie of unlimited power and wisdom. In the 70s, it was an expensive lab toy, with which people attempted to make huge computers emulate what they called "natural intelligence," or the structure and method of performing tasks. The scientific results and social implications of AI were—and still are—hotly disputed, and many of the original goals have proved unrealizable, misdirected, or just not commercially useful at present. Nevertheless, the spinoffs from AI research include many new techniques for problem solving and much valuable knowledge about how to define tasks accurately.

You no longer need a supercomputer to run AI-related programs; many such programs will run on modest machines such as the IBM PC/AT and compatibles. Most of the AI products available for PCs are "expert-system shells," tools that let you interrogate a human expert in a given field and build not only his factual knowledge, but also his approach to problem solving, into an "expert system." GoldWorks from Gold Hill Computers is an example. Such a system can help a nonexpert in a certain field to perform a complex task that requires insight into the relative importance of the phenomena observed under varying conditions.

Another AI-based technique that may have important implications for both the hardware and the software of massively parallel systems is the neural network, which is a network of small processors (or their software equivalent) that purports to model the interconnections and behavior of the neurons in the human brain. A large neural network requires extensive computing power and resources, but at least two simulators that run on PCs and compatibles—Netwurkz from DAIR Computer Systems and Awareness from Neural Systems—can demonstrate the more-obvious properties of neural networks and allow you to familiarize yourself with these properties.

New programming techniques have also emerged from AI studies, as have some new programming languages (and new dialects of established languages) that facilitate them. These techniques can enhance both the performance and the user interface of more traditional applications, such as database managers.

Before examining the details of expert-system shells, neural networks, and language tools, it may be helpful to consider briefly what AI is and how AI programs differ from traditional programs. "Artificial intelligence" is the general term for an academic field of research that studies the parameters of task performance by designing a system to perform a task, and then seeing how well the system succeeds.

If you wonder how that procedure differs from the design of any other system, consider Elaine Rich's definition: "Artificial intelligence is the study of how to make computers do things at which, at present, people are better" **(Ref 1)**. If you're still confused, ponder the further simplification of the cynic who said: "If we know how we do it, it ain't AI."

One of the dilemmas that AI-systems designers face is that human language is governed by all kinds of implicit assumptions. For example,

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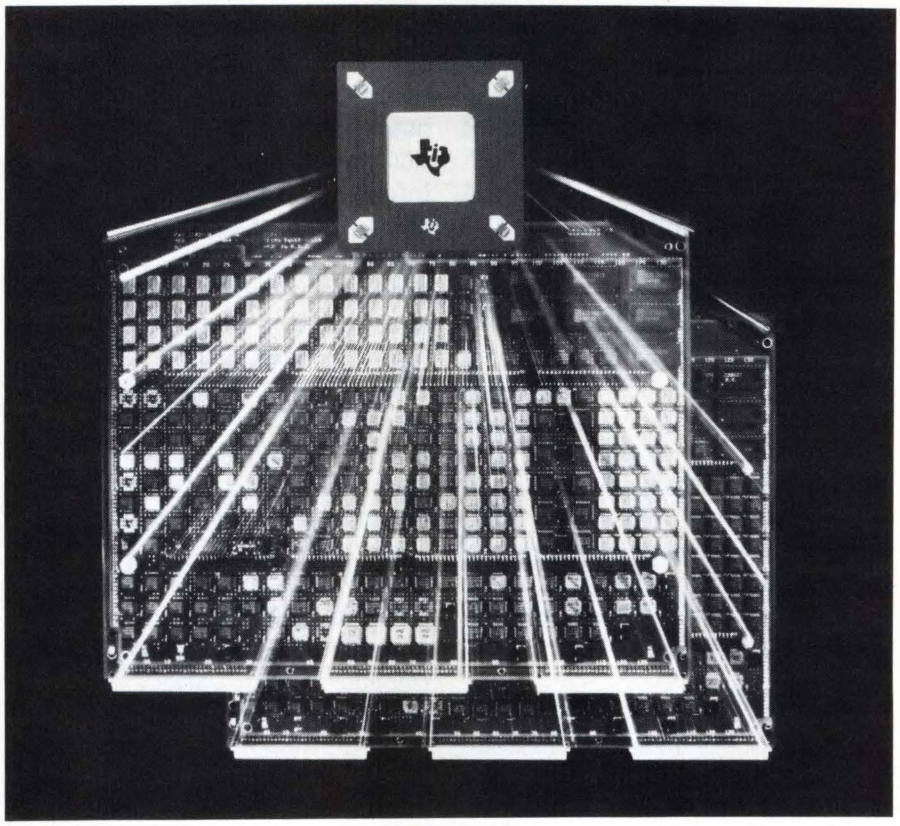
suppose that a computer has control of robotic arms and hands, has definitions of the words "fry," "egg," "pan," "boil," and "stove" in its memory, and has access to those items. We can tell the computer to fry an egg, but we shouldn't be surprised if the computer attempts to perform the task by placing the egg in the pan without breaking the shell. If the computer has to learn that "egg" implies "without the shell" in the context of frying, can we expect it to know that the same word implies "in the shell" in the context of boiling? It is this type of assumption about our environment, not to mention the ambiguity of natural languages, that makes computer simulation of human behavior so difficult to achieve.

You can see, therefore, that AI studies are important for anyone who is designing a system that must take into account the nature of its environment and that must, like a human, attempt to find solutions to problems when the data is incomplete. At a practical level, AI studies have brought new approaches and technological advances to a huge range of disciplines, including natural-language processing, computer vision, speech recognition, robotics, automatic programming and heuristic systems (systems that learn from their experiences).



Lisp programs run fastest on a machine whose native language *is Lisp. The heart of Texas Instruments' Explorer workstation is this Lisp CPU chip.*

Expert systems are data-driven

Traditional application programs, such as database managers, are procedure-driven. That is, they process the information contained in the database according to a fixed set of instructions. Knowledge-based programs, such as expert systems, are far more flexible; they dynamically determine the sequence of rules to be employed while the program is running, and they do so on the basis of both the desired result and the data that's available to them.

Another difference between procedural programs and expert systems is that the former use only forward chaining to determine the sequence of rules the program employs. That is, they proceed from a fixed set of input data to a fixed goal by applying the rules in sequence. Expert systems can also employ backward chaining; that is, they can start from a particular goal, break it into several subgoals, and work backward through the rules until the available data fits one or more of the subgoals. If the system does not find an exact match, it can ask for more data; if additional data is not available, the system can indicate the closeness of the match as a percentage, and can also—at any time —explain the rules that it applied in order to reach a particular conclusion or recommendation.

An expert system consists of two major components. One is a *knowledge base* that can store data in a form that allows the representation of both facts (declarative knowledge) and rules of thumb for relating them (procedural knowledge). The other is a *control structure* (also called a *rule interpreter* or an *inference engine*) that determines the manner in which the knowledge is to be used.

An expert-system shell contains an empty knowledge base and an inference engine, but also contains an editor or some other means of eliciting and storing items of both declarative and procedural knowledge. The vendor usually licenses both a development system that includes all three major components (and often some helpful utility programs) and a run-time system that consists only of the knowledge-base framework and the inference engine. You can distribute the run-time system as part of any expert system that you develop with the package.

Inexpensive expert-system shells

A typical example is the Exsys shell from Exsys Inc. Its development system for IBM PCs and compatibles costs $395; its run-time system costs $600 for unlimited distribution. You can license both systems for $900. The shell is written in C, which gives it high execution speed and efficient memory use. If your PC has 640k bytes of RAM, you can develop systems with as many as 5000 rules. The inference engine can use both forward and backward chaining; you can exchange data with most spreadsheets and database programs; and you enter all input in English text, in algebraic notation, or via menu selections. You can get a demonstration disk that has all the features of the full system (including a printed manual, sample expert systems, and a tutorial on how to create expert systems) but allows you to save only 25 rules to disk. The demo disk costs $15.

Costly expert-system shells

A much more elaborate, flexible, and costly development system is GoldWorks from Gold Hill Computers Inc. This system runs on 80286- or 80386-based machines that have at least 512k bytes of main memory and 5M bytes of extended memory. The system is a frame-based one, which provides flexibility of knowledge representation—in other words, each data object is not only named, but also contains descriptions of all its parts and their attributes (such as quantity, color, relationships to other parts, etc). The inference engine allows both forward and backward chaining, and provides control mechanisms that handle user-defined rule priorities and certainty factors, as well as rule-inspecting and -debugging facilities. You can exchange data with spreadsheets and database managers. In addition, you get extensive tutorial material, not only on how to create expert systems but also on Lisp programming and AI strategies. The developer's interface includes an Emacs-like editor, a large-memory Lisp interpreter and compiler, and a variety of debugging tools. Prices start at $7500.

An optional training program called Axle, also from Gold Hill, gives a stage-by-stage demonstration of the development of four different types of expert systems: a manufacturing system, an aerospace system, and two planning systems, one for an industrial application, and the other for oil exploration. These sample systems include methods for diagnosing equipment malfunctions and help in making decisions about tasks and resources. The program runs on 80286- and 80386-based PCs, and costs $1995.

Although Texas Instruments (TI) is best known in the AI field for software that runs on the TI Explorer workstation, whose native language is Lisp, TI also provides expert-system shells that run on PCs and compatibles. At the low end of the company's Personal Consultant series is PC Easy, which runs on PCs or PC/XTs and costs $495. At the high end is PC Plus, which runs on 80286- or 80386-based machines and costs $2950. Knowledge bases created with PC Easy are upwardly compatible with PC Plus knowledge bases, and both are compatible with the Explorer Symbolic Processing System. TI supplies demonstration disks for PC Easy and Plus.

An interesting newcomer to the ranks of expert-system shells is CxPERT ($495 from Software Plus). Like other shells, it provides you with a knowledge-representation framework, user-interface mod-

An AI reading list

If you want to know more about artificial intelligence, you'll find the following publications informative. They can also direct you to further, more specialized reading.

1. *AI Expert*, CL Publications Inc, 650 Fifth St, Suite 311, San Francisco, CA 94107. Phone (415) 957-9353. $27/year (12 issues). Interesting for both the professional and the novice in the AI field. Rather similar in character to *Computer Language*, it addresses both general problems and the tricks of the trade.

2. *AI Magazine*, American Association for Artificial Intelligence (AAAI), 445 Burgess Dr, Menlo Park, CA 94025. Phone (415) 328-3123. Yearly membership, $25; 5 issues/year. The professional journal of scientists involved in AI research. A must if you're involved in AI projects.

3. *AI Trends*, DM Data Inc, 6900 E Camelback Rd, Suite 1000, Scottsdale, AZ 85251. Phone (602) 945-9620. In the US, $295/year (12 issues); elsewhere, $345/year. Describes trends, important issues, and the administrative and economic vicissitudes of the major players in the AI field.

4. *Artificial Intelligence Letter*, Texas Instruments, Data Systems Group, Box 2909, M/S 2222, Austin, TX 78769. Includes case histories, the viewpoints of eminent AI experts, and a conference calendar.

5. *Understanding Artificial Intelligence*, by Henry C Mishkoff (1985). The Texas Instruments Learning Center, Box 225474, MS-8218, Dallas, TX 75265. $14.95. A first-class introduction to the AI field, with clear descriptions of the various branches, the issues involved, and some of the products. The book was originally issued in conjunction with the first of the TI-sponsored Satellite Seminars on AI. Highly recommended.

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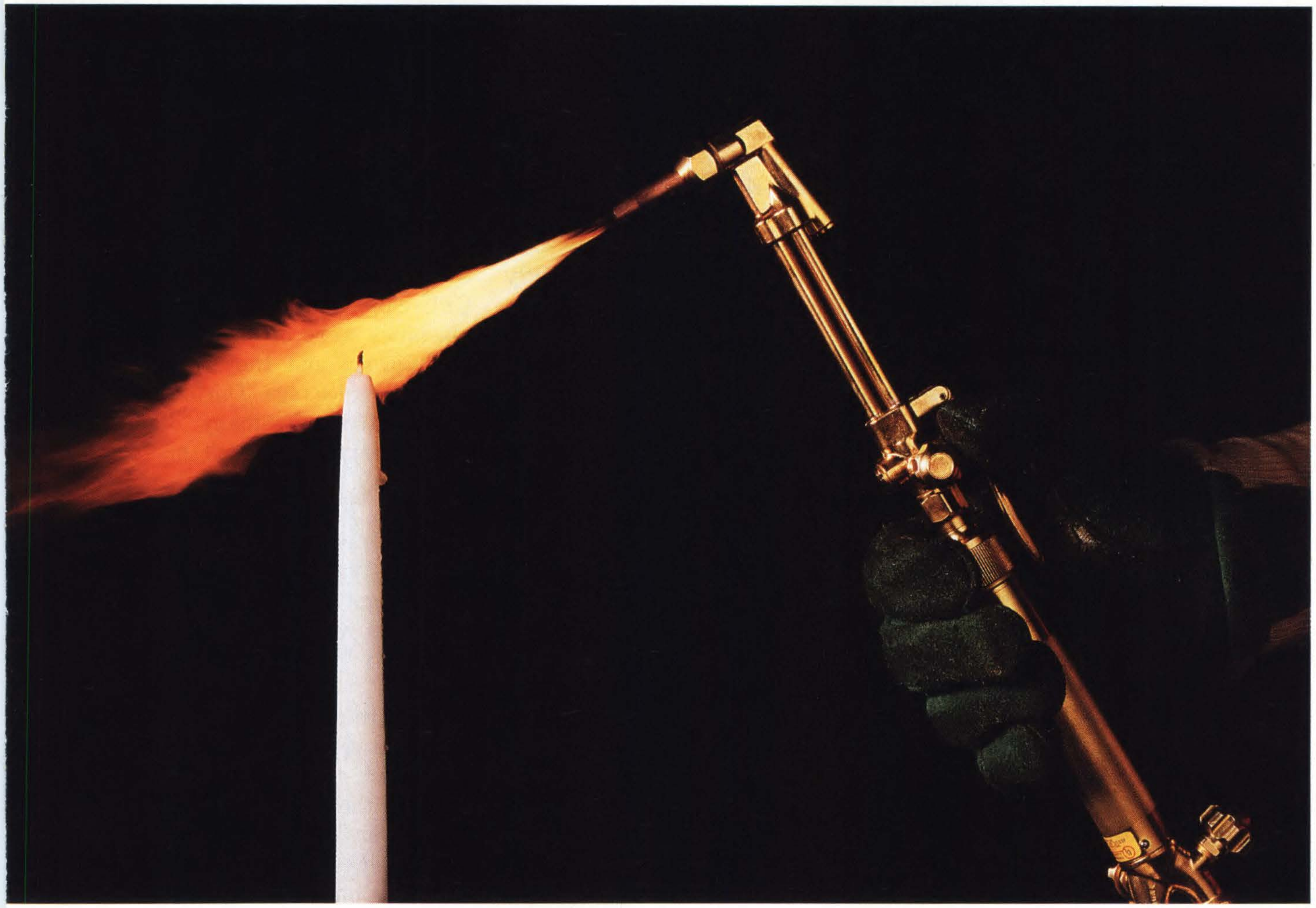

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ules, and an inference engine that allows several layers of backward chaining. According to one reviewer, the forward-chaining feature is somewhat rudimentary, but it's nevertheless very flexible. The unusual feature of this shell, which is written in C, is that it encourages you to use standard C code to perform tasks that the high-level constructs don't support. You create knowledge-base modules in a mixture of C and a knowledge-representation language (KRL) source code; these modules contain the rules, attributes, menu text, and logic that compose the expert system. The KRL compiler processes these modules to produce a C source file and a header file, which you compile with the Microsoft or Lattice compiler. You can then link your object modules to the object libraries supplied with the shell, as well as to other C programs or routines.

Neural networks open new doors

Neural networks have probably existed in rudimentary form for a number of years, but have only recently become practical. They are still immature, but—theoretically—they promise dramatic advances in the technology of pattern recognition. What's important about them is that they're capable of learning, from examples, to recognize not only specific shapes and patterns, but also a gestalt. In other words, they can learn to recognize the clues that allow us, for example, to abstract the concept "dog" from the specifics "Doberman" and "Yorkshire terrier," despite the differences in size, shape, and hair texture. Only three neural-network systems are as yet available for PCs, and they all require the computing power and speed of an 80286-based machine.

At the low end of the scale is Netwurkz ($79.95) from DAIR Computer Systems. This product is limited in scope and capability, but it serves as a demonstration of the more-obvious properties of neural networks. It does, however, provide facilities that let you develop simple programs other than those supplied as examples. Another demonstration and learning system is Awareness ($250) from Neural Systems.

At the high end is the NDS system from Nestor Inc ($7500 for the PC/AT version). The NDS system emulates the action, as we currently understand it, of the biological neural networks used by the human learning and classification processes. It will learn to recognize images such as industrial objects, alphanumeric characters, and signatures if you present it with examples of those images. The package is menu driven and highly interactive. It is written in C, and it includes extensive diagnostic facilities for fine-tuning its recognition performance. It also provides an interface to Datacube's (Peabody, MA) MaxiVision image-processing hardware for the PC/AT. The combination creates an intelligent vision system that manufacturers can employ in factory automation at a cost of less than $20,000.

Tsk! Tsk! Such language!

Hardly any programming topic (except one's choice of editor) can so reliably start a heated discussion as one's choice of programming language. Opinions on AI languages just add fuel to the fire. The traditional language for AI programming has for many years been Lisp, because its features make it admirably suited to handling software objects that embody both attributes and procedures specific to those objects. In the last few years, however, other languages have started to edge Lisp out of its formerly preeminent position. Even such a dyed-in-the-wool Lisp proponent as Symbolics Inc is starting to rewrite its AI products in the C language, for the sake of portability.

There are several reasons for this shift. First, Lisp is a memory hog; it is liable to create many noncontiguous islands of abandoned data to which pointers no longer exist. Periodically, the memory must be homogenized into contiguous used and free areas by a time-consuming process called "garbage collection." Second, Lisp runs fastest on machines whose native language is Lisp. Until Texas Instruments produced the Explorer CPU chip, and Symbolics came out with the Ivory CPU chip, the only dedicated Lisp machines were of mainframe size and power, and they had corresponding price tags. Third, Lisp has fragmented into many dialects, which certainly doesn't make for portability. And, last, the syntax is not easy. Experts will assure you that it's possible to write a Lisp program that other people can read and understand easily, but their antagonists will warn you that you might get "Lost In Silly Parentheses."

If you're already a Lisp fan, consider the versions available for the PC, which range from TI's $95 PC Scheme, through the $495 Star Sapphire version of Common Lisp (Sapiens Software), to Gold Hill's Golden Common Lisp for 80286-based machines at $1995. The Star Sapphire package is interesting because it compiles programs to C; to use it, you'll need 640k bytes of RAM, a hard-disk drive, and a C compiler that supports the Huge memory model. For those who want to try out Lisp at minimal expense, however, there's a public-domain, object-oriented dialect called XLisp that you can download from many PC-based bulletin boards for the price of a phone call.

Object-oriented languages

The principal rival of Lisp in the AI field is probably C, partly because of its steadily increasing popularity as an all-purpose language, and partly because AT&T's superset of the language, called C++, is readily available for the PC. This augmented version of C is an object-oriented language. It provides such features as classes, inheritance,

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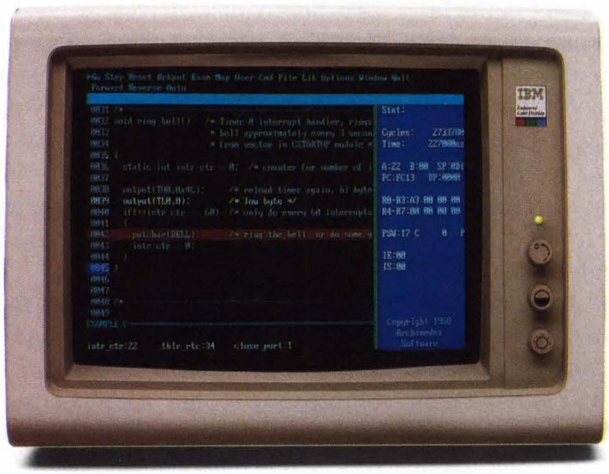

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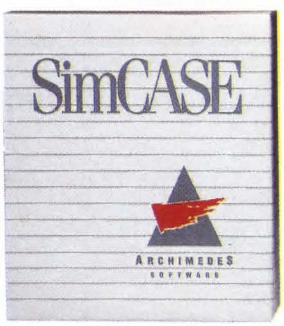

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member functions, constructors and destructors, data hiding, and data abstraction, which are virtually essential for any sophisticated AI programming. In particular, the "classes" feature lets you create modules that contain their own data and data-related operations; you can compile these modules independently, just as you would do in a Modula-2 system. You can save your modules in separate files and reuse them in other C++ programs. C++ usually comes in the form of a translator from C++ to standard C source code, so you'll be able to use your existing C compiler. C++ translators are available from Guidelines Software Inc ($295) and Oasys. The Oasys version is available for many different machines and their most common C compilers. It costs $495.

If you just want to experiment with the C++ language, you can do so inexpensively by using Zortech's $99.95 compiler. Unlike the other packages, which translate C++ code to standard C source code for later compilation and linking, Zortech's product is a true compiler that generates relocatable object modules for 8088-based machines. Zortech can also supply Bjarne Stroustrup's book *The C++ Programming Language* ($29.95), which contains the standard specifications of the C++ language. Stroustrup designed the language.

Prolog, the new AI language

Prolog is a nonprocedural programming language. It is conceptually simple and extremely powerful, but so different from procedural languages such as Lisp and C that it's difficult to learn, especially if you're experienced in using a procedural language—you have to develop a totally different way of thinking in order to use it effectively. The language is object-oriented, and it embodies such features as backtracking, which allows the execution of statements to take place not only from top to bottom and left to right (as in procedural languages), but also from right to left and from bottom to top.

The two major implementations of Prolog for IBM PCs and compatible computers are Arity/Prolog and Turbo-Prolog. Arity's package ($650) includes both a compiler and an interpreter. You can also get the Arity/Expert System and Arity/SQL as options for $295 each.

Borland's Turbo Prolog 2.0 ($149.95) also runs on IBM PCs, PS/2s, and compatibles. You must have at least 348k bytes of RAM (640k bytes are recommended) and two floppy-disk drives (a hard-disk drive is recommended). The package allows you to work with multiple internal databases, as well as with an external database system, so you can develop very large databases. It also includes the source code (written entirely in Turbo Prolog) of a Prolog interpreter. There are step-by-step instructions for including the interpreter in your own application programs and for customizing it to suit your needs. The package provides windowing facilities, and is entirely compatible with Turbo C, so that programs written

For more information . . .

For more information on the AI software development tools discussed in this article, contact the following manufacturers directly, circle the appropriate numbers on the Information Retrieval Service card, or use EDN's Express Request service.

Arity Corp
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in either of the languages can call routines (or complete programs) that are written in the other language.

Smalltalk and Modula-2

Two other languages that are well suited to AI-related projects are Smalltalk and Modula-2, though at present these are less widely known and used than Lisp and Prolog. Both are object-oriented languages, and both allow you to construct independently compiled, reusable software modules. Smalltalk comes in two versions for IBM PCs: a full version of the original language (developed at the Xerox PARC research center), which comes from Softsmarts and costs $995; and a subset that comes from Digitalk Inc and costs $99. This subset is not a toy—all the basic features are present, and you can use it to develop commercially useful applications.

Many Modula-2 compilers are available for PCs (**Ref 2**). Typical compilers are Stony Brook Modula-2 ($345) and QuickMod ($95). Together they form an integrated compiler and interpreter package somewhat similar to Turbo Prolog. Both come from Stony Brook Software Inc.

The developers mentioned represent only a small portion of the entire market for AI-related products. More than 50 vendors now offer such products, most of which are expert-system shells and language-development tools. If neural networks live up to their promise, you can expect to see vendors applying them to improve automated manufacturing equipment and to fulfill part of the modern technological wish list—by permitting the development of such items as a voice-activated typewriter and a reliable language translator. Artificial intelligence may yet prove to be the dreamchild of the 50s that will come of age in the 90s. **EDN**

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1. Rich, Elaine, *Artificial Intelligence*, McGraw-Hill, New York, NY, 1981, pg 1.
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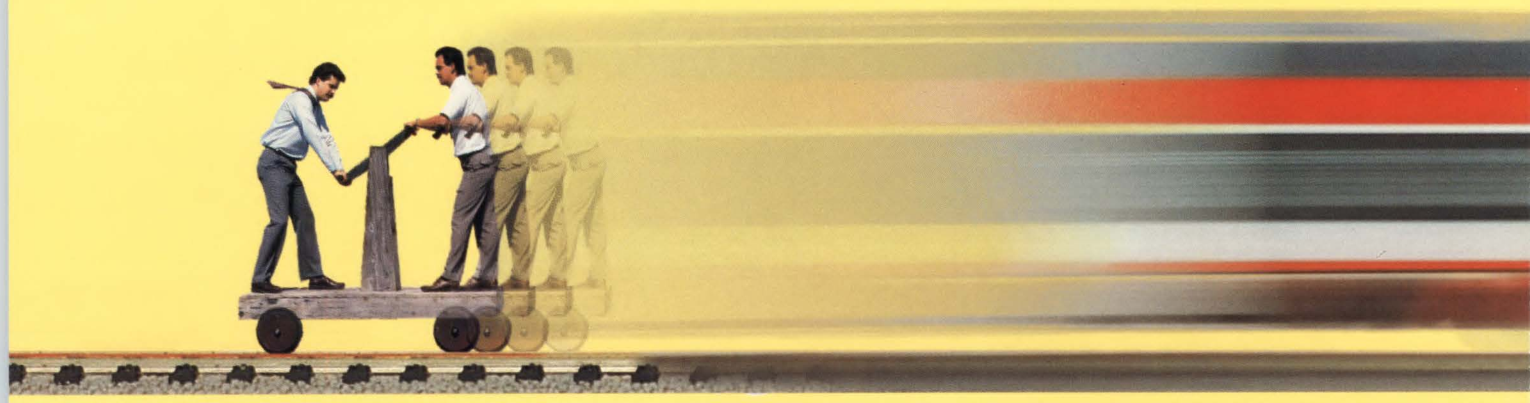

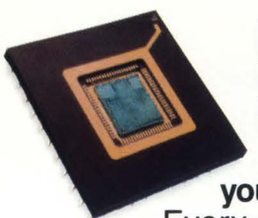

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10	15.0	400	0.4	0.10	0.10	20	0.10
8	12.0	320	0.5	0.12	0.12	16	0.12
5	7.5	200	0.8	0.20	0.20	10	0.20
1	1.5	40	4.0	1.00	1.00	2	1.00

*Instruction Rate Measured In Millions Of Instructions Per Second.

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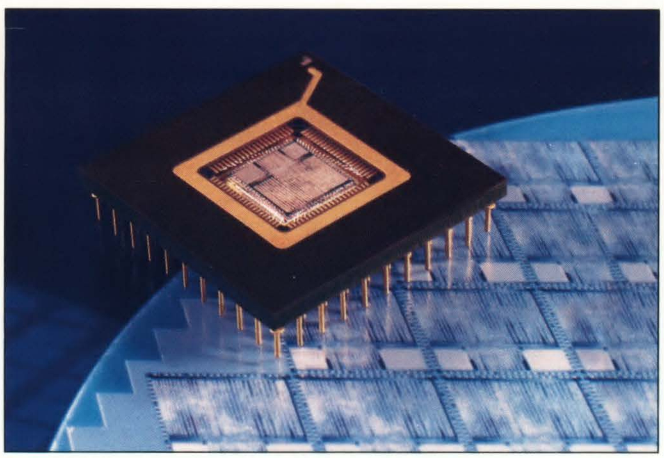

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Timer/Counters (on-chip)	3 ea. — 16 bit	3 ea. — 16 bit
Interrupt Controller (on-chip)	NMI and 13 Maskable (Expandable off-chip)	NMI and 13 Maskable (Expandable off-chip)
Memory (on-chip)	256 x 16 Parameter Stack 256 x 21 Return Stack	64 x 16 Parameter Stack 64 x 21 Return Stack
Wait State Controller (on-chip)	Yes	Yes
ASIC Bus™	16 bit	16 bit
16 x 16 Multiply	Single Cycle	20 Cycle
32/16 Divide	21 Cycle	21 Cycle
32/16 Square Root	25 Cycle	25 Cycle
Address Range	1 Mbyte	1 Mbyte
Data Bus	16 bit	16 bit
Byte Operations	Yes	Yes
Package	84 pins	84 pins
883C Compliant	1Q CY89	Not Planned
Semicustom Migration Path	Yes	Yes
Rad-Hard Migration Path	Yes	Not Planned
32 bit Migration Path	Yes	Yes
Development System	Yes	Yes
Forth Compiler	Now	Now
C Compiler	4Q CY88	4Q CY88
Prolog Compiler	1Q CY89	1Q CY89

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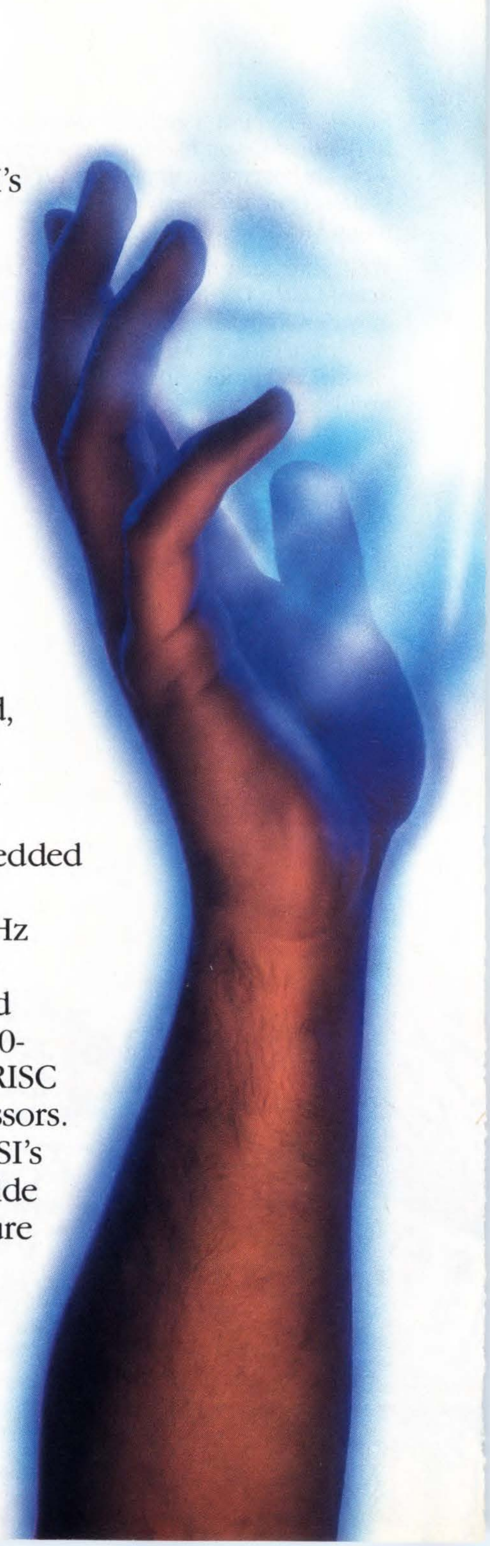

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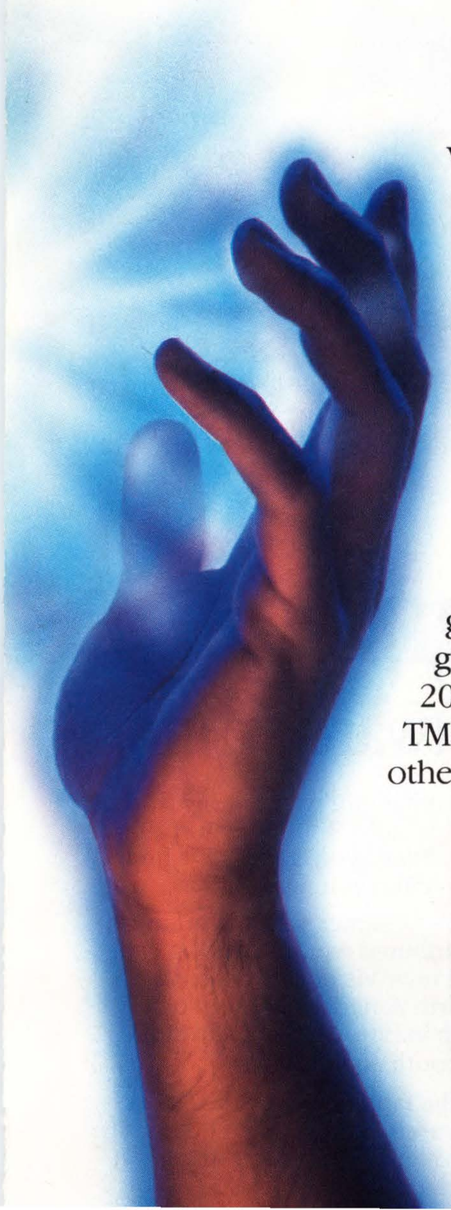

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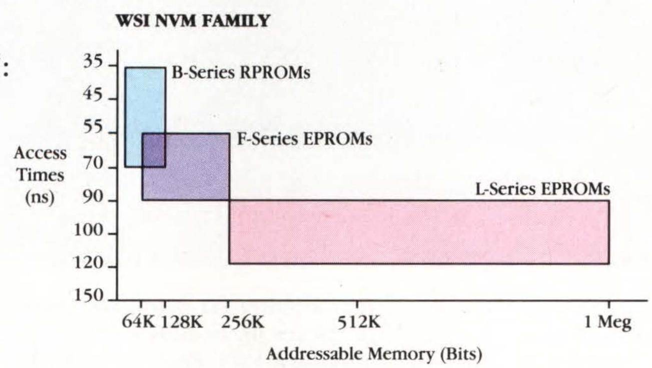

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WS57C65	55ns	70ns	4K x 16 CMOS EPROM
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WS57C49B	35ns	45ns	8K x 8 CMOS RPROM
WS57C43B	35ns	45ns	4K x 8 CMOS RPROM
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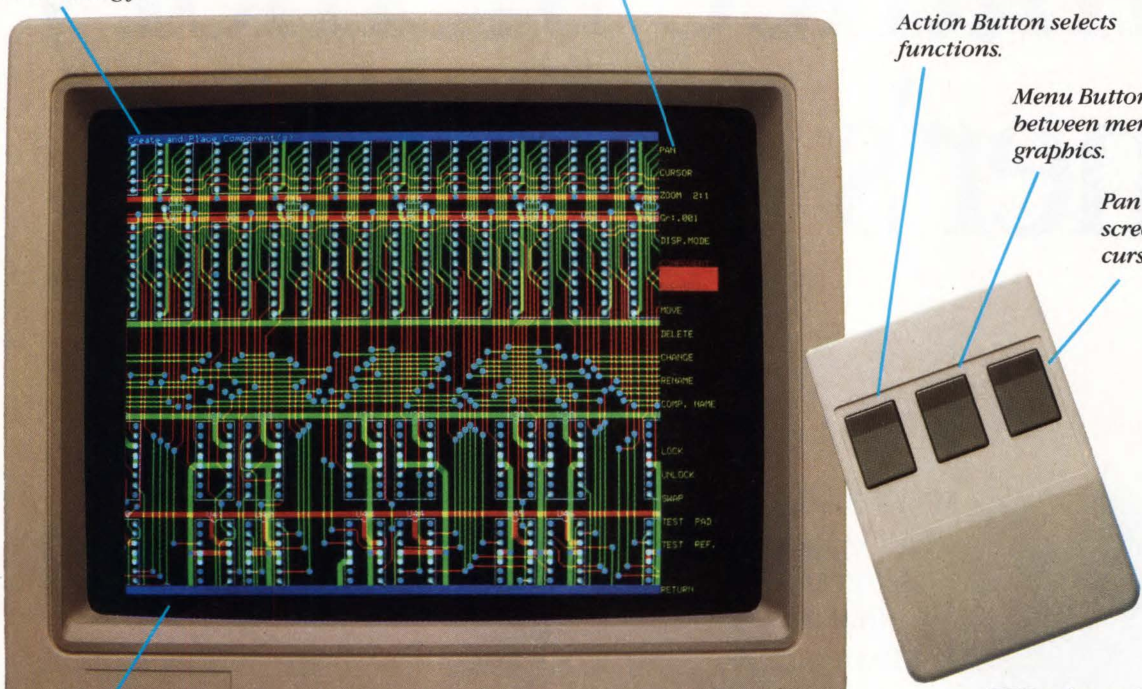

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Dynamic-RAM-controller ICs squeeze maximum performance from DRAMs

Steven H Leibson,
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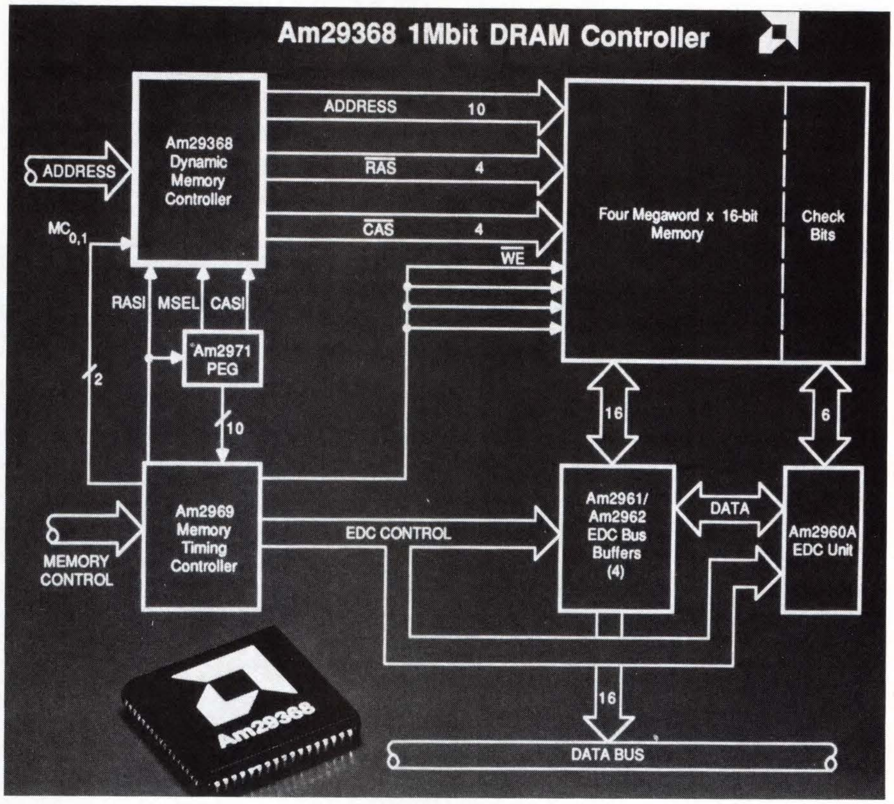

DRAM controllers that lack RAS/CAS- or refresh-timing *generators—such as AMD's Am29368 DRAM-controller IC—can give you more flexibility to meet unusual DRAM sequencing requirements, but at a cost—they need additional ICs to create the timing signals that generate the sequencing.*

Despite this year's acute parts shortage and the subsequent price increase, dynamic RAMs (DRAMs) still cost less than static RAMs (SRAMs) on a bit-by-bit basis, and they still take up less room on your pc board. However, DRAMs employ address-multiplexing and capacitive-storage techniques, which make them fussy about timing: The wrong timing signals can make them lose data, causing you thorny problems when you design DRAM controllers for memory subsystems.

For years, engineers have designed DRAM-controller circuits with general-purpose MSI components and delay lines. The current crop of DRAM-controller ICs, however, solves DRAMs' timing problems much more efficiently in terms of cost, pc-board space, and signal quality. In addition, many of the latest parts can help you take advantage of advanced DRAM features such as burst access. The cost of these controller ICs has dropped over the past few years, so they represent a more attractive alternative than ever to designing your own controller.

Critical timing requirements

When you use DRAMs in a system design, your controller circuitry must satisfy three critical timing requirements: RAS (row address strobe) and CAS (column address strobe) sequencing, refresh, and RAS precharge. DRAMs are also quite sensitive to signal undershoot. If your circuitry does not meet these DRAM timing and signal requirements, your system either will not work at all—if you're lucky—or will exhibit recurring, intermittent memory lapses. These failures are tough problems to troubleshoot, so you should take extraordinary measures to prevent them when designing a DRAM-based subsystem.

DRAM timing basics

The DRAM multiplexed-addressing sequence boils down to the same four steps for both read and write cycles. First, you present a row address, comprising half of the memory location's address bits, to the DRAMs' address inputs. Then you assert RAS, causing the DRAM to latch the row address. Next, you present the column address—the second half of the memory address—to the DRAM's address inputs. Finally, you assert CAS, causing the DRAM to latch the column address. The address lines' timing must meet an assortment of setup-and-hold-time specifications with respect to both RAS and CAS.

One way to classify DRAM-controller ICs is by the presence or absence of on-chip RAS/CAS timing. Both types of controller have been available for some time (a selection of both appears in **Table 1**). Controllers with on-chip timing include the Texas Instruments (TI) THCT4502B and SN74ACT4503 and the National Semiconductor DP8400 controller series. TI's controllers generate the RAS/address/CAS sequencing with synchronous, clocked circuits, and National Semiconductor's devices incorporate precise silicon delay lines. In addition, you can control the timing on the National Semiconductor parts with external circuitry.

Some DRAM controllers contain no timing circuits; they provide RAS, CAS, and multiplexer-control inputs that permit other circuitry to control the timing. One such device is the Am2968A from Advanced Micro Devices (AMD); it was one of the first DRAM-controller ICs to appear. Its RASI (RAS input), MSEL (multiplex select), and CASI (CAS input) pins accept timing signals from external circuitry.

Because of its early introduction, the Am2968A has become sufficiently popular to gain two alternate-source vendors: Motorola offers the MC74F2968A and Texas Instruments offers the SN74ALS2968 and a similar part, the SN74ALS2967; the latter has low-true RASI and CASI signals. These controllers have 9-bit, 2-to-1 address multiplexers, so they accommodate DRAMs having capacities as large as 256k bits. AMD and TI now offer the Am29368 and the SN74ALS6302, respectively. These two controllers closely resemble the original Am2968 design, but they have an extra bit in the address multiplexer, so they support 1M-bit DRAMs. If you prefer low-true RASI and CASI signals, you can choose TI's SN74ALS6301 controller, which fills that bill.

TABLE 1 — REPRESENTATIVE DRAM-CONTROLLER ICs

MANUFACTURER	PART NUMBER	LARGEST RAM TYPE SUPPORTED (BITS)	BANKS	ADDRESS LATCHES	RAS/CAS TIMING
ADVANCED MICRO DEVICES	Am2968A	256k	4	YES	EXTERNAL
	Am29368	1M	4	YES	EXTERNAL
	673102	256k	4	YES	INT/EXT
	673103	1M	4	YES	INT/EXT
	673104	1M	4	YES	INT/EXT
AT&T	WE 32103	1M	4	YES	INTERNAL
HITACHI	HD63487[2]	256k×4 STATIC COLUMN	1	NO	INTERNAL
INTEL	8207	256k	4	YES	INTERNAL
	82C08	256k	2	YES	INTERNAL
MOTOROLA	MC74F2968A	256k	4	YES	EXTERNAL
NATIONAL SEMICONDUCTOR	DP8409	256k	4	YES	INT/EXT
	DP8419	256k	4	YES	INT/EXT
	DP8420	256k	4	YES	INTERNAL
	DP8421	1M	4	YES	INTERNAL
	DP8422	4M	4	YES	INTERNAL
	DP8429	1M	4	YES	INT/EXT
NCR	52C40[2]	4M	4	YES	INTERNAL
SIGNETICS	74F764	256k	1	YES	INTERNAL
	74F765	256k	1	NO	INTERNAL
	74F1764	1M	1	YES	INTERNAL
	74F1765	1M	1	NO	INTERNAL
TEXAS INSTRUMENTS	SN74ACT4503	1M	4	YES	INTERNAL
	SN74ALS2967	256k	4	YES	EXTERNAL
	SN74ALS2968	256k	4	YES	EXTERNAL
	SN74ALS6301	1M	4	YES	EXTERNAL
	SN74ALS6302	1M	4	YES	EXTERNAL
	THCT4502B	256k	4	YES	INTERNAL
VLSI TECHNOLOGY	VL4500A	64k	2	YES	INTERNAL
	VL4502	256k	4	YES	INTERNAL
	VL86C110	1M	2	NO	INTERNAL

NOTES:
1. PRICING FOR INTEL AND AT&T PARTS IS FOR 10-MHz VERSIONS
2. SEE **BOX**, "SPECIALIZED DRAM CONTROLLERS"

One reason that DRAM controllers without on-chip RAS/CAS timing have remained popular is that they allow you to generate unconventional CAS sequencing. For memory-subsystem designs that employ special DRAM features such as page- or nibble-access modes, your controller circuitry must generate multiple CAS cycles for each RAS cycle. The DRAM controller must be able to change address lines while continuing to assert CAS for static-column mode access. Controllers without on-chip timing circuits give you a good compromise between function and density when you employ DRAM burst-access sequences. Most DRAM controllers with internal timing generators do not support such burst-access sequences, so if you use the controller in such a design, you must circumvent the internal generators.

Special parts for burst access

When used in conjunction with a burst-access DRAM-controller design, TI's SN74ALS6310 and SN74ALS6311 ICs help you take advantage of DRAMs' static-column or page-mode access features. The parts employ 14-bit address comparators to determine whether the current access cycle has the same DRAM row address as the preceding cycle. This detection function allows external circuitry to postpone the termination of the preceding RAS cycle and the initiation of an additional CAS cycle, if necessary. Each device costs $7.20 (1000).

You can create timing signals for DRAM controllers by using a counter IC and some decoding logic, a

ON-CHIP REFRESH SUPPORT	PRICE[1]	SPECIAL DEVICE FEATURES
COUNTERS	$19 (100)	EXTERNAL CAS TIMING SUPPORTS NIBBLE-MODE ACCESS
COUNTERS	$30 (100)	EXTERNAL CAS TIMING SUPPORTS NIBBLE-MODE ACCESS
COUNTERS	$19 (100)	TWO CAS OUTPUTS FOR BYTE ENABLES IN 16-BIT SYSTEMS
COUNTERS	$29 (100)	TWO CAS OUTPUTS FOR BYTE ENABLES IN 16-BIT SYSTEMS
COUNTERS	$36 (100)	FOUR CAS OUTPUTS FOR BYTE ENABLES IN 32-BIT SYSTEMS
CONTROLLER	$50 (1000)	DUAL-PORT ARBITER, SUPPORTS OVERLAP OF MEMORY ACCESS AND MMU TRANSLATION
CAS BEFORE RAS	$25 (5000)	MEMORY-INTERFACE CHIP FOR COMPANY'S HD63484 ADVANCED CRT CONTROLLER
CONTROLLER	$28.60 (1000)	CONTROLS COMPANION ERROR-CORRECTION CHIP AND PROVIDES MEMORY SCRUBBING
CONTROLLER	$13.20 (1000)	POWER-DOWN MODE KEEPS DRAMS REFRESHED
COUNTERS	$17.55 (100)	EXTERNAL CAS TIMING SUPPORTS NIBBLE-MODE ACCESS
CONTROLLER	$6 (1000)	INTERNAL OR EXTERNAL REFRESH CONTROL, REQUIRES EXTERNAL REFRESH CLOCK
CONTROLLER	$11 (1000)	INTERNAL OR EXTERNAL REFRESH CONTROL, REQUIRES EXTERNAL REFRESH CLOCK
CONTROLLER	$12 (1000)	WAIT-STATE GENERATOR; MEMORY INTERLEAVING; SUPPORTS NIBBLE, PAGE, AND STATIC-COLUMN ACCESS
CONTROLLER	$15 (1000)	WAIT-STATE GENERATOR; MEMORY INTERLEAVING; SUPPORTS NIBBLE, PAGE, AND STATIC-COLUMN ACCESS
CONTROLLER	$20 (1000)	DUAL-PORT; WAIT-STATE GENERATOR; MEMORY INTERLEAVING; SUPPORTS NIBBLE, PAGE, AND STATIC-COLUMN ACCESS
CONTROLLER	$15 (1000)	INTERNAL OR EXTERNAL REFRESH CONTROL, REQUIRES EXTERNAL REFRESH CLOCK
CONTROLLER	$23.73 (1000)	DUAL-PORT I/O BUFFER CONTROLLER; ADDRESS AND LENGTH COUNTERS ON BOTH PORTS
CONTROLLER	$9 (1000)	DUAL-PORTED; SUPPORTS EXTERNAL MULTIPLEXING FOR DRAMS LARGER THAN 256k
CONTROLLER	$9 (1000)	DUAL-PORTED; SUPPORTS EXTERNAL MULTIPLEXING FOR DRAMS LARGER THAN 256k
CONTROLLER	$11 (1000)	DUAL-PORTED; SUPPORTS EXTERNAL MULTIPLEXING FOR DRAMS LARGER THAN 1M
CONTROLLER	$11 (1000)	DUAL-PORTED; SUPPORTS EXTERNAL MULTIPLEXING FOR DRAMS LARGER THAN 1M
CONTROLLER	$15.60 (1000)	INTERNAL OR EXTERNAL REFRESH INITIATION
COUNTERS	$11.40 (1000)	EXTERNAL CAS TIMING SUPPORTS NIBBLE-MODE ACCESS
COUNTERS	$11.40 (1000)	EXTERNAL CAS TIMING SUPPORTS NIBBLE-MODE ACCESS
COUNTERS	$21.60 (1000)	EXTERNAL CAS TIMING SUPPORTS NIBBLE-MODE ACCESS
COUNTERS	$21.60 (1000)	EXTERNAL CAS TIMING SUPPORTS NIBBLE-MODE ACCESS
CONTROLLER	$8.40 (1000)	ON-CHIP ARBITRATION BETWEEN READ/WRITE ACCESS AND REFRESH
CONTROLLER	$4.95 (10,000)	INTERNAL OR EXTERNAL REFRESH INITIATION
CONTROLLER	$7.84 (10,000)	ON-CHIP ARBITRATION BETWEEN READ/WRITE ACCESS AND REFRESH
CONTROLLER	$14.12 (10,000)	ON-CHIP MMU, 3-CHANNEL DMA CONTROLLER, PAGE-MODE ACCESS LOGIC

delay line, or a timing-generator PLD. Counters cost very little, but the combination of a counter and decoding circuits may not be able to create the precise timing resolution you seek. Delay lines provide very precise timing signals with a resolution of a few nanoseconds, and they operate asynchronously, which is advantageous for many designs. Delay lines are often expensive, however.

PLDs give you a lot of flexibility to create complex timing sequences. An example of such a PLD is AMD's \$14.75 (100) Am2971A programmable event generator (PEG), an improved version of the company's Am2971, which runs at 100 MHz and can switch any of its 12 outputs at 10-nsec intervals. (The original Am2971 runs at 70 MHz and can only switch output states every other clock cycle.) The Am2971A has an on-chip phase-locked loop, so it can run at a frequency that's a multiple of your system's clock frequency. AMD offers a \$200 adapter and software kit, AmPegasus, that allows you to program the Am2971 and Am2971A on a Data I/O (Redmond, WA) Model 29 programmer.

Don't forget the refresh

Once you have a memory subsystem's RAS/CAS timing worked out, you must accommodate the DRAMs' need for refresh cycles. Because DRAMs store data as charge on capacitors, each DRAM memory cell must be refreshed periodically. The traditional refresh technique involves a RAS-only cycle, although some DRAMs implement additional schemes. Every RAS address must be exercised within a refresh-time interval specified by the DRAM manufacturer. Failure to refresh the DRAMs allows the stored charge to bleed off the capacitors and produces memory lapses.

Most DRAM controllers incorporate some sort of refresh-support circuitry, because the function is crucial to proper DRAM operation. Simpler DRAM controllers have a counter that maintains the value of the next row address to be refreshed. You must add a refresh timer to help these parts generate refresh cycles. Here again, you can use a counter IC or a PLD to generate the necessary timing. Or you can use a device designed specifically for that purpose, such as TI's SN74ALS6300 refresh timer, which costs \$7.20 (1000).

More advanced DRAM controllers incorporate complete refresh-control circuitry that generates refresh cycles at appropriate intervals and arbitrates among memory-access requests from other system components (the μP, the DMA controller, etc) and the on-chip refresh timer. On-chip arbitration lets you avoid adding extra circuitry to the memory subsystem's critical timing path and can reduce the time needed to arbitrate between access and refresh cycles.

For example, National Semiconductor's DP8422, which incorporates both a refresh controller and a refresh arbiter, has an address-strobe-to-CAS delay of 79 nsec. That delay represents the device's critical timing path. The company's DP8429 controller, which does not incorporate a refresh arbiter, has a critical-path RASIN-to-CAS delay of 70 nsec.

Although the DP8429 initially appears to be faster than the DP8422, it's actually not. To make the DP8429 perform memory accesses as quickly as the DP8422, you must make sure that the refresh-arbitration circuitry you place between the DP8429 and your μP adds no more than 9 nsec of delay to that critical path. Some lower-performance-system designs use the host μP or a DMA controller to refresh the DRAMs, so they don't need circuitry to arbitrate between access and refresh cycles and they don't require a DRAM controller with a refresh arbiter.

A rest stop for tired DRAMs

Once you've satisfied both the RAS/CAS and the refresh timing, you may also need to ensure that the DRAMs' RAS-precharge requirements are met. The RAS-precharge period allows the DRAMs to rest

Special DRAM controllers suit niche applications

Although most DRAM controllers fall into the general-purpose category, a few companies now offer specialized devices for niche applications. These controllers allow DRAMs to work in designs that previously employed static RAMs (SRAMS). For example, Hitachi's HD63487 Memory Interface and Video Attribute Controller (MIVAC) joins the company's HD63484 advanced CRT controller to as many as four 256k×4-bit static-column DRAMs. Thus, five ICs can replace as much as 0.5M bytes of SRAM.

NCR's 52C40 CMOS Memory Array Controller (CMAC) targets I/O applications that require high-speed, dual-ported buffer memories. The CMAC addresses as many as 16M words of DRAM and supports data-transfer rates to 3M words/sec. Each of the device's two ports incorporates an address register and a transfer-length counter so that address generation can occur entirely on the chip during transfers, without intervention by the host μP. Because the buffer-memory data path does not flow through the CMAC, you can implement any word width your application requires.

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MT5C2564	64K X 4	**25ns**	PDIP, CDIP, SOJ, LCC
MT5C2565	64K X 4 $\overline{OE}$	**25ns**	PDIP, CDIP, SOJ, LCC
MT5C2568	32K X 8	**25ns**	PDIP, CDIP, SOJ, LCC
MT5C6401	64K X 1	**15ns**	PDIP, CDIP, SOJ
MT5C6404	16K X 4	**15ns**	PDIP, CDIP, SOJ
MT5C6405	16K X 4 $\overline{OE}$	**15ns**	PDIP, CDIP, SOJ
MT5C6406/7	16K X 4 S. I/O	**15ns**	PDIP, CDIP, SOJ
MT5C6408	8K X 8	**15ns**	PDIP, CDIP, SOJ, LCC
MT5C1601	16K X 1	**15ns**	PDIP, CDIP, SOJ
MT5C1604	4K X 4	**15ns**	PDIP, CDIP, SOJ
MT5C1605	4K X 4 $\overline{OE}$	**15ns**	PDIP, CDIP, SOJ
MT5C1606/7	4K X 4 S. I/O	**15ns**	PDIP, CDIP, SOJ
MT5C1608	2K X 8	**15ns**	PDIP, CDIP, SOJ

*Slower speeds also available.

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CIRCLE NO 74

between access cycles. During RAS precharge, a DRAM recovers from a previous cycle by charging internal nodes to appropriate reference-voltage levels, in preparation for the next cycle. DRAMs require RAS-precharge periods between successive access cycles, following an access and just before a refresh cycle, and just before an access cycle that immediately follows a refresh cycle.

If you fail to comply with a DRAM's RAS-precharge requirements, you invite memory failures. Many μPs normally allow ample time between access cycles for RAS precharge, but adding refresh cycles and DMA accesses to the cycle mix can complicate system timings and create RAS-precharge period violations. Multiprocessor-based designs can also encounter RAS-precharge problems.

A DRAM controller that incorporates a RAS-precharge timer and a refresh controller helps you avoid RAS-precharge problems. National Semiconductor's DP8420, DP8421, and DP8422, for example, contain a programmable timer that enforces a delay of 1 to 3 clock cycles between accesses. However, you can add circuitry to less-complex controllers to serve the same purpose. In simpler systems that lack DMA controllers and do not employ multiple processors, you may find that you don't need RAS-precharge timing circuitry, because the system's design inherently precludes such problems.

Two ports may be better than one

Shared-memory, multiprocessor systems place additional burdens on the memory-subsystem designer beyond the need to avoid RAS-precharge violations. Besides the refresh-cycle arbitration circuitry, you need circuitry to arbitrate among multiple access requests. For synchronous systems, arbitration generally doesn't present too much of a problem, but asynchronous arbitration logic introduces one of the worst problems a logic designer can face: metastability.

The data sheets, application notes, and devices *packaged in the $149 Memory Management Design Kit from Texas Instruments constitute a complete memory-subsystem design package. The kit also includes floppy disks containing graphic-symbol libraries from Logic Automation (Beaverton, OR) and FutureNet (Chatsworth, CA); the libraries support the automated design of memory subsystems that use parts from the kit.*

When an arbitration flip-flop enters a metastable state because of setup-and-hold violations, its outputs assume an indeterminate value. In practice, that means that either no requesting processor will be granted access to the memory subsystem, or more than one processor will be granted simultaneous access. Either case generally results in a catastrophic system crash. Asynchronous, multiport arbiters constructed from MSI components are riddled with metastability problems.

Some DRAM-controller vendors offer dual-ported parts and attack the metastability problem in a variety of ways. National Semiconductor's DP8422 contains synchronous dual-port arbitration circuitry. Your design must meet the part's setup-and-hold requirements. For systems in which the various requesters all run on synchronized clocks, this approach is the simplest solution.

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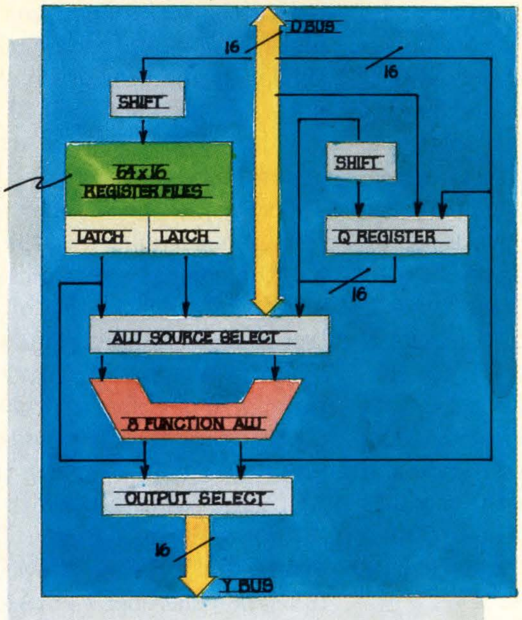

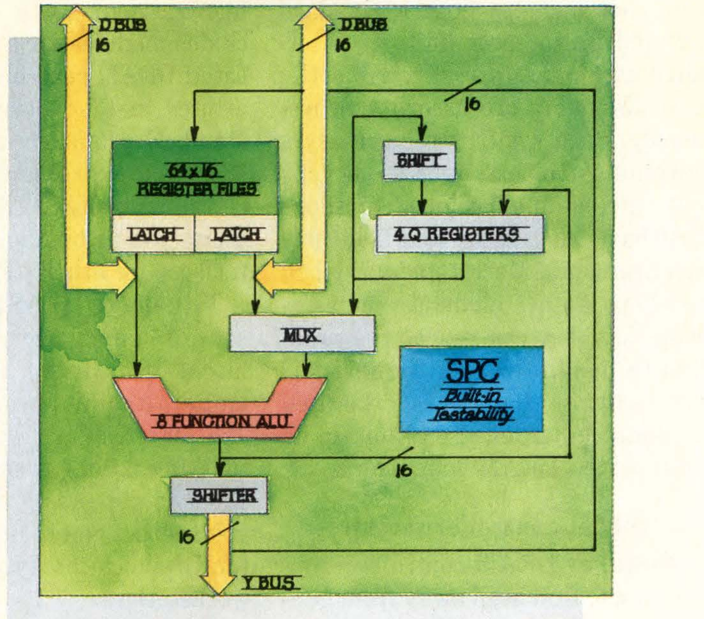

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However, not all multiprocessor systems have the luxury of synchronous operation. For example, a system that includes both a standard μP and a processor built from bit-slice components rarely runs the two dissimilar processors synchronously. Such systems require asynchronous arbiters built from very fast, metastable-hardened flip-flops that have small setup-and-hold-time requirements. Metastable-hardened flip-flops do not eliminate metastability but they can reduce the problem to insignificance. Signetics is one company that has incorporated metastable-hardened flip-flops in its dual-ported DRAM controllers.

The DRAM-controller toolkit

Multiport DRAM controllers represent the first step away from general-purpose parts. If you think your design might benefit from an even more tailored device, consider using TI's DRAM-controller ASIC toolkit, which lets you employ the company's 1-μm ASIC process to build custom controllers with as many as four ports. The toolkit includes modules for a fairly sophisticated DRAM controller, for a 4-port arbiter, and for several interfaces to standard μPs such as the Motorola 68020 and 68030 and Intel's 80186, 80286, and 80386. The company can assist you in building processor interfaces for other μPs as well.

TI defines an ASIC toolkit as a set of supermacros (functional blocks or modules). Its DRAM-controller toolkit works with its TSC500 standard-cell library. The toolkit costs between $10,000 and $20,000, depending on the modules you license, and it runs on the Mentor Graphics family of engineering workstations.

The toolkit's DRAM controller contains several programmable or selectable functions, including RAS/CAS timing, latch-and-go circuitry that allows the host μP to initiate a write to memory and then immediately proceed to the next bus cycle before the write operation is complete, a row-detection comparator similar to that provided by the company's SN74ALS6310 and SN74ALS6311, and a wait-state generator.

Because of the number of different options available to the controller, the company recommends that you make at least some of the controller's programming signals accessible to external circuitry, either through input pins or via a set of control registers. By adding such programmability, you can create an ASIC that you can incorporate in several different designs. This programmability also allows you to tune the controller's DRAM timing sequences once the ASIC is installed on a pc board. The ability to perform such fine-tuning can be critical when you need to squeeze every

Careful layout optimizes memory performance

The main enemy of precise DRAM timing control is capacitance contained in the pc-board traces and in DRAM address-line inputs. Large capacitive loads slow DRAM-controller performance, a factor you must take into account when calculating the overall performance your memory subsystem will deliver. The amount of capacitance your memory subsystem presents to the controller depends on the number and type of DRAMs you use and on the pc-board layout.

Further, if you add external buffers to help the DRAM controller drive high capacitances, you'll have to account for the buffer delays in your timing calculations. If the controller you select does not have a sufficient number of RAS outputs to drive the DRAM banks your application requires, you'll have to add external multiplexing circuitry. You may also need to add external multiplexers to the DRAM controller's CAS outputs for 16-bit-word, 32-bit-word, and wider memory subsystems that must also support byte-wide transfers. Most DRAM controllers lack multiple CAS drivers. Some other devices that do have more than one CAS output can't use these CAS drivers to perform byte-mode accesses. Multiplexers introduce additional delay.

Because it's very tough to accurately predict and model these buffer delays, multiplexer delays, and pc-board capacitances before fabricating a pc board and building a prototype memory subsystem, you should design flexibility into the address-sequence timing for a DRAM array. No amount of CAE modeling is going to allow you to build an optimized circuit from the loose characterizations of MSI components and modeled pc-board-trace characteristics. If you use a DRAM controller with internal timing, you'll want to make sure the part allows you to tweak sequence timing. If you use external circuitry for sequencing control, be sure to build some timing leeway into that circuitry.

Line reflections also hamper your ability to accurately model the performance of a memory subsystem. The long traces generally used to wire large DRAM arrays are transmission lines. You must either terminate these lines to prevent reflections or take reflections into account.

If your design employs proper terminations and output buffers capable of driving the line's characteristic impedance, you'll observe incident-wave unnecessary nanosecond out of the memory's access time.

One module this DRAM controller toolkit does not include is a set of DRAM output drivers. All of the DRAM controllers listed in **Table 1** can drive the high-capacitance loads of large DRAM arrays, but TI's 1-μm process can't build such husky output circuits. If you use this toolkit to design an ASIC DRAM controller, you should plan to add external buffers to your final circuit. Buffers add additional delay to the DRAM control-signal timing, so access to the controller's programmable timing features will be even more important.

The toolkit's four arbiter ports employ double-latch synchronizers to handle asynchronous access requests. The latches in the synchronizer operate from opposite edges of the controller's 50-MHz clock. TI claims it has thoroughly characterized the metastable characteristics of flip-flops built with its 1-μm process and verified that flip-flops entering a metastable state at one edge of the clock will recover in less than 10 nsec—before the next clock edge. Thus, the second synchronizer latch prevents any metastability that might occur in the first latch from confusing the arbiter. This synchronization technique adds a clock delay of between 0.5 and 1 (less than 20 nsec) to a memory subsystem's access time.

Controllers tailored to a μP

You may not need to resort to an ASIC in order to obtain a specialized DRAM controller. VLSI Technology and AT&T manufacture controllers specifically adapted to μPs from those companies. Both companies' parts illustrate ways in which you can closely integrate DRAM-controller functions in a system.

AT&T's WE 32103 DRAM controller is a companion part for the company's WE 32100 32-bit μP. Because the controller is intimately mated to the processor, it can boost the memory subsystem's performance beyond the level you might achieve with a general-purpose part. For example, the controller initiates memory cycles early in the processor's bus cycle by emitting an appropriate row address and asserting RAS, but it delays CAS until its chip-select input is asserted. In the event that the current bus cycle is not directed at the DRAM array, the controller terminates the memory cycle without asserting CAS, transforming the operation into an extra refresh cycle.

Likewise, by using low-order, untranslated address bits for the row address, the controller can initiate a memory cycle before the processor's memory-management unit (MMU) translates a logical address to a physical address. This feature allows the controller to overlap MMU

switching in your circuit—in other words, the voltage at the DRAM's input will reach proper logic levels when the incident wave reaches that pin.

However, if your signal lines are unterminated and the output buffers in your design can't drive the line's characteristic impedance, or if you employ a series line termination (limiting the output buffer's drive current), you'll observe reflected-wave switching: The voltage at the DRAM's input will move halfway towards the buffer's output voltage when the incident wave passes it and will match the driver's output voltage after the wave is reflected at the far (unterminated) end of the line. Thus, reflected-wave switching takes somewhat longer than incident-wave switching because signals must propagate over longer paths before switching occurs.

Signetics' DRAM controllers give you a choice between incident-wave switching and reflected switching. The company's 74F764, 74F765, 74F1764, and 74F1765 controllers all incorporate unterminated output drivers, which provide incident-wave switching at the expense of allowing undershoot. Significant voltage undershoot can wreck DRAM performance, but you can add line terminations to reduce this problem. The company also offers these same four devices with internal terminations at the same price as the unterminated parts. These parts (designated by a -1 suffix on the part number) provide reflected-wave switching and reduce undershoot. Signetics claims that arrays driven by its reflected-wave parts generally need no further termination.

You must also be very careful to provide good grounding and power-supply paths to the DRAM controller, because large DRAM arrays exhibit highly capacitive loads. At times—such as during a refresh cycle—the DRAM controller may try to change the logic levels on all of the address lines in the entire memory array simultaneously. During such events, the current flowing through the DRAM controller's power and ground pins will peak as charge stored in those address lines is dumped. If you don't provide low-impedance paths and adequate bypass capacitance to the ground and power pins, the logic levels inside the chip will shift as the ground rises and V_{CC} droops, causing the controller to behave unpredictably.

and memory-subsystem operation, further improving system performance. The DRAM controller can perform burst-access cycles, which also enhance system performance, on page- and nibble-mode DRAMs for WE 32100 double- and quadruple-word data transfers.

Similarly, VLSI Technology's VL86C110's memory controller is closely coupled to the company's VL86C010 32-bit RISC (reduced instruction set computer) μP. Acorn Computers Ltd (Cambridge, UK) developed the controller as part of a chip set for a series of low-cost, 32-bit workstations, but VLSI Technology markets the part to other companies as well.

The VL86C110 incorporates several functions not generally found in general-purpose DRAM controllers. For example, the device contains a 3-channel DMA controller, which was originally included in the IC's design to support video, sound, and cursor operations in Acorn's workstations. The DRAM controller translates the RISC μP's ability to signal the occurrence of sequential memory accesses into multiple-CAS access cycles for page-mode DRAMs. The controller also incorporates an MMU that's tailored to the Acorn workstation's memory map and ROM interface circuitry; the MMU accommodates ROMs with access speeds as slow as 450 nsec. Consequently, the VL86C010 contains a clock generator that drives the RISC μP and allows the controller to stretch the clocks during accesses to slow ROMs.

The diversity and price range of the DRAM controllers listed in **Table 1** demonstrate that no single component can possibly meet the needs of every application. Fortunately, this diversity works to your advantage. If you carefully list your application's needs and prioritize the features you'd like, you'll undoubtedly find a controller that meets your requirements. **EDN**

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Article Interest Quotient
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For more information . . .

For more information on the DRAM-controller ICs mentioned in this article, contact the following manufacturers directly, circle the appropriate numbers on the Information Retrieval Service card, or use EDN's Express Request service.

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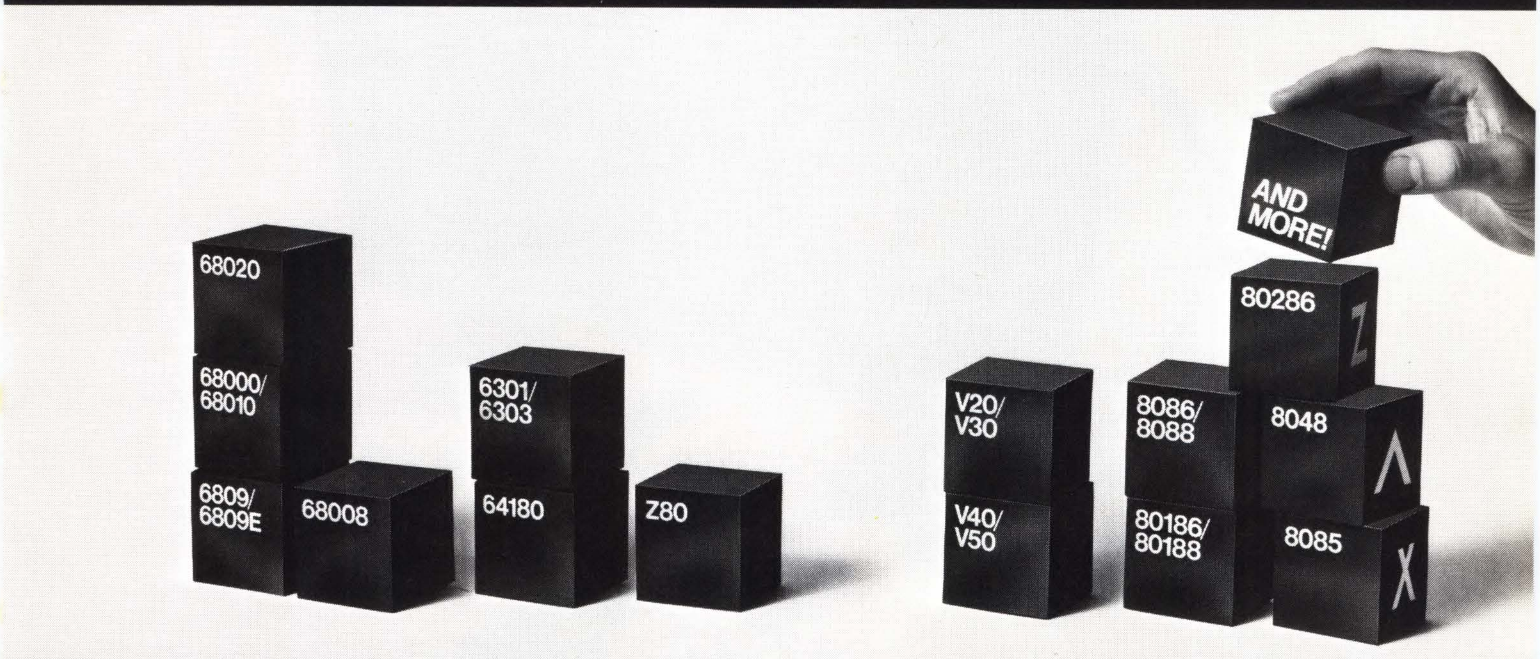

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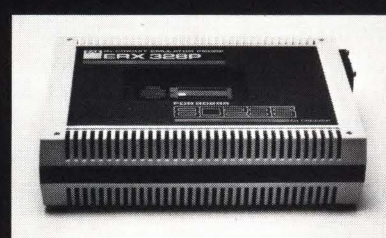

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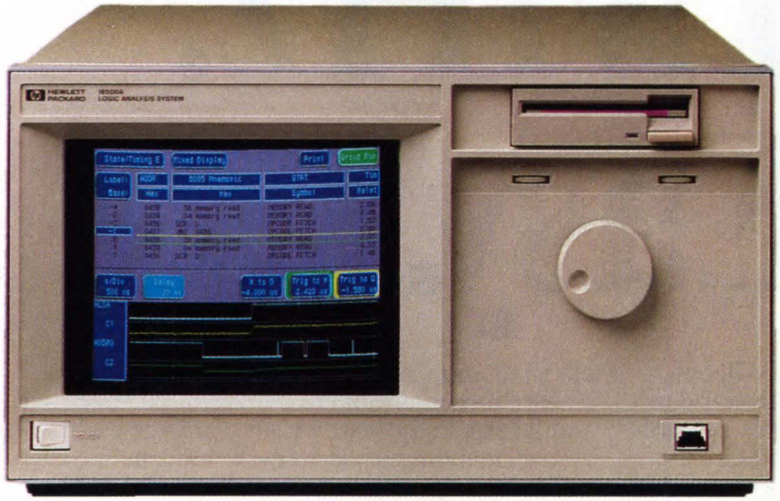

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Communications and development package links real-time environment to Unix

Combining communications and software development, the Unibridge package links Unix host systems to OS-9-based real-time target systems. The package allows the systems to communicate via the Ethernet LAN protocol and the TCP/IP (Transmission Control Protocol/Internet Protocol). You can use the Unibridge package to develop software on a Unix host, then download OS-9-compatible code to the real-time target.

The software package includes a C-language cross-compiler for the Unix host, communications software for the Unix host and OS-9 target, and a C compiler and a debug package for the OS-9 target. The C cross-compiler outputs executable OS-9 memory modules. After downloading the modules via the network, you can debug the code at the source or symbolic level with the OS-9-based debugger.

In addition, the implementation of the TCP/IP allows the user to access the entire OS-9 operating system from the Unix host. The software supports remote log-in with the Telnet TCP/IP terminal-emulation application; it also supports file transfers with the TCP/IP file-transfer-program application, thus allowing you to perform debug operations from the Unix host.

After debug, you can deploy the OS-9-based target as a stand-alone system, or you can employ the target as a real-time front end to a Unix-based supervisor system. The downloaded code can access all of the shareable system modules in OS-9 such as a library of I/O and mathmatical routines. In diskless applications, the entire OS-9 operating system, and the C compiler and debugger can be stored in ROM.

The company presently offers the Unibridge package for Sun workstations, Hewlett-Packard Series 300 workstations, and DEC VAX systems. Unibridge for the VAX works with the VMS operating system as well as with DEC's version of Unix. The package costs $6500.

—Maury Wright

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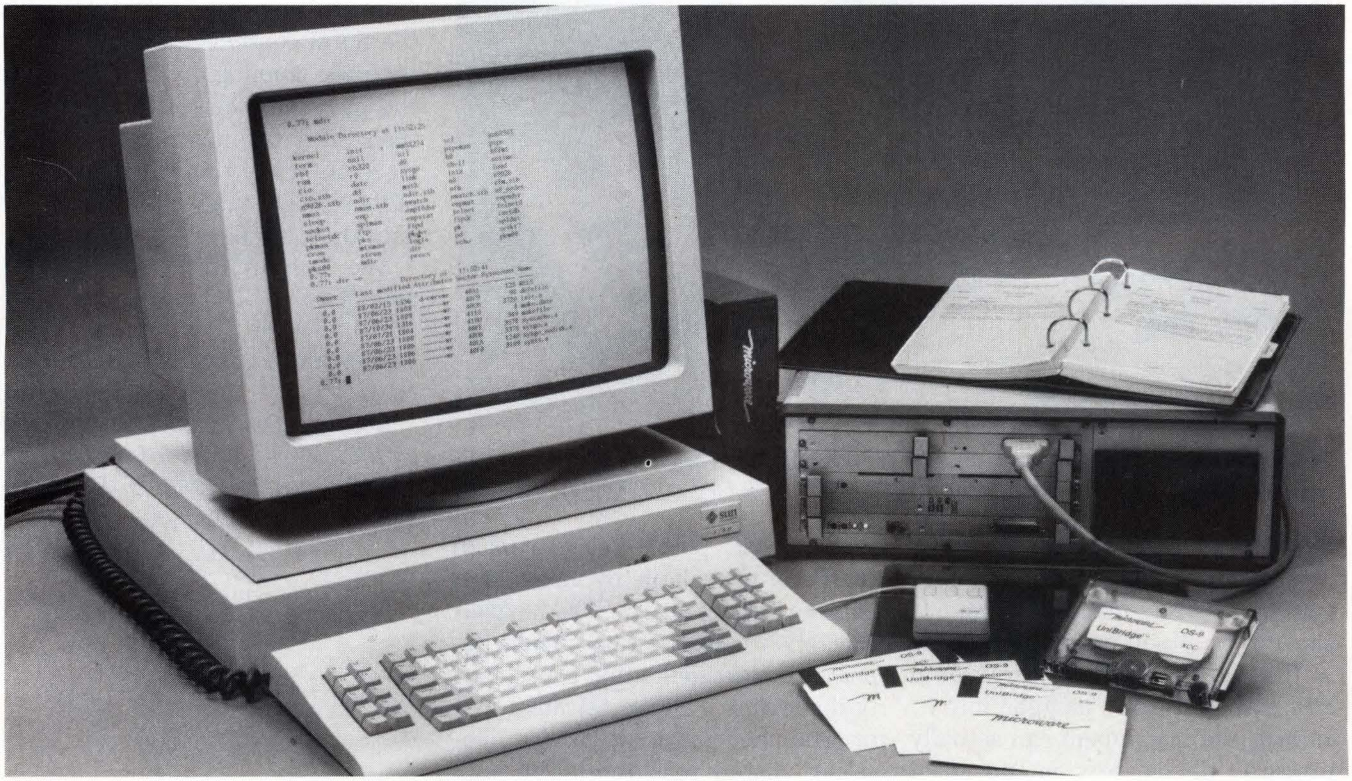
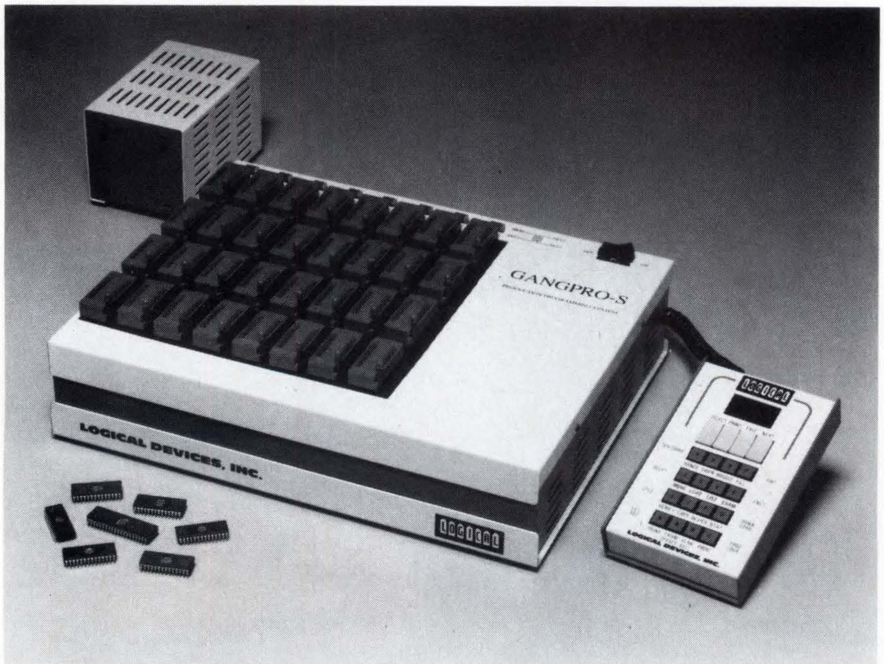


Unix systems can host real-time software development efforts *with the Unibridge software package. The software links target systems based on the OS-9 real-time operating system to Unix-based hosts via Ethernet and TCP/IP.*

Unit gang-programs bipolar and MOS PLDs and upgrades to handle EPROMs and μPs

It's been less than a year since the first programmer appeared that could gang-program MOS PLDs—that is, write the same information into more than one IC at a time. Till now, no widely available programmer could gang-program ECL and other bipolar PLDs. The Gangpro-SP changes that situation. It can gang-program both MOS and bipolar PLDs in 20- and 24-pin DIPs, and you can order it in special con-



This stand-alone programmer *can program 32 EPROMs. When configured to program 20- and 24-pin PLDs (and optionally, EPROMs and μPs,) it has eight programming stations.*

figurations that handle plastic leaded-chip carriers and pin-grid packages with as many as 68 pins. It can do PLD set programming as well—that is, write *different* data into each of the ICs plugged into it. In fact, the instrument can actually program device sets composed of several types of ICs, though when operating in this mode it isn't as fast as it is when programming devices of a single type.

Clearly, the designers of the Gangpro-SP had production applications in mind; the unit is a standalone programmer with 512k bits of program RAM expandable to 4M bits—enough to hold eight JEDEC files. You can operate the programmer with a small handheld keypad included in the base price (or you can connect an ASCII terminal to the RS-232C port). You can make the RAM nonvolatile by installing a battery backup option. The keypad-controlled configuration should appeal to departments that can't justify dedicating a PC or terminal to a programmer and have trouble allocating shared resources. The only time you need to connect a PC is when you update the library of programming algorithms stored in EEPROMs inside the unit; the vendor distributes library updates on PC-formatted disks.

You can upgrade the unit to gang-program EPROMs and some single-chip microprocessors, as well as PLDs. (The configuration that handles 20- and 24-pin DIP PLDs can program eight EPROMs at once; a version that handles *only* EPROMs can program 32 devices simultaneously.) The EPROM/μP programming capability gives the instrument broad enough device coverage to make it the only production programmer in many companies. Another feature that should make the programmer popular in production is its internal clock/calendar. It can store the times at which you modify the RAM contents; a label-printing program running on a PC linked to the programmer's serial port can then print out labels that you can place on newly programmed ICs to indicate the exact version of the data they embody.

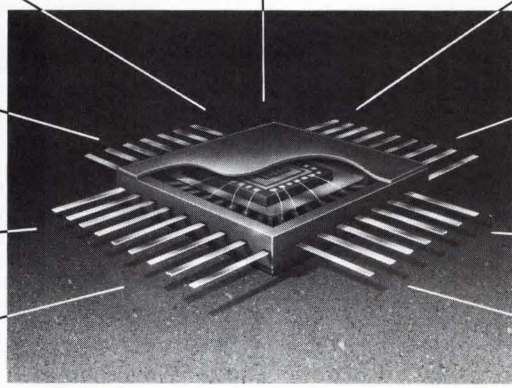
The Gangpro-SP8 (with eight 20- and 24-pin PLD programming stations) sells for $7995. The EPROM-μP upgrade costs $600/station.

—Dan Strassberg

Logical Devices Inc, 1201 NW 65th Pl, Fort Lauderdale, FL 33309. Phone (800) 331-7766; in FL, (305) 974-0975. TLX 383142.

Circle No 703

SONY'S ECL LOGIC HAS THE GUTS TO CHALLENGE GaAs PERFORMANCE.



When you need high-speed logic, it really pays to look into Sony's ECL logic family.

Because like GaAs technology, you'll find incredibly fast process speeds. Up to 4 GHz.

But unlike GaAs technology,

you'll also find amazingly low costs and design simplicity.

Not to mention that our ECL technology, unlike most, requires very low power. Under 1 watt, in many cases.

Sony's ECL logic family is made possible by our unique 1-micron, 10-GHz, FT process. The very process that's made our high-speed, 8-bit, 300 MSPS, A/D converters so popular.

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SONY'S HIGH-SPEED ECL LOGIC FAMILY

Part Number	Function	tpd	fmax	Power	Package
CXB1100Q	Quad 3-in OR/NOR	390 ps	1.5 GHz	530 mW	24 FLAT
CXB1101Q	Quad 3-in AND/NAND	470 ps	1.5 GHz	700 mW	24 FLAT
CXB1102Q	Quad 2-in EXOR/NOR	490 ps	1.5 GHz	680 mW	24 FLAT
CXB1103Q	Quint Line Receiver	410 ps	1.5 GHz	650 mW	24 FLAT
CXB1104Q	Dual D Flip Flop	620 ps	3.2 GHz	520 mW	24 FLAT
CXB1105Q	Triple Fan-out Buffer	590 ps	1.5 GHz	720 mW	24 FLAT
CXB1106Q	4-Stage Ripple Counter		3.4 GHz	720 mW	24 FLAT
CXB1107Q	Decision Circuit		3.2 GHz	430 mW	24 FLAT
CXB1108Q	Laser Driver		2.0 GHz	740 mW	16 FLAT
CXB1109Q	Quad D-FF with Master Reset	620 ps	3.4 GHz	790 mW	24 FLAT
CXB1110Q	16 to 1 Multiplexer	610 ps	1.5 GHz	680 mW	24 FLAT
CXB1111Q	Look Ahead Carry Block	580 ps	1.5 GHz	610 mW	24 FLAT
CXB1112Q	Phase Frequency Detector	720 ps	0.8 GHz	500 mW	24 FLAT
CXB1113Q	4 to 1 Multiplexer		2.0 GHz	950 mW	24 FLAT
CXB1114Q	1 to 4 Demultiplexer		2.5 GHz	1100 mW	24 FLAT
CXB1130Q	9, 8, 4-bit Multiplexer		1.6 GHz	730 mW	32 FLAT
CXB1131Q	9, 8, 4-bit Demultiplexer		1.6 GHz	1000 mW	32 FLAT
CXB1132Q	9, 8, 4-bit Universal Shift Register		1.3 GHz	910 mW	32 FLAT
CXB1133Q	22, 15, 7-Stage Scrambler		1.6 GHz	600 mW	24 FLAT
CXB1134Q	22, 15, 7-Stage Descrambler		1.6 GHz	610 mW	24 FLAT
CXB1135Q	8-16 bit Comparator		1.3 GHz	630 mW	32 FLAT
CXB1136Q	8-bit Universal Counter		1.2 GHz	730 mW	32 FLAT
CXB1137Q	8-bit Shift Matrix	1250 ps		700 mW	24 FLAT
CXB1138Q	4-bit Arithmetic Logic Unit	1460 ps		680 mW	24 FLAT

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Just call the Sony representative nearest you, or call (714) 229-4192. Or write Sony Corporation of America, Component Products Division, 10833 Valley View Street, Cypress, CA 90630. FAX (714) 229-4271.

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VA Sterling (703) 478-2480
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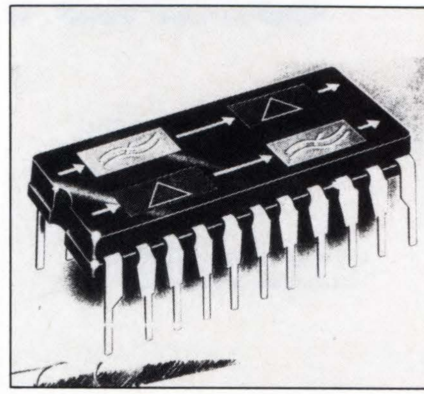
CIRCLE NO 78

Delta codec meets requirements for military communications

Meeting the requirements of the NATO Eurocom D1-IA8 specification, the FX619 full-duplex, single-chip CVSD (continuously variable slope delta) codec is suitable for use in a variety of military communications systems including delta multiplexers, switches, and telephones. Because it includes both encoder and decoder sections, as well as the audio filters that are required on the encoder input and decoder output, the device can significantly reduce component count, particularly on multichannel line cards. All you need to add are input and output buffers to convert the unbalanced input and output of the FX619 to the balanced 600Ω input and output required by the Eurocom spec. Fabricated in CMOS, the device operates from a single 5V supply and draws a typical supply current of 4.5 mA in its active mode, and 500 μA in its standby mode.

You can program the delta codec's sampling rate to 16k, 32k, or 64k bps, with all timing for the device's switched-capacitor filters and CVSD modulator and demodulator derived from an on-chip oscillator that accepts a 1.024-MHz crystal. Or, you can clock the device from an external clock source to achieve sampling rates within the range of 8k to 64k bps. The device provides clock outputs that allow you to synchronize external circuitry to the codec.



Incorporating input and output filters, as well as a full-duplex delta codec, *the FX619 can reduce parts counts in military communications equipment.*

For multiplexer applications, an enable input allows you to enable or disable the encoder section of the device. Other features include an encoder forced-idle mode that generates a 10101010-output bit stream, and a decoder forced-idle mode that produces an output bias of half the supply voltage. You can also program the device to perform either a 3- or 4-bit companding algorithm.

The FX619 is available in a 22-pin ceramic DIP or a 28-lead ceramic surface-mount package. It has an operating temperature range of −40 to +85°C and is processed to MIL-STD-883C requirements. It sells for £20 (1000).— ***Peter Harold***

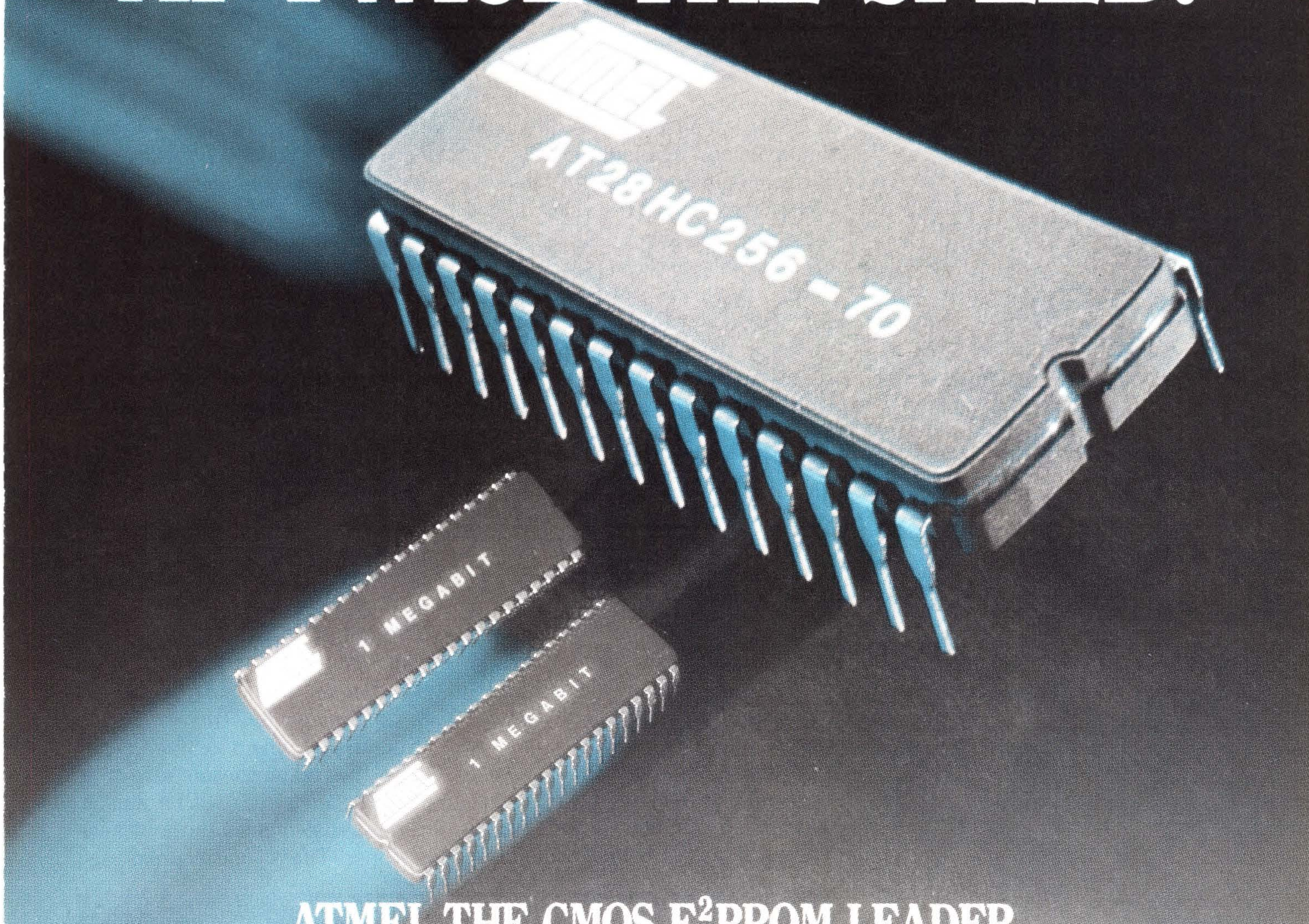
Consumer Microcircuits Ltd, 1 Wheaton Road, Witham, Essex CM8 3TD, UK. Phone (0376) 513833. TLX 99382.

Circle No 701

Mx-Com Inc, 4800 Bethania Station Rd, Winston-Salem, NC 27105. Phone (919) 744-5050.

Circle No 702

RELIABILITY AT TWICE THE SPEED.



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256K CMOS E²PROM Family

Density	Part Number	Organization	Speed (ns) 70	90	120	150	200	250	300	350	Package P	D	L	J	F	Mil 883C
256K	AT28C256	32K x 8				•	•	•	•	•	•	•	•	•	•	•
256K	AT28HC256	32K x 8	•	•	•						•	•	•	•	•	•

P-Plastic; D-Ceramic Dip; L-Leadless Ceramic; J-Plastic j-leaded; F-Flat Pack

ATMEL®

CIRCLE NO 80

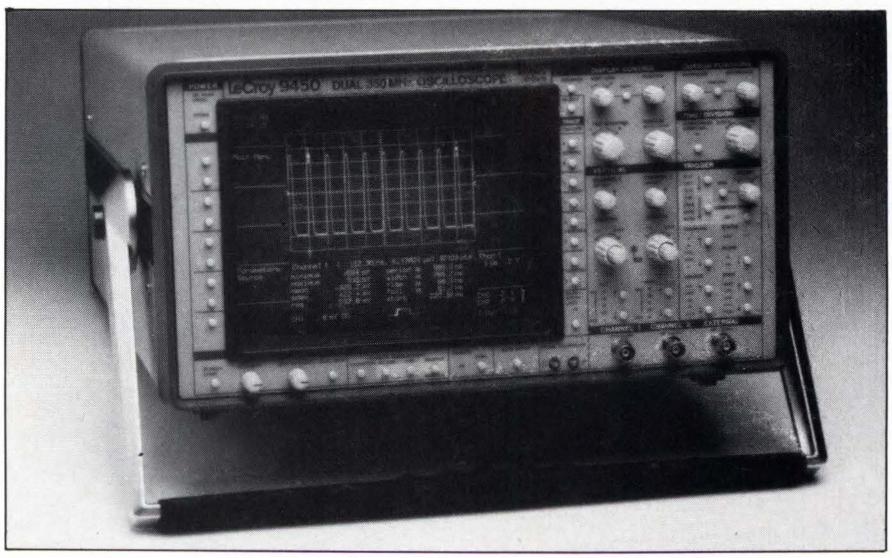
DSO 400M - sample /sec stores 50k-word records

A DSO (digital-storage oscilloscope) whose maximum sampling rate is the same as the LeCroy 9450's—400M samples/sec—but whose maximum record length is a fairly standard 1k words can sample at its maximum rate only at sweep speeds faster than 250 nsec/div. The 9450 is different. Using flash ADCs, it can sample two channels simultaneously to 8-bit precision at 400M samples/sec, and it can do so with its sweep speed set from 1 nsec to >10 μsec/div. It owes this unusual ability to acquisition memories that, with 50k words of battery-backed RAM for each of the scope's two channels, are approximately 50 times as deep as those of most competitive scopes. Each memory can store a single waveform record, or you can partition it to store as many as 200 records.

The 9450 is neither the least nor the most expensive high-performance DSO on the market today, but the array of features it offers *in addition to* its unusual memory depth clearly make it worth a careful look by anyone considering the purchase of a DSO with fast real-time-sampling capability. People who take a close look are bound to be impressed by the clarity of the 4096×4096-pixel display on the 5×7-in., amber-phosphor CRT and the scope's ability to expand a portion of a waveform for close inspection—as much as 1000 times horizontally or 10 times vertically.

A noteworthy feature of the display is the way it portrays waveforms. To avoid an effect known as "perceptual aliasing" the scope draws straight lines between sampled data points. But to avoid confusing you about where the data was actually sampled, it highlights the sampling points.

Like many DSO manufacturers, LeCroy has taken considerable care to provide its scopes with a human interface that mimics those of analog scopes. The 9450, of course, aug-



***A 5×7-in. amber-phosphor CRT** and controls that look and feel familiar to analog-scope users hide a number of unusual features of this 400M-sample/sec DSO. For example, two 50k-word display memories allow you to use the maximum sampling rate with relatively long-duration sweeps.*

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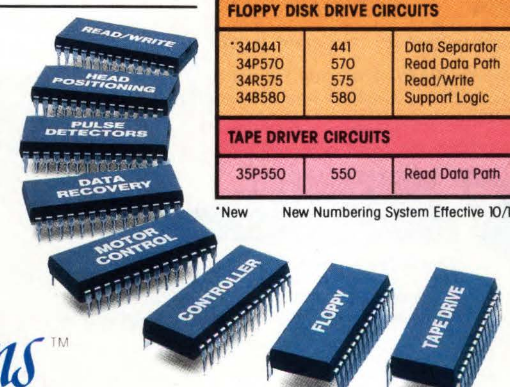
MICROPERIPHERAL IC SELECTION CHART

SSI Device Numbers		Head Type	# of Channels	Max Input Noise nV/√Hz	Max Input Capacitance (pf)	Read Gain (typ)	Write Current Range (mA)	Power Supplies	Read/Write Data Port(s)
New	Old								
HDD READ/WRITE AMPLIFIERS									
32R104B	104	Ferrite	4	2.4	23	35	15 to 45	+6V, −4V	Differential, Bi-directional
32R104BLN	104L	Ferrite	4	1.7	23	35	15 to 45	+6V, −4V	Differential, Bi-directional
32R114	114	Thin Film	4	1.1	65	123	55 to 110	±5V	Differential/Differential
32R115	115	Ferrite	2, 4, 5	1.8	20	40	30 to 50	±5V	Differential, Bi-directional
32R117	117	Ferrite	2, 4, 6	2.1	23	100	10 to 50	+5V,+12V	Differential/TTL
32R117A	117A	Ferrite	2, 4, 6	1.7	20	100	10 to 50	+5V,+12V	Differential/TTL
32R188	188	Ferrite	4	2.4	18	43	35 to 70	+6V, −5V	Differential, Bi-directional
32R501	501	Ferrite	4, 6, 8	1.5	23	100	10 to 50	+5V,+12V	Differential/TTL
*32R510A	510A	Ferrite	2, 4, 6	1.5	20	100	10 to 40	+5V,+12V	Differential/TTL
*32R511	511	Ferrite	4, 6, 8	1.5	20	100	10 to 40	+5V,+12V	Differential/TTL
*32R512	512	Thin Film	8	0.9	32	150	10 to 40	+5V,+12V	Differential/TTL
*32R514	514	Ferrite	2, 4, 6	1.5	20	150	10 to 40	+5V,+12V	Differential/TTL
32R520	520	Thin Film	4	0.9	65	123	30 to 75	±5V	Differential/Differential
32R521	521	Thin Film	6	0.9	65	100	20 to 70	+5V,+12V	Differential/TTL
*32R522	522	Thin Film	4, 6	1.0	32	100	6 to 35	+5V,+12V	Differential/TTL

SSI Device Numbers		Circuit Function	Features
New	Old		
HDD PULSE DETECTION			
32P540	540	Read Data Processor	Time Domain Filter
32P541	541	Read Data Processor	AGC, Amplitude & Time Pulse Qualification, RLL Compatible
HDD DATA RECOVERY			
32D531	531	Data Synchronizer	Data Synchronizer/Write Precompensation
*32D532	532	Data Separator	Data Synchronizer/2, 7 RLL ENDEC
*32D533	533	Data Synchronizer	Data Synchronizer/Write Precompensation
*32D534	534	Data Separator	Data Synchronizer/MFM ENDEC/Write Precompensation
*32D535	535	Data Separator	Data Synchronizer/2, 7 RLL ENDEC/Write Precompensation
HDD HEAD POSITIONING			
32H101A	101A	Preamplifier-Ferrite Head	AV = 93, BW = 10MHz, e_n = 7.0nV/√Hz
32H116	116	Preamplifier-Thin Film Head	AV = 250, BW = 20MHz, e_n = 0.94nV/√Hz
*32H567	567	Servo Demodulator	Di-bit Quadrature Servo Pattern: PLL Synchronization
*32H568	568	Servo Controller	Track & Seek Mode Operation; Microprocessor Interface
*32H569	569	Servo Motor Driver	Head Parking, Spindle Motor Braking
HDD SPINDLE MOTOR CONTROL			
32M590	590	2-Phase Motor Speed Control	±0.035% Speed Accuracy; Unipolar Operation
32M591	591	3-Phase Motor Speed Control	±0.05% Speed Accuracy; Unipolar Operation
*32M593	593	3-Phase Motor Speed Control	±0.037% Speed Accuracy; Bipolar Operation
HDD CONTROLLER/INTERFACE			
*32B450A	450A	SCSI Controller	Async transfer to 2MBPS; Initiate/Target Modes; Internal Drivers; CMOS
*32C452	452	Storage Controller	20Mbits/sec; CMOS; Programmable; AIC-010 Compatible
*32C453	453	Buffer Controller	Non-mux addressing to 16K; CMOS; AIC-300 Compatible
32B545	545	Support Logic	Includes ST506 Bus Drivers/Receivers
FLOPPY DISK DRIVE CIRCUITS			
*34D441	441	Data Separator	High Performance Analog Data Separator, NEC 765 Compatible
34P570	570	Read Data Path	2 Channel Read/Write With Read Data Path
34R575	575	Read/Write	2, 4 Channel Read/Write Circuit
34B580	580	Support Logic	Port Expander, Includes SA400 Interface Drivers/Receivers
TAPE DRIVER CIRCUITS			
35P550	550	Read Data Path	4 Channel Read/Write With Read Data Path

*New New Numbering System Effective 10/1/87



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LabVIEW Instrumentation Software.
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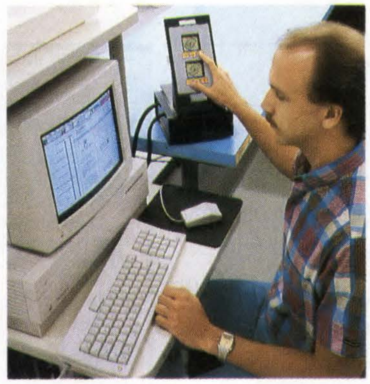
EDUCATION
University of Southwestern Louisiana

"LabVIEW is the best single software entity that has been written to date for any computer for any purpose." Dr. John O'Dell, professor of Mechanical Engineering, uses LabVIEW in his course on computer-controlled systems.

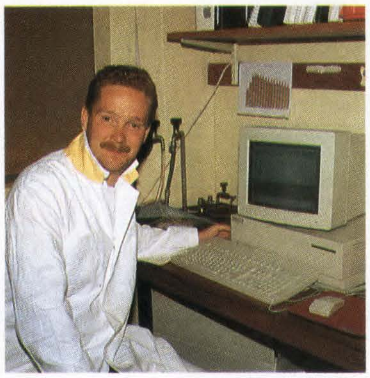


AUTOMATED TESTING
Sundstrand-Sauer

"With LabVIEW, I have reduced testing time for our control panels from 15 minutes to less than 1 minute." Jay Herman is in charge of testing Sundstrand control panels used on concrete paving machines. A GPIB-controlled power supply tests the power requirements for these machines. Analog and digital lines on the control panel are tested with the NB-MIO-16 board.

MEDICINE
Sahlgren University Hospital–Sweden

"Without any earlier experience with programming, we were writing our own applications after the LabVIEW 3-day training course." Dr. Anders Ullman uses LabVIEW in clinical pharmacology. Muscle contractions evoked by nerve stimulation or by different drugs are measured via isometric force transducers with a plug-in analog input board. Each channel is monitored on a LabVIEW strip chart.

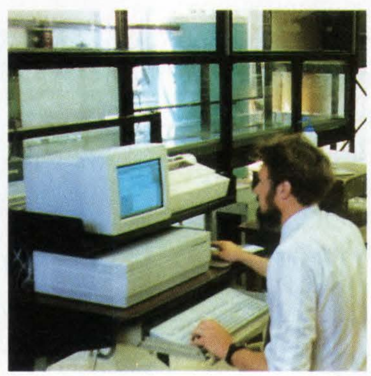


PHYSICS
The University of Texas at Austin

"We initially set up our system on a MicroVAX. It took 6 months. With LabVIEW and a Macintosh II, we got it working in a couple of weeks." Azucena Overman, graduate student in the Physics Department, researches the chemical properties of surfaces. In her research, LabVIEW controls GPIB instruments and graphs the data collected.

OPTICS
Newport Corporation

"LabVIEW is the software system we needed to complement our instruments." Scott Jordan includes LabVIEW with a Newport Optical Power Meter and a Newport Programmable Controller in a laser control system marketed by Newport Corporation.



CIVIL ENGINEERING
Stanford University

"LabVIEW is the most flexible data acquisition software I've ever seen—it's also a bit of fun." Dr. Steven Monismith of the Civil Engineering Department uses an experimental pond to research double diffusive systems. LabVIEW and an NB-MIO-16 board measure signals from temperature and conductivity probes in the pond, and control a motor that varies the depth of the probes.

SEMICONDUCTOR RESEARCH
Raytheon Company

"LabVIEW is the system of choice for data acquisition." John Day uses LabVIEW and GPIB instruments to measure physical properties of GaAs semiconductors. LabVIEW generates graphs of capacitance versus frequency and capacitance versus voltage.

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SIMULATION
Engineering Measurements Company

"LabVIEW saved me several months of development." John Waers simulates digital signal processing algorithms with LabVIEW. The algorithms are burned into EPROMs on intelligent flow meters manufactured by Engineering Measurements Company.

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LeCroy boasts about the 9450's flexible triggering: Not only can it delay starting a sweep for a selectable interval following a trigger condition, but it can also delay the sweep until it has recognized a selected number of trigger events—the number can be as large as a billion. A glitch-capture feature lets you trigger on pulses either narrower or wider than a selected duration, and the duration can be as small as 2.5 nsec. Several pattern-triggering modes let you set the scope to trigger only after specified data patterns appear at the two signal inputs, the trigger input, or some combination of the three.

In addition to real-time sampling of periodic or nonperiodic waveforms, the 9450 can also perform random equivalent-time sampling of periodic signals. It can do so at an effective rate of 10G samples/sec. When performing equivalent-time sampling, the scope's frequency response is governed by the 350-MHz bandwidth of its input channels, not by the sampling rate.

The 9450 includes RS-232C and IEEE-488 ports. You can power it from 110 or 220V ac from 48 to 440 Hz. It weighs 33 lbs and has a list price of $18,900. Delivery is four to eight weeks ARO.

—Dan Strassberg

LeCroy, 700 Chestnut Ridge Rd, Chestnut Ridge, NY 10977. Phone (914) 425-2000. TWX 710-577-2832.

Circle No 705

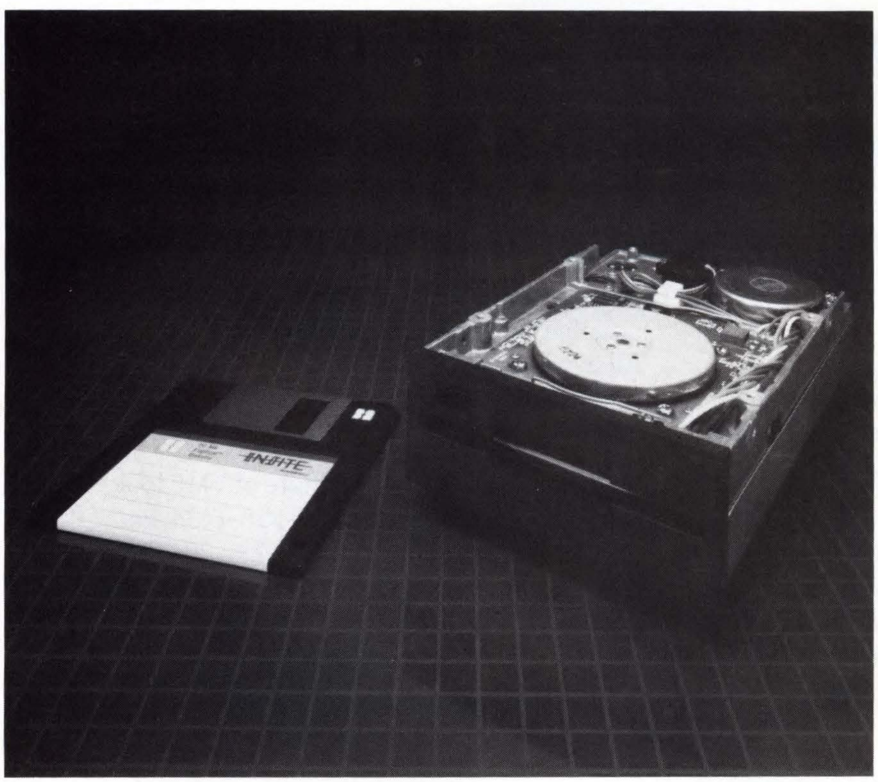
Disk drive offers 25M bytes of removable storage

The Model I325 Floptical disk drive is a removable-disk storage system in a 3½-in. format. It provides 25M bytes of unformatted disk capacity and 20.8M bytes of formatted memory. Combining magnetic recording and the high track densities of an optical servomechanism, the drive delivers the best features of both technologies.

Providing portability, data security, and unlimited storage capacity, the drive combines the benefits of a removable, flexible medium with the low cost of a 20M-byte drive. Servo techniques developed for compact disks let the drive employ floppy-disk-drive elements such as spindle- and stepper-actuator motors, disk-loading mechanisms, and spindle clamps. This design translates to cost savings in production.

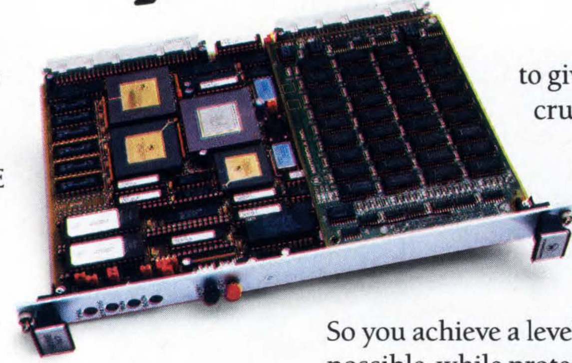
The drive accepts a double-sided, high-density diskette. The manufacturer optically inscribes 1250 concentric grooves that are spaced approximately 20 μm apart. This arrangement provides a track density of 1250 tpi. Track densities of conventional magnetic floppy-disk drives range from 48 to 135 tpi; pure optical disk drives have densities over 15,000 tpi.

Because the tracks are invulnerable to erasure, the encoded optical tracks on the floppy's medium provide the servo for the drive. In addition, you don't need a defect-free servo pattern as you do in a



Combining magnetic recording with optical servo tracking, *the Model I325 Floptical disk drive provides a low-cost, 20M-byte storage system with removable flexible medium.*

"Their new 030 board isn't really a single-board computer. It's a single-board system."



OEMs weren't prepared for the level of *functionality* our new MVME147 processor module delivers. On one standard VME card, it packs virtually all the functions you need to build a small, multi-user system.

How? Mainly through ASICs like the single-chip VMEbus interface and Peripheral Channel Controller. Plus high-density on-board DRAM (4 or 8 Mbytes), SCSI interface and Ethernet chip set. To even come close in functionality, it would take as many as *five* conventional modules.

Besides which, the 147 outperforms everything in sight. It takes maximum advantage of Motorola's new 32-bit MPU—the MC68030—coupled with a floating-point coprocessor. Both running at up to 25 MHz, to give you outstanding number-crunching power.

And since the 147 features both UNIX® and real-time operating system support, you can plug it into your existing 020-based architecture and software base. So you achieve a level of integration never before possible, while protecting your existing investment. All of which gives you unprecedented price/performance advantages for just $3747 in OEM quantities of 100.

To get an idea of what the future of VME looks like, call us today—toll free: 1-800-556-1234, Ext. 230; in California, 1-800-441-2345, Ext. 230. Or write: Motorola Microcomputer Division, 2900 Diablo Way, Tempe, AZ 85282.

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MOTOROLA *Microcomputer Division*

Approaching our technology from your point of view.

CIRCLE NO 89

magnetically encoded servo. The drive records data on the magnetic medium between the servo tracks. A magnetic head reads and writes data at a recording density of 23.3k bpi.

Closed-loop optical servos enable the head to follow any data-track eccentricities caused by the drive or the medium. The servo uses LEDs similar to those in compact disks. To provide a position-error signal, the servo tracks the LED's reflected light through a low-cost optical lens onto a quad-element photodetector. The average seek time for the drive is 65 msec.

Before production, the company modifies a standard 3½-in. removable disk so that medium manufacturers don't have to alter their manufacturing processes. Using a proprietary servo formatter, the vendor licenses manufacturers to supply the diskettes.

The drive comes with an embedded disk controller and a common-command-set SCSI. The controller includes provisions for data formatting, error checking and correction, and defect mapping. For an IBM PC, PC/XT, PC/AT, or compatible computer without a SCSI host adapter, the company provides an optional host adapter. The drive is compatible with Apple's SCSI.

The company currently offers the units in evaluation-unit quantities. Volume production will begin in the fourth quarter of 1988. The disk drives will cost less than $250 (OEM qty).—***John Gallant***

Insite Peripherals, 2363 Calle del Mundo, Santa Clara, CA 95054. Phone (408) 727-8484. FAX 408-727-7917.

Circle No 706

Low-cost PC clone serves as real-time system

Configured as a real-time software-development workstation, the System 120 costs $9250. The development system runs the vendor's compilers, assemblers, debuggers, monitor ROMs, editors, and real-time operating systems. In addition, the workstation can control proprietary in-circuit emulators and logic and software-performance analyzers. All the code that you develop will run on the company's Multibus systems and the workstation.

The workstation employs a 16-MHz 80386 μP and the IBM PC/AT backplane of the vendor's System 301 PC/AT clone. It comes with a 2M-byte RAM, a 360k-byte floppy-disk drive, and a 40M-byte hard-disk drive. You can expand the RAM to 16M bytes and the hard disk to 80M bytes. In addition to the company's iSDM monitor ROM, the workstation comes with a clone BIOS ROM. The workstation can communicate over the DOS Open-Net LAN. The maker claims that the workstation can use most IBM PC/AT cards in its eight expansion slots.

The workstation's software package comprises both a configurable and a preconfigured iRMX II.3 operating system, PL/M, a 386 assembler, the AEDIT screen editor, and the Soft-Scope II source-level debugger. You can target real-time development for the host workstation or for other systems that use iRMX. Other languages such as Fortran, Pascal, and C are available.

The iRMX II operating system used in the System 120 provides programming facilities for interrupt management with custom exception handlers; support for multiple real-time tasks; preemptive, priority-based scheduling with round-robin (time-slice) scheduling within a priority level; and intertask communication through mailboxes and semaphores. Diskless OEM versions are available for $3800 (50).

—Charles H Small

Intel Corp, Literature Dept #W464, Box 58065, Santa Clara, CA 95052. Phone (800) 548-4725.

Circle No 704

The System 120 is an IBM PC/AT clone that *comes with a complete line of real-time software-development tools.*

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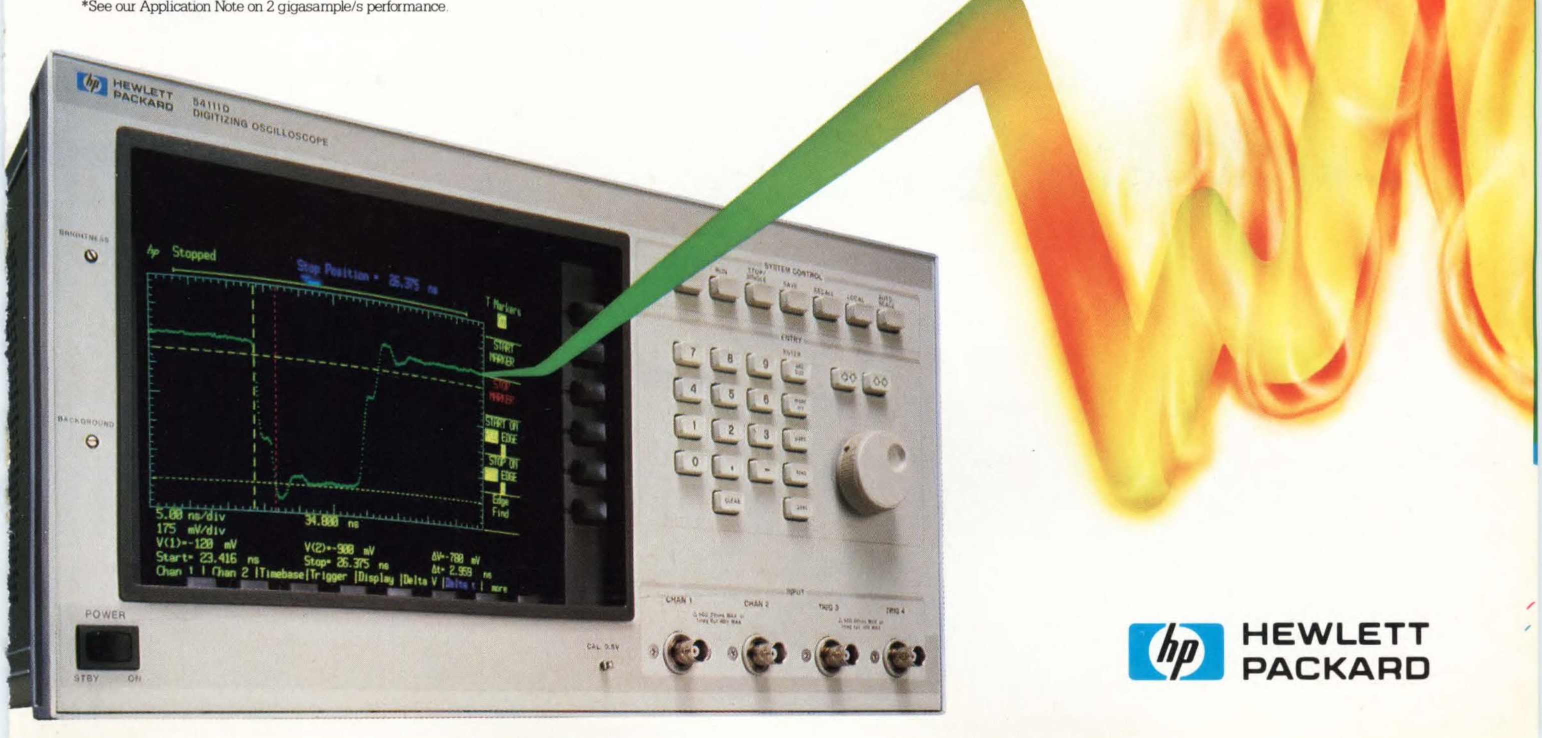

HEWLETT PACKARD

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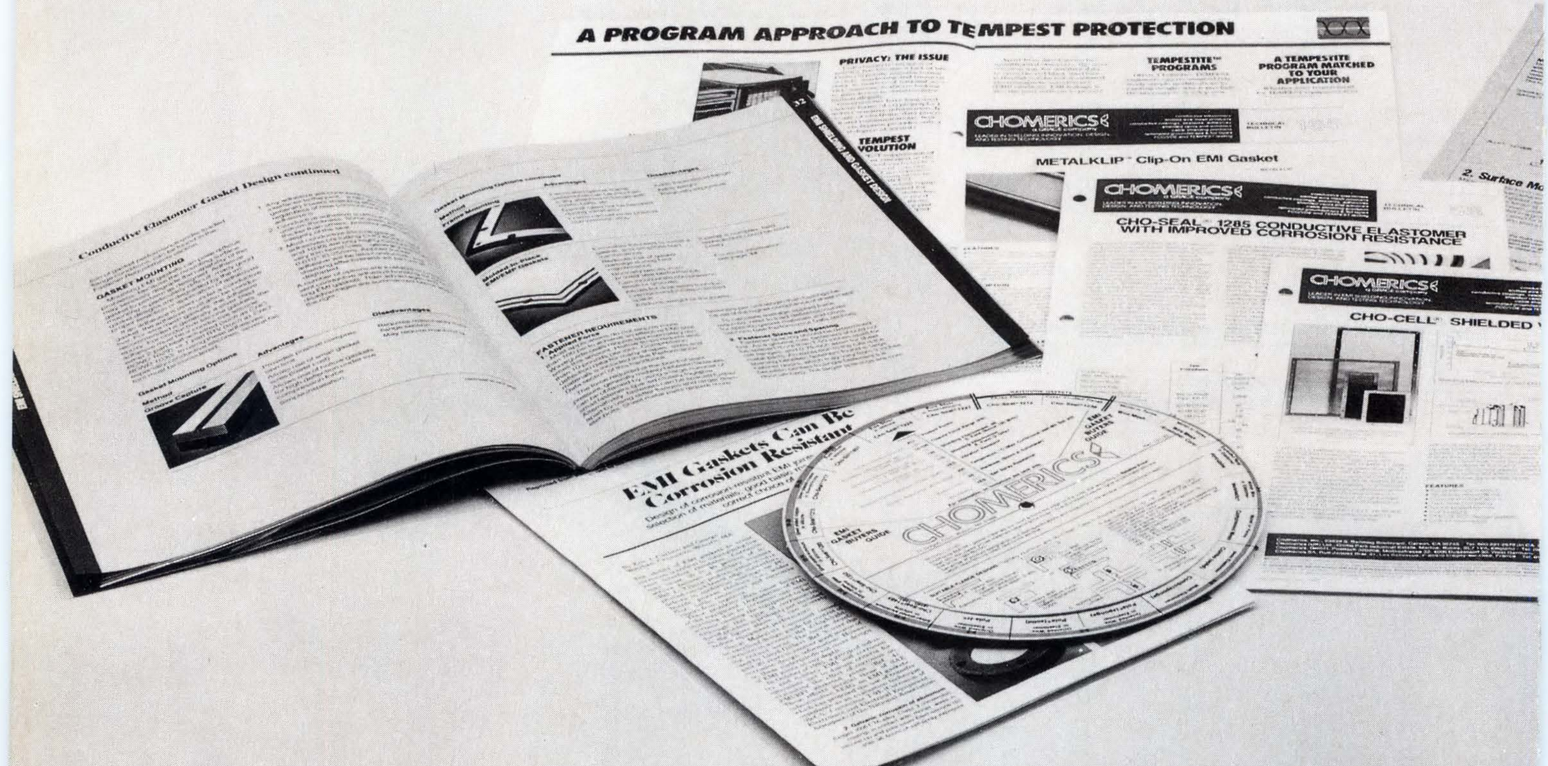

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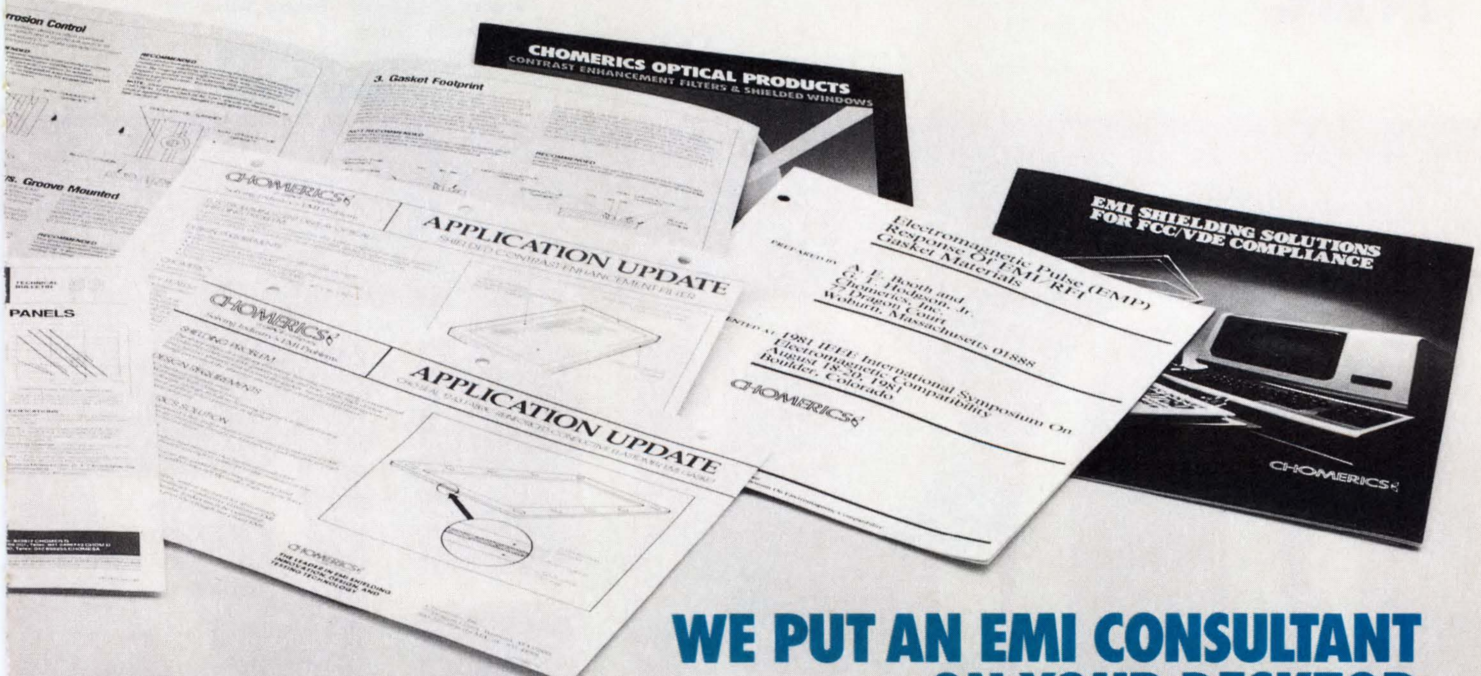
READER'S CHOICE

To assist you in solving your EMI problems, we've organized some key references around major areas of interest. We invite you to circle the corresponding number(s) on the reader service card.

- **Incorporating EMI shielding in your design**
  CIRCLE NO. 39
- **Applications and material selection**
  CIRCLE NO. 40
- **FCC/VDE compliance for commercial equipment**
  CIRCLE NO. 41
- **MIL-SPEC compliance for military systems**
  CIRCLE NO. 42
- **TEMPEST applications**
  CIRCLE NO. 43
- **EMI testing**
  CIRCLE NO. 44



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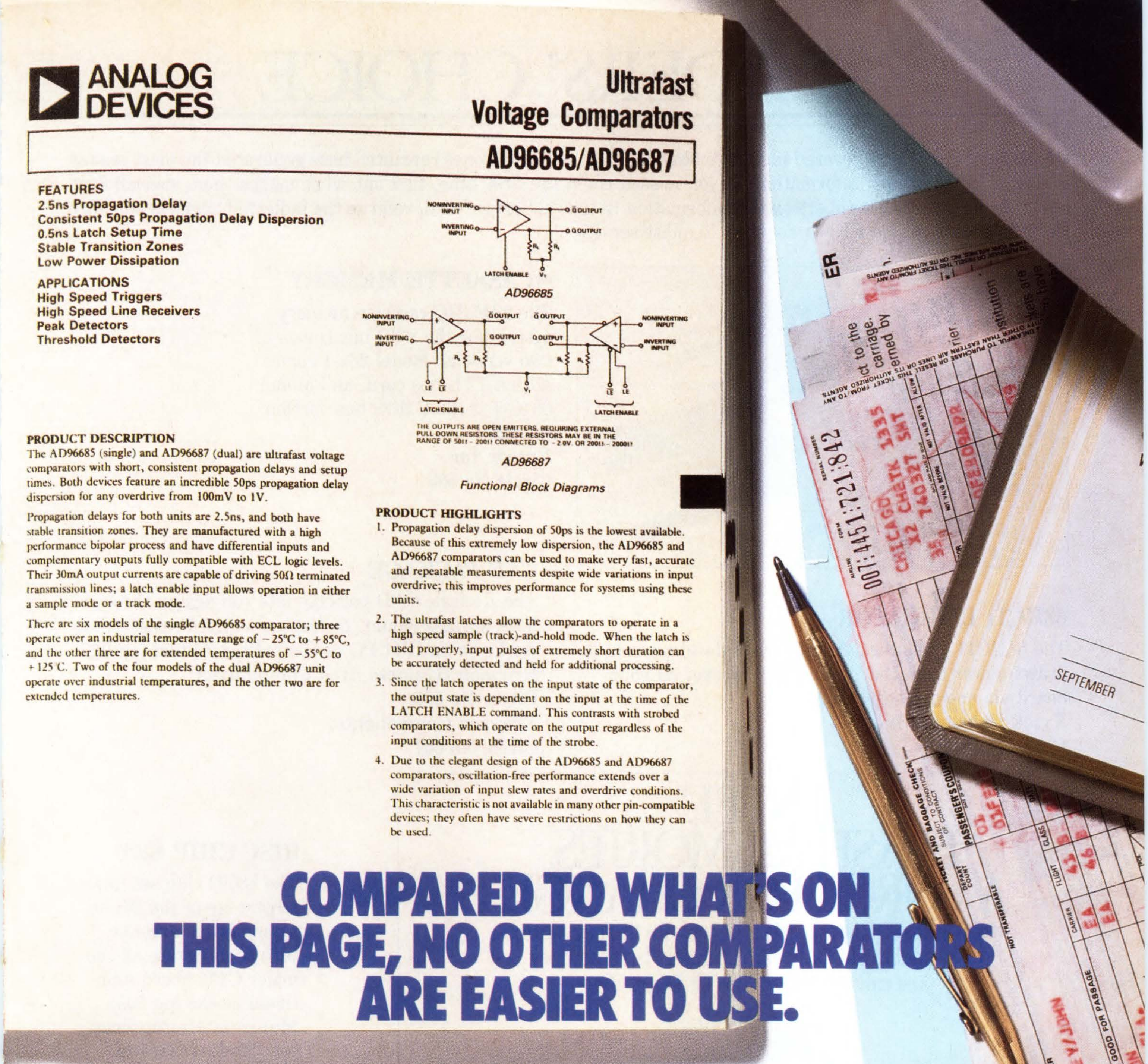
CIRCLE NO 91



ANALOG DEVICES

Ultrafast Voltage Comparators

AD96685/AD96687

FEATURES
2.5ns Propagation Delay
Consistent 50ps Propagation Delay Dispersion
0.5ns Latch Setup Time
Stable Transition Zones
Low Power Dissipation

APPLICATIONS
High Speed Triggers
High Speed Line Receivers
Peak Detectors
Threshold Detectors

AD96685

AD96687

Functional Block Diagrams

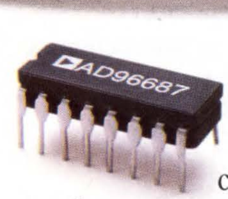
PRODUCT DESCRIPTION
The AD96685 (single) and AD96687 (dual) are ultrafast voltage comparators with short, consistent propagation delays and setup times. Both devices feature an incredible 50ps propagation delay dispersion for any overdrive from 100mV to 1V.

Propagation delays for both units are 2.5ns, and both have stable transition zones. They are manufactured with a high performance bipolar process and have differential inputs and complementary outputs fully compatible with ECL logic levels. Their 30mA output currents are capable of driving 50Ω terminated transmission lines; a latch enable input allows operation in either a sample mode or a track mode.

There are six models of the single AD96685 comparator; three operate over an industrial temperature range of −25°C to +85°C, and the other three are for extended temperatures of −55°C to +125°C. Two of the four models of the dual AD96687 unit operate over industrial temperatures, and the other two are for extended temperatures.

PRODUCT HIGHLIGHTS
1. Propagation delay dispersion of 50ps is the lowest available. Because of this extremely low dispersion, the AD96685 and AD96687 comparators can be used to make very fast, accurate and repeatable measurements despite wide variations in input overdrive; this improves performance for systems using these units.
2. The ultrafast latches allow the comparators to operate in a high speed sample (track)-and-hold mode. When the latch is used properly, input pulses of extremely short duration can be accurately detected and held for additional processing.
3. Since the latch operates on the input state of the comparator, the output state is dependent on the input at the time of the LATCH ENABLE command. This contrasts with strobed comparators, which operate on the output regardless of the input conditions at the time of the strobe.
4. Due to the elegant design of the AD96685 and AD96687 comparators, oscillation-free performance extends over a wide variation of input slew rates and overdrive conditions. This characteristic is not available in many other pin-compatible devices; they often have severe restrictions on how they can be used.

COMPARED TO WHAT'S ON THIS PAGE, NO OTHER COMPARATORS ARE EASIER TO USE.



If the output from your present comparator makes it difficult to use, take a look at the incomparable AD96685 and AD96687. They're the only comparators whose propagation delays remain constant to within 50 picoseconds for any overdrive from 100mV to 1V, so you always get consistent output.

The AD96685 and AD96687 also give you consistent speed, since they switch in 2.5ns, with a setup time of 0.5ns. And they have remarkably stable transition zones, which minimize oscillation.

But speed isn't achieved at the expense of power. The single AD96685 dissipates a mere 118mW, and the dual AD96687 needs just 237mW.

In addition, the AD96685 and AD96687 each have an offset voltage of 1mV typical for a consistent starting point, and an input voltage range of −2.5V to +5V.

Now despite all these advantages, you won't have to change your board design for the AD96685 and AD96687. They're ECL-compatible and drop-in replacements for standard devices.

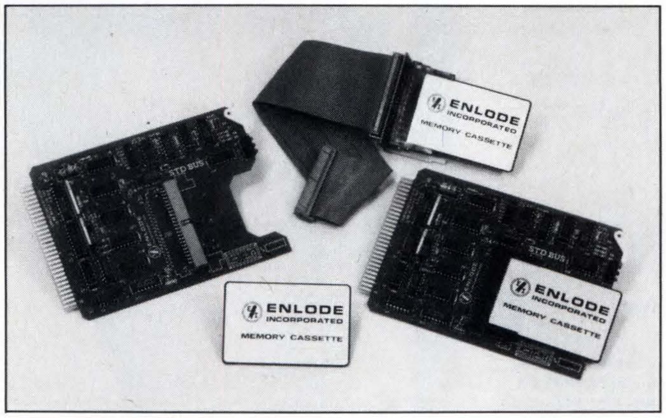
If you'd like a further comparison of the AD96685 and AD96687, call your nearest Analog Devices sales office, or our applications engineers at (919) 668-9511.

ANALOG DEVICES

Analog Devices, Inc., One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106; Headquarters: (617) 329-4700; California: (714) 641-9391, (619) 268-4621, (408) 559-2037; Colorado: (719) 590-9952; Maryland: (301) 992-1994; Ohio: (614) 764-8795; Pennsylvania: (215) 643-7790; Texas: (214) 231-5094; Washington: (206) 251-9550; Austria: (222) 885504; Belgium: (3) 237 1672; Denmark: (2) 845800; France: (1) 4687-34-11; Holland: (1620) 81500; Israel: (052) 911415; Italy: (2) 6883831, (2) 6883832, (2) 6883833; Japan: (3) 263-6826; Sweden: (8) 282740; Switzerland: (22) 31 57 60; United Kingdom: (932) 232222; West Germany: (89) 570050

READERS' CHOICE

Of all the new products covered in EDN's **May 26, 1988,** issue, the ones reprinted here generated the most reader requests for additional information. If you missed them the first time, find out what makes them special: Just circle the appropriate numbers on the Information Retrieval Service card, refer to the indicated pages in our **May 26, 1988,** issue, or use EDN's Express Request service.



◀ CASSETTE MEMORY

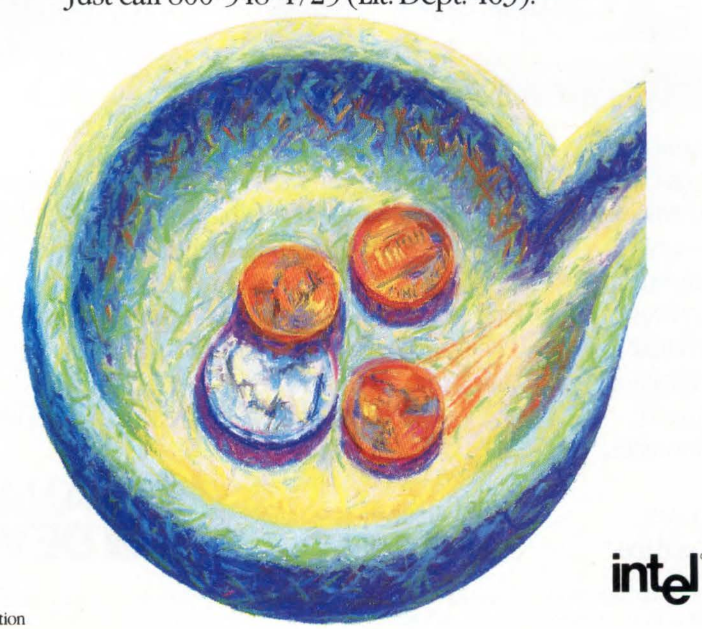
The 234/334C cassette memory system for the STD bus comes in two versions: Model 234-1 comes with a TTL bus card, and Model 334C-1 is the CMOS bus version. (pg 220).
Enlode Inc.
Circle No 603

68HC11 EMULATOR

The 68HC11 emulator aids microcode development. It draws power from the 52-pin PLCC socket on your board via one cable (pg 260).
Xytek Industries Inc.
Circle No 602

CAD PACKAGE

The Resicalc CAD package lets you design through-hole, surface-mount, or leadless-carrier resistor networks on an IBM PC or compatible system (pg 94).
Ericsson Business Area Components.
Circle No 606
Ericsson Components.
Circle No 607



RISC CHIP SET

The 88000 chip set takes advantage of the silicon-saving RISC architecture to integrate all the major CPU-board functional blocks (pg 103).
Motorola Microprocessor Products Group.
Circle No 604
Motorola Microcomputer Div.
Circle No 605

ACCELEROMETER

The SXL Series accelerometers employ a 0.16×0.16-in. sensor chip and have 200g measurement capability (pg 240).
Sensym Inc.
Circle No 601

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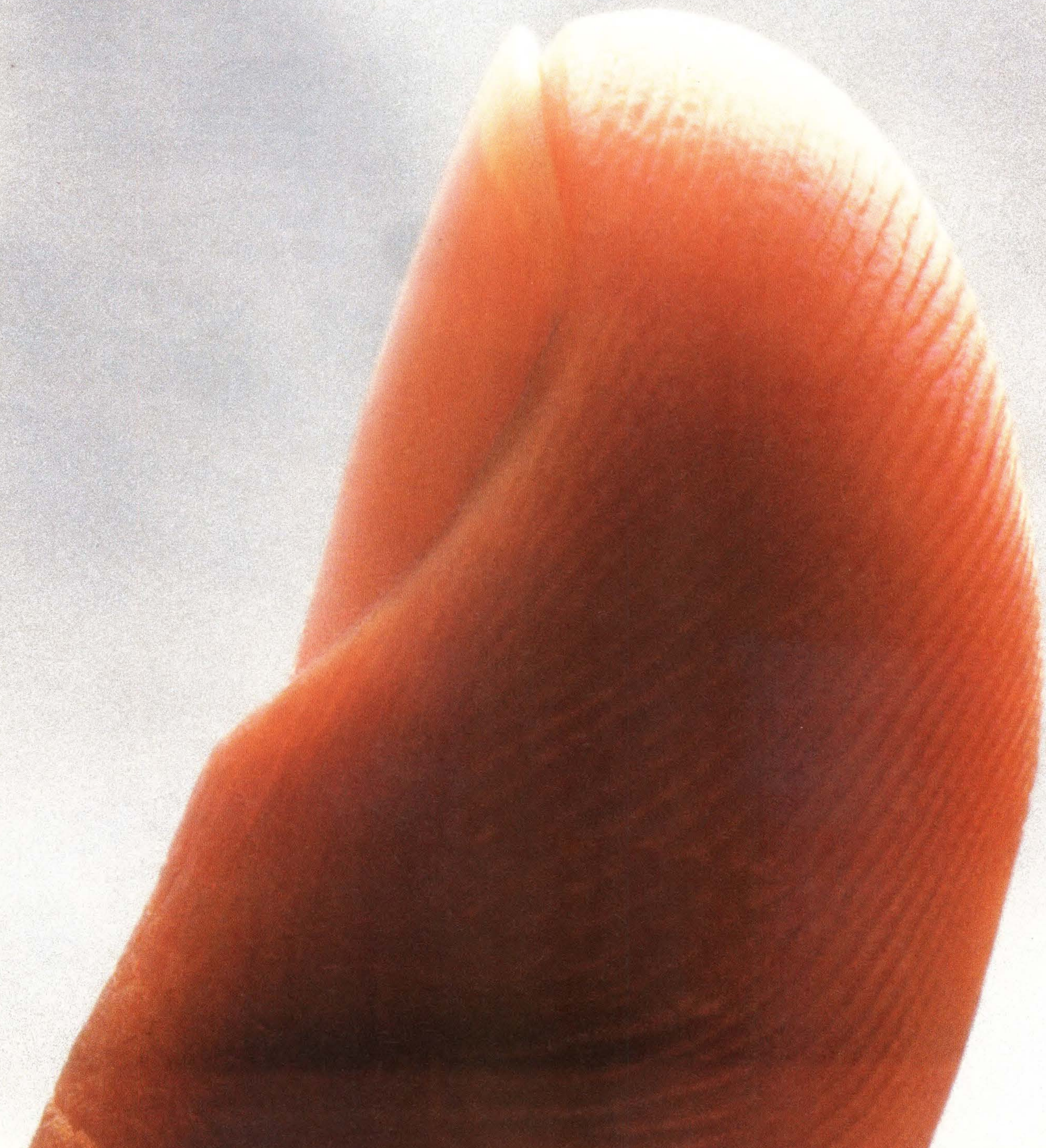

CIRCLE NO 93

Attention: Power Supply Designers

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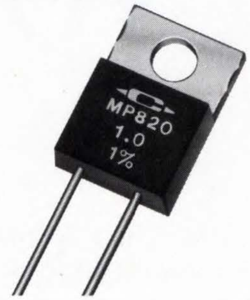
Non-Inductive with Values Down to 0.1Ω

Type MP Kool-Tab™ Power Film Resistors
20 Watts in the TO-220 Package



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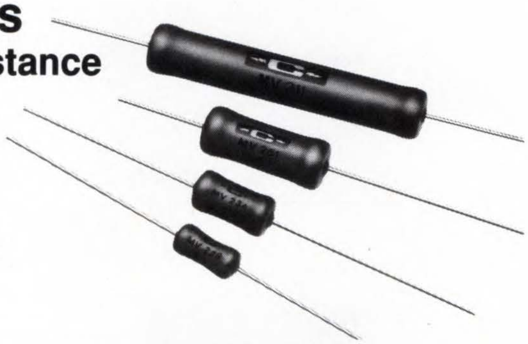
- ***Now available as low as 1 Ω***
- ***Non-Inductive***
- Made with Micronox® resistance film
- 20 Watts at 25°C case temperature
- Standard resistance tolerance of ±1%.

Type MV Power Film Resistors
Axial Lead Design with Very Low Resistance



NEW

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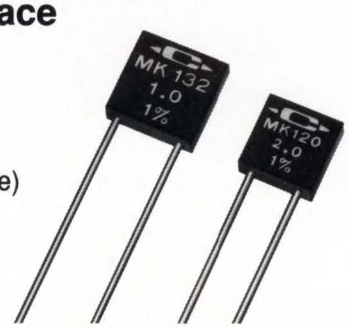
- Made with Micronox® resistance film
- Wattage ratings from 2 watts to 10 watts
- Standard resistance tolerance of ±1%

Type MK Precision Power Film Resistors
Radial Lead Design Takes Less Board Space



NEW

- ***Now available as low as 1 Ω***
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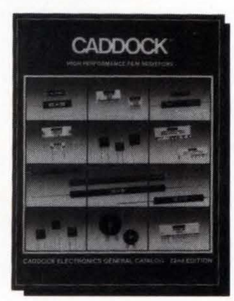
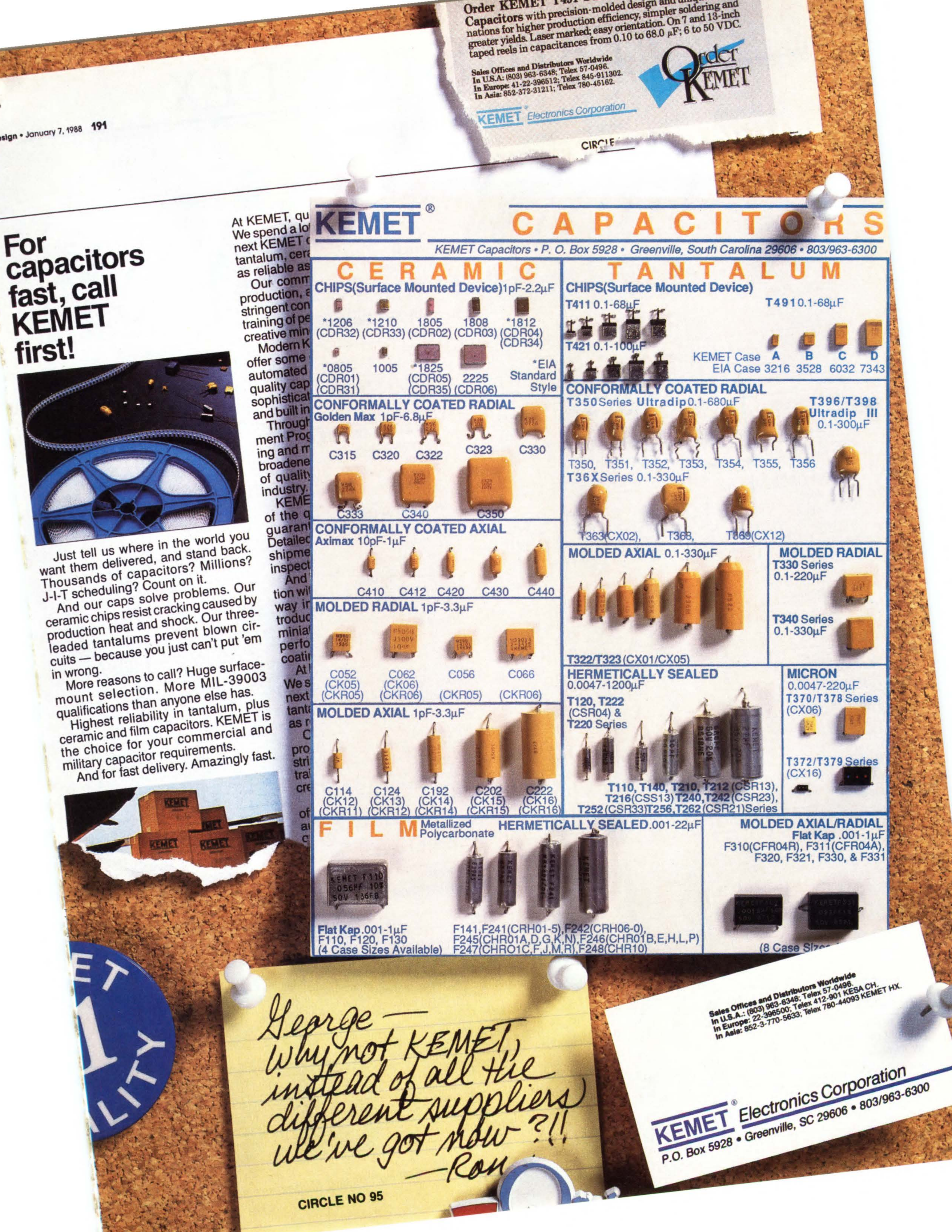


CIRCLE NO 94



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*0805 (CDR01) (CDR31) 1005 *1825 (CDR05) (CDR35) 2225 (CDR06) *EIA Standard Style
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Golden Max 1pF-6.8μF
C315 C320 C322 C323 C330
C333 C340 C350
CONFORMALLY COATED AXIAL
Aximax 10pF-1μF
C410 C412 C420 C430 C440
MOLDED RADIAL 1pF-3.3μF
C052 (CK05) (CKR05) C062 (CK06) (CKR06) C056 (CKR05) C066 (CKR06)
MOLDED AXIAL 1pF-3.3μF
C114 (CK12) (CKR11) C124 (CK13) (CKR12) C192 (CK14) (CKR14) C202 (CK15) (CKR15) C222 (CK16) (CKR16)
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T396/T398 Ultradip III 0.1-300μF
T350, T351, T352, T353, T354, T355, T356
T36X Series 0.1-330μF
T363(CX02), T368, T369(CX12)
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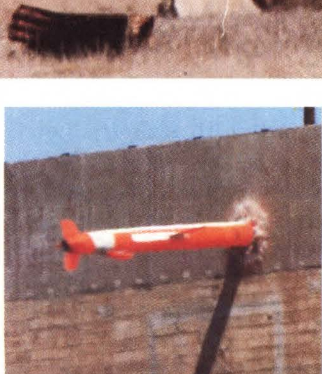
LEADTIME INDEX

Percentage of respondents

ITEM	Off the shelf	1-5 weeks	6-10 weeks	11-20 weeks	21-30 weeks	Over 30 weeks	Average (weeks)	Last month's average (weeks)
TRANSFORMERS								
Toroidal	0	13	56	25	0	6	**10.6**	**10.6**
Pot-Core	0	11	55	28	0	6	**10.9**	**12.5**
Laminate (power)	0	32	37	26	0	5	**9.3**	**11.7**
CONNECTORS								
Military panel	0	0	27	55	9	9	**16.0**	**11.5**
Flat/Cable	9	47	35	9	0	0	**5.1**	**5.7**
Multi-pin circular	0	28	38	28	6	0	**9.6**	**9.2**
PC (2-piece)	7	20	46	27	0	0	**8.4**	**6.7**
RF/Coaxial	6	22	39	33	0	0	**8.8**	**7.8**
Socket	11	37	33	19	0	0	**6.4**	**6.6**
Terminal blocks	8	57	23	12	0	0	**4.9**	**4.0**
Edge card	5	26	58	11	0	0	**6.9**	**6.0**
D-Subminiature	12	24	48	12	4	0	**7.2**	**6.0**
Rack & panel	0	17	66	17	0	0	**8.3**	**9.0**
Power	0	22	57	21	0	0	**8.3**	**7.6**
PRINTED CIRCUIT BOARDS								
Single sided	5	49	41	5	0	0	**5.0**	**5.8**
Double sided	0	38	56	6	0	0	**6.2**	**6.7**
Multi-layer	0	8	64	28	0	0	**9.7**	**10.6**
Prototype	0	83	10	7	0	0	**3.5**	**3.7**
RESISTORS								
Carbon film	30	24	22	24	0	0	**6.0**	**4.3**
Carbon composition	24	28	16	32	0	0	**6.9**	**3.5**
Metal film	23	25	26	26	0	0	**6.7**	**4.6**
Metal oxide	16	32	26	26	0	0	**6.8**	**5.4**
Wirewound	9	28	36	27	0	0	**7.7**	**6.3**
Potentiometers	0	44	33	23	0	0	**7.2**	**6.1**
Networks	8	42	25	25	0	0	**6.8**	**7.0**
FUSES	44	28	20	8	0	0	**3.4**	**3.2**
SWITCHES								
Pushbutton	12	42	31	15	0	0	**5.7**	**5.9**
Rotary	0	45	38	17	0	0	**6.6**	**5.8**
Rocker	5	42	32	21	0	0	**6.7**	**6.9**
Thumbwheel	0	47	29	24	0	0	**7.1**	**8.2**
Snap action	5	42	32	21	0	0	**6.7**	**5.9**
Momentary	12	41	35	12	0	0	**5.5**	**6.5**
Dual-in-line	13	31	37	19	0	0	**6.6**	**7.7**
WIRE AND CABLE								
Coaxial	26	59	11	4	0	0	**2.7**	**5.2**
Flat ribbon	24	56	16	4	0	0	**3.0**	**4.4**
Multiconductor	17	54	25	4	0	0	**3.7**	**5.4**
Hookup	33	48	15	4	0	0	**2.8**	**3.3**
Wirewrap	30	45	15	10	0	0	**3.7**	**4.8**
Power cords	15	52	22	11	0	0	**4.5**	**5.1**
POWER SUPPLIES								
Switcher	0	20	60	20	0	0	**8.4**	**8.6**
Linear	8	25	50	17	0	0	**7.2**	**8.0**
CIRCUIT BREAKERS	10	25	45	15	5	0	**7.8**	**8.8**
HEAT SINKS	9	48	26	17	0	0	**5.7**	**6.7**
BATTERIES								
Lithium coin cells	6	52	24	12	6	0	**6.4**	**6.5**
9V alkaline	20	47	20	13	0	0	**4.6**	**2.9**
Real-time clock back-up	8	25	50	17	0	0	**7.2**	**5.7**
RELAYS								
General purpose	14	41	28	17	0	0	**5.7**	**5.6**
PC board	8	46	21	25	0	0	**6.6**	**5.5**

ITEM	Off the shelf	1-5 weeks	6-10 weeks	11-20 weeks	21-30 weeks	Over 30 weeks	Average (weeks)	Last month's average (weeks)
Dry reed	14	21	29	36	0	0	**8.5**	**6.3**
Mercury	10	10	30	50	0	0	**10.6**	**11.2**
Solid state	5	33	33	29	0	0	**7.9**	**9.2**
DISCRETE SEMICONDUCTORS								
Diode	22	29	19	19	11	0	**8.0**	**6.2**
Zener	20	33	7	33	7	0	**8.3**	**7.6**
Thyristor	10	29	29	32	0	0	**8.0**	**6.6**
Small signal transistor	24	23	19	24	10	0	**8.4**	**4.9**
MOSFET	10	25	35	30	0	0	**8.1**	**7.9**
Power, bipolar	19	25	35	25	6	0	**8.0**	**7.8**
INTEGRATED CIRCUITS, DIGITAL								
Advanced CMOS	0	19	43	38	0	0	**9.9**	**10.1**
CMOS	10	28	28	31	3	0	**8.5**	**8.0**
TTL	14	20	33	33	0	0	**8.3**	**5.6**
LS	23	31	23	23	0	0	**6.1**	**6.5**
INTEGRATED CIRCUITS, LINEAR								
Communication/Circuit	8	26	33	33	0	0	**8.4**	**9.1**
OP amplifier	22	26	26	26	0	0	**6.7**	**7.6**
Voltage regulator	18	32	23	27	0	0	**6.8**	**6.3**
MEMORY CIRCUITS								
DRAM 16K	0	7	20	40	0	33	**18.3**	**14.6**
DRAM 64K	0	12	22	44	0	22	**15.8**	**14.6**
DRAM 256K	0	11	6	39	11	33	**20.0**	**19.5**
DRAM 1M-bit	0	13	7	27	20	33	**20.5**	**22.6**
SRAM 4K × 4	0	7	27	33	13	20	**17.1**	**15.3**
SRAM 8K × 8	0	6	17	32	17	28	**19.6**	**16.6**
SRAM 2K × 8	0	6	24	28	24	18	**18.3**	**17.8**
ROM/PROM	0	14	29	43	7	7	**13.4**	**13.2**
EPROM 64K	0	16	36	26	11	11	**13.6**	**11.4**
EPROM 256K	0	19	19	42	10	10	**14.3**	**13.9**
EPROM 1M-bit	0	17	17	41	17	8	**15.1**	**15.8**
EEPROM 16K	0	15	38	38	0	9	**12.2**	**14.7**
EEPROM 64K	0	15	31	46	0	8	**12.6**	**14.1**
DISPLAYS								
Panel meters	0	27	53	20	0	0	**7.9**	**7.3**
Fluorescent	0	10	45	45	0	0	**11.0**	**10.4**
Incandescent	9	28	36	27	0	0	**7.7**	**6.3**
LED	26	13	48	13	0	0	**6.1**	**7.1**
Liquid crystal	7	7	50	36	0	0	**9.9**	**12.2**
MICROPROCESSOR ICs								
8-bit	0	28	28	44	0	0	**9.8**	**8.9**
16-bit	0	27	27	46	0	0	**10.0**	**9.2**
32-bit	7	13	40	40	0	0	**9.8**	**12.0**
FUNCTION PACKAGES								
Amplifier	9	19	45	27	0	0	**8.3**	**8.9**
Converter, analog to digital	7	29	29	35	0	0	**8.5**	**9.4**
Converter, digital to analog	9	19	36	36	0	0	**9.0**	**9.6**
LINE FILTERS	9	28	27	36	0	0	**8.4**	**7.9**
CAPACITORS								
Ceramic monolithic	13	40	27	20	0	0	**6.1**	**7.0**
Ceramic disc	18	32	29	21	0	0	**6.3**	**6.1**
Film	19	33	26	22	0	0	**6.2**	**6.4**
Aluminum electrolytic	10	29	29	29	3	0	**8.3**	**7.7**
Tantalum	16	28	34	19	3	0	**7.1**	**8.0**
INDUCTORS	0	25	56	19	0	0	**8.0**	**8.5**

Source: Electronics Purchasing Magazine's survey of buyers.



In a Navy test, a Tomahawk cruise missile exploded into a concrete building. When the dust settled, little remained but gravel and fragments of casing.

And the Abbott model C28D0.8 you see here.

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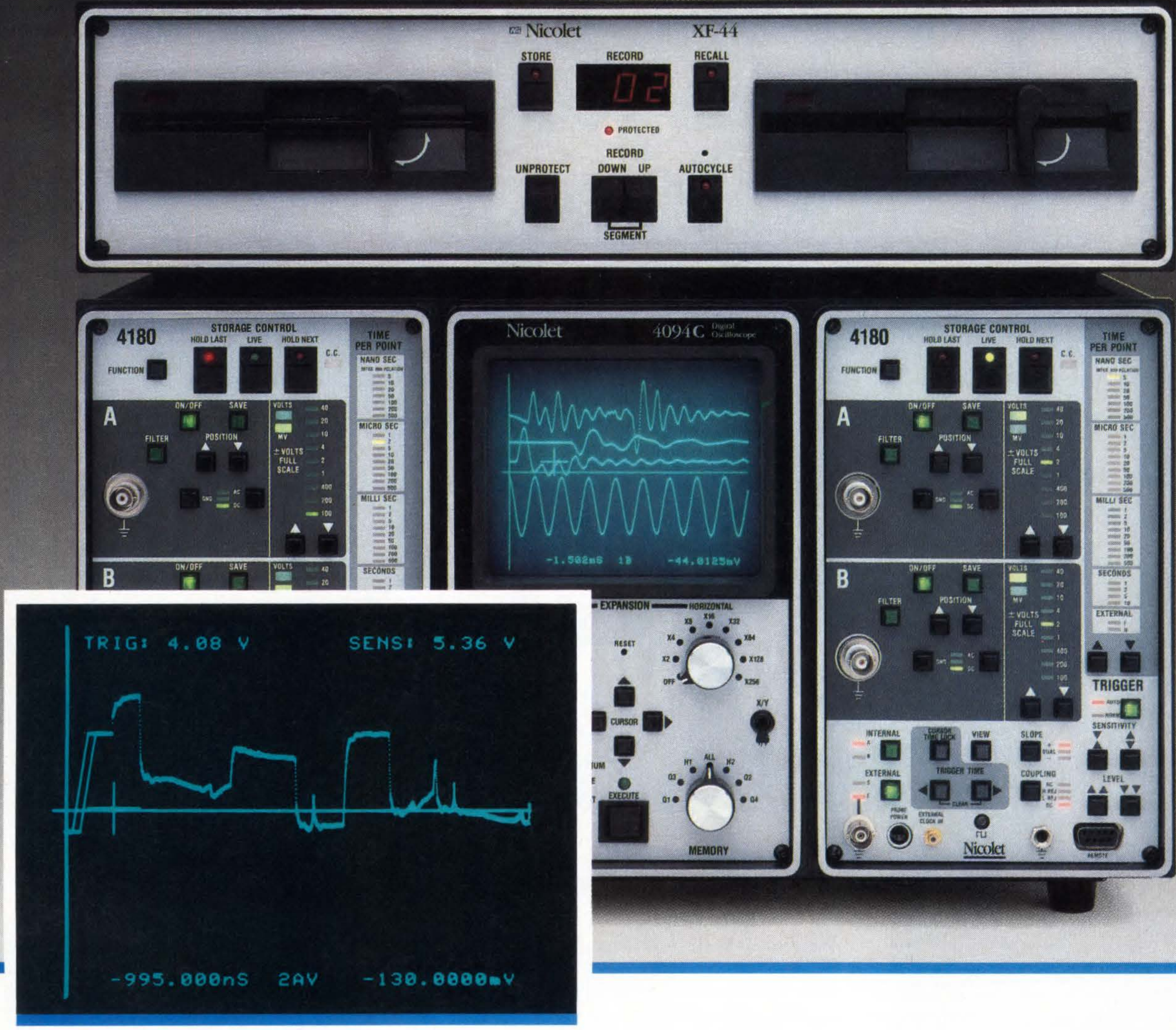

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The technology and manufacturing processes for flat-panel displays are changing fast—particularly for large-area displays with expanded information content. In choosing a model, however, you need to consider other aspects, too, from brightness and contrast to viewing angles. And don't forget the price—it can decide the issue.

Light weight and compact design are the hallmarks of flat-panel displays. Now manufacturers are also improving their manufacturing materials and processes to raise performance levels and lower costs as well. (Photo courtesy Planar Systems)

Flat-panel displays

Dave Pryce, *Associate Editor*

Flat-panel displays are changing the way we view information, not only in wrist watches and calculators but in bigger applications like portable computers and terminals that require complex graphics. Manufacturers have continued to refine some of the smaller and simpler products that have been around for years, but it's within the realm of displays with large areas and expanded information content that you can see significant trends and sometimes dramatic progress. In these areas, manufacturers are working to make flat-panel displays that are suitable for more and more complex applications, while improving performance levels of those displays and lowering their cost.

The LCD (liquid-crystal display) is well known for its nearly universal use in digital watches and pocket calculators. Perhaps less well known is the use of LCDs and VFDs (vacuum-fluorescent displays) in such applications as automotive dashboards. Many of today's cars—to the dismay of the purist—use LCDs and VFDs to replace traditional analog speedometers, tachometers, and gauges for oil pressure, water temperature, and gasoline. VFDs, along with LCDs and PDPs (plasma display panels), are also frequently used as readouts in gasoline-station pumps and industrial control equipment. And the LCDs, PDPs, and ELDs (electroluminescent displays) that are available in expanded information content versions are very practical for use in portable computers and in applications that require complicated graphics.

The LCD has probably saved the individual consumer hundreds of dollars in battery replacement costs—its predecessor, the LED (light-emitting diode), burned out batteries at a furious rate. LCDs have more modest power requirements; a digital watch with an LCD typically operates for two years or more on its original battery. Their low power requirements make them particularly suitable for portable computers.

Active-matrix enhances large-area LCDs

One recent development that has contributed to the growing popularity of LCDs is the active matrix. Alphasil Inc, for example, makes custom and semicustom active-matrix LCDs that contain amorphous-silicon, thin-film transistors (TFTs) that switch individual pixels (dots) on and off; external row- and column-drivers are still required. All of Alphasil's active-matrix flat-panel displays (AMFPDs) offer at least a 10:1 contrast ratio.

AMFPDs are available as reflective, transmissive, or

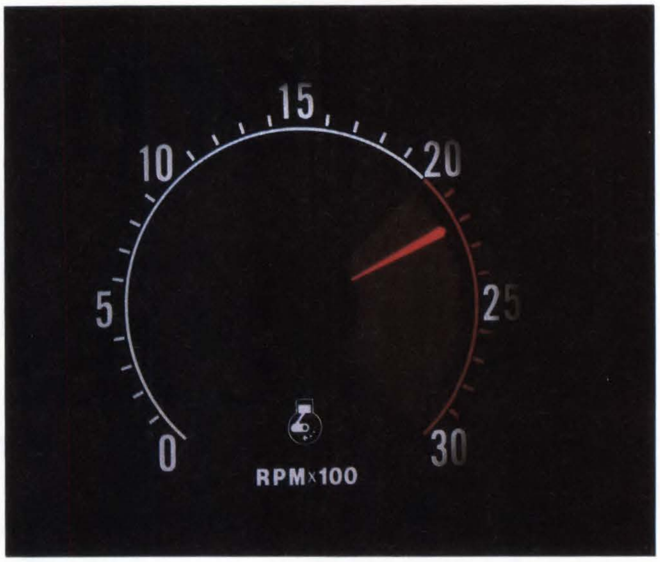
LCDs have probably saved the individual consumer hundreds of dollars in replacement battery costs.

transflective displays. Like most other LCDs, the reflective AMFPDs contain no backlighting. Because reflective units depend on ambient light alone to illuminate the screen, they perform best when that light is high. The transmissive displays are backlit continuously when in use and are thus suited for indoor applications where the ambient light is low. Transflective displays can operate either way; they're most appropriate where displays must operate in a wide range of indoor and outdoor lighting conditions. For backlighting, both the transmissive and transflective screens use a low-power, high-efficiency neon fluorescent tube. Alphasil also offers thin-film electroluminescent (EL) backlighting for situations where the lower surface brightness that the backlighting creates under ambient light is not a problem.

Alphasil's products include AMFPDs with matrices of 640×200 (CGA), 640×350 (EGA), 640×400, 640×480 (VGA), and 640×640 pixels. The 640×350-pixel unit has an active display area of 3.5×5 in. and contains 224,000 pixels with a built-in 2:1 redundancy. According to Alphasil, all of the displays feature a viewing angle of 160° for any pixel, a minimum contrast ratio of 10:1, and power consumption of less than 3W with backlighting. All models have a refresh rate of 60 Hz and include digital and RGB interfaces. These large-area displays, which are available in sizes through 5×5 in., are fairly expensive, and find primary use in military and avionics applications. Prices depend on the particular display; they range from about $1000 to $2000 in small quantities.

Panasonic Industrial makes dot-matrix LCD modules that fit the large-area category without using the active-matrix technology. The EDM-DG648A01D (8-in. diagonal) and the EDM-DG64AA41D (9.5-in. diagonal) are both birefringent displays (see **box,** "A glossary of display terms," pg 144). The 8-in. display has a 640×200-pixel format with an effective viewing area of 6.46×4.886 in. The 9.5-in. display has a 640×400-pixel format with a viewing area of approximately 8.078×5.04 in. These LCD modules can display a sufficient amount of alphanumerics and graphics to replace CRTs in most configurations. The dot size is 0.00827×0.022 in. (0.21×0.56 mm) for the 8-in. display, and 0.011×0.011 in. (0.28×0.28 mm) for the 9.5-in. display. Both modules operate from 5 and 24V dc supplies. For applications in low-light work areas, an optional EL backlight is available. The displays cost from $200 to $250 each.

Industrial users are also finding LCDs functional.



***This automotive tachometer display** is typical of the applications for Taliq Corporation's liquid-crystal film. By combining light-controlling liquid-crystal thin films with graphic overlays and color reflectors, the company can produce complete front-panel assemblies.*

Seiko Instruments, for example, makes LCD modules that are used in various industrial displays. Its alphanumeric models range in capacity from 1×16 to 4×40 characters. Featuring blue characters on a white background, these modules have high contrast and a wide viewing angle.

Sharp Electronics Corp makes several large-area LCDs. Their dot-matrix monochrome types include formats of 640×400, 640×480, and 720×400 dots. The viewing areas of these displays are 8.589×5.476 in., 9.338×7.09 in., and 10.24×5.79 in, respectively. All are double-supertwist types that offer high contrast. The 640×480-dot display is particularly well suited for use with the IBM VGA graphics standard. Sharp recently introduced a small-area (3-in. diagonal) color display with a 384×240-dot format that uses active-matrix TFT technology.

LC film can be colorful

Although most manufacturers are still developing color technology for large-area displays with expanded information content, Taliq Corporation is already providing some solutions to the need for color in limited information content applications. Based on a technology it calls nematic curvilinear-aligned phase, Taliq makes plastic liquid-crystal film that's used in its custom Varilite color displays. By combining layers of light-controlling liquid-crystal thin film with graphic overlays, color reflectors, and membrane switches, Taliq manufactures fully integrated front-panel assemblies that are useful in automotive, industrial, medical, office-automation, and home-appliance applications.

Taliq sells sheets of liquid-crystal film as well as complete custom displays. A sheet of 12 numeric (7-segment), or alphanumeric (16-segment) characters costs $19.50 for 1-in.-high characters and $27.30 for 2-in.-high characters. You can order the film in red, green, blue, yellow, or orange. The film has die-cut adhesive on both sides. A typical prototype order for a custom display costs $3000 to $5000 and includes all engineering and art-work charges, and 5 to 10 samples. Pricing for large quantities depends heavily on the actual display; a typical automotive tachometer display, for example, might cost $6 at the 25,000-piece level.

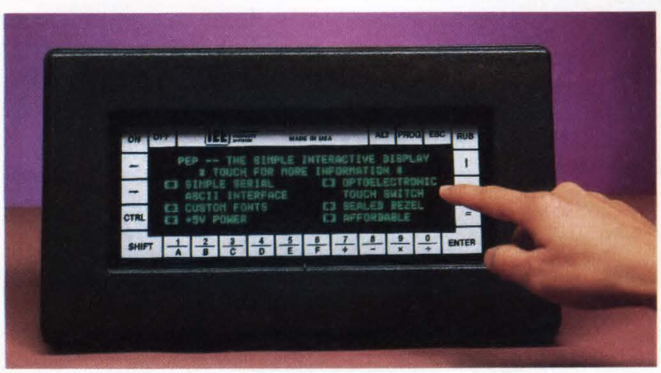
The bright blue-green color of a VF display is eye pleasing and it's undoubtedly a major factor in VFDs' popularity. Although usually limited to small-area displays with limited information content, VFDs are widely used in automobiles, medical equipment, industrial controllers, and point-of-sale terminals. At least one company offers a VF display that combines expanded information content with a display area large enough to make it suitable for both text and graphics.

VF display features touchscreen

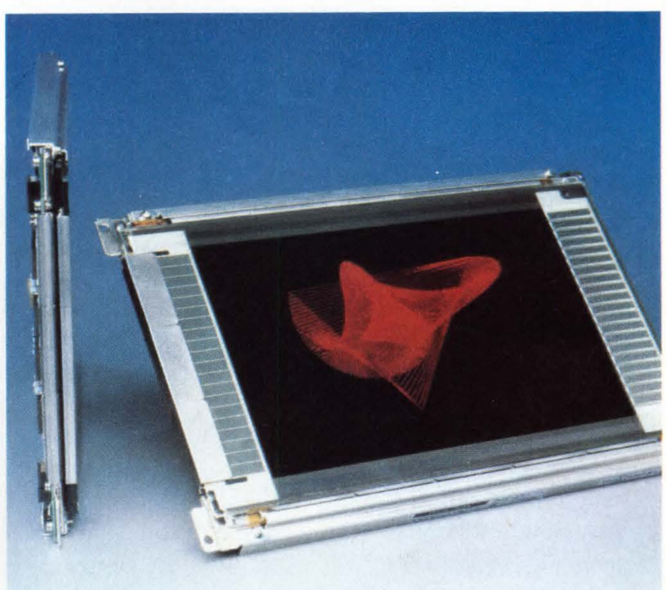
Industrial Electronic Engineers (IEE) makes a variety of VFD modules (they also make EL and plasma displays). The IEE model 4283-01, for example, is one of a family of display modules that uses VF technology to good advantage. The module integrates a 6-line by 40-character VF display with an infrared touchscreen. Each of the display's 240 characters is formed by a 5×7-dot matrix that is 0.197-in. high. The module has three software-controlled brightness levels ranging as high as 185 fL. In addition, a wide spectrum of colored filters is available for particular applications. These display characteristics, combined with the touchscreen, make the 4283-01 suitable for a variety of menu-driven applications.

Unlike resistive-membrane and capacitive touchscreens, the infrared type used in the 4283-01 uses no overlays that could obscure the display in any way. The module provides for 969 active switch locations and is immune from false triggering by ambient light—even direct sunlight. You can use this display module to store and retrieve as many as 127 user-programmable messages by means of its 8k bytes of CMOS RAM. A battery-backup circuit retains the messages in the event of power failure. The module operates from a single 5V supply; an onboard μP controls all display and touchscreen operations, a diagnostic test program, and the serial data interface with the host computer. Prices for the 4283-01 start at $800 (100).

Futaba Corporation is also pushing the application boundries for VF displays into previously uncharted areas. The Futaba GP1019A03A uses a high-resolution display technology that allows a pixel pitch of 0.0074×0.01 in. (0.1875×0.225 mm). This VFD module has a pixel count of 640×400 in a display area of 4.72×3.54 in. Its luminous display is a distinctive green



This interactive touch-entry display module *from IEE integrates a 6-line by 40-character VF display with an infrared touchscreen.*



Featuring a distinctive orange color, *this plasma panel from Fujitsu provides a high-resolution 640×400-dot display and a 10-in. (diagonal) viewing area.*

The VF display's bright, green-colored display is easily visible.

color, whose wavelength is about 500 nm (you can modify this color by the use of filters). The luminance of the display is moderately high—40 fL (140 cd/m^2). It operates from supply voltages of 5 and 135V dc. You connect the display module to the host system via the horizontal sync, vertical sync, and data (RGB) signals. By combining any two of the R,.G and B inputs, you can produce a halftone display. Using a liquid-crystal color shutter (Sony-Tektronix 7-in. LCCS) provides a display in three colors, which tend to be combinations of orange and green. The GP1019A03A VFD module costs $795 in lots of 100 pieces.

Although large-area plasma displays bear little physical resemblance to the Burrough's Nixie tube, the basic operating principle is the same. The Nixie tube, popular in the early sixties, contained a series of electrodes in the shape of numerals (0 to 9) and a neon gas mixture. Later in that decade, Beckman and Sperry introduced segmented displays that included multiple digits and alphanumeric capabilities in a single glass envelope. The same visible glow (typically orange-red) emanates from today's plasma displays (PDPs). In all cases, the glow results from the ionization of a neon gas. The gas discharge, or ionization, occurs when electrodes within the gas are subjected to a minimum threshold voltage.

PDPs come in a wide variety of shapes and sizes, ranging from small alphanumeric and bar-graph displays to large-area displays suitable for text and graphics in computer and video terminal applications. Companies such as Cherry Electrical Products, Dale Electronics, Dixy Corporation (Fuji Electronics),

A guide to flat-panel displays

Flat-panel displays have a long way to go before they supplant cathode-ray tubes. CRTs, which are one of the last strongholds of vacuum-tube technology, still account for nearly 70% of the estimated $9 billion electronic display market. They are inexpensive when compared with other technologies, and they have the best resolution and color capability. What's more, they're widely available. The CRT screen is also equal, or superior, to other displays in terms of brightness, contrast, and general visibility. Their main disadvantages are bulkiness, weight, and high power requirements—factors that are of particular importance for battery-operated and portable equipment. What follows is a list briefly explaining the different flat-panel technologies that may someday replace CRTs in most applications.

ELD (electroluminescent display)—ELDs depend on the properties of substances such as Zn doped with Mn to luminesce when subjected to a high voltage. The higher the voltage, the brighter the luminance. This effect also can generate gray-scale images. A dot-matrix ELD panel consists of column electrodes behind a layer of luminescent material, with transparent row electrodes in front of the material. ELDs offer high resolution and exhibit a yellow-on-black display of high contrast that is pleasing to the eye. This type of flat panel is useful for applications that require both large-area displays and expanded information content, such as portable computers.

There are two basic types of ELDs: ac thin-film (ACTFEL) and dc thick-film (DCTFEL). Although both types can produce the same levels of light intensity, contrast, and resolution, manufacturers of each type claim certain cost or performance advantages. In the past, both types have shown signs of wearing out earlier than CRT counterparts, whose half-life is typically 10,000 hours. New materials and processing techniques, and the use of electronic circuitry, however, have largely eliminated these premature effects of extended use. ACTFEL displays, for example, used to show latent images on the screen as they got older, but symmetric driving circuits have overcome this problem.

LCD (liquid-crystal display)—In a twisted-nematic LCD display (TNLCD), a liquid-crystal mixture is sandwiched between two glass plates that are coated with a polarizer and lined with transparent electrodes. The application of an electric field shifts the nematic molecules so that they line up with the field, and so changes the molecules' optical characteristics. The refractive index of these molecules depends on their orientation relative to the direction of the incident

Fujitsu Components, Interstate Electronics Corp (IEC), Industrial Electronic Engineers (IEE), and NEC Electronics, all make plasma displays. AC-memory, ac-refresh, and dc-refresh are the three principal plasma-display technologies in use at this time (see **box,** "A guide to flat-panel displays").

Dale Electronics, for example, makes bar-graph plasma displays that use multiple segments to create a 10-in.-high single-bar model (PBG-C7005), and a 7.78-in.-high dual-bar model (PBG-C7008) that sell for $55 and $48, respectively (100). They also make a full-field, dot-matrix graphic display (APD-192G088-1) that has 192 columns and 88 rows. This display includes all drive electronics and a μP-based controller. Designed for use in computer terminals and other systems requiring a self-contained readout, the display is programmable to

Text continued on pg 146

***An IBM PC portable** demonstrates the use of Alphasil's active-matrix LCD. The portable system provides a way for OEMs to demonstrate their own applications before investing in a custom or semicustom display.*

light. In a standard LCD panel, the application of an appropriate (low) voltage aligns the crystals so that they either transmit or block the polarized light. A dichroic dye included in the crystal material colors the light that passes through it.

LCDs are quite inexpensive, consume very little power, and are thin, durable, and lightweight. Their major disadvantages are poor contrast, low brightness, and a reduction in performance as display size increases. The newer active-matrix types overcome some of these disadvantages but, because each pixel requires a separate drive transistor, the display and the drive circuitry are more complicated—and expensive—than conventional types. Backlighting of LCDs is becoming common for applications where the ambient light level is low.

PDP (plasma display panel)— All plasma displays contain a gas, usually neon, that glows when subjected to a high voltage. In a dot-matrix display, this voltage is applied between two sets of electrodes; one set runs vertically, the other runs horizontally; the gas is in between the two. Plasma displays exhibit a characteristic orange or red-orange color.

There are three basic plasma technologies: dc-refresh, ac-refresh, and ac-memory. The basic difference between the refresh types and ac-memory plasma displays is that the memory display includes dielectric layers: AC-memory displays have dielectric layers that separate the gas from the activating electrodes. The dielectric in an ac-memory display restricts the electrodes to capacitive coupling with the gas, a condition that allows the gas to stay lit until another signal turns it off. This action serves to create a kind of pixel memory, which eliminates the need for screen refresh in ac-memory plasma displays. Both the ac- and dc-refresh types require refreshing at least once every 1/60 of a second to prevent flickering.

VFD (vacuum-fluorescent display)—VF displays are well suited for applications that need only limited information content, such as dashboard displays in cars. For displays of less than about 200 characters, this type offers the best cost/character ratio. VFDs have a pleasant blue-green color that is usually brighter than either PDPs or ELDs. VFDs use essentially the same operating principle as a triode vacuum tube: The phosphor-coated anode segments radiate light when struck by electrons emitted by the filament cathode, and a metal-mesh grid controls the flow of electrons from the cathode to the anode. Phosphor alignment problems for high-end applications tend to reduce production yields.

A glossary of display terms

Acuity—The uniformity of light emission across a pixel and its degree of edge definition. Assuming the contrast ratio is high enough for easy distinction of off- and on-pixels, the uniformity of emission of the on-pixels, together with the size and shape of the pixels themselves, dictates the sharpness of the images.
Aspect ratio—The ratio of the display's width to its height. The aspect ratio of the typical TV screen or IBM monitor is 4:3. Flat-panel displays come in a variety of aspect ratios, depending on the particular application.
Birefringence—Double refraction. The splitting of a light beam into two light waves when the beam enters a crystal. The resultant two light waves vibrate in directions that are perpendular to each other.
Brightness—The light-intensity, or luminosity, of the display. Brightness is measured in foot lamberts (fL), or in candelas per meter squared (cd/m^2). Note: 1 cd/m^2=0.292 fL.
CGA—Color-graphics adapter. An electronic display standard that specifies a resolution of 640×200 pixels in the 2-color mode, and 320×200 pixels in the 4-color mode (from a palette of 16 colors). The horizontal scanning frequency is specified as 15.75 kHz.
Contrast Ratio—The ratio of on-pixel brightness compared to the off-pixel brightness. It represents the difference in light intensity between the foreground and background of a display. Black and white provide the ideal contrast. Depending on the type of display, contrast ratios for flat-panel displays vary from a value of less than 3:1 for some LCD types, to values of 20:1 or more for some ELD types. The perceived contrast depends on the ambient light, but a contrast of about 7:1 is generally considered as an acceptable ratio. Above a ratio of about 15:1, the human eye perceives little difference in contrast.
Controller—A pc board that goes behind the display (or in the computer bus). The controller lets the computer communicate with the display. For a CRT raster-scan display, the controller provides the signals needed for horizontal sync, vertical sync, and serial data. Flat-panel displays usually require an additional signal—the dot-clock signal—to control the transfer speed of the pixel information.
CRT—Cathode-ray tube—An electron tube used in TV receivers, oscilloscopes, radar equipment, and computer equipment to display data. Usually rectangular with a 4:3 aspect ratio, CRTs' diagonal measurement ranges generally from about 5 to 28 in. The diagonal of CRT monitors for computers or video terminals are typically between 12 and 14 in.
Display size—The illuminated area of the display that is available for viewing data. Manufacturers of CRTs usually measure them according to their *diagonal* sizes. For flat-panel displays, manufacturers usually specify the height and width.
Dithering—A computer-graphics technique used to provide shading by turning points on a pixel on and off. In monochrome plasma displays, for example, each pixel can consist of a cluster of four points (sub-pixels), each of which can be on or off. By turning these sub-pixels on in various combinations, the plasma display can show four levels of brightness, or gray-scale shading.
Dot—See **Pixel.**
Dot-clock signal—The signal that controls the pixel rate for the display system. Digital technologies, such as flat-panel displays, require this signal to tell the host system how fast to read the individual pixel information from the system to the panel. This signal is not required for CRT analog displays.
Duty cycle—Response time. The amount of time it takes for an electronic display to refresh every pixel on the screen. The maximum acceptable time is about 16.6 msec, which corresponds to a minimum refresh rate of 60 Hz. At refresh rates slower than about 60 Hz, the human eye begins to detect a flicker in the display.
EGA—Enhanced-graphics adapter. An electronic display standard that specifies a resolution of 640×350 pixels with 16-color capability (from a palette of 64 colors). Included in this standard are 80- and 40-column

text modes, and CGA emulation.

ELD—Electroluminescent display.

Fill factor—The percentage of the total area of the display that is illuminated at any given time, compared with the surrounding nonilluminated area. Displays with a low fill factor (20%) tend to look like a collection of dots. Displays with fill factors of 50% or more exhibit greater apparent brightness and are generally more readable and aesthetically pleasing.

Flat-panel display—An electronic display with a package thickness that is a fraction of the display's height or length. Flat-panel displays include ELD, LCD, LED, PDP, and VFD types (see **box,** "A guide to flat-panel displays," pg 142). Package thickness, which is typically 0.75 to 1.5 in., varies approximately from 0.5 in. to 2.5 in. The pc board containing the electronics sometimes accounts for a significant portion of the total thickness.

LCD—Liquid-crystal display.

LED—Light-emitting diode. A display that uses diodes made of gallium arsenide or gallium arsenide phosphide to emit light when current is supplied.

Nematic—Threadlike—the typical shape of a liquid-crystal molecule.

PDP—Plasma display panel.

Pixel—A picture element. The smallest unit of a video display. In CRT applications, the pixel's color and intensity is coded into an electrical signal for transmission from the system to the display. For flat-panel displays, "pixels" and "dots" are interchangeable.

Plasma—An ionized gas containing an approximately equal number of positive and negative charges. The gas emits light when subjected to a sufficiently high voltage.

Resolution—A somewhat nebulous term that manufacturers of flat-panel displays define in different ways. A number of factors determine the real or visually apparent resolution. These factors include the pixel (dot) size and pitch, the number of lines per inch, and the total number of pixels. Although the type of display (ELD, LCD, PDP) can have a significant effect on the apparent resolution because of differences in contrast and brightness, the best quantitative measurement is probably the total pixel count in a given area.

Sparkling—A computer-graphics technique that turns off a pixel every other time the screen is refreshed. Unlike CRTs, which typically use high-persistence phosphors, flat-panel displays turn off when the power to a pixel is removed. Sparkling can provide a 2-value gray scale that is satisfactory for a monochrome display or the 2-color 640×200-pixel CGA mode. For the 4-color 320×200-pixel CGA mode, flat-panel displays sometimes use dithering to provide a 4-value gray scale.

Super-twist LCD—A liquid-crystal display that rotates the plane of polarization in the range of 180 to 270° in contrast with a conventional twisted-nematic LCD, which imposes only a 90° twist on the plane of polarized light passing through the display. In addition, an alignment layer in the display provides a pre-tilt of from 10 to 30°. The pre-tilt and increased twist give super-twist LCDs contrast ratios of about 10:1 and viewing angles as high as 60°.

Twisted-nematic LCD—Also, TN-LCD. A display in which the liquid-crystal material imposes a 90° rotation (twist) on the plane of polarized light passing through the display. Conventional TN-LCDs have contrast ratios of less than 3:1 when viewed head on, and exhibit viewing angles of less than 40°.

VGA—Video-graphics array. An electronic display standard that specifies a resolution of 640×480 pixels with 16-color capability, and 320×200-pixel resolution with 256-color capability (from a palette of 256k colors) The array's functions are available on an add-in board as an adapter.

Viewing angle—The range of angles at which you can read a display, measured in angular degrees of distance from the perpendicular. A viewing angle of 120°, for example, lets you read the display at any angle from 0 to 60° from a plane that is perpendicular to the surface of the display. A conical viewing angle lets you read from above, below, or either side of the display.

The ubiquitous orange-colored plasma display is used in a wide range of applications from gas-station pumps to personal computers.

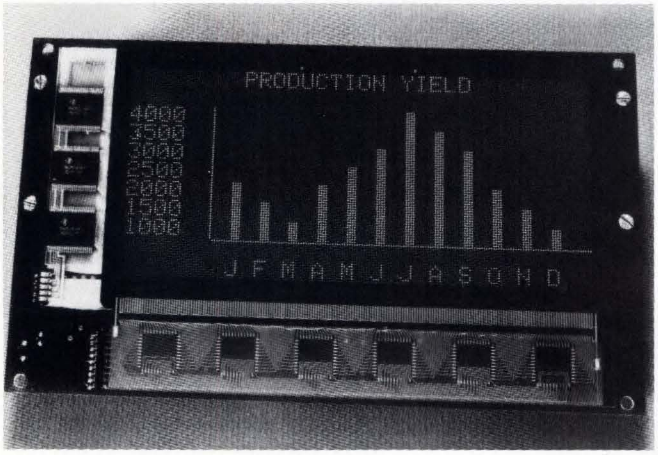
operate in a serial or parallel mode, and contains all the necessary refresh memory, character generation, and control logic. A 4k×8-bit EPROM generates 256 characters consisting of 128 ASCII characters and 128 block graphics characters. The viewing area of the $699 (100) display is 7.66-in. wide by 3.5-in. high.

Plasma display uses PWM

Dixy Corporation makes a plasma graphics display (D0640AX) that has a light intensity of 35 fL, which is about 20% brighter than its earlier models. The viewing area of the display is 10.086×6.30 in., the viewing angle is 115°, and the resolution is 640×400 pixels. Using pulse-width modulation, the DO640AX provides 16 gray-scale levels. The scan frequencies for this orange neon display are 21.0526 MHz (dot clock), 24.8262 kHz (horizontal sync), and 56.4334 Hz (vertical sync). You can adjust the display for dot-clock phase, horizontal location, vertical location, brightness, and signal polarity. Samples cost $1950 each.

Although most suppliers of plasma displays that use ac-memory technology sell exclusively to the military, Fujitsu Components also sells its products commercially. According to Fujitsu, ac-memory displays offer three major advantages compared to other plasma-display technologies: Continuous pixel illumination provides a high resolution. A steady brightness eliminates the flickering that screen refreshing can sometimes cause. And the displays have a higher reliability rate (the company specifies an MTBF rate of 50,000 hours).

Fujitsu's FPF-8050-HFUG module features a 640×400-dot viewing area of 8.3×5.2 in. (10-in. diagonal). The display's 0.008-in. (0.2-mm) pixels are arranged in a 0.013×0.013-in. (0.33×0.33 mm) dot pitch. The assembled display, including drive circuitry mounted to the back of the panel, is just over 1-in. thick. The use of 64-bit LSI drivers reduces power consumption to 35W at 100% illumination. This orange-on-black display has a character brightness of 44 fL, a contrast ratio of 20:1, and a viewing angle of 120°. Designed for use in such applications as medical instrumentation and transportable computers, the FPF-8050-HFUG costs $945 (the cost decreases to between $400 to $500 if you buy 5000 units in a year).



Dot-matrix plasma displays are useful for charting graphic data. *This 192-column by 88-row panel from Dale Electronics is used in computer terminals and other systems that require self-contained readouts.*

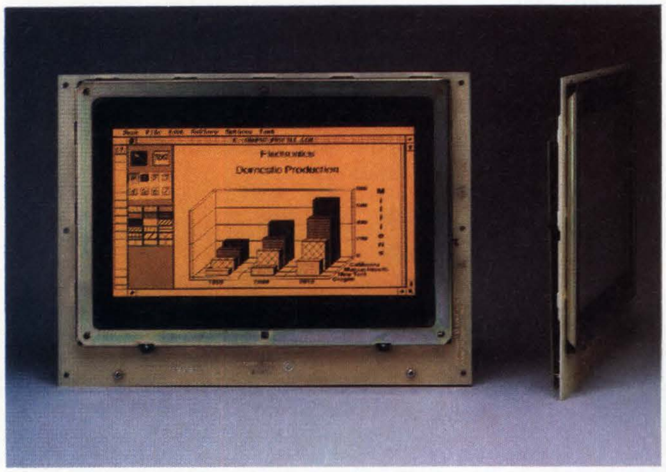
Although electroluminescent displays are not yet a major factor in the total market for flat-panel displays, electroluminescent displays (ELDs) are gaining popularity. For one thing, the characteristically bright, high-contrast, yellow-on-black display is probably more pleasing to the eye than any other type of flat-panel display. What's more, as manufacturers of large-area ELDs succeed in reducing manufacturers costs and power consumption, you can expect to see more of these attractive displays in such applications as computer terminals and transportable computers.

The Seal-Touch Terminal from Digital Electronics Corp is a $3950 ELD that's suitable for the shop floor. Its 9-in. (diagonal) panel features an infrared touchscreen in a completely sealed cast aluminum case. The package is lightweight and compact—it measures 10.5×11.5×3-in.—so you can mount it on a bench, a wall, or other equipment. The Seal-Touch unit emulates VT-52, VT-100, and VT-220 terminals. It has an 80×25-character format, line graphics, downloadable fonts, pop-up touch menus, and onscreen touch keypads. An auxiliary port lets you use the unit with an attachable keyboard. The terminal supports RS-232C, RS-422, or RS-485 interfaces.

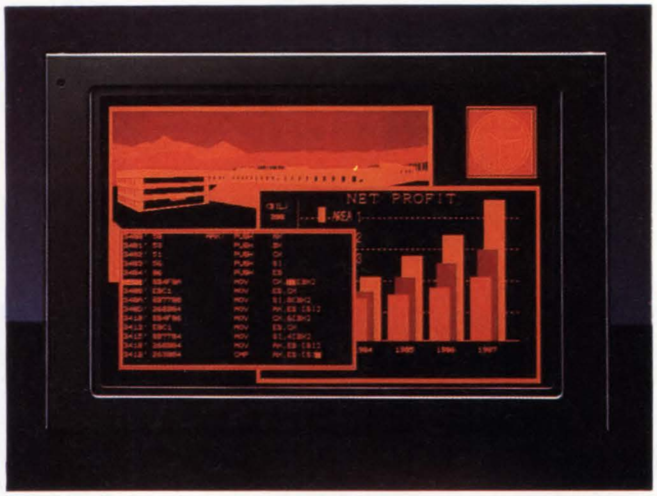
ELDs overcome their drawbacks

Despite the fact that EL displays are aesthetically appealing, they have not yet been widely accepted because, relatively speaking, they have cost a lot and they haven't lasted very long. But these barriers to their success are disappearing as manufacturing implements new processing techniques and materials as well as new driving schemes.

Stand-alone ELDs are available from several companies. Finlux Inc (Lohja Corp), Planar Systems, and Sharp Electronics make ac thin-film (ACTFEL) displays; Cherry Electrical Products makes dc thick-film



This EGA-compatible EL display, the EL8358HR, is suitable for MS-DOS-based text and graphics applications. *The Planar Systems display has a resolution of 640×400 pixels and a viewing area of 5×8 in. The high-contrast module has a 30-fL pixel brightness.*



Featuring a light intensity of 35 fL and a resolution of 640×400 pixels, *this Dixy plasma display panel has a viewing area of 256×160 mm.*

(DCTFEL) modules. Finlux Inc, for example, now uses a thin-film deposition process, which it calls atomic-layer epitaxy. The process gives the ZnS active layer more uniformity. According to the company, this process not only enhances the overall performance of the display, but also improves manufacturing yields and lengthens the operating life of the product.

Finlux makes ELDs with pixel counts from 320×256 to 640×400 at prices from $590 to $730 (100). All of the company's displays have yellow foregrounds with a 520-nm wavelength. Their emission spectrum is 60-nm wide. A typical pixel luminance is 26 fL (90 cd/m^2); the displays' contrast ratio is greater than 10:1.

Finlux's MD640.400 display has a screen resolution of 640×400 pixels, which lets you display high-resolution graphics of 25 lines of text at 80 characters per line. This display includes a display-driver board that features a digital interface consisting of four TTL-level signals: video data, video clock, horizontal sync, and vertical sync.

EL display features dc/dc converter

The MD640.400 has a viewing area of 4.806×7.68 in. and scans at a refresh rate of 60 Hz. The screen has a matrix of 0.009-in. (0.22-mm) square pixels on a 0.012-in. (0.3-mm) pitch, which is equivalent to about 83 pixels/in. Its viewing angle is 140°. The display comes with a dc/dc converter that you can either use remotely or mount at the rear of the assembly. The converter, which operates on dc inputs of 5V and 12 to 15V, consumes about 16W of power. Finlux is actively working on the development of large-area EL multicolor displays, but production of these types is several years away. Gray-scale displays will be available in several sizes next year.

Planar Systems, a major supplier of ACTFEL displays, has several models of various sizes and pixel counts in its product line. Most notable is its EL8358HR, a display with a high-resolution (640×400-pixel) viewing area of about 5×8 in. It's EGA compatible and suitable for use with MS-DOS-based text and graphics. The EL8358HR is priced at $675 (1000), including the power supply.

Planar has recently upgraded all of its ELDs, including the EL8358HR. Pixel brightness for that model is now 30 fL (compared to the previous 20 fL), and maximum peak power consumption is down from 25W to between 14 and 16W (the typical average is 10W). Like Finlux, Planar uses square pixels that are 0.0087 in. (0.22 mm) on each side and have a 0.012-in. (0.3 mm) pitch, which gives the display a density of 83 pixels/in.

When you use the circular-polarizing filter that comes standard with the EL8358HR, you get a contrast ratio of 60:1. The filter doesn't enhance the contrast; rather it reduces any glare or reflection that might affect your view of the panel. As is customary, Planar defines contrast as the ratio of light intensity between the on-pixel and the off-pixel (see **box,** "A glossary of display terms"). The contrast ratio for the EL8358HR 30 to 0.2 fL, or 150:1 (the filter reduces this ratio to 60:1). One might argue that a contrast ratio of 60:1 is superfluous, but Planar points out that, in

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EL displays are gaining in popularity; their high-contrast, yellow-on-black color is aestheically pleasing.

situations where the display is viewed briefly from a distance, this high ratio is advantageous. The company does agree, however, that for constant close-up viewing of equipment like computer screens, you might want to lower this ratio by reducing the brightness of the display.

Planar has developed an RGB color display for use in military applications and is working on reducing the costs of the materials and manufacturing process so that the display will be commercially viable. It expects to be able to produce economical commercial displays in about two years.

It's important to get the right RGB balance

One technical problem with RGB displays involves obtaining both chromaticity and intensity values that strike the right balance of red, green, and blue. This balance is important in order to accommodate the varying sensitivity of the human eye to different wavelengths of color. The display's luminescent material is the key to the light intensity of these colors, and chemistry plays a dominant role in achieving the proper balance. Monochrome EL displays typically use Mn-doped ZnS to produce their characteristic yellow color, but the color blue, for example, requires Ce-doped SrS. To obtain the red and green colors for an RGB display, manufacturers use the same ZnS used for a monochrome display, but the doping agents are more exotic chemicals than Mn. Another problem in the making of RGB displays is that you need more pixels for any given area. For example, a 640×480-pixel monochrome display translates into a 1920×480-pixel RGB display.

Cherry Electrical Products has been a leading maker of gas-plasma displays for the past 15 years. Now it's starting to be prominent in ELD arena. Cherry uses a dc thick-film approach that it claims offers advantages over the more common ac thin-film types such as simple and rugged construction, the absence of potential thin-film dielectric breakdown, and higher manufacturing yields. Moreover, the Cherry EL displays are very thin; including the electronics board, they measure less than 0.6-in. thick.

Cherry offers two 640×200-pixel EL displays with a viewing angle of 160°. The EL1C-A000 has an active viewing area of 8.96×3.9 in. The EL1C-B000 has an active viewing area of 7.68×4.8 in. The pixel size and pitch (aspect ratio) differ with the model number. The pixels in the A000 display measure 0.010×0.017 in. and have a pitch of 0.014 in. (horizontal) by 0.020 in.

With its characteristic yellow-on-black color, EL displays provide high contrast. *This electroluminescent flat-panel display from Digital Electronics Corp has an infrared touchscreen and is completely sealed in a cast aluminum case for use in harsh environments.*

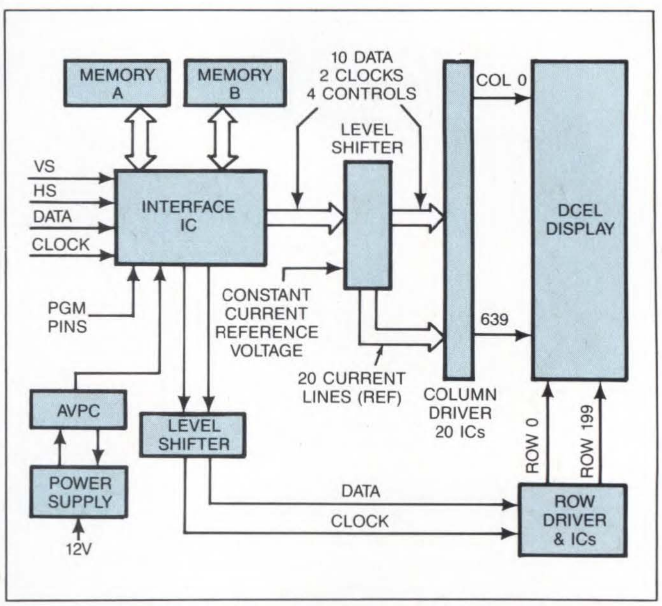

Fig 1— DCTFEL displays require specialized drive circuitry. *This circuit works with Cherry's electroluminescent models and provides data and timing signals for the row drivers and constant-current column drivers. Video data with a frame rate of 60 Hz is translated into a 240-Hz frame rate for the column drivers.*

Plasma displays are often combined with infrared touchscreen panels for use in industrial control applications.

(vertical); its aspect ratio is 1.4:1. In the B000 display, the pixels measure 0.008×0.0202 in. and have a pitch of 0.012-in. horizontal by 0.024-in. vertical; its aspect ratio is 2:1. Pixel luminance is nominally between 20 and 25 fL, and Cherry specifies less than 30% degradation in brightness over 10,000 hours. Both models sell for $565 (100) ($250 in OEM quantities).

AC thin-film vs dc thick-film displays

Although there are numerous small differences between ac thin-film (ACTFEL) and dc thick-film (DCTFEL) displays, the major difference involves the operation of the two types of displays. An ac thin-film display is capacitive in nature and its brightness is limited by drive voltage and by pulse-repetition frequency. A dc thick-film display is resistive in nature and its brightness is proportional to its constant drive current. Cherry spent several years developing its dc thick-film displays, and their successful operation owes nearly as much to their electronics drive circuitry as it does to their basic construction.

The Cherry drive circuitry **(Fig 1)** uses some custom and standard ICs from Siliconix and Texas Instruments. The interface IC provides data and timing signals for the constant-current column drivers, row drivers, and control signals. The frame rate for incoming video data is 60 Hz; for data output to the column drivers, it's 240 Hz. The higher frame rate for the column drivers provides a brighter display with less power consumption, thus lengthening the life of the EL display.

Four TTL signals—vertical sync, horizontal sync, data, and clock—control the circuit operation. The level-shifter IC converts the 5V CMOS-logic outputs of the interface IC to 12V signal levels needed for the column drivers. It also converts a 0 to 12V analog reference to a constant current capable of driving 20 column drivers. The column-driver IC provides a controlled capacitive charging current, and an illuminating current with a programmable range from 100 μA to 1 mA. The row-driver IC sinks a minimum of 200 mA when on. The power supply operates from a single 12V input. An automatic voltage- and pulse-control circuit adjusts the output of the power supply to provide a preset luminance level throughout the life of the panel. Cherry has two excellent papers on the development and construction of its EL displays and the electronic drive circuitry **(Refs 1 and 2).**

Flat-panel displays employ several different technologies and are available in a range of sizes and shapes. From simple bar graphs to displays large enough for use in computers, you have a wide choice when looking for a display to suit a particular application. LCDs, VFDs, and PDPs will likely continue to dominate

Manufacturers of flat-panel displays

For more information on flat-panel displays, contact the following manufacturers directly, circle the appropriate numbers on the Information Retrieval Service card, or use EDN's Express Request service.

Alphasil Inc
1045 Mission Ct
Fremont, CA 94539
(415) 651-3636
Circle No 650

Cherry Electrical Products
3600 Sunset Ave
Waukegan, IL 60087
(312) 662-9200
Circle No 651

Dale Electronics Inc
2064 12th Ave
Columbus, NE 68601
(402) 564-3131
Circle No 652

Digital Electronics Corp
31047 Genstar Rd
Hayward, CA 94544
(415) 489-3500
Circle No 653

Dixy Corp
24050 Madison St, Suite 102
Torrance, CA 90505
(213) 373-0555
Circle No 654

Finlux Inc
20395 Pacifica Dr
Cupertino, CA 95014
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2. Glaser, David, and George A Kupsky, "DC electroluminescent 640×200 display panel," Cherry Display Products Corp, El Paso, TX.

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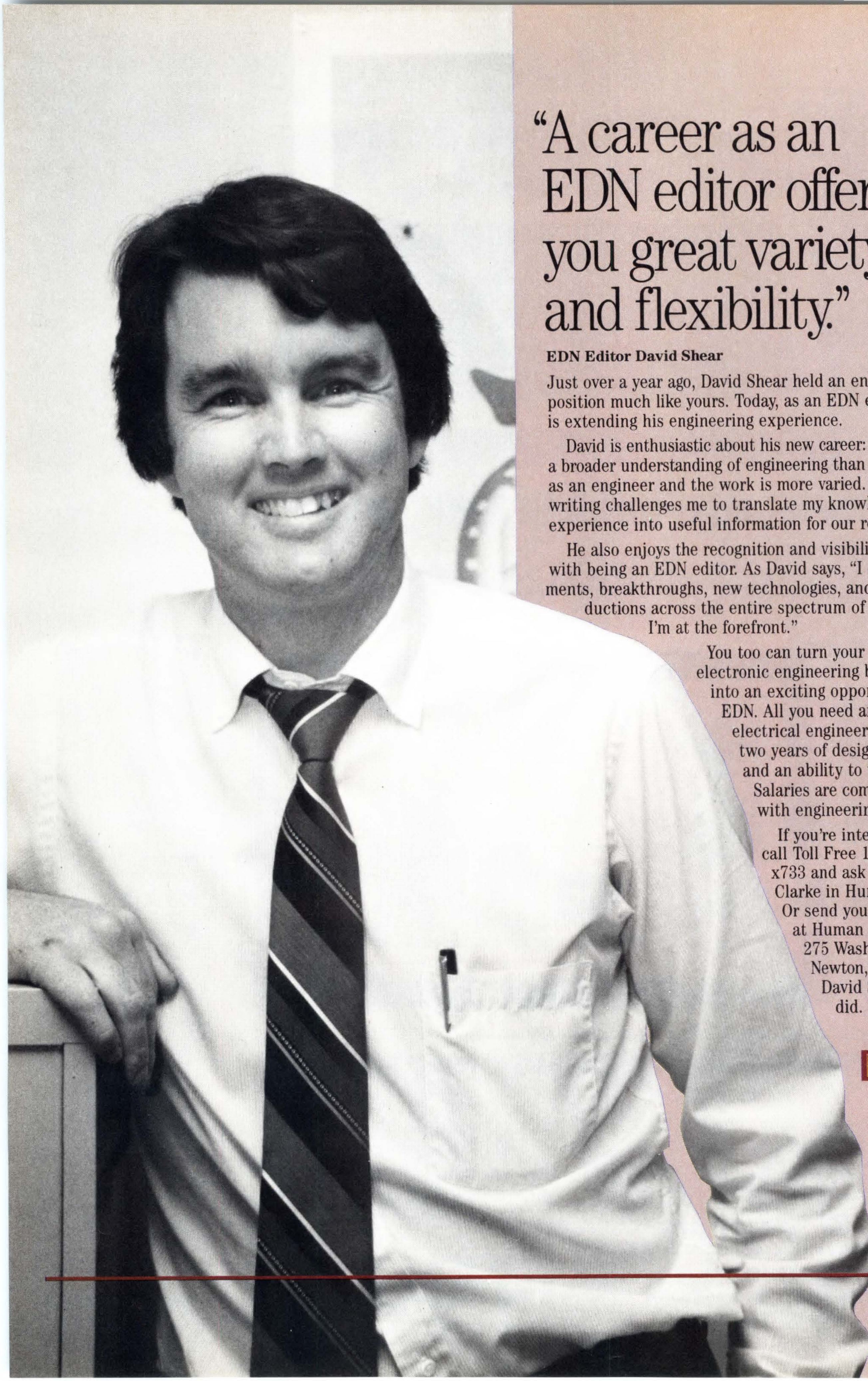

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Futaba Display	Futaba Module	Pixels (Row X Char.)	Brightness (FT-L)	Module Dimensions (in.)
GP1005B	GP1005B03	128X64	400	7.28X3.35X1.77
GP1006B	GP1006B04	256X64	200	9.84X3.35X1.77
GP1009B	GP1009B03	240X64	200	6.2X2.76X1.57
GP1010B	GP1010B01	176X16	200	7.32X2.16X1.70
GP1002C	GP1002C02	320X240	100*	7.10X6.30X1.60
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40SD42Z	M40SD42	40X1	5X12	0.344	9.45X2.16X.88
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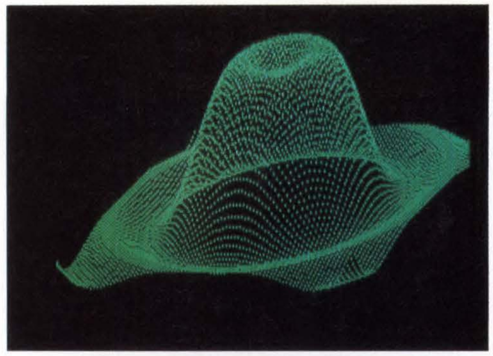

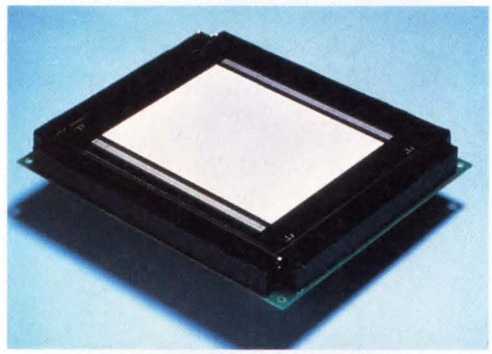

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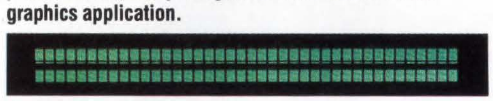

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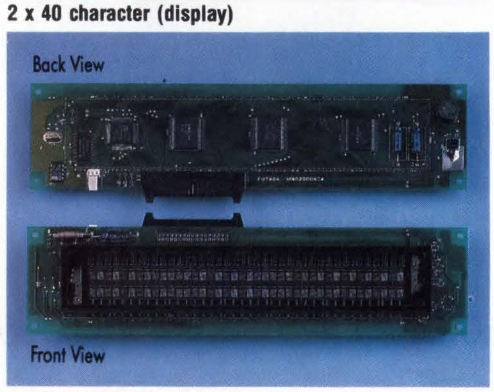

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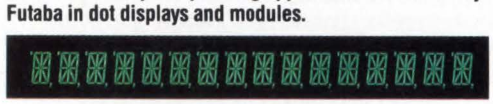

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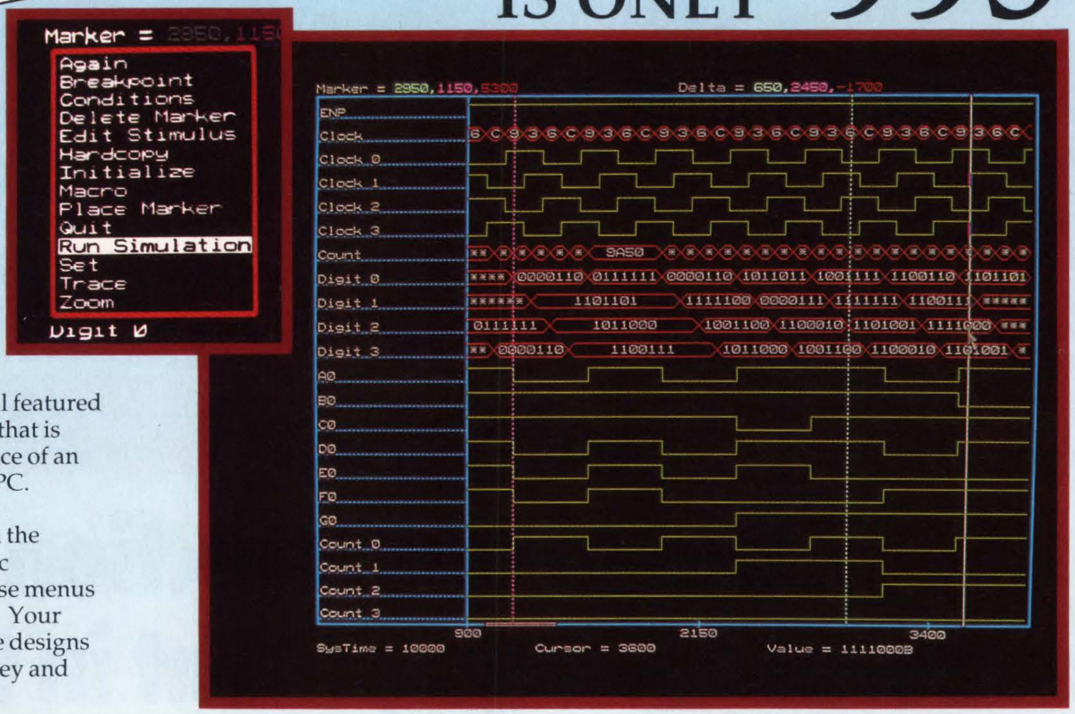

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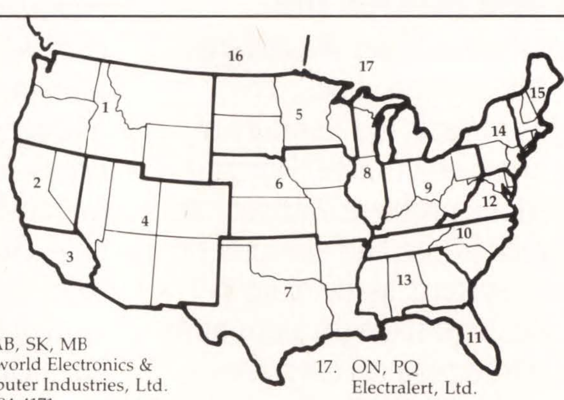

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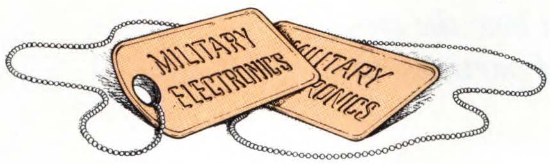

Simulation helps you design radiation-hard circuits

You no longer need to use guesswork, rules of thumb, or prohibitively expensive test protocols to predict the effects of manmade and naturally occurring radiation on spaceborne electronic assemblies. Circuit simulation can help you develop radiation-hardened designs quickly and economically.

Kevin Walsh, *Electrical Engineering Software* and Gary Lum, PhD, *Lockheed Missiles and Space Co*

To ensure the reliable operation of spaceborne electronic systems, you must consider radiation effects such as single-event upset (SEU), a condition that can bring on system failure. Circuit-simulation software can help you predict the effects of SEU on your spaceborne circuits and systems. Such software lets you model the effects of SEU on your system and identify critical circuit nodes—nodes susceptible to state changes that can cause system failure.

By combining the computer simulation with dosimetric data obtained in the lab, you can then construct a survivability profile for your system. The survivability profile defines the radiation levels your system will tolerate. With that information, you can make corrections at the design stage to harden your circuits against the effects of an SEU occurrence. (Note, however, that SEU is not the only radiation effect that you need to be concerned about. Van Allen-belt radiation, for example, can cause long-term degradation in system performance even when it doesn't cause SEU.)

Upsets result when particles hit silicon

Single-event upset occurs when a high-energy ionizing particle irradiates a circuit or passes through an IC. In spaceborne systems, SEU can result from radiation that occurs naturally in space—cosmic radiation or Van Allen-belt radiation—or it can result from manmade sources such as nuclear explosions. The most common effects of SEU are logic-bit flips in high-density circuits, including MSI, LSI, and VLSI circuits. As **Fig 1a** shows, these state changes result when charged particles deposit charge in a semiconductor device's sensitive junction region. Protons are a special case—they create nuclear reactions, each of which generates a number of secondary reactions, including nuclear recoils, that deposit charge **(Fig 1b)**. Most SEU errors are correctable or "soft" errors; usually, when a cell suffers SEU it demonstrates no degradation or change of hardware characteristics.

However, recent data indicates that SEU can cause device latchup in power MOSFETs. In such cases, SEU can cause permanent damage. If you're designing circuits for use in environments where SEUs are likely to happen, you need to understand the effects of ionizing particles on semiconductor devices so that you can protect your systems.

By analyzing models of key portions of circuits, simulation can tell you how the circuits will react when charged particles hit semiconductor surfaces.

Examining an electronic system for susceptibility to environmental radiation can be time-consuming, especially if the system consists of multiple ICs. If you know what circuits and subsystems are most likely to be affected by radiation, you can reduce the time you spend in simulating the circuit. For example, unless you take special precautions, the probability is high that SEU will alter data stored in memory elements—these elements react dramatically to SEU, and most systems contain a lot of them. It doesn't matter how data gets into a memory cell; the system can't distinguish correct information from information altered by radiation. Moreover, SEU-induced state changes can cause significant system damage. So IC memories are logical candidates for detailed simulation.

Another circuit area to explore is the registers in microprocessors. Registers often contain pointer information that, if altered, can cause the retrieval or processing of spurious data. Systems with sequential logic also suffer from potentially damaging state changes. A state change in one node can affect the proper sequencing of the signals through the logic. SEU can affect synchronous logic, but it corrupts the data only when it occurs on the clocking phase. SEU also affects analog circuits, but not as dramatically, because analog circuits typically aren't state oriented. Nevertheless, understanding the impact of SEU on analog circuits and hardening your circuits against it can make your systems more reliable.

Upset in a static RAM—a case in point

Fig 2 is a schematic of a cell in a nonvolatile RAM, a RAM that normally retains data as long as you don't remove power from it. This cell is typical of the multiple cells that make up the RAM. As a memory cell, it's particularly susceptible to SEU-induced state changes. The accumulation of charge on the nodes that make up the cell controls the cell's state. Although the simula-

Simulator makes radiation hardening easy

When you perform circuit simulation, you must be able to describe how particles interact with semiconductor material and to analyze the electrical result. The Precise ASD software package from Electrical Engineering Software provides an easy way for design engineers to describe these behaviors and simulate them. The software runs on a variety of systems, from workstations to supercomputers. The simulator's functions are mathematical expressions that can depend on time, frequency, temperature, or any variable you choose. Because the simulation program evaluates them as the simulation progresses, these functions serve to model a variety of effects, from time-dependent switches to photocurrents generated in silicon material by nuclear explosions.

You can use the package, for example, to describe what would happen if you were to connect a photocurrent generator to key silicon junctions of an IC. The derivation of the photocurrent translates into a mathematical expression that you then transfer to the Precise simulator. The photocurrent definition is:

$$I_{PP}=\gamma\cdot q\cdot g\cdot A\cdot L(\mathrm{erf}(t/\tau)-u((t-PW)/\tau))+\gamma\cdot q\cdot g\cdot A\cdot W(u(t)-u(t-PW)),$$

where I_{PP}=photocurrent in amperes, γ=dose rate in rads, $q=1.6\times10^{-19}$ coulombs, $g=4.2\times10^{13}$ carriers/(rad·cm^3), A=area of junction in cm^2, L=diffusion depth in cm, τ=minority current lifetime in sec, PW=photocurrent pulse width (duration) in sec, W=depletion depth in cm, u(x)=a unit step function of x, and erf(x)=dimensionless error function. The function erf(x) equals

$$1-(1+a_1x+a_2x^2+a_3x^3+a_4x^4)^{-4}+E(x),$$

where $a_1 \ldots a_4$ are coefficients and $E(x)\leq 5\epsilon^{-4}$.

You can use Precise to evaluate the photocurrent equation by creating a function file with the system editor and defining the expression. This expression uses a unit step-function definition, u(t−PW). To simulate what would happen when you stimulate a circuit with the function, you place dependent current sources that reproduce the function at the circuit's critical pn junctions. Simulating with this photocurrent definition can give you an indication of how the circuit would respond to the photocurrents that would be generated by a thermonuclear explotion covers a single cell, controlled sources simulate the presence of other cells. You can adjust these controlled sources to model different RAM sizes. To model the remaining cells, you multiply the source outputs by an appropriate constant.

To predict the effect of a particle's entering a circuit, you require a model for the current that's created as the particle moves though the material. As the particle passes through the depletion layer and into the substrate, it produces a track of mobile holes and electrons. These charges form along the track of the particle. The charges distort the charge distribution in the semiconductor material and cause funnel-shaped equipotential surfaces to extend into the substrate. The gradient of these equipotentials propels electrons (which are produced as the particle passes through the material) back up through the funnel, as **Fig 1a** shows.

Sufficient charge buildup will cause a change in the cell's state. If the particle passes close to the node, the charge accumulates in picoseconds. If the particle passes further from the node, the charge-collection time is on the order of nanoseconds or microseconds. The current created by the particle depends on the semiconductor material, the charge collection, and the angle at which the particle hits.

By performing simulation, you can predict what particles and particle energies will cause the memory cell to change state. First, you must analyze the circuit with a transient simulation while using dependent-current-source modeling to model the particle's motion through the material. Next, you change the current to reflect the incident particles' differing amounts of energy and the range of angles at which they hit the semiconductor. After trying different system-hardening techniques, you can compare the circuit's response to the same upset. By simulating the circuit's response to upsets, you can test alternatives quickly, accurately, and inexpensively. If your circuit-simulation program

sion **(Fig A)**.

The simulator lets you analyze the transient response while varying other parameters. This mixed-domain, or 2-dimensional, analysis gives you a family of responses based on the setting of the parameter. You can add a third dimension with the SET command. In this case you might use SET to establish a third analysis dimension in which pulse width (PW) is a parameter.

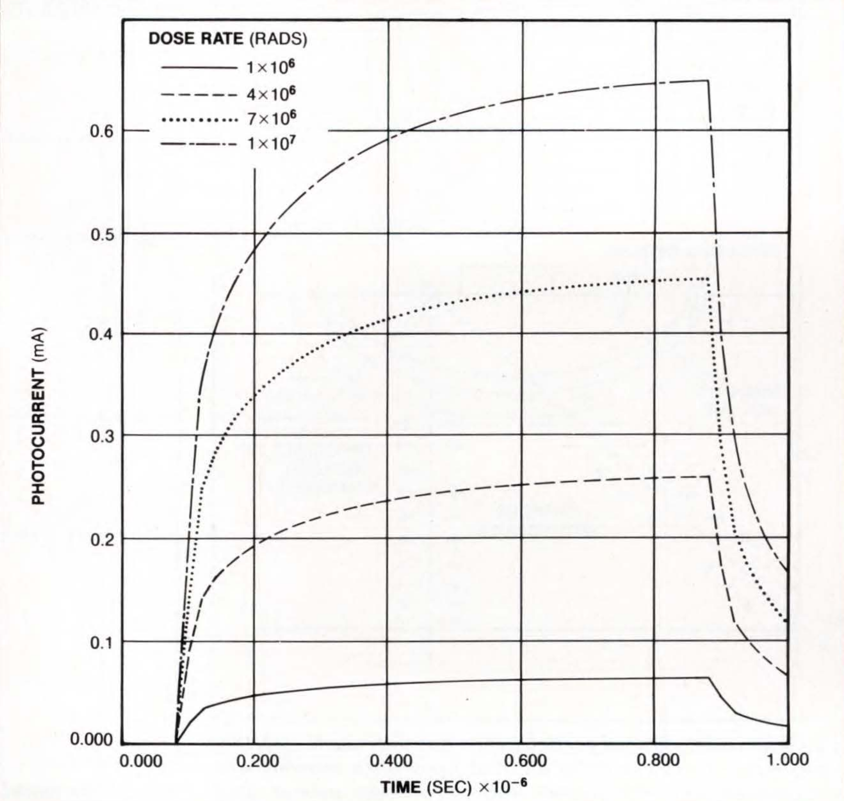

Fig A—A simulated photocurrent source *shows a current buildup that reaches its final value in under a microsecond.*

The most common effects of single-event upset are logic-bit flips in high-density circuits, including MSI, LSI, and VLSI circuits.

permits you to use a flexible definition of current, it can provide a picture of the survivability of the circuit state as particles with different energy hit the cell at varying angles of incidence.

Equations describe the SEU function

The simulator models the effect of a particle passing through a RAM by placing a current source on the RAM circuit, as **Fig 2** illustrates. The current source is in parallel with the transistor on which the particle can have the most effect, given the circuit configuration. In this case, the most susceptible transistor is Q_4—because

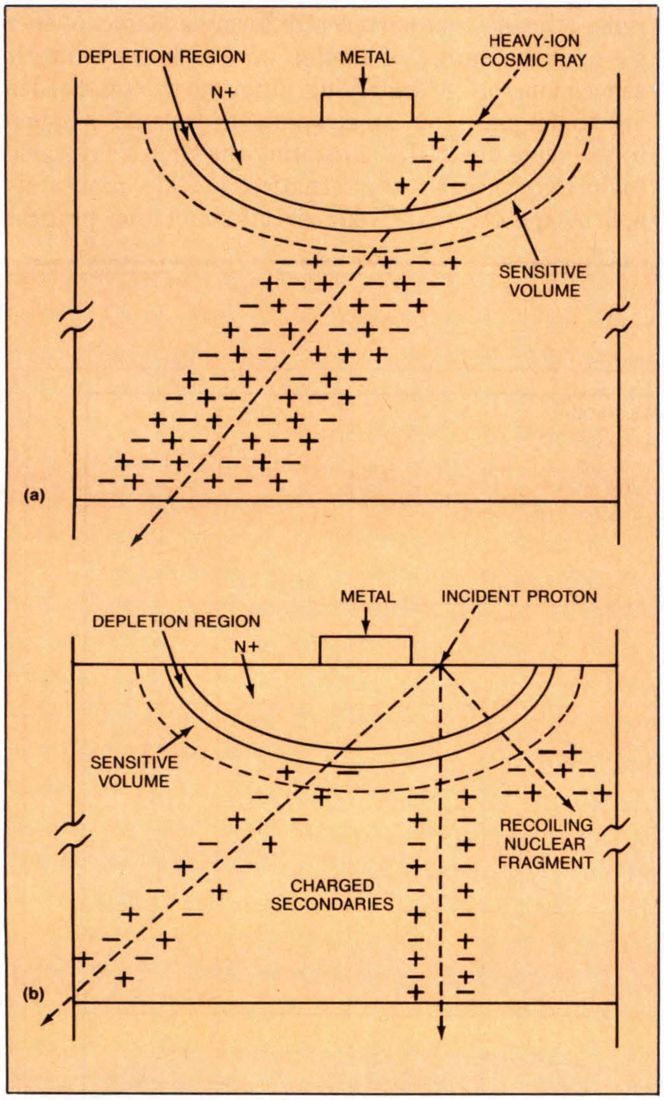

*Fig 1—**When most charged particles** enter a semiconductor die, they deposit charge in regions of the die, and hence often interfere with device function **(a)**. Protons create nuclear reactions, each of which generates secondary reactions that deposit charge **(b)**.*

OUT_2 is high. Over time, current builds up at the OUT_1 node. This current changes the basic state of the node. The analytical approximation of the current is:

$$I(t)=I_0\sec\theta(\epsilon^{t/\alpha}-\epsilon^{t/\beta}),$$

where I_0 is approximately the maximum current; θ is the angle of incidence of the particle to the IC; α is a collection time constant of the junction; and β is the time constant for initially establishing the ion track. Typical values for α and β are 150 psec and 40 psec, respectively. The maximum current, I_0, is proportional to the energy of the particle and the doping profile of the semiconductor material. I_0 varies according to the particle type—heavy ions, alpha particles, or protons. The total current increases as the angle of incidence varies from grazing to near normal.

If you formulate the basic equation as a time-dependent function, you can analyze it with a simulator such as Precise (see **box,** "Simulator makes radiation hardening easy"). Precise lets you define and name the function in an independent file so you can easily reference it in different circuit locations. You place the current-source element, which references the function, on the latch node of the RAM cell **(Fig 2)**.

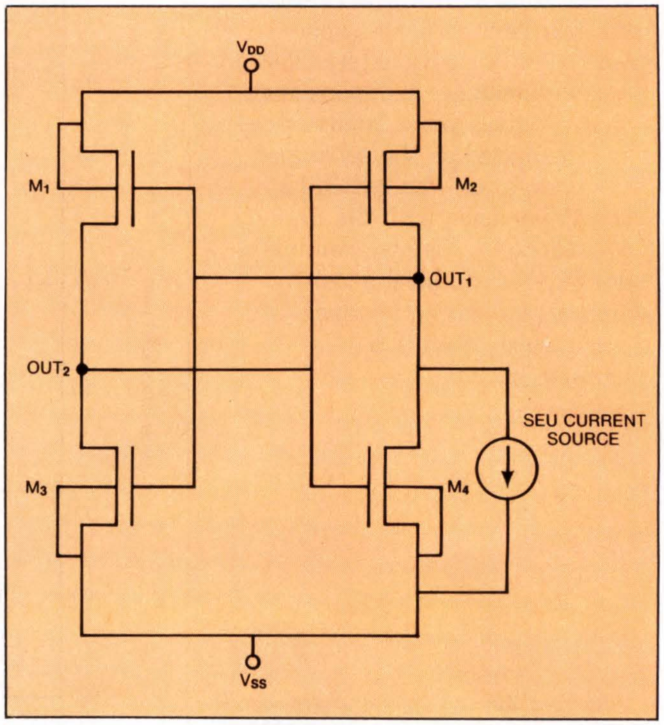

*Fig 2—**You model the effect of radiation** on this static-RAM cell by placing a current source in parallel with one transistor.*

In Precise notation, the function called "SEU" is defined thus:

FUNCTION SEU(I0,ANGLE)
I0*1/COS(ANGLE)*[EXPN(TIME/150PS)-EXPN(TIME/40PS)].

The current source, which represents the SEU function, is defined as:

ISEU Node1 Node2 SEU(I0,ANGLE),

where ISEU is the current-source definition, Node1 and Node2 define the connection of the source to the circuit, and SEU is a call to the current function that defines the particle's penetration of the semiconductor material vs current and time. You define the function by using a simple mathematical syntax available in the Precise simulator. This special language syntax lets you define behaviors quickly and easily. In this case, the function definition takes advantage of the language syntax that allows TIME to appear as a variable in the function. In addition, the SEU function has two arguments: I_0 passes into the function and takes values based on the particle of interest and the doping profile; ANGLE is the value that determines how the particle strikes the semiconductor material.

Fig 3 shows the actual current generated from the SEU function by a particle (whose energy is represented by an I_0 of 0.5 mA) that strikes the IC die at incidence angles ranging from 0.1 to 1.3 radians (approximately 6 to 70°).

Ready . . . set . . . simulate!

You now simulate the RAM cell to see its response to the application of a selected particle energy at different angles. Precise's mixed-domain capability allows you to vary two different domains in the same simulation. In this case, you vary time and particle angle. The SEU function changes the amount of current delivered to the node during the transient analysis. While holding I_0 constant at 0.5 mA, you vary ANGLE from 0.1 radians to 1.1 radians. **Fig 4** shows the result as a family of curves that represents the cell reaction to the particle current's striking at different angles. The grazing angle of 0.1 radians does not cause the cell to change state. However when the angle reaches 1.1 radians, the current is sufficient to change the state of the cell. The penetration of a charged particle and its subsequent

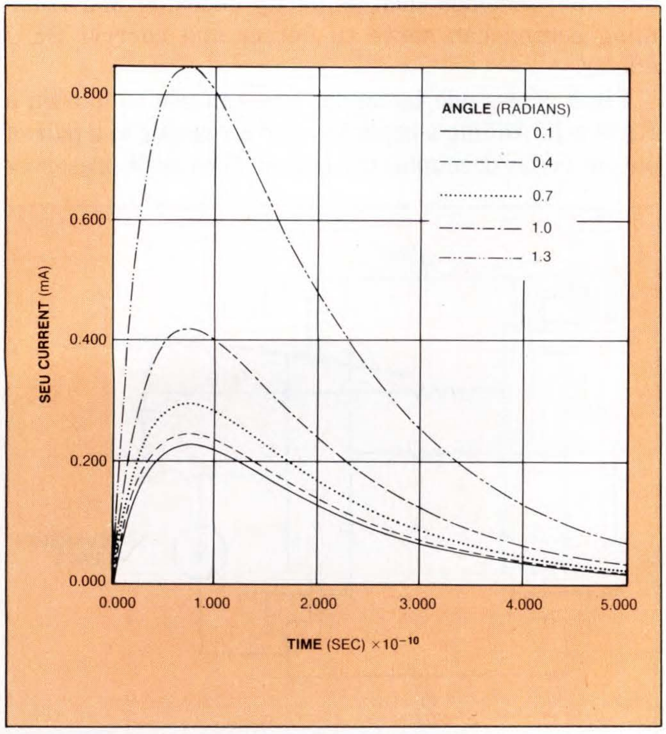

Fig 3—When particles of a given energy level *strike a silicon die at angles of 0.7 radians or less, the peak current barely exceeds 0.2 mA. At larger angles, the current increases rapidly, though.*

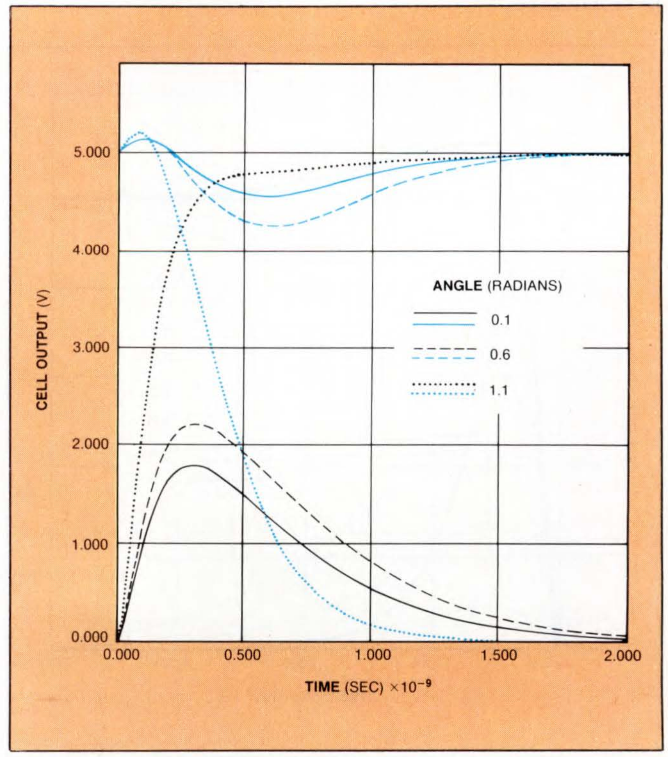

Fig 4—A particle striking the static-RAM cell *at an angle of 1.1 radians or more will change the cell's state from 0 to 1 or from 1 to 0.*

Unless you take special care, SEU will probably alter data stored in memory elements—and most systems have a lot of memory elements.

reaction with the semiconductor material at this current and angle is an SEU that causes a state change in the RAM cell.

For further analysis, you next set the particle angle at the nominal value of 0.7 radians. To see how sensitive the cell is to particles of different energy, you now simulate a variation in particle energy. You use particle energies that result in currents ranging from 0.1 to 1.1 mA. The resulting graph **(Fig 5)** shows how level shift varies with particle energy for this range of currents.

Hardening isn't necessarily hard to do

The modifications necessary to minimize the effects of SEU on your assemblies fall into three design categories: process, chip, and system. Your choice of a hardening approach will depend on your design objectives and the cost of the approach. Techniques for hardening circuits, for example, usually increase circuit costs by increasing die size or adding circuit elements for decoupling. Further, because it introduces large RC time constants, decoupling can also reduce circuit speed. You must judge each hardening technique on its effectiveness, its cost, and its effect on the system's performance.

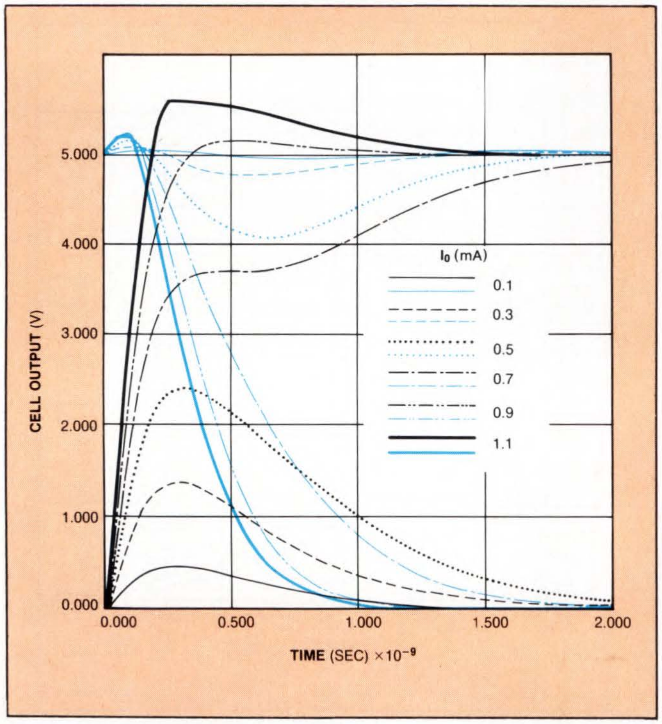

Fig 5—As incident-particle energy increases, *the cell's output shifts but returns rapidly to its original level. Particles whose energy exceeds a threshold level cause the cell's state to flip.*

Certain semiconductor-fabrication processes minimize SEU by using epitaxial silicon structures to truncate the charge-funneling effect. SOS (silicon-on-sapphire) or SOI (silicon-on-insulator) devices can serve this purpose. These devices can be very thin, having shallow junctions, in order to minimize the interaction time of the particles with the junctions. Retrograde junctions or buried, heavily doped layers can also help to preserve the state of the cell.

In chip design, varying the geometry to increase device widths can help preserve the cell state. By both varying the device geometry and increasing the supply voltage, you can achieve a fairly high level of hardness with relative ease. The use of decoupling resistors and capacitors or diodes can preserve the state of a latch. Adding local circuit redundancy by including additional components can strengthen nodes' resistance to state changes. You should examine the critical paths of sequential circuits for susceptible nodes. If several flip-flops are connected in series, path isolation or decoupling can prevent the propagation of an error that occurs when the state of the first flip-flop changes. Finally, from a systems point of view, using error-detection schemes such as parity checking and Hamming coding can serve to detect and correct SEU effects.

Fig 6 shows one technique you can use to harden a RAM cell. Adding a capacitor and a resistor to a pair of output nodes decouples the nodes. The result preserves

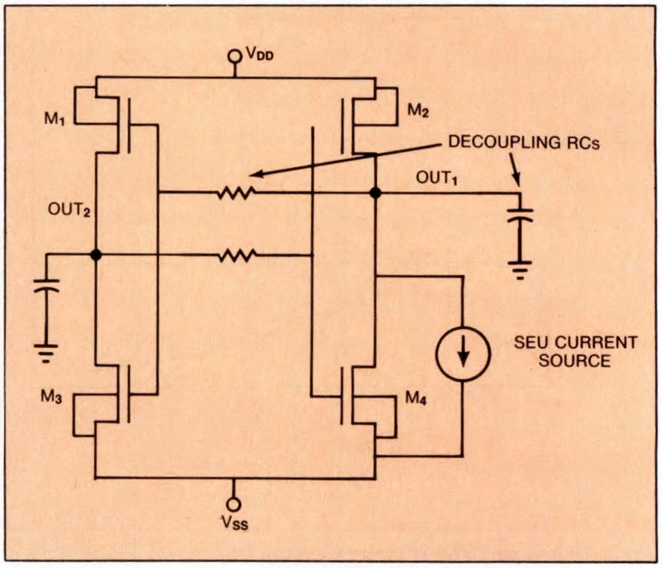

Fig 6—Adding a pair of RC networks *to the static-RAM cell yields a hardened design without requiring you to change the device geometries or the fabrication process.*

With simulation, you can predict what particles and particle energies will cause a memory cell to change state.

the charge on the node during an upset, making the circuit less likely to switch states.

To study the impact of the added components, you can run another transient simulation. From **Fig 7** you can see that the particle energy that caused a change in the cell state no longer has an effect; however, the additional components increase the circuit's complexity. You can also change the device geometries to prevent an upset from causing a shift in state. Because it doesn't increase circuit complexity, changing geometry can be more cost effective than adding components. You can easily test this hardening alternative by changing the device dimensions and resimulating. To study the cell reaction to the SEU function, you set up the device dimensions as Precise variables and conduct the simulation with varying device widths and lengths.

Simulation helps raise reliability

Analyzing SEU by using simulation is an effective means of identifying potential circuit problems before they occur in production systems: In effect, simulation lets you harden a system before building it. Further, simulation is a cost-effective alternative to dosimetric prototyping for SEU analysis. Finally, circuit simulation is a fast and accurate method of studying different hardening techniques for overall effectiveness. Although the example presented here addresses only SEU, simulation is just as useful for analyzing other environmental effects on circuits—for example, temperature and mechanical stress—as well as the effects of parameter variation in manufactured components.

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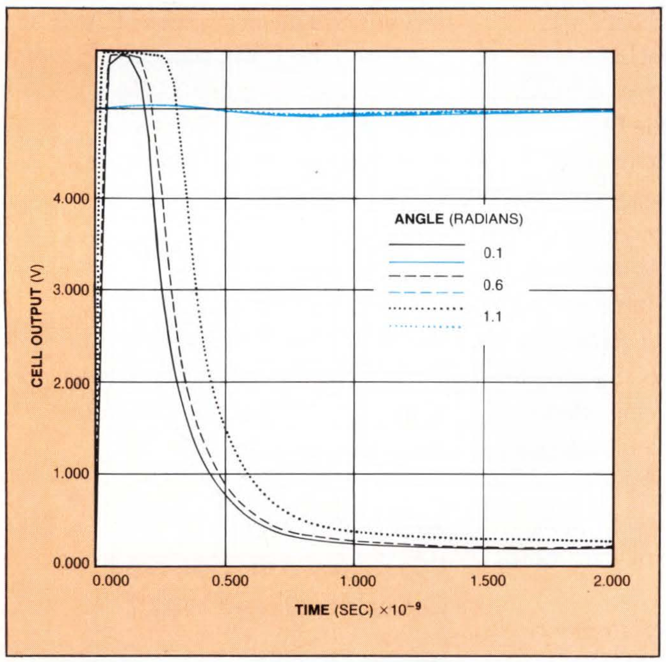

***Fig 7—When you add components to the design** and run another transient simulation, you find that particles that caused the original cell to change states no longer affect the cell's output.*

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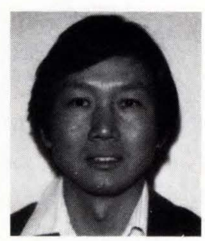
Authors' biographies

Kevin Walsh is vice president of marketing at Electrical Engineering Software (Santa Clara, CA), where he has been employed for three years. He holds a BS in electrical engineering and computer science from the University of California at Berkeley. Kevin has been working in the computer software field for over 10 years. He is a member of IEEE, and in his spare time he enjoys sailing, skiing, and golf.



Gary Lum is a staff engineer and device physicist at Lockheed Missiles and Space Co (Sunnyvale, CA). He has been with the company for six years. He holds a BS in physics from the University of California at Berkeley and MS and PhD degrees in physics from the University of Oregon. Before joining Lockheed, he worked at Intel on the development of large-capacity EEPROMs. Gary is a member of the American Physical Society, and is too engrossed in his work to list any spare-time activities.

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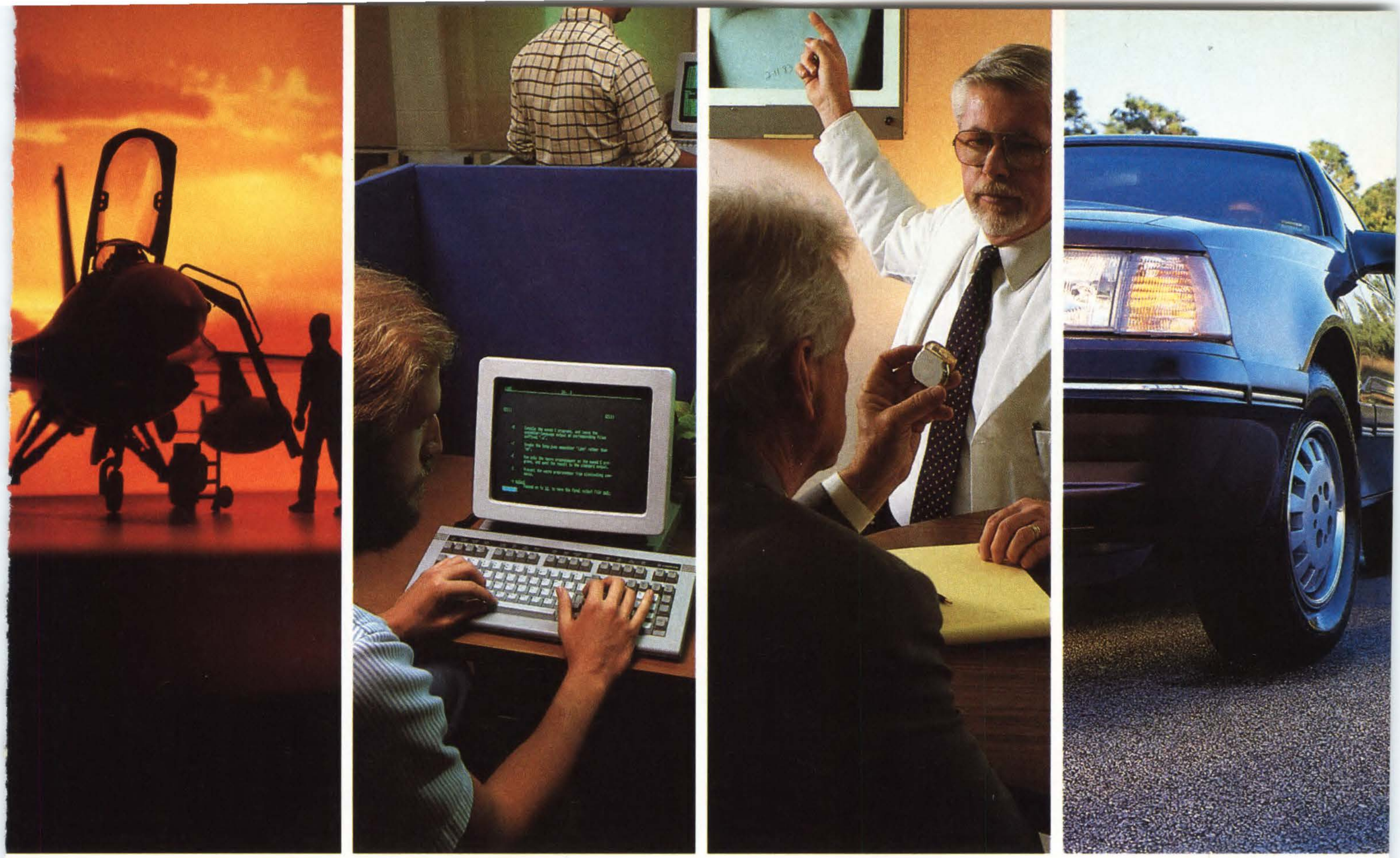

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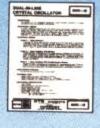

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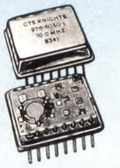

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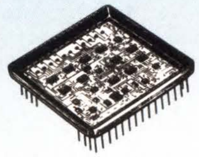

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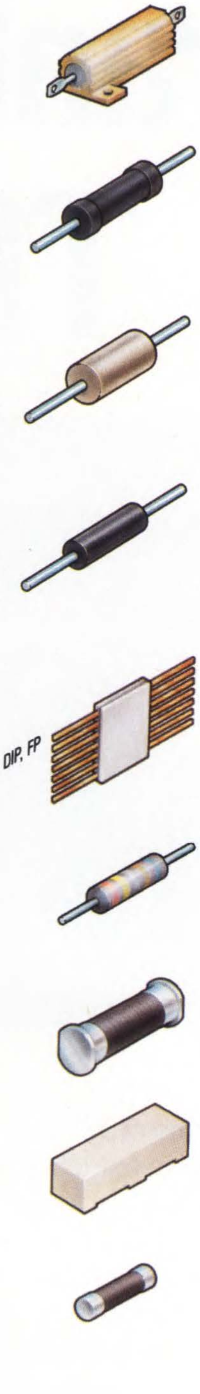

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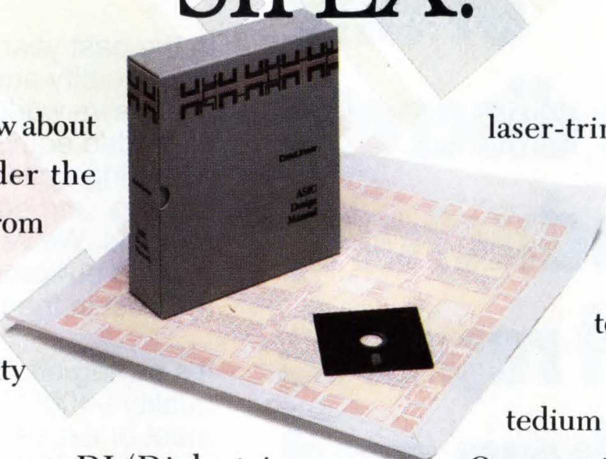

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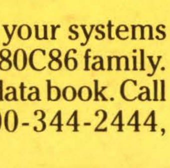

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Peer-to-peer protocol facilitates real-time communications

The low communications overhead of the CSMA/DCR peer-to-peer protocol makes it desirable for real-time network applications. Further, the protocol's guaranteed network-access time relieves the designer from worst-case haunts.

Deif N Atallah, *Intel Corp*

By definition, real-time-communication networks need to transfer information between nodes as quickly as possible. Preferably, these transfers should occur within a guaranteed maximum time limit. Networks have traditionally achieved real-time communications via some type of master/slave protocol, contention-based protocol, or token-based protocol—each with their own advantages and disadvantages. A relatively new contention-based protocol, based on the advantages of each of these methods, enhances the information-transfer rate of a real-time network.

A master/slave protocol is a popular method for real-time communications because it guarantees that all the nodes on the network will gain access. Examples include the Synchronous Data Link Control (SDLC) and High Level Data Link Control (HDLC) protocols. A master/slave protocol requires the management of a significant amount of overhead, however, which in itself occupies valuable bandwidth. A master node has to first poll the slave nodes to initiate communication, and it must then take control of the link to ensure that communication takes place. If the network has multiple masters, they must arbitrate for control of the network, so that a maximum access time cannot be guaranteed.

Token-passing protocols, in contrast, guarantee a maximum access time for each node on the network by sequentially passing a token around to each node. To avoid contention, each node must acquire the token before transmitting information. Even if the network is quiet, however, a node must wait until the token goes all the way around the network. If there are many nodes on the network, the guaranteed maximum access time can be long. Examples of token-passing protocols are the IEEE 802.4 and 802.5.

A peer-to-peer communication protocol such as the Carrier Sense Multiple Access with Collision Detection (CSMA/CD), which is what Ethernet uses, has low communications overhead. It can't guarantee a maximum access time to the network, however, because it resolves contention problems statistically. The CSMA/CD lets a node monitor the network for a quiet period in which to send its message. If messages from two nodes collide, the two nodes have to wait for a random interval of time and then they attempt to retransmit. Although you can choose network parameters to minimize the

The CSMA/DCR protocol guarantess a maximum access time to the network, yet it has the same low communications overhead as the CSMA/CD.

probability of successive collisions, you can't be guaranteed of a maximum access time because of the protocol's nondeterministic recovery mechanism.

Determinism offers a guarantee

A variation of the CSMA/CD protocol, the CSMA/DCR (deterministic collision resolution), merges the advantages of the aforementioned protocols. The protocol features the same low communications overhead as the CSMA/CD, yet guarantees a maximum access time to the network.

The protocol operates in a peer-to-peer CSMA/CD mode until a message collision occurs. Any node on the network can initiate communications without polling for a response. This lack of polling overhead maximizes the link's bandwidth. Essentially, the physical layer of the OSI (open system interconnection) model looks for opportunities to transmit by monitoring the network's activity. This network-access scheme, coupled with the guaranteed access time of the resolution phase, produces a very efficient network even during heavy traffic conditions.

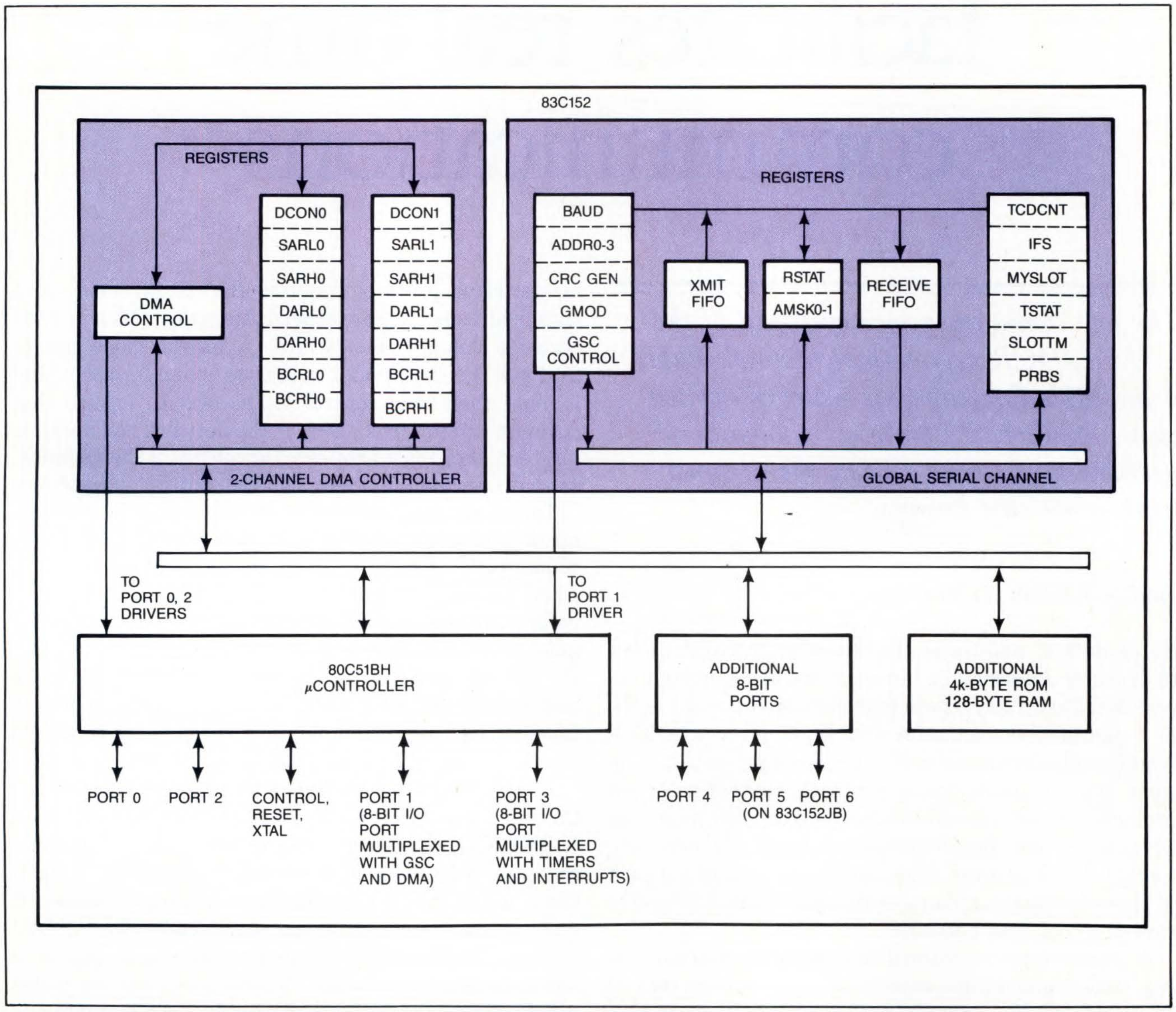


***Fig 1—The 83C152 communication controller** has a multiprotocol Global Serial Channel (GSC) and two DMA channels functioning as peripherals for the 80C51BH μcontroller. Different versions of the 83C152 offer additional ports.*

When a collision takes place, all of the nodes on the network, regardless if they are involved in the collision, enter into something called a resolution phase. The worst-case access time is equal to the maximum time of the resolution phase, which you can calculate from the network's configuration and parameters. During the resolution phase, the protocol assigns each node on the network a programmable time slot for data transmission. During its alloted time slot, a node has the option of transmitting a message. The node's maximum allocated frame length determines the length of the message. This type of recovery sequence eliminates the possibility of successive collisions.

A single IC can do it all

The Intel 83C152 is an example of a single-chip VLSI communication controller that implements the CSMA/DCR protocol **(Fig 1)**. (It implements several others as well, including the CSMA/CD protocol.) The IC has an 80C51BH microcontroller core that contains an asynchronous serial port, 4k bytes of ROM, 128 bytes of RAM, four 8-bit parallel-I/O ports, and two 16-bit timer/counters. The IC also has an extra 4k bytes of ROM and an extra 128 bytes of RAM.

The core interfaces to two on-chip peripherals: a 2-channel DMA controller, and a multiprotocol serial channel, the Global Serial Channel or GSC. The DMA channels service both the GSC and the local serial channel. The DMA channels offload the communications overhead from the CPU and arbitrate for shared-memory resources via a hold and a hold-acknowledge bus-access control. The 83C152 interfaces to a serial backplane through open-collector drivers and receivers. To drive larger networks, it uses active drivers such as RS-485 transceivers **(Fig 2)**.

Initially, the user code loads the network parameters, including the nodes' slot position, the interframe space (IFS), the slot time (ST), and the maximum number of slots for the network, into the GSC's internal registers. The controller permits 63 nodes on the network to participate in collision resolution. The network can also have an additional node that doesn't participate in collision resolution. The controller must assign slot number 0 to this additional node to prevent it from transmitting during the resolution phase. A data-gathering station would be a typical example of a node with slot number 0.

During the resolution phase, the slot numbers decrement from the maximum number of nodes on the network to slot number 1. The GSC loads the prepro-

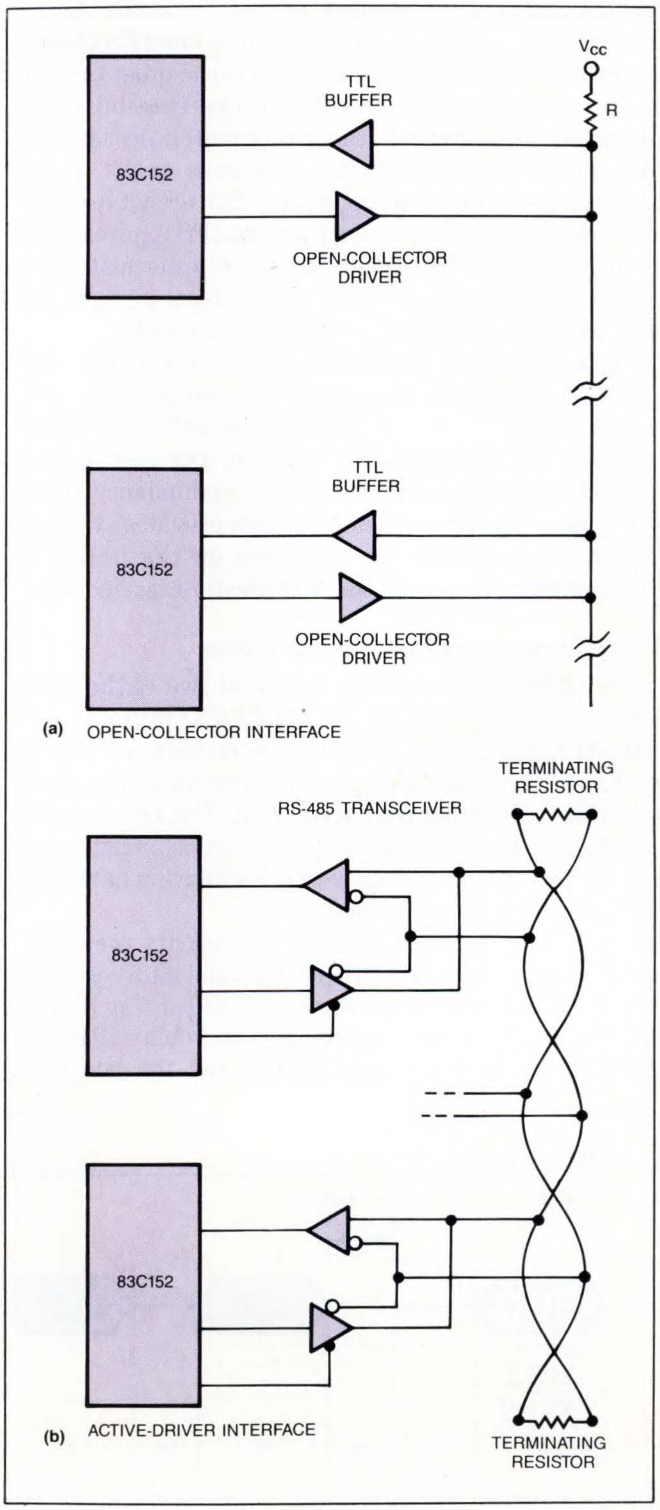


***Fig 2—You can interface** the 83C152 to a backplane using open-collector TTL buffers **(a)**. The multiprotocol controller can also interface to larger networks via RS-485 transceivers **(b)**.*

During the resolution phase, the CSMA/DCR protocol assigns each node on the network a time slot for data transmission.

grammed maximum number of slots into the decrementing slot counter. It must then wait one IFS after it senses that the link is idle. The IFS is the quiet time on the network between successive frame transmissions. Following this interval, the slot counter decrements when either of the following conditions occur: A slot time expires without detecting any link activity, or the controller detects link activity and an IFS expires after the link becomes idle. When the slot counter matches a node's assigned slot number, the protocol permits the node assigned to that slot number to transmit.

Fig 3 depicts the resolution phase of a 6-node network. The CSMA/DCR protocol encapsulates data into frames similar to the CSMA/CD protocol: Each frame consists of a preamble bit pattern, the destination address, a message field, and cyclic-redundancy check (CRC) bits. The preamble bit pattern provides synchronization data for all the receivers on the network, allowing them to decode the Manchester-encoded data.

Now you can calculate the worst case

The CSMA/DCR protocol relies on two of the same network parameters that the CSMA/CD protocol uses—the IFS and the ST. The network nodes must wait at least one IFS while doing peer-to-peer communications and when recovering from a collision. The IFS also lets the physical medium recover after a transmitted frame and ensures that the other network sublayers have time to synchronize data for transmission.

The ST, or collision window, represents the maximum amount of time that there is invalid data resulting from a collision on the network. It is at least as long as the sum of the round-trip propagation delay (RPTD), the collision-detection time (CDT), and the jam time

TABLE 1—NETWORK PARAMETERS

DATA PROTOCOL	CSMA/DCR
DATA RATE	2M BPS
NETWORK LENGTH	500m
WORST-CASE ACCESS TIME	8 mSEC
INTERFRAME SPACING	96 BIT PERIODS = 48 μSEC
JAM TIME	32 BIT PERIODS = 16 μSEC
COLLISION-DETECTION TIME	1 BIT PERIOD = 0.5 μSEC
SLOT TIME	64 BIT PERIODS = 32 μSEC
ROUND-TRIP PROPAGATION DELAY	4.7 μSEC ≈ 10 BIT PERIODS

(JT). The RPTD is equal to twice the network length divided by the propagation speed (approximately 2.1×10^8 msec). The CDT is the time required for the circuitry to detect a collision. The JT lasts for either a 16 or a 32 bit period, depending on the number of CRC bits you program into the 83C152. The 83C152 detects a collision on every bit by verifying whether the transitions of the Manchester code are valid.

The 83C152 programs the IFS and the ST in multiples of the bit period. (A bit period is the inverse of the bit rate). The controller programs each IFS and ST independently; the maximum length of each can be 256 bit periods. During the resolution phase, the calculated worst-case access time is equal to the ST plus an IFS plus the sum of the maximum frame time alloted for each node and an IFS for each frame. In other words:

$$\text{Access Time(WC)} = \text{ST} + \text{IFS} + \Sigma(\text{Maximum Frame Time}(i) + \text{IFS}),$$

where the access time(WC) is the worst-case access

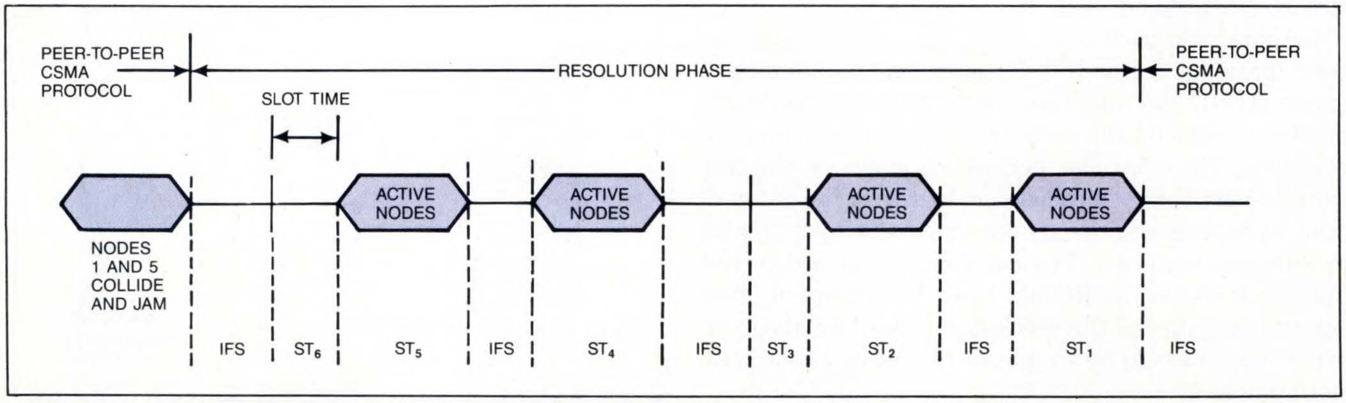


***Fig 3—In this sample configuration of a 6-node network** operating with the CSMA/DCR protocol, nodes 1 and 5 collide during peer-to-peer CSMA communications. When the network becomes idle, all the nodes on the network enter the resolution phase. After an interframe space (IFS), the slot counter decrements from ST_6 to ST_1. Active nodes transmit frames during their respective slot assignments.*

time; the ST>RTPD+CDT+JT as stated above; the sum takes into account all the nodes on the network; and the maximum frame time(i) is the maximum frame time of the *i*th node.

When all of the network nodes have the same maximum frame time size, the worst-case access time is

$$\text{Access Time(WC)} = \text{ST} + \text{IFS} + n \times (\text{Maximum Frame Time} + \text{IFS}),$$

where n is the number of nodes on the network. In both formulae, the frame time is equal to the number of bits in a frame divided by the bit rate.

An example will help to illustrate how the network parameters determine the access time. Consider the case of a 2M-bps control network that communicates over a data link having 32 nodes. Two of the nodes have a maximum frame size of 500 bytes, which is typical of a motor controller. The remaining 30 nodes have maximum frame sizes of 20 bytes, which is typical for devices such as sensors and valves. For this sample network, and for the accompanying network parameters listed in **Table 1**, the worst-case access time is approximately 8 msec.

Because the CSMA/DCR protocol guarantees a maximum access time, you can adjust the network parameters for optimum operation. For the same 2M-bps network, **Fig 4** shows the variations in worst-case access time that result when you manipulate two network parameters—the maximum frame size and the number of network nodes. Curves for other network parameters are similar, and therefore you can custom-

LISTING 1—SAMPLE CODE FOR THE 83C152's GSC

```
MOV GMOD, #7CH          ; select CSMA protocol, Manchester
                        encoding, 32-bit preamble, 32-bit
                        Autodin CRC, alternate back-off,
                        transmitter operation with internal baud
                        generator and 16-bit addressing.
CLR DMA                 ; select GSC operation without DMA
MOV BAUD, #00H          ; set baud rate to 2 Mbps for 16 MHz
                        clock
ANL PCON, #0F7H         ; select receiver operation with
                        internal baud generator
MOV ADR0, #05H          ; set first station address to 1005H
MOV ADR1, #10H
MOV ADR2, #06H          ; set second station address to 2006H
MOV ADR3, #20H
MOV IFS,  #060H         ; set Interframe Spacing to 96 bit times
MOV SLOTTM, #40H        ; set Slot Time to 64 bit times
MOV TCDCNT, #20H        ; set maximum number of stations to 32
MOV PRBS, #0FFH         ; freeze the Pseudo-Random Binary
                        Sequence generator for proper DCR
                        operation
MOV MYSLOT, #0C5H       ; select station slot assignment to 5,
                        select DCR mode and DC-type jam.

     Depending on the application, the transmitter and the
receiver can be enabled when required using the following
instructions:

SETB TEN                ; enable the transmitter
SETB GREN               ; enable the receiver
```

ize a network to meet a specified worst-case access time.

At first glance, you might think that you could tailor a network so that the nodes with the higher slot numbers would have lower access times than the nodes with lower slot numbers. After all, the slot counter decrements from a high count to a lower one. Consider the following worst-case scenario, though. The network is in a resolution phase and the slot counter is at a count equal to n. At this time, say, the node with an assigned slot number of n+1 receives an interrupt and wants to

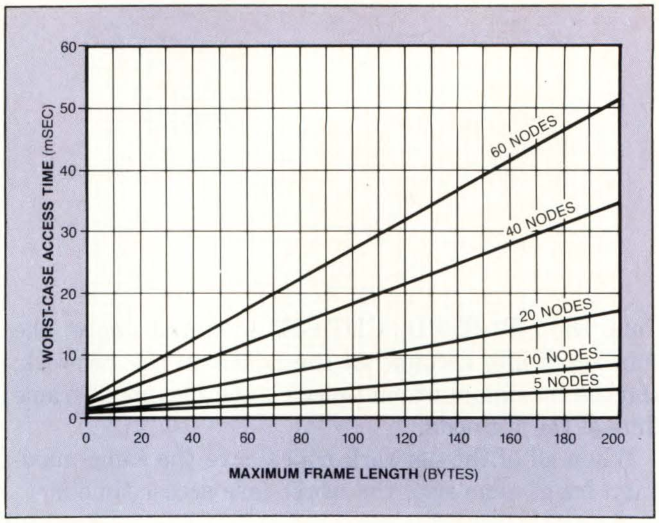


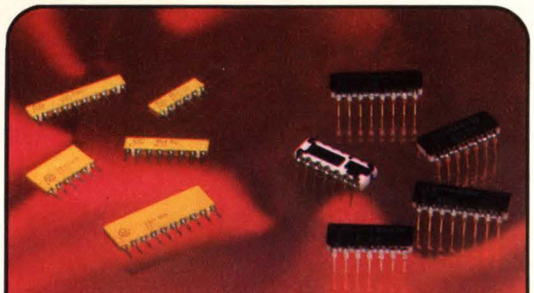
*Fig 4—**This graph plots the worst-case access time** for a 2M-bps CSMA/DCR network having the same length, interframe space, and slot time as the one in **Fig 3**. As you can see, the worst-case access time varies according to the number of nodes and the maximum alloted frame length per node.*

LISTING 2—SAMPLE CODE FOR THE 83C152's DMA CHANNELS

```
SETB DMA                    ; select DMA to service transmitter (DMA
                            is a bit in TSTAT register)
MOV DCON0, #88H             ; select DMA channel 0 for transmitter,
                            DMA demand mode by serial channel and
                            external memory as source.  The GO bit
                            is not set yet.
MOV DCON1, #29H             ; select DMA channel 1 for receiver, DMA
                            demand mode by serial channel and
                            external memory as destination.  The GO
                            bit is set.
MOV SARH0, #10H             ; Source for channel 0 is memory
                            starting at
MOV SARL0, #00H             ;    address 1000H
MOV DARH0, #00H             ; Destination for channel 0 is Transmit
                            FIFO
MOV DARL0, #85H
MOV BCRH0, #00H             ; Transmit a count of 10 bytes
MOV BCRL0, #0AH
MOV SARH1, #00H             ; Source for channel 1 is Receive FIFO
MOV SARL1, #0F4H
MOV DARH1, #20H             ; Destination for channel 1 is memory
MOV DARL1, #00H             ;    starting at address 2000H
MOV BCRH1, #00H             ; receive up to 64 bytes
MOV BCRL1, #40H

     Depending on the application, the transmitter and the
receiver are enabled when required using the following
instructions:

SETB TEN                    ; enable the transmitter and then set
                            the GO
ORL DCON0, #01H             ;      bit for the DMA to start
                            transmission.
SETB GREN                   ; enable the receiver
```



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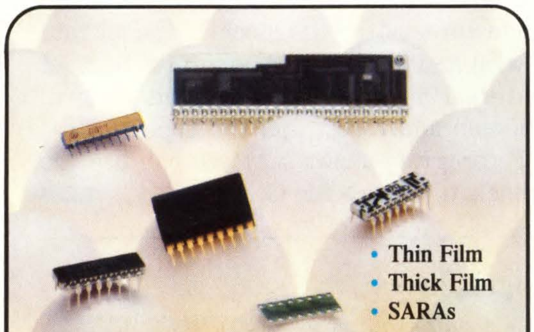

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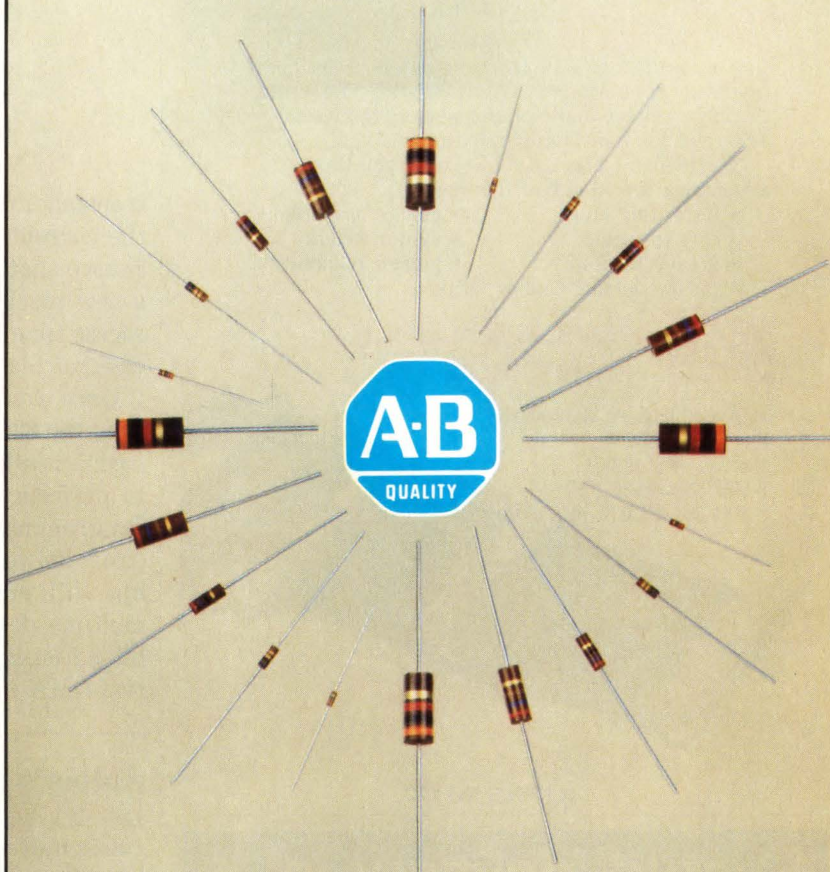

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transmit immediately. Before the node can transmit, the current resolution phase must count out, and if by chance another collision occurs at the end of that phase, a new resolution phase must begin to decrement. The access time for the n+1 node would then be the worst-case calculated value.

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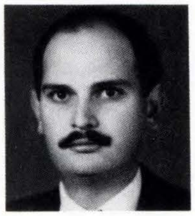
Author's biography



Deif N Atallah is a staff engineer with Intel's Embedded Operation Group in Chandler, AZ. He is currently responsible for the product architecture of 32-bit embedded controllers. He obtained his BSEE from Alexandria University, Egypt, and his MSEE degree from Penn State University. Deif enjoys world traveling, camping, and photography.

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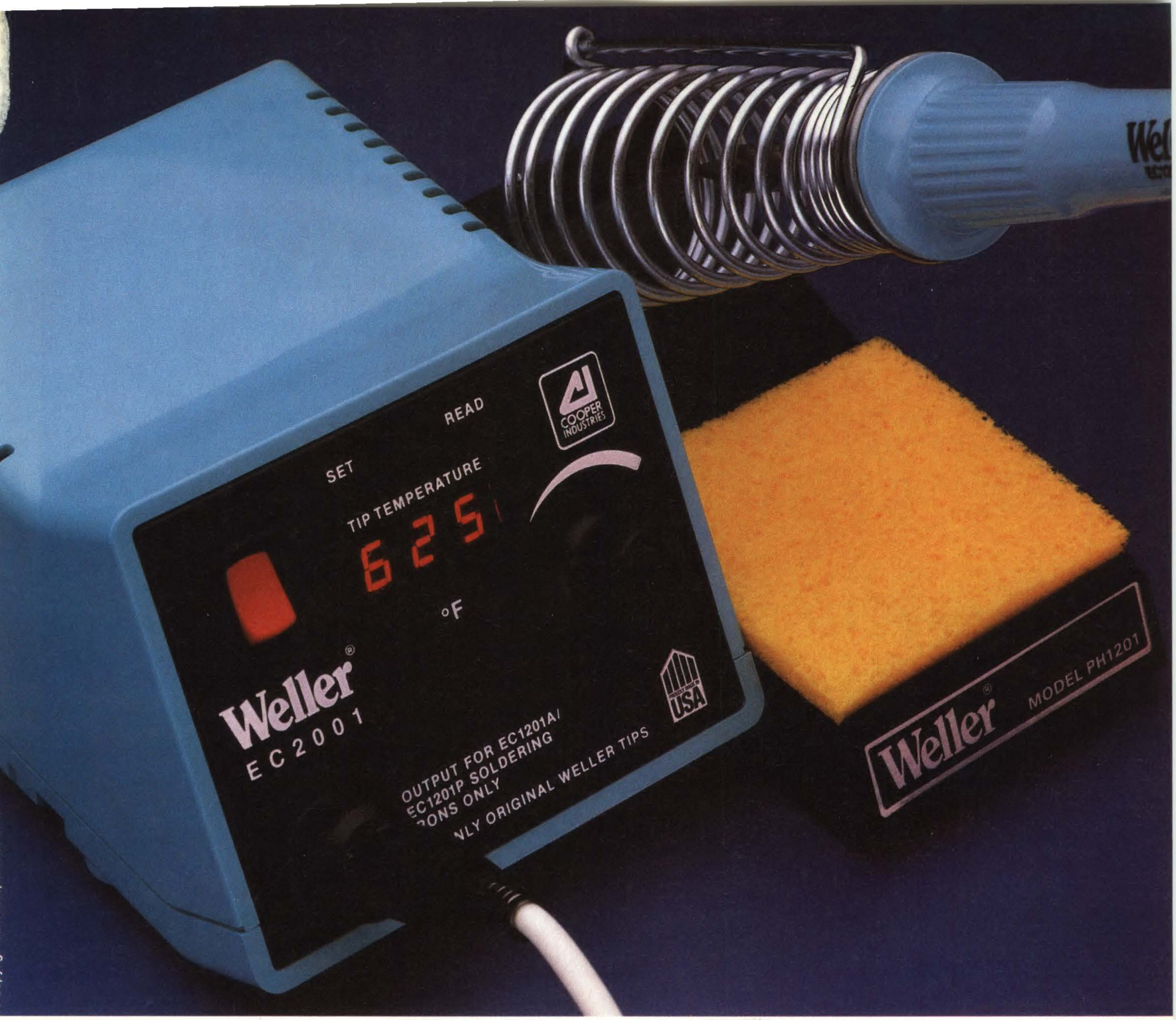
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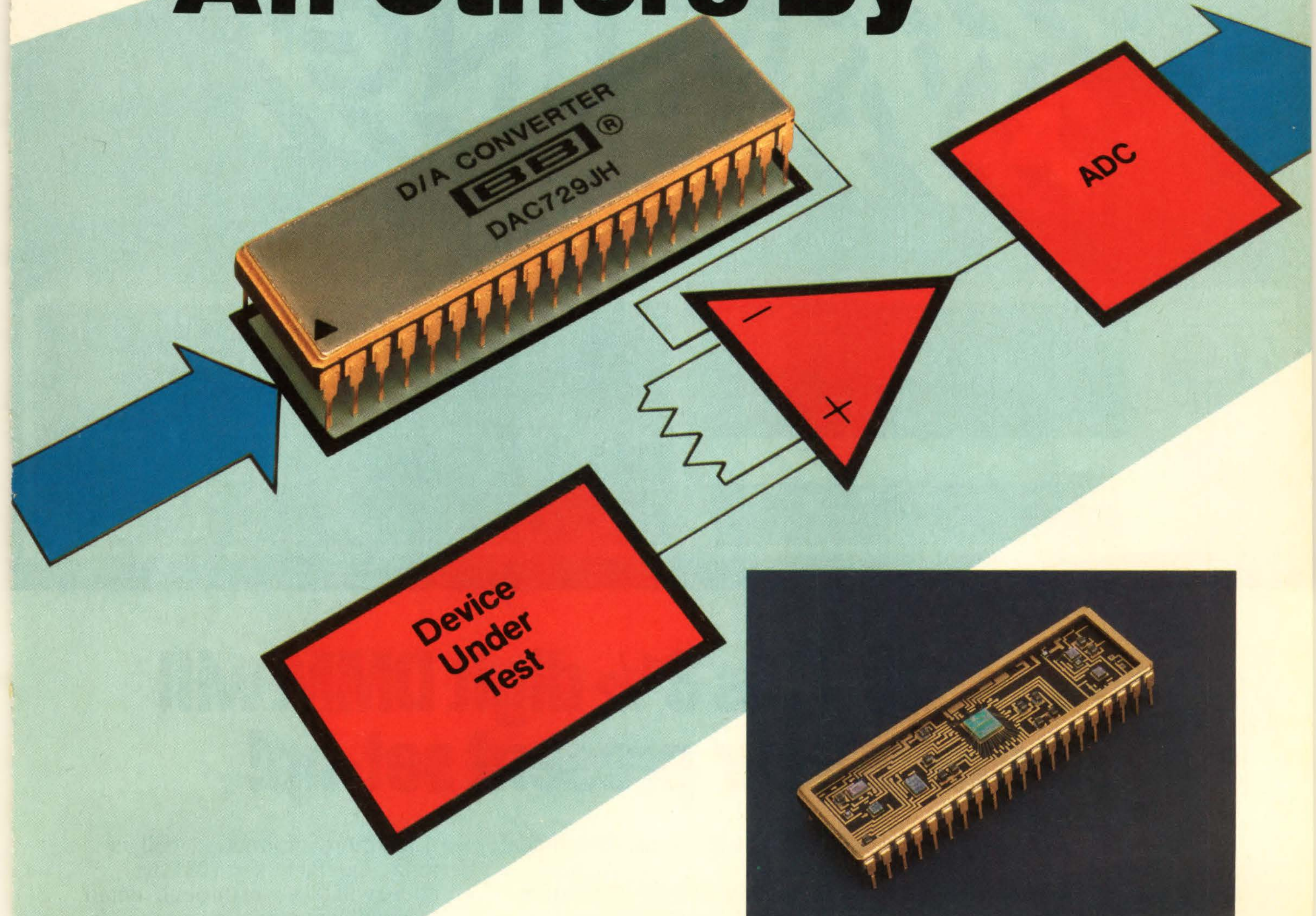

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Testability is crucial in PLD-circuit design

Compared with standard logic parts, PLDs tend to have higher defect rates and require a larger investment in test-program development. As a result, engineers must make testability a prime design goal to ensure that the final product can be manufactured and tested economically.

Peter de Bruyn Kops, *Anvil Software*

In increasing numbers over the past few years, board designers have felt the lure of PLDs. Two basic reasons underlie the devices' popularity. One, PLDs are much more powerful than 7400 Series TTL parts and, two, they are much easier to troubleshoot than gate arrays. A logic error found in a PLD prototype board in the morning can often be fixed by that afternoon—something that gate-array users can only dream of. Today, it's not uncommon for a board to contain 50 or more PLDs.

PLDs do require more test-development effort than standard TTL parts, however, and the reason for this is also quite basic. In standard-logic design, the test department creates a test program, puts it in a library, and then reuses it many times over the years. The test engineers have easy access to all the standard logic-test programs they need. A PLD test program, in contrast, is not reusable. A 16L8 PLD design test program, for example, is good for only one particular design; any other 16L8 design will require a different test program.

The rationale for testability

To make it worthwhile to design with PLDs, therefore, you have to design with testability in mind and ensure that the test department can test your circuits within a reasonable length of time and for a reasonable expenditure. A PLD is not very testable if it requires a million dollar tester that holds 1 million vectors. A PLD is also not very testable if it takes a genius three weeks to develop an adequate test. For a board with 50 PLDs, a realistic prediction of test-development time is less than a day per device—except in the highest volume manufacturing operations. Simply stated, the effectiveness of the test engineers is inversely related to the sophistication of your design.

For the purposes of this article, assume that your test engineers have been blessed with good documentation and an automatic test-vector generator (ATG) that can create tests for a variety of combinatorial and sequential PLD designs. By comparing the following untestable or difficult-to-test circuits with their enhanced-for-testability counterparts, you will achieve an understanding of how your design practices will hinder or help subsequent testing of the devices. If you decide

A designer's interests are best served when the test engineers have good documentation and a state-of-the-art automatic test generator.

to heed these design tips, you'll decrease manufacturing time and costs and shorten test-development time—and you may also win some friends in the test department.

Oscillator circuits create problems

Oscillators are easy to create with a PLD (**Fig 1a**), but testing a PLD-based oscillator isn't so straightforward. Whereas PLD testers can readily strobe settled states, oscillator circuits typically require testing of their test frequency and duty cycle. At best, a PLD tester will find such a task difficult, and for many PLD testers it's impossible.

An ATG cannot usually handle an oscillator. Even worse, the oscillator may interfere with the automatic-test generation for other parts of the design. If you want to develop a PLD-based oscillator, you should add an Enable signal so that you can turn the oscillator off (i3 in **Fig 1b**). Optimally, the Enable signal should be on a dedicated pin. In addition, try to add extra logic, which will allow you to stabilize the oscillator output in both the one and the zero states. This capability will expedite parametric testing.

PLD-based pulse, or glitch, generators (**Fig 2a**) are just as troublesome to develop tests for as are oscillators. Without proper communication between the design and test departments, the test engineer will have no way of knowing whether the detected signal transition is a legitimate generator output or a system glitch.

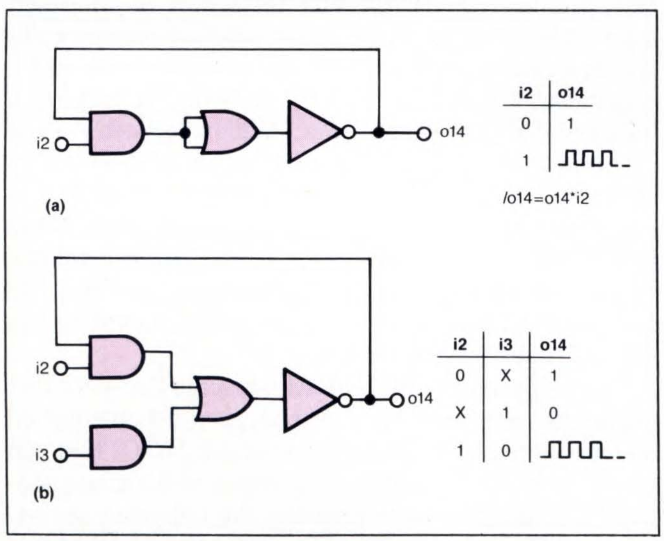


Fig 1—Although it's easy to create oscillators with PLDs (a), the testers commonly used for PLDs cannot easily evaluate the performance of an oscillator. If you redesign the circuit and add an Enable signal (i3), the oscillator can be turned off during testing (b).

If the pulse is indeed a legitimate output, the test engineer will have to develop a special test program and use a more expensive tester to determine that the pulse does indeed occur and that it has the right width.

ATGs typically cannot accommodate glitch generators. And again, the glitch generator may interfere with the automatic-test generation for the rest of the board. As before, try to include additional logic (**Fig 2b**) that will stabilize the generator output (to both the one and the zero states) to facilitate parametric testing.

Meeting the demands of in-circuit testers

If your PLD design relies on feeding outputs back to inputs on the circuit board, watch out that you don't complicate in-circuit board testing. Depending on how the PLD connects to other devices on the board, external PLD feedback may compound the problem of testing the rest of the board.

Testing the PLD itself may also prove difficult, depending on the ATG's software and the source of any other vectors. If the ATG assumes that two pins can

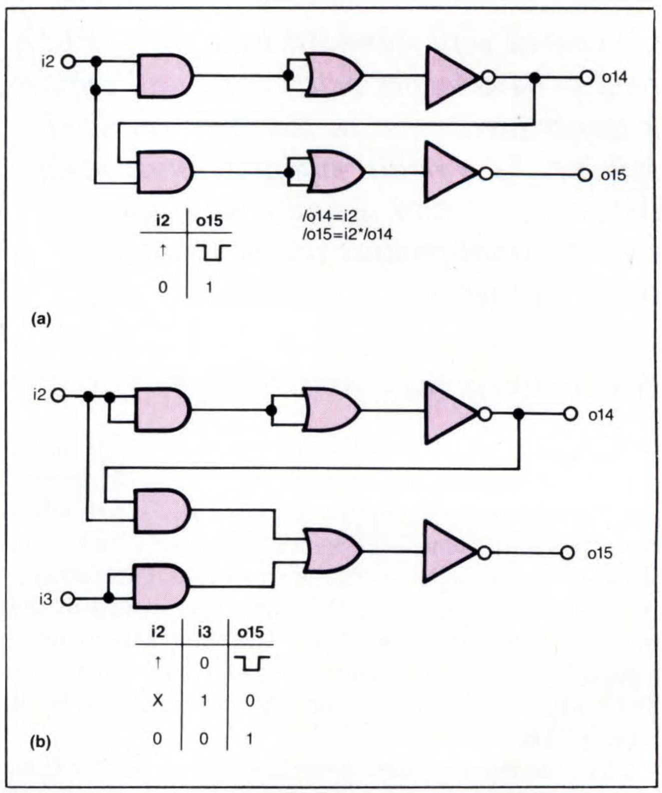


Fig 2—Automatic test-vector generators (ATGs) usually are incapable of testing pulse generators (a). The pulse generator can also hinder the ATG's capability to test other circuitry on the board. By adding logic (b), you can stabilize the generator's output.

move independently, the in-circuit board tester may not be able to use those vectors. Even if the ATG software can abide by the constraint of having two pins tied together, this restriction is still a hassle for the test engineer because it represents one more thing to remember and one more chance to make a mistake. If you need feedback, try to use a PLD with adequate internal feedback paths.

Most PLD-based designs seem to always hard-wire any 3-state outputs in the on condition, thereby creating problems for in-circuit test systems **(Fig 3a)**. A test engineer writing an in-circuit board test program will normally prefer to turn a 3-state output off and drive that output point with the tester. If the output is always on, the test engineer may need to overdrive the pin. Overdriving complicates the test and may make the test more difficult to debug. You can circumvent these problems by controlling all 3-state outputs with an Enable signal (i9 in **Fig 3b**).

Watch out for race conditions

The exception to this rule are memory elements with 3-state outputs. Memory elements created by feedback around a 3-state type of combinatorial output introduce some special testing subtleties **(Fig 4a)**. This type of design may necessitate that both the tester and the PLD be simultaneously active in order to reliably latch data. Referring to pin o15, when the test vector starts, i2 and i9 are low, and the tester is driving o15. When i9 goes high, the device output will turn on. The driver on a typical PLD tester will stay on for the entire test vector, which means that the tester and the chip will both be striving to establish the same output state.

During functional testing and with bipolar parts, this dual-drive condition isn't usually a problem, but it may prove troublesome with some CMOS devices. Moreover, even some good parts might fail if the tester performs an input-leakage test on that pin for that test vector. Many PLD testers automatically perform input-leakage tests when they initially drive a pin high or low.

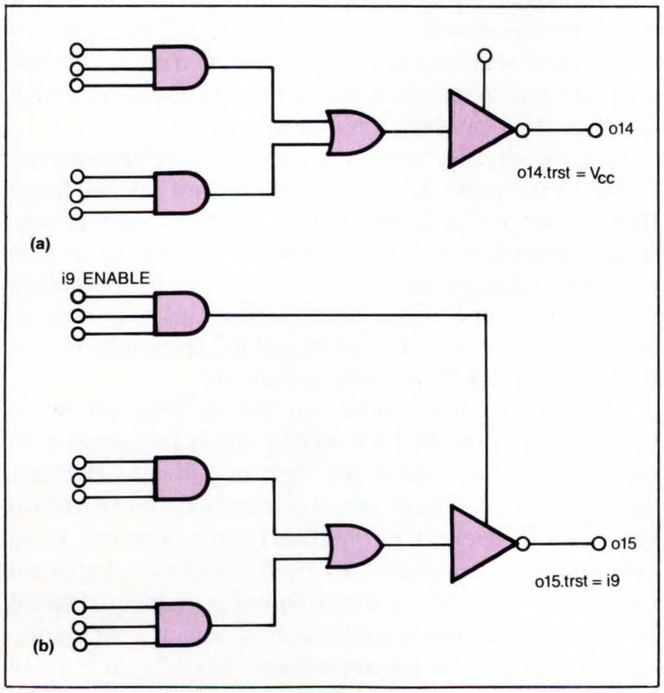
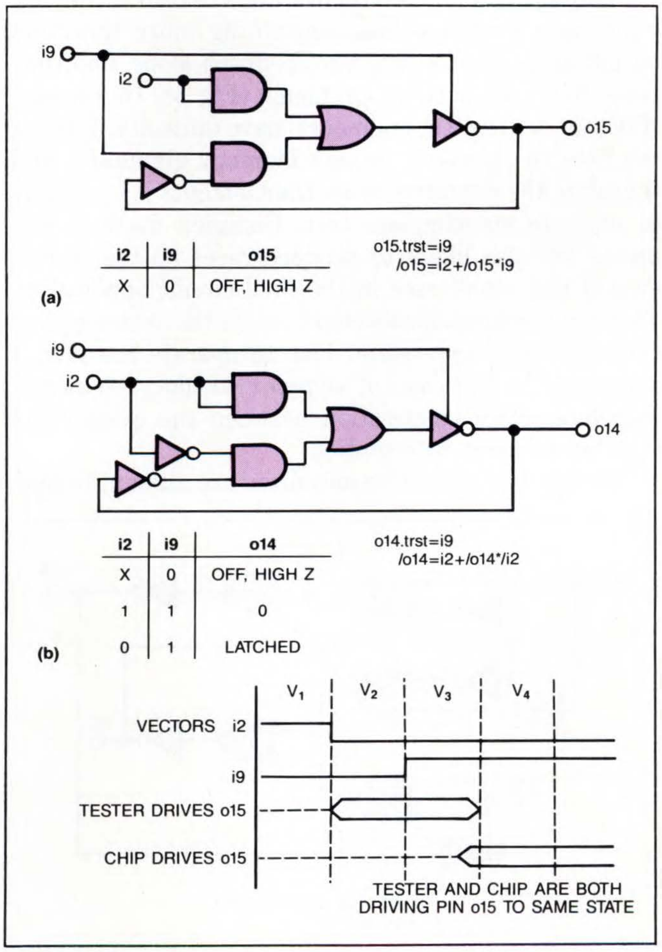


*Fig 3—**The majority of PLD-based designs** pose problems for in-circuit testing **(a)**. You must control 3-state outputs with an Enable pin if system performance is going to be evaluated using in-circuit testing techniques **(b)**.*



i2	i9	o15
X	0	OFF, HIGH Z

i2	i9	o14
X	0	OFF, HIGH Z
1	1	0
0	1	LATCHED

*Fig 4—**When you create a memory element** by using feedback around a 3-state type of combinatorial output **(a)**, you introduce special testing subtleties. If you remove i9 from the feedback path **(b)**, the circuit will be much more testable.*

A memory element created by feedback around a 3-state type of combinatorial output introduces some special testing subtleties.

If the PLD is driving the pin at this time, the test engineer will have to manually modify the test.

To avoid the simultaneous-drive situation, the test engineer can write the vectors so that they turn the tester driver on o15 off at the same time that i9 goes high. On most PLD testers, this action causes a race condition and may produce intermittent failures of good parts. If the engineer uses an expensive tester, it will turn the chip drive to o15 off a specified number of nanoseconds after i9 goes high and eliminate the race problem, but it will also require that the test engineer take special effort to modify the test program.

To make the circuit in **Fig 4a** more testable, you can modify the design to remove i9 from the feedback path **(Fig 4b)**. Once you make this change, the 3-state operation is independent of memory operation.

Complex memory elements are created either by building a feedback loop containing more than one output or by overlapping two feedback loops, and they pose their own peculiar problems **(Fig 5)**. In general, ATGs (as well as test engineers) have difficulty figuring out how to operate complex memory elements, and therefore the circuitry inside the elements is less likely to undergo an adequate test. Complex memory elements are also likely to produce races on the tester, even if they don't race in the final circuit application. These race conditions develop because the vector writer does not fully understand how to operate the circuit correctly. In the case of complex memory elements, therefore, close cooperation between the design and test departments is essential.

Designs that cannot be initialized are difficult to test,

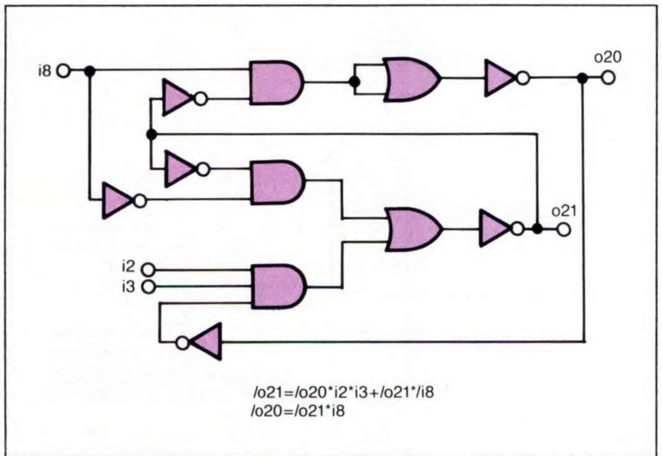


***Fig 5—Complex memory elements** are tough to test thoroughly because it's difficult for the test engineer—and the automatic test generator—to figure out how to operate the elements.*

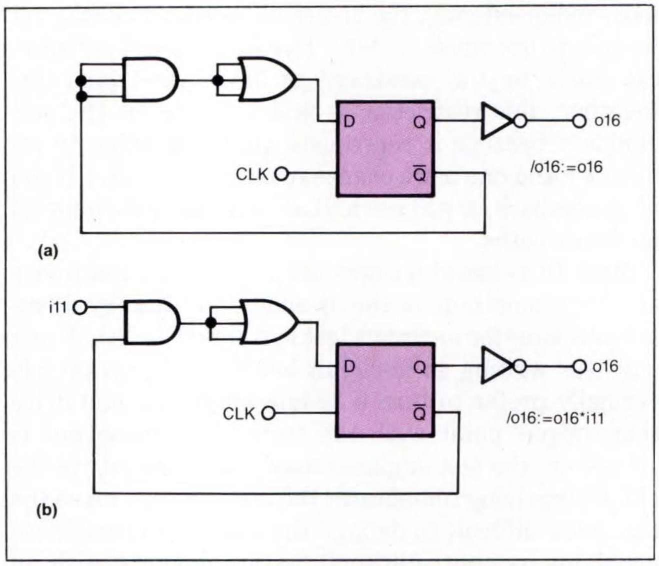


***Fig 6—Although circuits that cannot be initialized** are fairly common, they are very difficult to characterize **(a)**. The modified flip-flop circuit of **b** is much easier to test.*

but unfortunately such circuits constitute 10%—or more—of existing PLD designs. The toggle flip-flop of **Fig 6a** is a good example of a simple, common circuit that cannot be initialized. A test program needs to first initialize the device and then test it. If an ordinary sequence of vectors cannot initialize the device, the test engineer has to choose from three options, all of which unfortunately present some problems.

First of all, the test engineer can synchronize the tester to the part. A typical sychronizing scheme loops the test on one or more vectors until the output pins match predefined states. Not all testers have this capability, though, and some testers that do are limited to looping on one vector only. To use this match mode (as some tester manufacturers call it), the engineer has to determine which vectors to loop on.

The second option relies on the device's power-up state. Many of the PLDs available today power-up with the register bits either all high or all low. Because vendors of PLDs have not standardized the power-up state, PLD users who regularly mix sources need different test programs for each vendor—a logistical nightmare. Also, if the device contains memory created by feedback around a combinatorial output, the memory element cannot be initialized: There's no way to reliably know its power-up state. Another problem will surface if the device or the tester requires substantial time (100 msec or more) to power-down and power-up the device. A test that checks parameters (dc or ac) has

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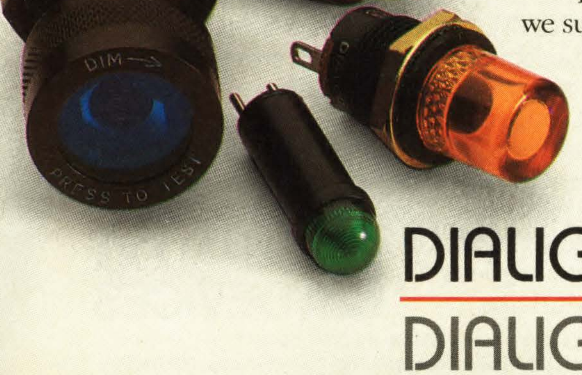

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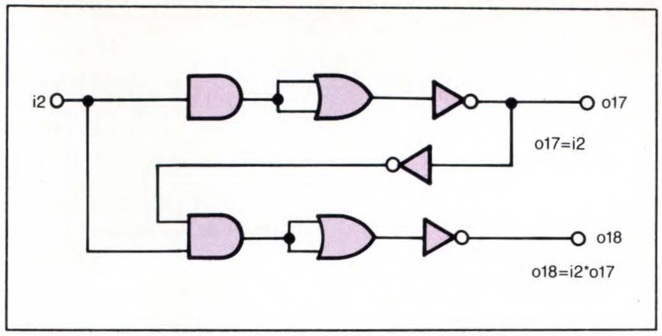


Fig 7—Circuit designers can, with good reason, design in time-sensitive redundancies to achieve a fault-tolerant design. Such designs can prove problematical for test engineers.

to run the vectors many times and therefore will need the power-up state to initialize each of these vector runs.

The third option is preloading. Many of today's PLDs support a preload feature that allows the test engineer to apply special voltages (10 to 13V typically) to some output pins. Preloading temporarily converts the output pins to input pins to directly set the internal-register states. The test engineer will encounter several problems with preloading: Each PLD manufacturer has a different protocol; many testers cannot support preload voltages; preloading is incompatible with in-circuit testing because the high voltages can damage other parts; and parametric measurements often are not reliable immediately after preloading.

You can make some of these problems tolerable for the test department if you set the initial state by preloading only on the first vector. However, most test departments prefer not to use preloading for initialization. Some ATG packages will accept starting-state data and generate the test starting from that point. These types of packages allow the test engineer to obtain some valid test data, but they also mean that more vectors have to be generated and they also necessitate more computer time. The increased number of vectors may increase test times, or it may reduce test coverage if the tester cannot hold that many vectors.

The best way to circumvent all of the above problems and improve the testability of a design that can't be initialized is to devote an unused input or combination of inputs to load the initial state **(Fig 6b).**

Difficult-to-initialize designs also pose problems when it comes time to create test vectors, but they do not cause problems with the tester itself. For example, the following specification describes a particularly difficult-to-initialize design: "When you clock the circuit 10 times, it will wind up in a known state, but the states prior to the tenth clock will be unknown." This type of circuit, where a combination of unknown states is supposed to produce a known state on another gate, mainly causes problems with logic simulators. You can eliminate testability problems resulting from difficult-to-initialize designs in the same manner as circuits that cannot be initialized at all.

Sequentially deep designs cause test difficulties for two reasons. They require a large number of test vectors, and they stipulate that either the test engineer or the ATG software spend a lot of time developing such vectors. A 10-bit counter that can be cleared and then counts up is a good example of a sequentially deep design. If a test engineer has to evaluate this part with a tester that is capable of holding only 512 vectors, test coverage will suffer. From the test department's point of view, the best solution is to modify the counter design so that it can be loaded with an arbitrary state. The ATG will then be capable of adequately testing it.

On some testers, sequentially deep designs can also limit the accuracy of ac measurements. These types of testers are most accurate when the transition they must measure occurs within a few vectors of the initialization point. In the 10-bit counter example from above, transitions in the high-order bits occur hundreds of vectors after initialization, which reduces timing accuracy. In a loadable 10-bit counter, these testers can accurately evaluate the transition from count 511 to count 512 with a few vectors by loading count 511 and clocking once.

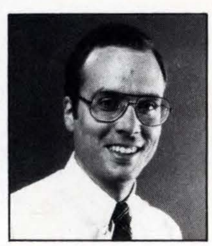
Watch out for redundancies

Time-sensitive redundancies are another cause of difficulties in testing because test generators and test engineers do not know if they should test the time-sensitive behavior. In ordinary cases, faults in the redundant logic are undetectable (that is, they are faults that cannot affect circuit operation), and some ATG packages can automatically filter them out **(Fig 7).** Obviously, if the fault can't affect circuit operation, there's no need to test for it.

These fault-tolerant circuits can prove very beneficial in some applications. If you choose to use such a circuit in your next PLD design, make sure you document the redundancy so the test engineer knows that he doesn't have to struggle with it. **EDN**

Author's biography

Peter de Bruyn Kops is director of engineering at Anvil Software (Nashua, NH). In this position, he is responsible for developing programmable-logic test generators. Peter hold a Bachelor of Arts degree and a Masters in Science degree from Harvard College.



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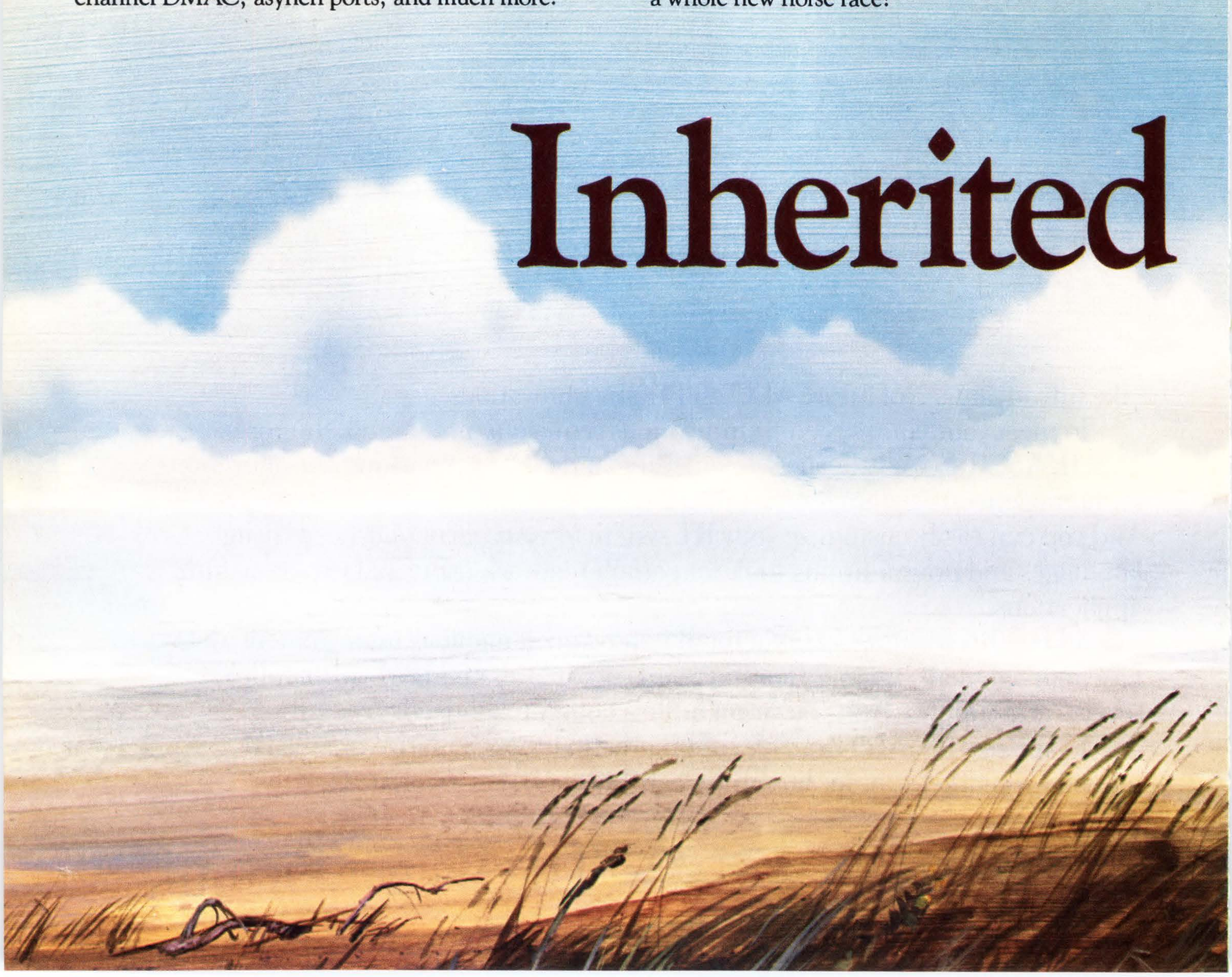

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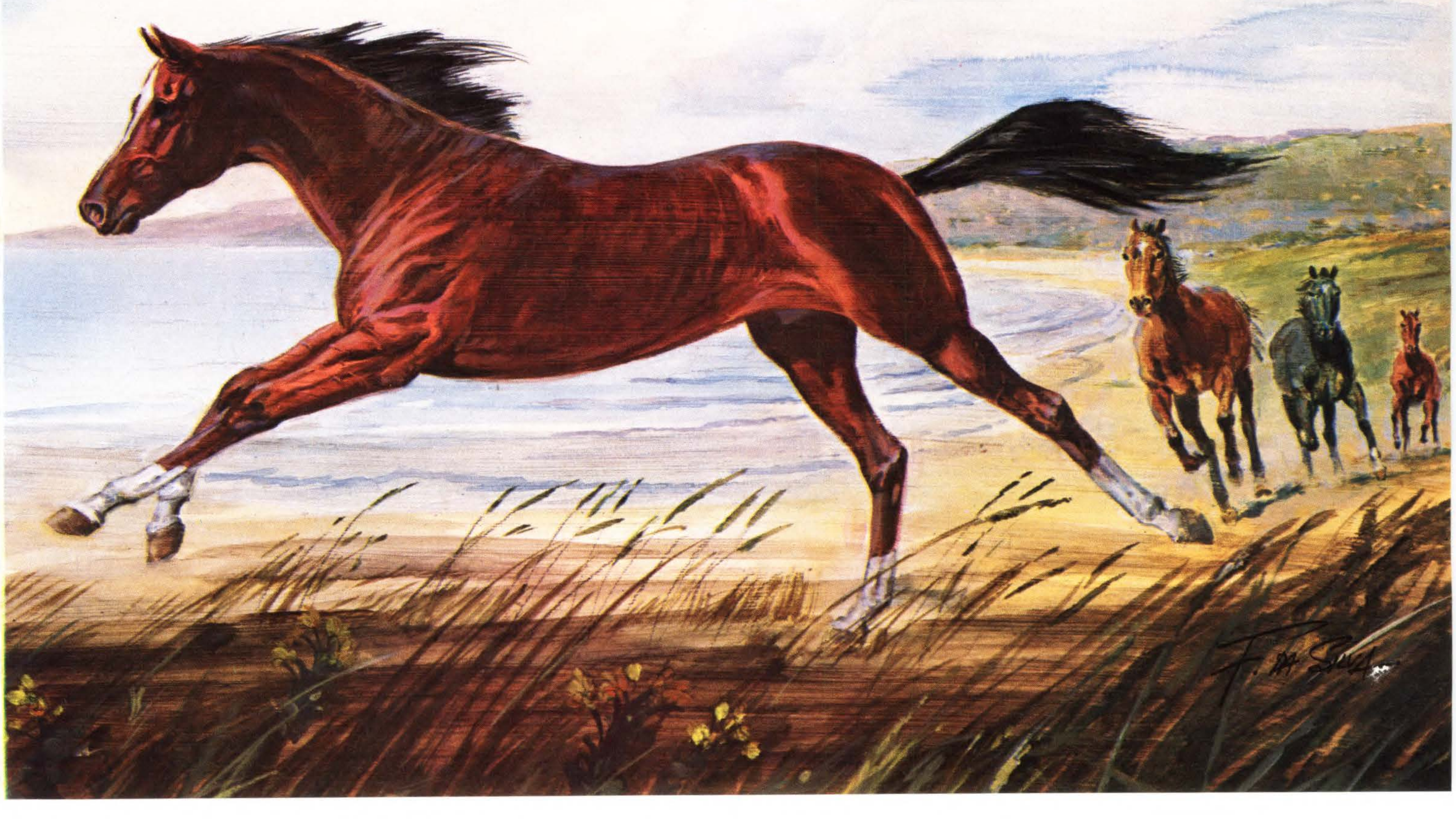

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CIRCLE NO 135

Retargetable tools ease microprogramming of SIMD processors

You can improve your single-instruction, multiple-data processors dramatically by using effective organization and management techniques. Retargetable tool sets can help you program these massively concurrent SIMD processors conveniently, reliably, and inexpensively.

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Quantitative Technology Corp

One way to create programmable parallel computer systems is to use wide-instruction-word, single-instruction, multiple-data (SIMD) processors. But machines with concurrently functioning units require programs that are far more complex than similar programs for conventional sequential computers or microprocessors. Programming at the microcode level is therefore tedious and exacting—it calls for a special combination of talent and patience that not many programmers possess. Until recently, the only alternative was to lower performance and thus create a more manageable machine for the microprogrammers. However, using SIMD architectures is now a feasible option because automated tools for implementing microcode within those architectures are starting to appear, and these tools offer new methods for resolving the programming difficulties.

SIMD architectures have become the basis of most contemporary high-performance graphics and digital-signal-processing (DSP) systems. Such systems generally consist of custom, application-oriented processors built from a mixture of high-speed arithmetic, floating-point, DSP, and application-specific integrated circuits (ASIC), that provide excellent cost/performance value. In addition, it's possible to design wide-instruction-word SIMD processors in such a way that you can program them in a high-level language (HLL). This advantage becomes significant when optimizing compilers are available to translate HLL programs into *microcode* (for definitions of all the italicized words in this article, see **box,** "Microcode terms decoded").

The wide instruction words used in SIMD processors (from 64 to more than 1000 bits) can be extremely difficult to program efficiently. The reason is that every instruction word contains numerous fields, and every field controls different hardware elements. You must therefore program each field for each clock cycle of an instruction. Furthermore, because you can *pipeline* many hardware elements, one operation can take several instruction cycles to complete, and an operation's later stages may take place concurrently with the early stages of the next operation.

If an SIMD architecture must support large applica-

Programming at the microcode level requires a special combination of talent and patience that few programmers possess.

tion *microprograms*, the hardware designer can take advantage of some powerful chip families to quickly design systems that, because of extensive concurrency and pipelining, can perform exceptionally well. On the other hand, developing software for such an architecture is difficult. In the first place, microprograms are generally not written until after the design is set in silicon, so any early prediction of such a system's performance when running microprograms is just about impossible. Thus the hardware designer must speculate about the software needs, and major design flaws can go unnoticed until it's too late to rectify them. When you add to this the fact that each application program may require 100,000 or more *microinstructions* operating on such an architecture, the intractability of programming those applications is clear.

In fact, most vendors estimate that if traditional microcode development tools are used, writing and debugging microcode on wide-word, SIMD architectures costs between $1 and $2 per bit. Thus, an application requiring 100,000 microinstructions, where each microinstruction is 100 bits wide, might cost between $10 million and $20 million to develop.

In order to eliminate current design problems without sacrificing a high level of performance, a microcode development system should feature four basic characteristics:

- You should be able to easily *retarget* the tools for different architectures, including hypothetical machines. An automated system is inadequate if it works for only one design, or even for a limited number of designs. Designers must be able to

Microcode terms decoded

Code compaction—The process of scheduling a sequential list of straight-line micro-operations to execute concurrently on a parallel processing machine, without violating resource limitations or data dependencies.

Configure—To adapt retargetable program-development tools for a specific hardware architecture. Configuring involves writing a configuration file and processing it for use by the development tools.

Configuration file—A text file containing descriptions of the hardware and the properties of a target machine. This information is needed to adapt the retargetable program-development tools to a specific hardware architecture. The file is used as input to a configuration program that performs the adaptation of individual tools.

Data dependence—A relationship that involves the reliance of one operation on the data of another. An operation X is data-dependent on operation Y, if Y writes data that X reads.

Horizontal machine—A machine architecture in which independently programmable operations can occur simultaneously as well as sequentially. Such a machine may have multiple concurrent functional units but only a single program-sequence control unit.

Local compaction—Code compaction.

Microcode—A general term for the machine instructions that directly control the hardware resources of a machine.

Microinstruction (MI)—A source-level assembly-language instruction made up of zero or more micro-operations and corresponding to an object record.

Micro-operation—A primitive operation that controls specific hardware resources of the machine.

Microprogram—A sequence of microinstructions that together perform a specific function. A microprogram can exist at three levels: source, object, and loadable.

Pipelining—The process of combining operations in such a manner that successive operations are initiated before the first operation is completed. The number of cycle transitions that occur before completion of the first operation defines the depth of the pipeline.

Retarget—To change, or reconfigure, a program for an architecture that is different from the one you last worked on.

Software pipelining—A program-optimization technique that pipelines the operations of a program loop.

Target machine—The computer system for which microcode is written.

Trace scheduling—An optimization that speeds up the program paths that execute most frequently in a microprogram.

LISTING 1—C PROGRAM FOR A 4×4 MATRIX PRODUCT

```
int a[4][4];
int b[4][4];
int c[4][4];

main()
{ int i,j,k;

   for(i=0 ; i<4 ; i++)
        for(j=0 ; j<4 ; j++)
        {
             c[i][j] = 0;
             for(k=0 ; k<4 ; k++)
                  c[i][j] = a[i][k]*b[k][j]+c[i][j];
        }
}
```

explore new possibilities in order to make use of the most advanced technology. Limitations on system configuration hamper both their creativity and their ability to exploit new technology.

- You should be able to write microcode in a high-level language. An automated system must allow the reuse of existing microcode on new architectures. Reusability requires that microcode be written in a high-level, machine-independent language. A language that is appropriate, popular, and standardized has added value for the programmer.
- It should automatically (or at least semiautomatically) optimize microcode to effectively exploit concurrency and pipelines. New hardware technology is cost effective only if programming techniques are capable of yielding the full performance potential of the resulting system. Hand coding requires programmers who are both experienced with optimization methods and have an expert knowledge of the target hardware. Even with such expert programmers, hand coding for wide-word SIMD processors is, at best, very time-consuming and expensive. For complex, highly concurrent machines, hand coding can be too difficult for even experts to manage effectively and reliably.
- It should readily provide architectural performance profiles that reveal bottlenecks and other design flaws. The designer must be able to assess the effectiveness of an architecture, when running a representative benchmark suite of microprograms, by means of execution profiles. To obtain such execution profiles, the development system must include a retargetable simulator.

Taking these characteristics into account, let's see what tools you need to automate both the SIMD processor design and the microcode development for such processors. Keep in mind that all of the tools should be retargetable—that is, you are able to adapt them to any architecture, provided that a description of that architecture and its programming rules is available in a *configuration file*.

First of all you need an assembler and a linker that you can easily adapt to various symbolic assembly languages, including those for expressing horizontal instructions and pipelined operations.

Next, to reduce programming time and cost, and to facilitate the reuse of existing code, you need a compiler for a high-level systems-programming language like C. The HLL compiler should generate code for the selected assembly language. To exploit the low-level, fine-grain parallelism, it's critical that you have an optimizer that trace-schedules programs, pipelined loops, and scheduled concurrent operations, both for handwritten and compiled code. HLL compilers can have some built-in optimizing functions, but it's very likely you'll need a separate optimizer tool for fine-tuning the source code generated by the compiler.

A symbolic debugger is also essential, preferably one that shows you the HLL source code as well as the machine code that's currently executing. Debugging a complex single-thread program is often difficult without a source-level debugger—the mind boggles at the thought of debugging parallel or pipelined operations without this aid.

And finally, you need a simulator, not only to test and profile new programs, but to evaluate the performance of the proposed system even before it's committed to silicon.

Powerful chip families allow you to quickly specify systems that can use concurrency and pipelining extensively to achieve high performance.

$$\begin{pmatrix} c_{11} & c_{12} & c_{13} & c_{13} \\ c_{21} & c_{22} & c_{23} & c_{24} \\ c_{31} & c_{32} & c_{33} & c_{34} \\ c_{41} & c_{42} & c_{43} & c_{44} \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{pmatrix} \cdot \begin{pmatrix} b_{11} & b_{12} & b_{13} & b_{14} \\ b_{21} & b_{22} & b_{23} & b_{24} \\ b_{31} & b_{32} & b_{33} & b_{34} \\ b_{41} & b_{42} & b_{43} & b_{44} \end{pmatrix}$$

Fig 1—This general form of a 4×4 matrix multiplication *uses the standard approach of cross-product computations. It requires 64 additions and 64 multiplications.*

A tool set that includes all these programs offers a new approach to design. For example, you can develop large benchmarks of machine-independent C programs in advance of, or concurrently with, the processor design. First, you *configure* the entire tool set for that architecture by building a configuration file from which each tool can extract details of the machine-specific properties of the target architecture. Once you have configured the tool set for your design, you can begin the compilation, optimization, and assembly of system and application programs.

To obtain performance profiles and analysis, you run the compiled programs under the simulator. When design flaws or opportunities for improvement crop up, you can make changes and update the configuration file accordingly; the feedback loop then repeats. In situations where you need to compare and contrast alterna-

An integrated set of tools for microcde

The Software Foundry from Quantitative Technology Corporation (QTC) is an integrated family of software development tools that can easily be retargeted by designers of custom high-speed processors for different architectures. The family consists of six tools.

C compiler

The retargetable SF/C Compiler compiles C source code directly into optimized microcode. It performs the first of two stages of optimization: coarse-grain transformations of the programmer's code. This first optimizing stage includes eliminating common subexpressions, constant propagation, copy propagation, constant folding, strength reduction, and peephole optimizations. It also encompasses code motion, dead code removal, redundant code elimination, and register assignment.

Because it's retargetable, the package can compile machine-independent programs for a large number of architectures. A design team can thus write application code concurrently with, or even in advance of, the design of the architecture to which the microcode is targeted.

Optimizer

The S/F Optimizer performs the second stage of optimization. This tool reorganizes syntactically correct microcode so that it can do low-level, fine-grain code improvements. It can use any parallelism and pipelining available for a given processor architecture. It improves code efficiency by using compaction, loop folds, and *trace scheduling* optimizations that relate specifically to the target architecture. The SF/Optimizer produces code that typically runs many times faster than the input code.

To improve the microcode's efficiency, the SF/Optimizer operates in both an interactive and an automatic mode. In the interactive mode, the SF/Optimizer provides immediate feedback from the editor-assembler to the operator. This feedback assists the programmer by providing *data-dependency* and resource-usage information that is crucial to achieving an optimally written microcode program.

In automatic mode, the SF/Optimizer manipulates the input microcode, using several optimization techniques. One such technique is *code compaction*. Code compaction, operating on straight-line *micro-operation* sequences, produces code that runs more efficiently and takes less space in program memory.

The optimizer also optimizes via *software pipelining*. This operation provides significant speed improvements for sections of code that contain loops. Consider, for example, a simple loop that adds corresponding elements of two large arrays of numbers and stores the results in a third array. For processors that have parallel and pipelined computing resources, the Optimizer increases execution speed in loops by folding the microcode into a number of stages, each of which performs a portion of the total calculation. For example, it might fold a 12-operation tive designs, you can write several different configuration files and then evaluate the various processors under the benchmark programs.

When your design is completed, you need little extra time for completing the entire microprogrammed system, because you've probably already developed and debugged many of the microprograms with the tool set. If you need to adjust the programs further, you can use the assembler and optimizer to streamline potential program trouble spots for very high performance. This streamlining enhances the quality of your SIMD designs and can dramatically reduce design costs and system development time. The result is better systems

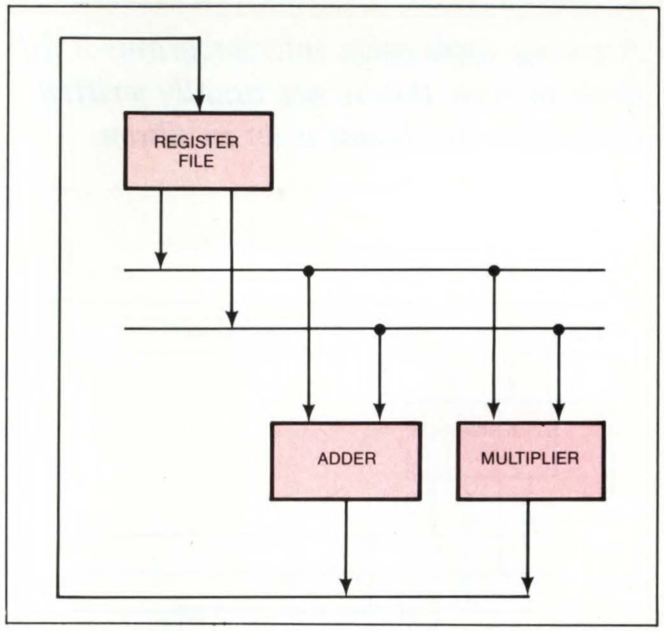

Fig 2—This simple design contains separate adder and multiplier units. *The additions and multiplications must be executed sequentially.*

straight-line loop into 4 stages, each of which takes only 3 cycles. Thus, when the processor executes the folded loop, only 3 cycles are needed to produce each result. This reduction in cycles improves the performance by a factor of four, compared to that of sequential code.

A third optimization involves *trace scheduling*. This process moves operations around control branches on the basis of the statistics on the relative execution frequencies of the various program paths. The goal is to speed up those program paths that are expected to run most frequently.

Assembler

The QTC SF/Assembler forms the foundation for all the tools in the family. It's a microcode meta-assembler that lets the developer customize a microcode programming language for a specific *target machine*. This tool supports the features found in many modern standard assemblers, like macros, include files, multiple code and data memories, conditional assembly, and modular, relocatable code.

The SF/Assembler is designed to give the users the flexibility to design syntax that has the attributes and power of a high-level language, while they retain explicit control of the machine resources. The package also accommodates those users who feel more comfortable defining their language syntax at the instruction-field level.

Linker

The SF/Linker allows you to combine object files from a number of separately assembled subprograms into a single program module. The linker then formats modules into one of several selectable standard output formats for loading either into the actual target hardware or into a software simulator of the hardware.

Simulator

The retargetable SF/Simulator runs on the development host and can simulate the execution of an assembly- or microcode-language program as it would run on the target machine. It uses a description of the target machine's hardware that is based on the same configuration file used by the SF/Assembler and SF/Optimizer. Because the SF/Simulator allows a large number of programmers to develop and check out applications code, regardless of the availability of the hardware, its use can substantially reduce the overall time for completion of a project.

Symbolic Debugger

The SF/Debugger permits the programmer to refer by name to the program variables whose contents he wishes to examine and modify. The SF/Debugger uses the SF/Simulator to execute the compiled code exactly as if it were running on the actual hardware. The SF/Debugger also provides a convenient interface to other programs, so that the user can write his own routines to communicate with actual hardware for hardware system debugging.

Assessing application microprograms is difficult because they're not usually written until after the design is set in silicon.

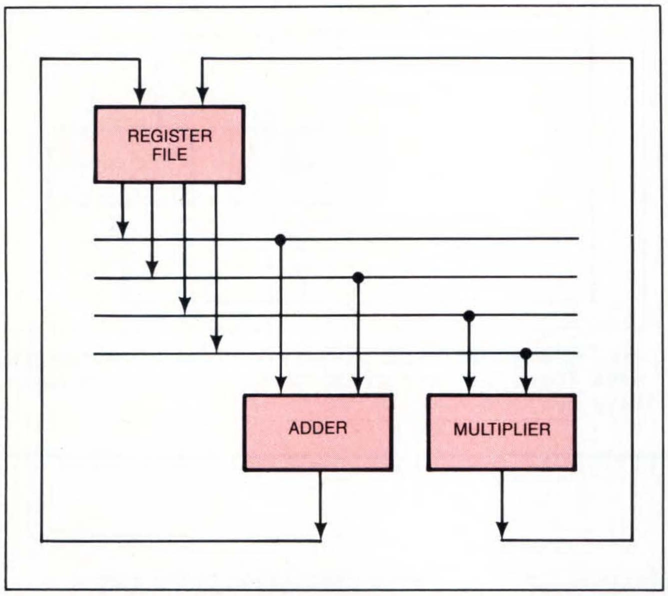

Fig 3—This design contains separate adder and multiplier units. *The additions and multiplications can be executed concurrently.*

that run faster and cost less.

To illustrate some of the benefits of such a tool set, consider a scenario in which you need to design a computer for fast execution of 4×4 matrix multiplications. This problem is very common in systems designed for high-performance image analysis and rendering. You'll typically work through several versions of the computer from a simple, conventional, sequential bit-slice design to an SIMD architecture.

Along the way, you'll need to know how effective the design is in two respects: First, how programmable is it? That is, will it be possible to write microcode for the machine so as to exploit the features designed to provide greater performance potential? Second, is the performance the machine was designed to provide achievable through microcoding?

Computing a 4×4 matrix illustrates concretely how you actually might use these tools. Matrix multiplication is a very common computation, so the following example touches only on the arithmetic operations and skips over the other issues, such as memory traffic, that a designer would normally have to take into account in the designing process. The example also assumes the presence in the design of all necessary loop operations, variable initialization, addressing, and memory accesses.

LISTING 2—INNERMOST LOOP OF SEQUENTIAL MICROCODE

```
Cycle 1. t = a[i][k] * b[k][j];
      2.                        ; No-op
      3. c[i][j] = t + c[i][j];
```

Work through a practical example

The problem is to efficiently compute c=a:b **(Fig 1).** You could just design a bit-slice architecture **(Fig 2)** that allows a single scalar addition or a single scalar multiplication in any instruction cycle. In this case, a scalar addition would execute in one cycle, and a scalar multiplication in two cycles.

A typical C program that computes a 4×4 product is shown in **Listing 1.** Simply counting the additions and multiplications reveals that the innermost loop of this program contains one addition and one multiplication, each of which is executed 4^3, or 64, times. A simple microcoded solution corresponding to the C loop contains the operations shown in **Listing 2.** If you count the instruction cycles needed to perform these operations, and then count the number of passes through the loop, you'll find that the complete matrix multiplication requires 3×4^3, or 192, instruction cycles.

Next, you might want to consider an architecture that can perform the scalar additions and multiplications concurrently **(Fig 3).** To obtain the concurrent operation, you have to change the configuration file (the

LISTING 3—PROGRAM THAT FOLDS THE INNERMOST LOOP

```
PREAMBLE TO THE INNERMOST LOOP:
Cycle 1.    t[1] = a[i][1] * b[1][j]          ;
      2.                                      ; No-op
    INNERMOST LOOP BODY (executed for k=2...4):
    Cycle 1.    c[i][j] = t[k-1] + c[i][j] # t[k] = a[i][k] * b[k][j];
          2.                                  ; No-op
POSTSCRIPT TO THE INNERMOST LOOP:
Cycle 1.    c[i][j] = t[4] + c[i][j]          ;
```


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An automated microcode development system must be retargetable to any hardware architecture if it is to be useful.

LISTING 4—PROGRAM THAT FOLDS BOTH INNERMOST AND MIDDLE LOOPS

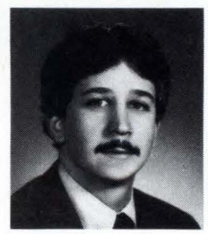
```
PREAMBLE TO THE MIDDLE LOOP:
Cycle 1. t[1] = a[i,1] * b[1,1]                     ;
      MIDDLE LOOP BODY (executed for j=1...3):
            INNERMOST LOOP BODY (executed for k=2...4):
            Cycle 1.                                      ; No-op
                     2. t[k] = a[i,k] * b[k,j] # c[i,j] = t[k-1] + c[i,j];
      POSTSCRIPT TO THE INNERMOST LOOP:
      Cycle 1.                                      ; No-op
               2. t[1] = a[i,1] * b[1,j+1] # c[i,j] = t[4] + c[i,j];
POSTSCRIPT TO THE MIDDLE LOOP:
Cycle 1.                                      ; No-op
        2. t[2] = a[i,2] * b[2,4] # c[i,4] = t[1] + c[i,4];
        3.                                    ; No-op
        4. t[3] = a[i,3] * b[3,4] # c[i,4] = t[2] + c[i,4];
        5.                                    ; No-op
        6. t[4] = a[i,4] * b[4,4] # c[i,4] = t[3] + c[i,4];
        7.                                    ; No-op
        8. c[i,4] = t[4] + c[i,4]             ;
```

C program, however, can remain the same). If you recompile the program, and the compiler performs only a *local compaction* of instructions (that is, the instructions are not moved around control block boundaries), you would obtain the same microcode.

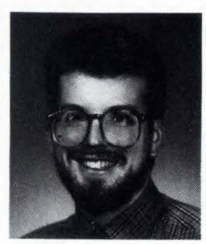
Because the next scalar multiplication can begin as soon as the addition at the bottom of the loop is done, you can improve the program's efficiency by overlapping the additions with the multiplications. Specifically you can optimize the program by unrolling and folding the innermost loop body to achieve the overlapping operations and then rerolling the innermost part. The result is shown in **Listing 3.** (The # delimiter separates operations that are executed in parallel.) The resulting code performs these arithmetic operations in $(2+(2)\times3+1)\times4^2$, or 144, instruction cycles (the parentheses in the arithmetic expression reflect the looping structure of the program).

A very powerful optimizer can automatically determine the benefit of performing this optimization, and then take things one step further. The optimizer would unroll, fold, and reroll the middle loop as well, and so reduce the total time still further. Most programmers would probably overlook this possibility, and those who recognized the possible benefits might shy away from it because of the complexity of the required code reorganization. The result of the transformation is shown in **Listing 4.** The highly optimized loop now requires only $(1+(2+(2)\times3)\times3+8)\times4$, or 132, instruction cycles. **EDN**

Authors' biographies



Robert A Mueller is QTC's director of research. He was previously president and founder of Horizon Research Labs, which was acquired by QTC in July 1987. Bob is currently on sabbatical leave from Colorado State, where he is associate professor and director of the firmware-engineering and micro-architecture design laboratory. He is a recognized expert on microcode optimization, and has published more than 75 papers. Bob holds a BS in computer science and an MS in mechanical engineering from Colorado State University and a PhD in computer science from University of Colorado. He's a member of the ACM and the IEEE. In his spare time, he enjoys bicycling.



Daniel R Benua develops new products for QTC as a senior software engineer. Before joining QTC early in 1984, Dan worked at Spacelabs. He holds an MSEE from Stanford University and a BSEE from Brown University, and is a member of the ACM.

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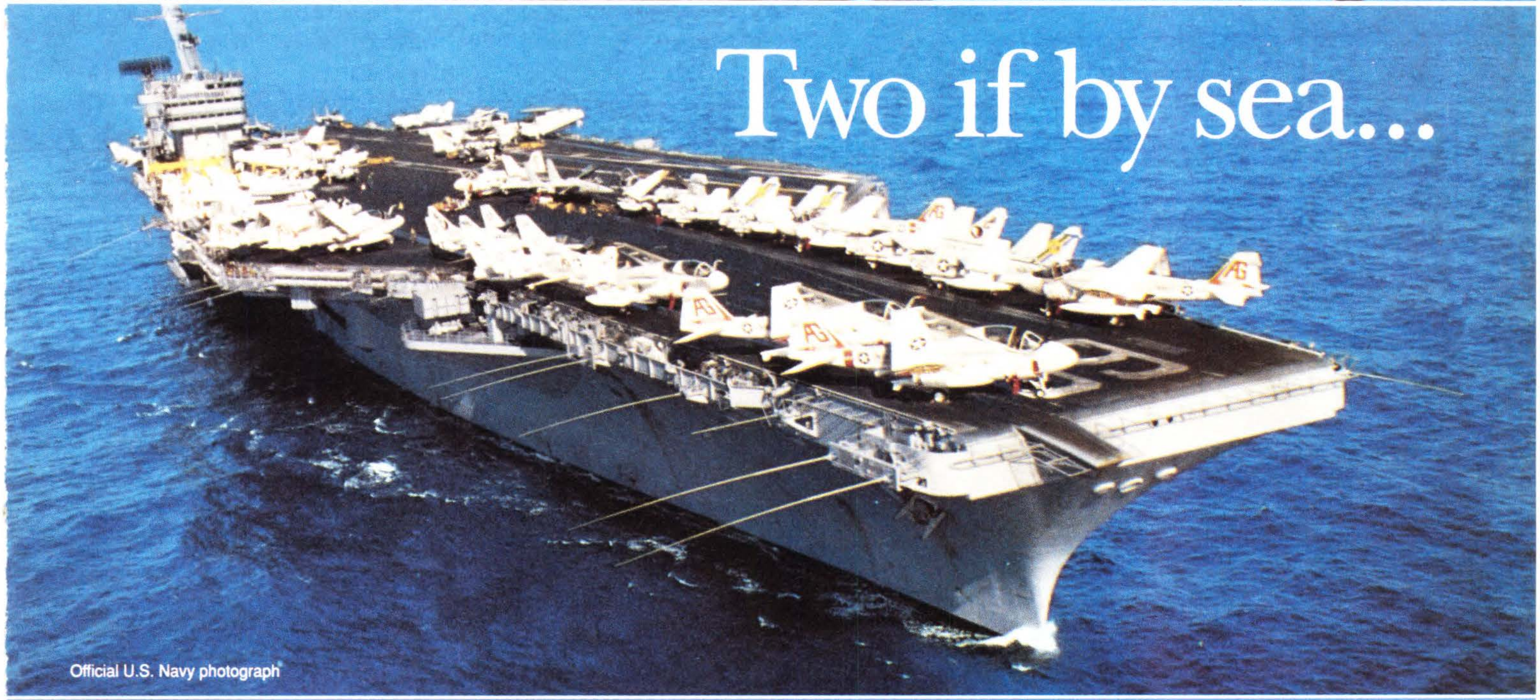
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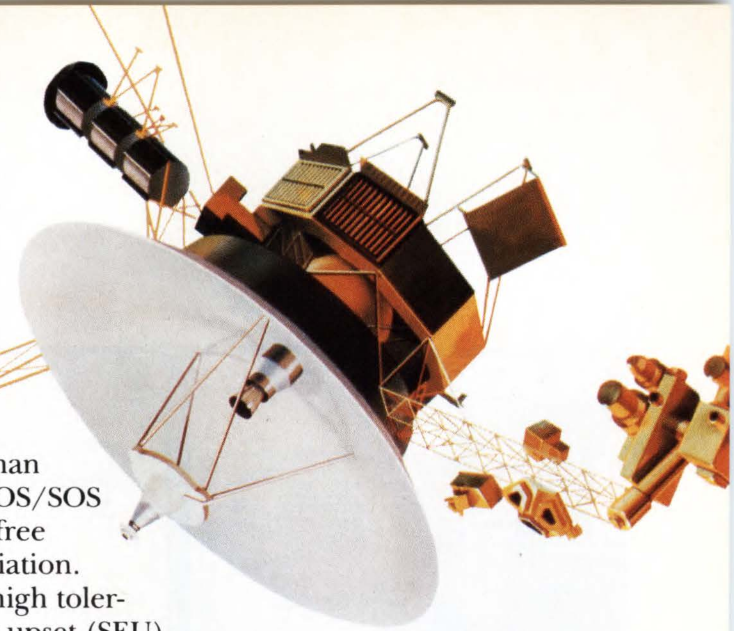

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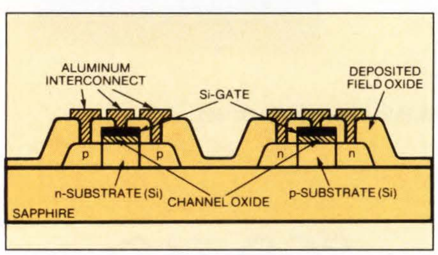

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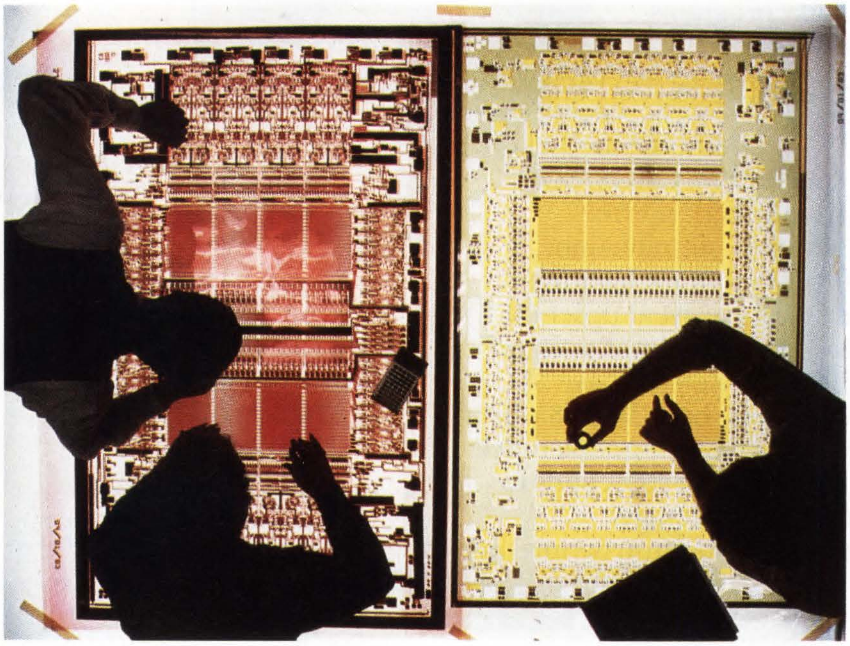

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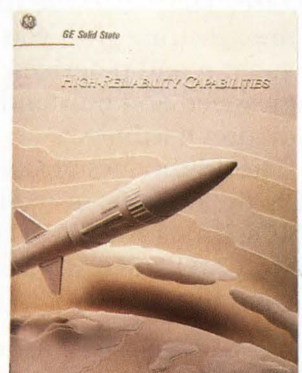

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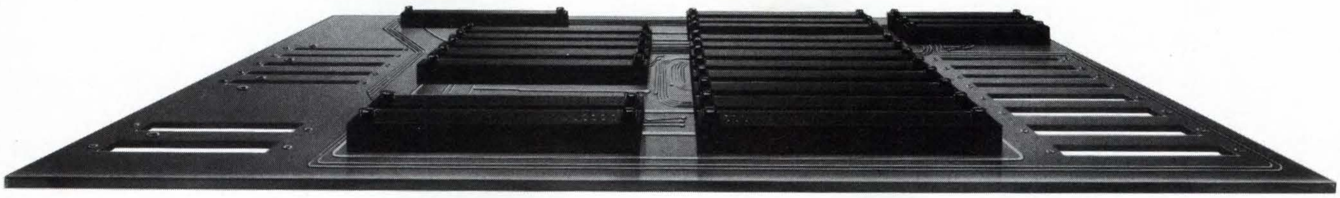

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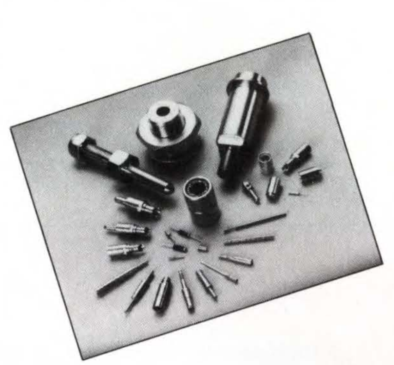

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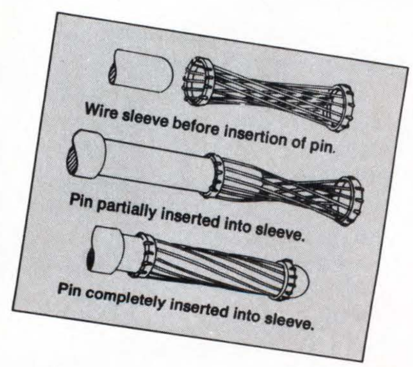

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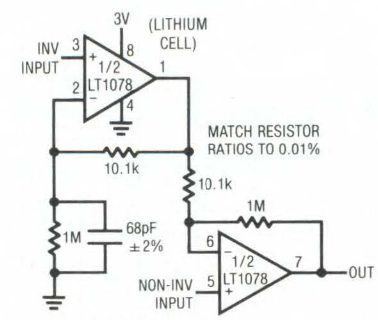

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CIRCLE NO 140

555 timer triggers phase-control circuit

J N Lygouras
University of Thrace, Xanthi, Greece

The control circuit in **Fig 1a** allows you to manually adjust the power delivered to a load. By changing the setting of potentiometer R_3, you change the phase angle at which the thyristor (Q_3) fires **(Fig 1b)**, thereby altering the load current's duty cycle. The adjustment range is about 0 to 180°. Q_3's off time is linear with R_3, but of course the resulting load power is not linear with R_3.

The full-wave diode bridge delivers pulsed-dc voltage to the load, making the circuit suitable for dc-control applications such as dimming. (The circuit can handle ac power if you substitute a triac for Q_3 and make slight modifications.)

IC_1 is a low-power—1 mW—timer configured as a monostable monovibrator. Zener diode D_1 and filter capacitor C_1, activated by pulses from the voltage divider R_1/R_2, form a dc supply for the timer. Q_1 turns on and applies a negative-going trigger to the timer (pin 2) each time Q_1's base voltage approaches 0V. In response, the timer issues a positive pulse that turns on Q_2 and turns off Q_1, removing load power for an interval equal to $1.1R_3C_2$. To increase the control resolution, you can lower the value of R_3, substitute a potentiometer with more turns, or add a fixed resistor in series with the potentiometer. **EDN**

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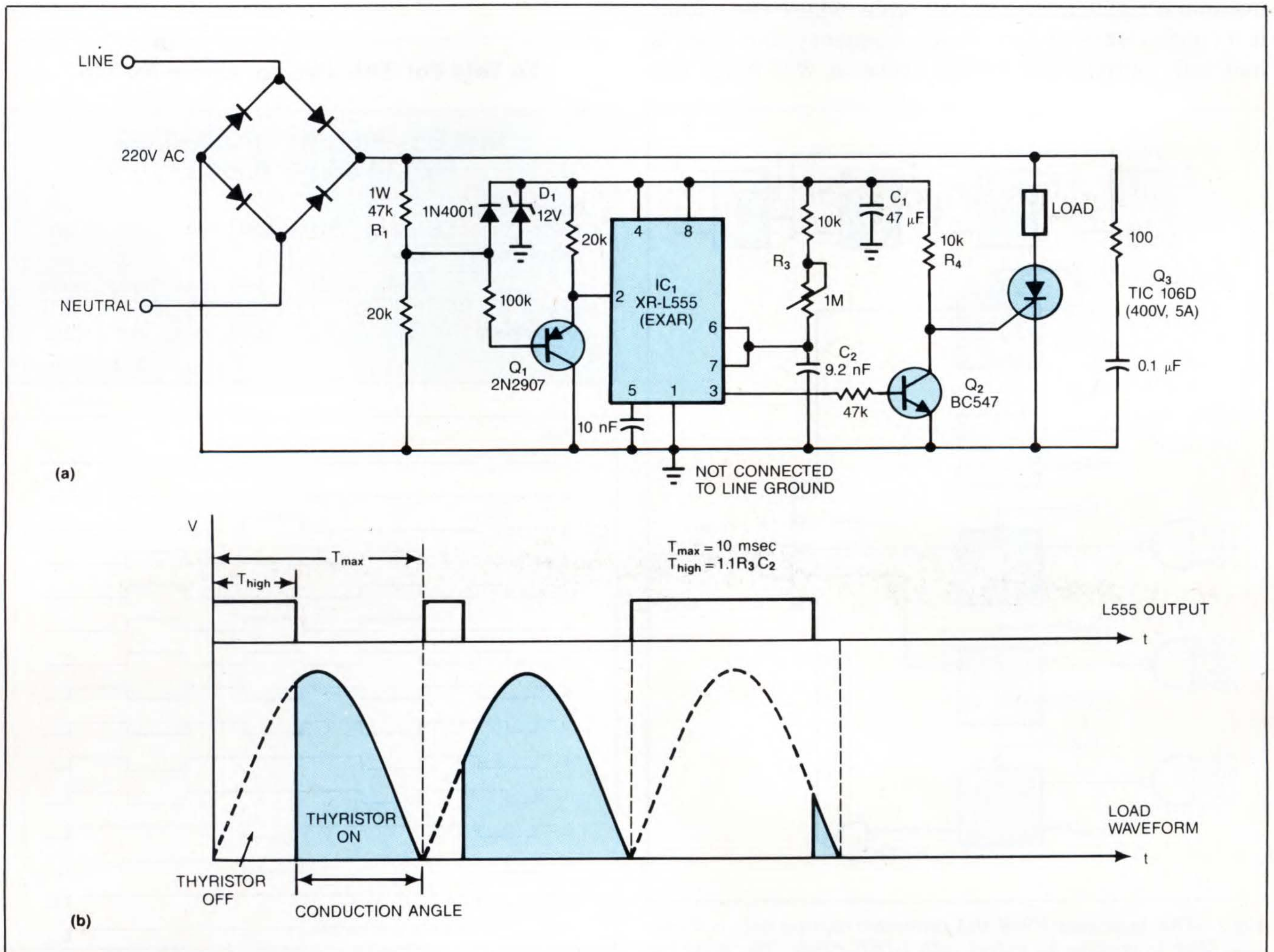

Fig 1—Adjusting this circuit's R_3 (a) varies the percent of each line cycle that power is applied to the load (b).

PWM DAC simplifies output filtering

Roy Sprowl
Litton, Chatsworth, CA

Composed entirely of logic gates, the PWM D/A converter of **Fig 1** is suitable for gate-array designs. The circuit's output signal requires less filtering than that of conventional PWM DACs. A single-pole filter, with a corner frequency (f_0) equal to 1/20th of the converter's sample rate, is sufficient to reduce the converter's output ripple to less than 1 LSB p-p. What's more, the filter requirement depends only on the sample rate and not on the converter's bit resolution. For a given level of ripple, a conventional PWM converter would require filtering in proportion to its bit resolution **(Table 1).**

Fig 2's waveforms illustrate the circuit's reduced need for filtering. A conventional PWM converter's maximum ripple occurs at half scale, where the output is a square wave at the sample frequency, but **Fig 1's** half-scale output is a square wave at 2^{n-2} times the sample frequency. In fact, **Fig 1's** maximum ripple does not exceed 3× that associated with the count 1 waveform of **Fig 2.**

Fig 1 has one potential drawback that conventional PWM D/A converters do not have. Because the rate of output transitions varies with the input code, unequal rise and fall times in the output cause a second-order nonlinearity error. This error value peaks at half scale and is most noticeable in fast or high-resolution versions of the converter.

Although the circuit is similar to a rate-multiplier IC, it has an asynchronous counter that enables its faster operation. You can scale the circuit for other bit resolutions; for an n-bit counter, the bit resolution equals n+1 bits. The n input bits are B_0-B_4 (in this case), and f_{CLK} is a square wave at 2^{n-1} times the sample rate. **EDN**

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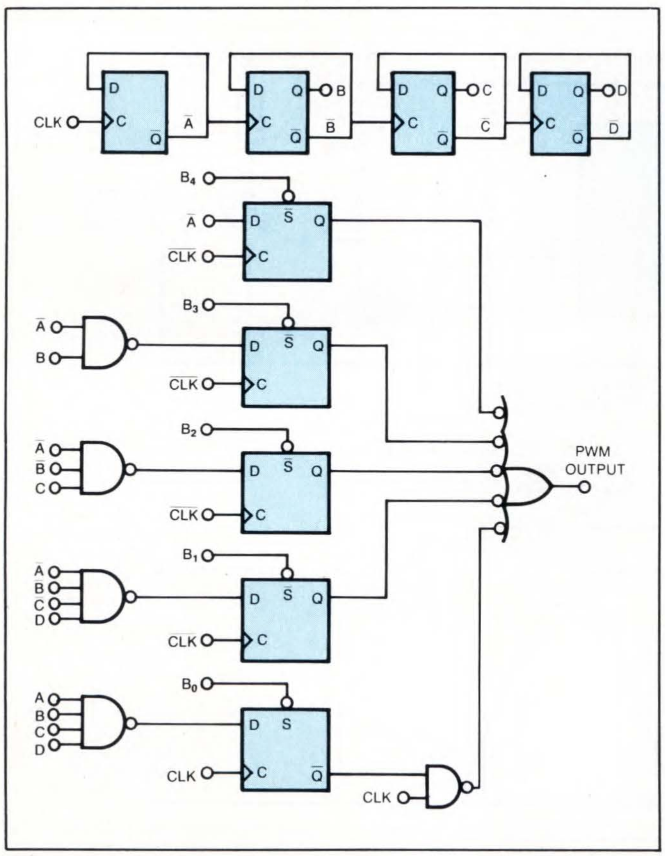

***Fig 1—This logic-gate PWM D/A converter** requires only a single-pole filter to produce an output with 1-LSB ripple. You make the connections indicated between the counter outputs shown at the top and the left-side input terminals.*

TABLE 1—FILTER FREQUENCIES FOR 1-LSB P-P RIPPLE

CONVERTER TYPE	Low-Ripple	PWM	PWM	PWM	PWM	PWM
RESOLUTION	n-bit	4-bit	6-bit	8-bit	10-bit	12-bit
f_0/f_{SAMPLE}	1/18.8	1/23.5	1/99	1/400	1/1600	1/6400
RIPPLE FREQUENCY	×1	×1.25	×5.2	×21.3	×85	×340

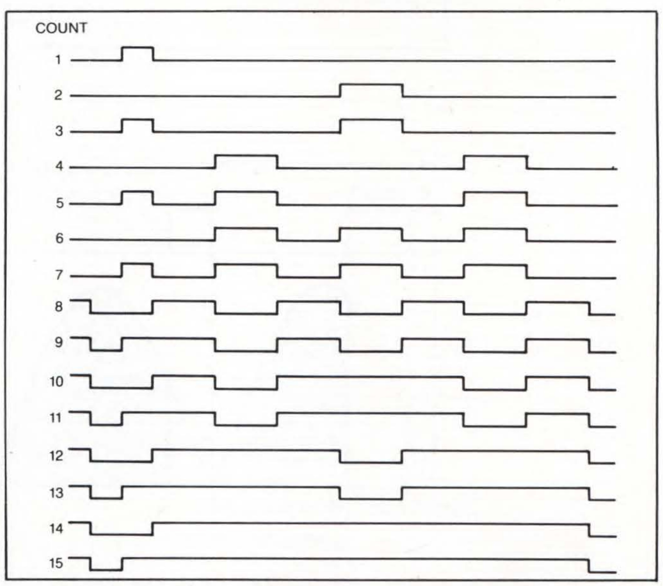

***Fig 2—Fig 1's circuit produces** these output waveforms in response to the counter's 16 output codes.*

Add text to composite-video signal

Stephen Tomporowski
Philips Medical Systems Inc, Shelton, CT

The **Fig 1** circuit shows a simple way to add text information to a composite-video signal that may be floating at some indeterminate dc level. The text generator and composite-video source must have the same sync signal.

The video-input and -output signals share the same terminal. C_3 couples the video signal to the output of a rectifier circuit that is based on a subvideo-speed op amp. (A faster op amp would clamp on individual sync pulses rather than on the video waveform's average value, as is desired.) C_3 accommodates applications in which the video blanking level is negative (below ground). By adding a second electrolytic capacitor in series, with their negative leads connected, you can eliminate the circuit's sensitivity to the polarity of the video signal's dc component. R_{11} serves as a pulldown resistor, and feedback resistor R_{10} ensures that TP6 remains at ground level.

Emitter follower Q_1 buffers the text signal, and R_5 serves as a gain control. A simple clamp circuit (Q_2) is sufficient for regulating amplitude because the text signal contains no gray-scale levels. Q_3 couples the text signal into the op-amp clamp circuit. Although a sync-driven clamp would offer higher performance, this type of circuit performs the function required of it—preventing the addition of text from creating a hump or a dip in the video waveform's blanking level. Such aberrations produce unsightly light or dark bars across the monitor screen's text display. **EDN**

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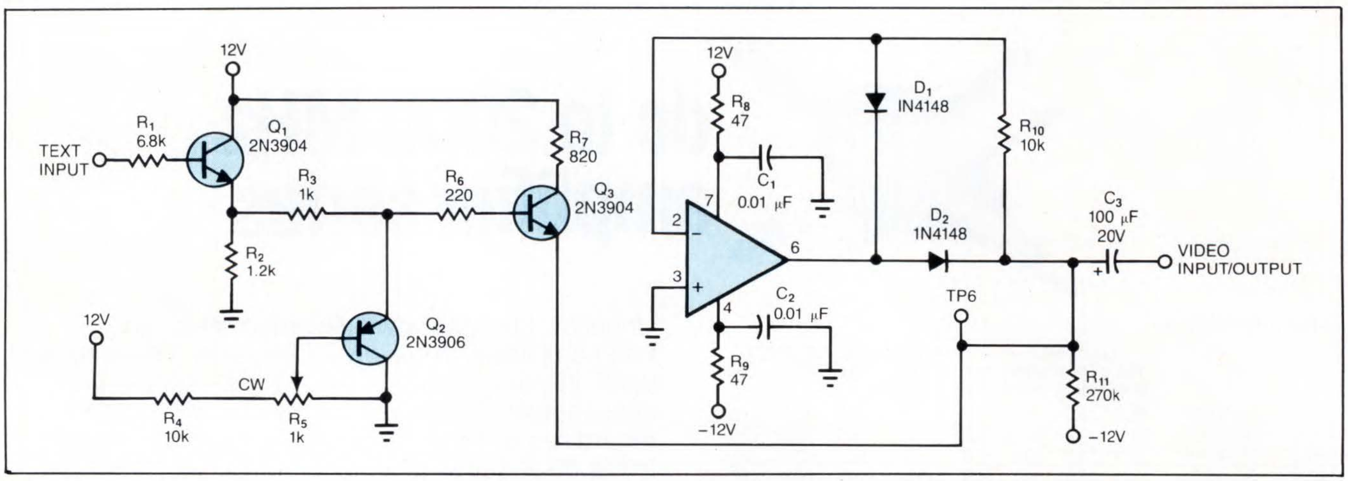

*Fig 1—**This circuit adds a text-information signal** to a composite-video signal of indeterminate dc level.*

First-order allpass filter uses an MF10

Kevin Hoskins
National Semiconductor Corp, Santa Clara, CA

You can use a first-order allpass filter to provide compensation for closed-loop control systems, or to remove the ringing on transmitted square waves by compensating for the transmission line's nonideal phase shift. In addition, you can use such a filter for motor control by creating a quadrature oscillator that generates sine and cosine waveforms. **Fig 1a** shows a conventional first-

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CIRCLE NO 142

order allpass circuit using an RC network and an op amp; **Fig 1b** shows an equivalent circuit based on ½ of an MF10 dual switched-capacitor filter. (If you don't need the other ½ of the filter section, use an MF5 single-section filter instead.)

For both **Fig 1** circuits, the phase response begins with 0° phase at dc, becomes 90° at the center frequency (f_O), and approaches 180° as the input frequency increases. Just as you would expect for an allpass-filter response, neither of the circuits alters the input amplitude. **Fig 1a**'s transfer function, normalized to $\omega=1$, is

$$\frac{V_{OUT}}{V_{IN}}=-\frac{s-1}{s+1}.$$

Fig 1b's realization of this function duplicates **Fig 1a**'s noninverting path by routing the input signal to pin 5, through the first integrator, through R_3, and back into pin 4. **Fig 1b**'s corresponding inverting path consists of the MF10's op amp, R_2, and R_1. The normalized transfer function for **Fig 1b** is

$$\frac{V_{OUT}}{V_{IN}}=\frac{-1\left(\frac{sR_2}{R_1}-\frac{R_2}{R_3}\right)}{s+\frac{R_2}{R_3}}.$$

Setting $R_1=R_2=R_3=10\ k\Omega$ reveals the similarity of **Fig 1b**'s transfer function to the **Fig 1a**'s transfer function:

$$\frac{V_{OUT}}{V_{IN}}=\frac{-1(s-1)}{s+1}.$$

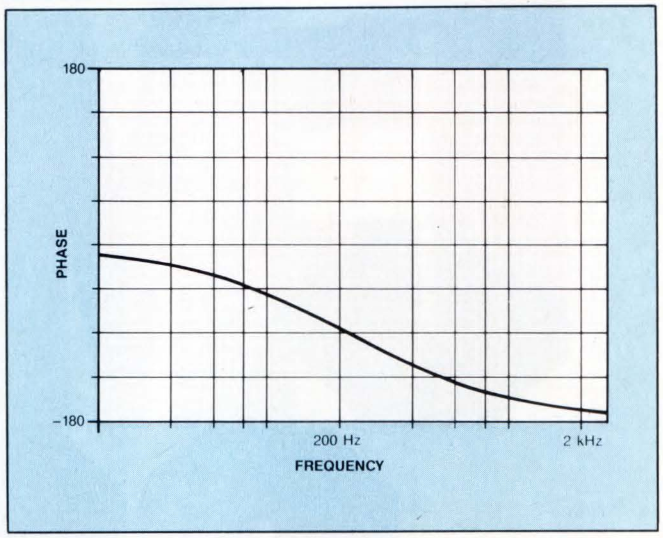

Fig 2—The phase response for Fig 1b *shows −90° at f_O (210 kHz).*

Fig 2 shows the phase response of the **Fig 1b** circuit when f_{CLK}=210 kHz. When the circuit uses 1% resistors, the amplitude response is flat to within ±0.3 dB. The center frequency equals $f_{CLK}/50$ or $f_{CLK}/100$, depending on the connection to pin 12. You can change f_O simply by changing f_{CLK}. Note that **Fig 1b** also provides a first-order lowpass-filter output at pin 2, with a gain of −2. This output's −3-dB f_O is the same as that of the allpass-filter output—$f_{CLK}/50$ or $f_{CLK}/100$. **EDN**

To Vote For This Design, Circle No 746

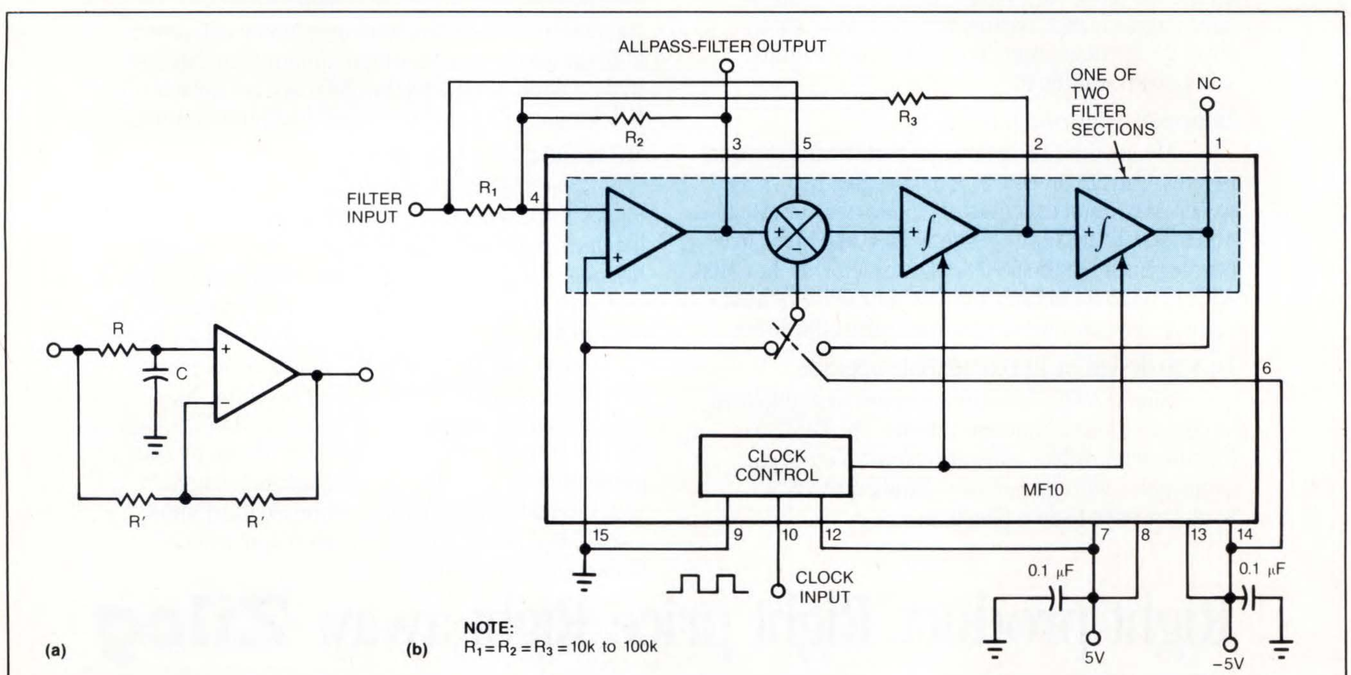

Fig 1—The op amp circuit (a) *and the switched-capacitor-filter IC* ***(b)*** *both provide a first-order, allpass-filter response.*

DDC NEWS

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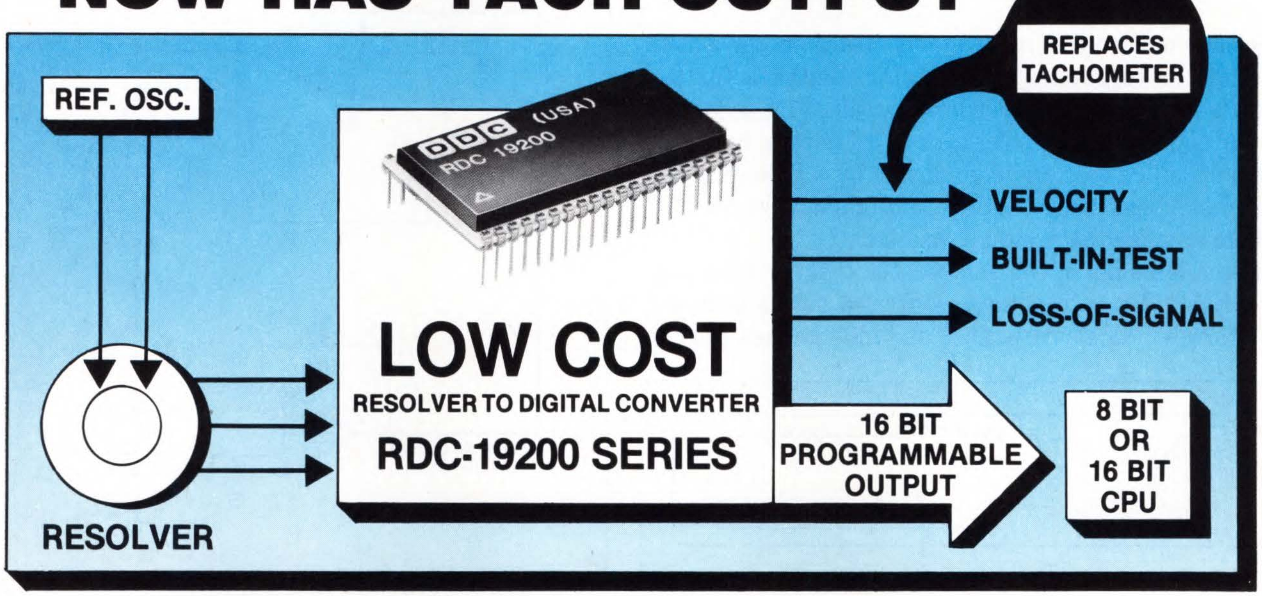

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Motor controller eliminates tachometer

Barry Friedman
Copley Controls, Newton, MA

Precision motion-control systems use a motor-driven tachometer to generate electronic feedback for the motor's servoamplifier in order to attain 0.1% accuracy. If your application can tolerate 2 to 3% errors, however, you can reduce cost and complexity by eliminating the tachometer and using the servomotor's own back-EMF voltage as a feedback signal instead.

A simple model of the servomotor **(Fig 1)** shows the back EMF (V_e) as a voltage source in series with the armature winding's resistance and inductance. You can

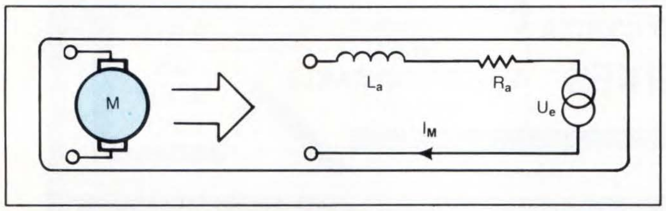


Fig 1—A first-order model of a servomotor *includes the motor's armature inductance (L_a), armature-winding resistance (R_a), and back-EMF source (V_e).*

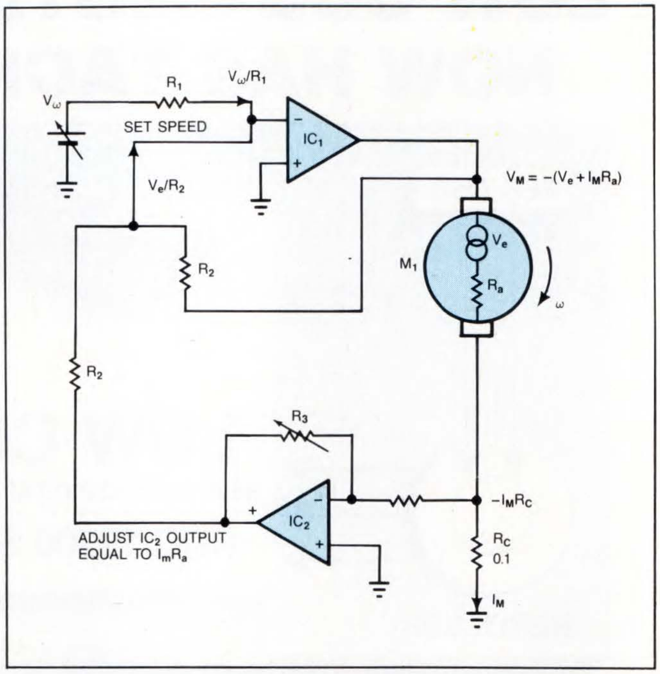


Fig 2—This generalized schematic illustrates *the principle of using V_M as a feedback signal, after first subtracting the motor armature's error-producing IR drop.*

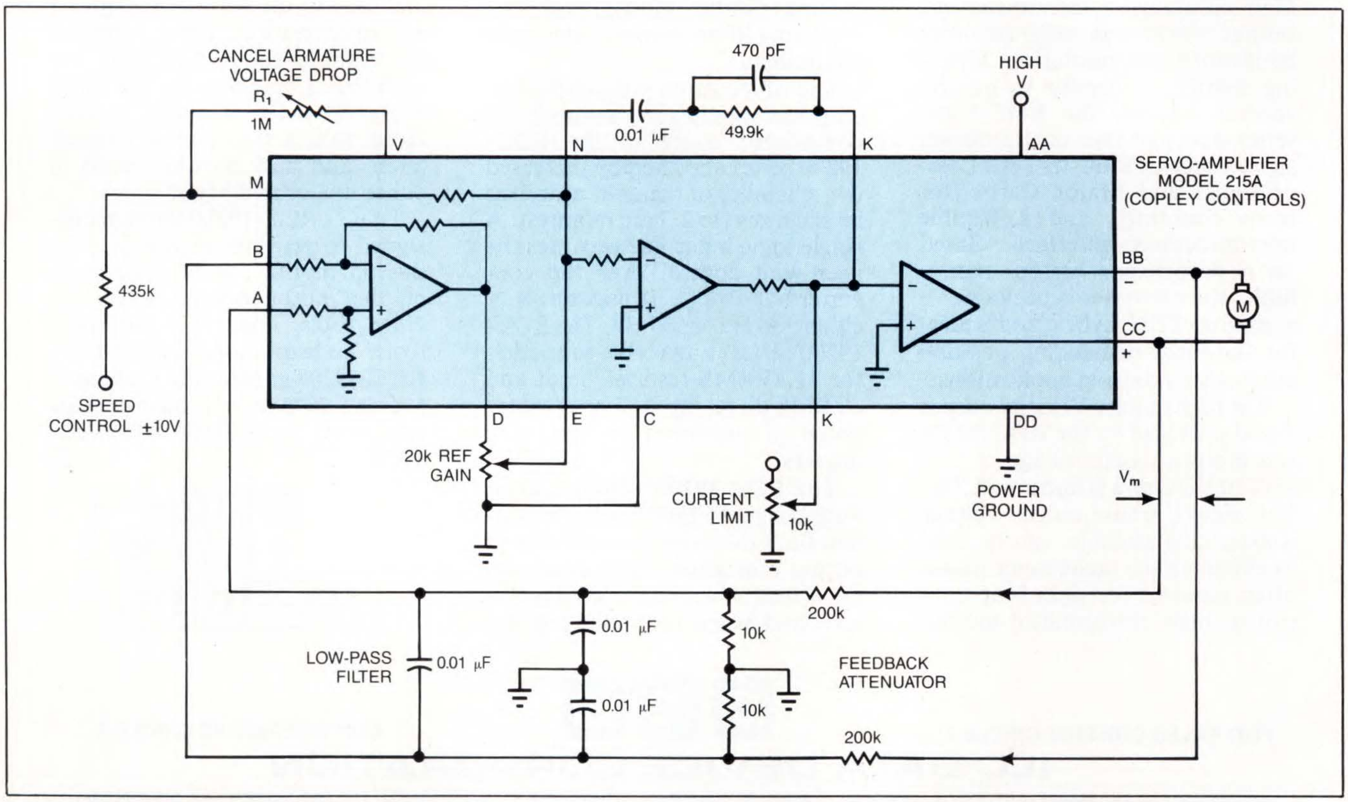
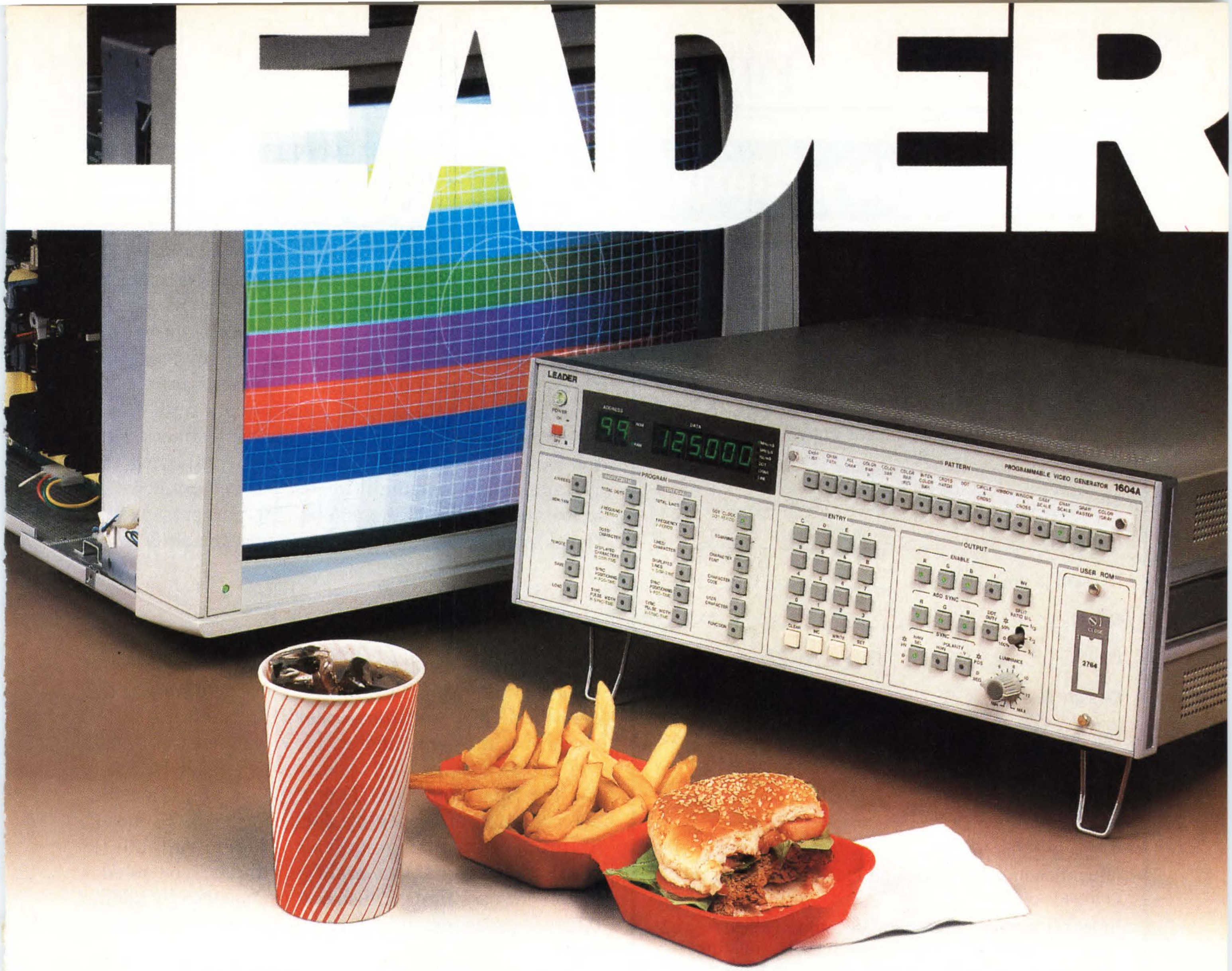


Fig 3—This circuit uses the Fig 2 approach *and makes use of a current-sensing circuit internal to the servoamplifier.*



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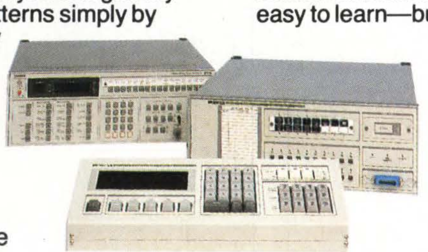

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(Must accompany all Design Ideas submitted by US authors)

Entry blank must accompany all entries. Design entered must be submitted exclusively to EDN, must not be patented, and must have no patent pending. Design must be original with author(s), must not have been previously published (limited-distribution house organs excepted), and must have been constructed and tested.

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

Signed ______________________________

Date ______________________________

ISSUE WINNER

The winning Design Idea for the May 26, 1988, issue is entitled "Tachometer circuit reduces parts count," submitted by William McClelland of Stahl Research (Port Chester, NY).

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

ignore the inductance for steady-state conditions, but the armature current flowing in R_a creates a voltage error in series with V_e. Consequently, the voltage across the armature terminals ($V_e+I_MR_a$) represents pure back EMF only for zero armature current (as, for example, when you turn off the power and let the motor coast to a stop).

Fig 2 shows a circuit that subtracts the error term I_MR_a from the motor voltage V_M, leaving only the desired V_e term for use as a feedback signal. The current-sense resistor, R_C, enables op amp IC_2 to generate the I_MR_a-cancellation voltage; feedback resistor R_3 lets you calibrate the system by adjusting that voltage. The servoamplifier, IC_1, then produces the drive voltage (V_M) by summing the currents proportional to I_MR_a, V_M, and the command variable V_ω:

$$\frac{V_\omega}{R_1}=\frac{V_e}{R_2}\Rightarrow V_e=V_\omega\frac{R_2}{R_1}.$$

Fig 3's implementation of this approach incorporates a specific servoamplifier. Because products such as this one, the Copley Controls Model 215A, deliver a differential output (V_M) as high as 150V, you must attenuate the feedback signal with resistive dividers (200 kΩ to 10 kΩ for this example). This type of amplifier also achieves high efficiency by delivering a PWM output. To produce an analog-equivalent signal suitable for feedback to the servoamplifier's input, you need a simple lowpass filter, which you can achieve by adding 0.01-μF capacitors to the resistor network already in place.

The servoamplifier includes a current-sensing circuit normally used for the remote indication or control of torque, which enables it to cancel the motor armature's I_MR_a term with the help of an external 1-MΩ potentiometer (R_1). R_1 also controls the degree of positive feedback (damping). You should set the potentiometer to its maximum value, and then adjust the system for optimum speed stability by gradually decreasing the resistance setting. **EDN**

To Vote For This Design, Circle No 749

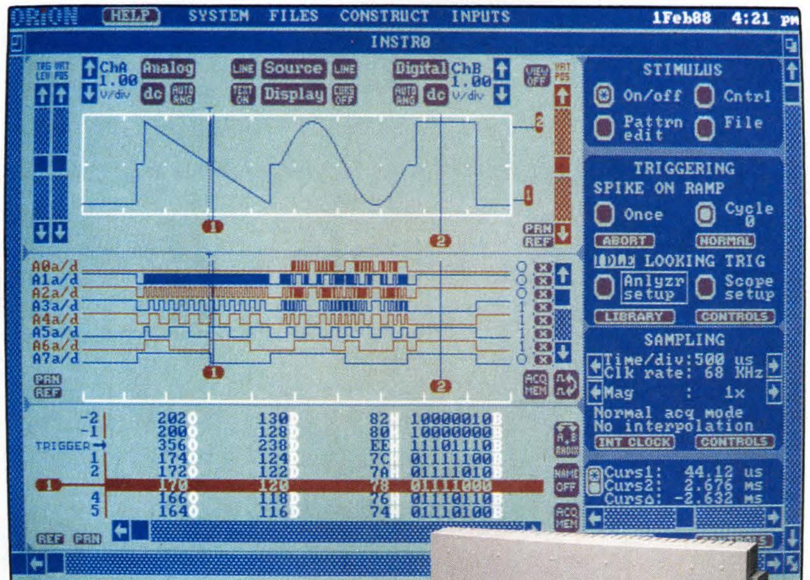
Introducing OmniLab 9240.
Totally Integrated Scope-Analyzer-Stimulus.

■ Combine a 100 MHz digital oscilloscope with a time-aligned, 200 MS/s 48-channel logic analyzer. Next add synchronized analog **and** digital stimulus generators. Then a remarkable new triggering system. What you have is the 9240 — a whole **new class** of instrumentation. Expressly designed to speed challenging analog and digital analysis. And get you from concept to product faster.

■ The 9240 is based on an innovative new instrument architecture that merges high-speed universal hardware and seamlessly-integrated software to create high-performance capabilities not available in separate instruments. Analog and digital traces are always time-correlated in a unique, single screen display. SELECT™ triggering bridges scope and analyzer techniques. And OmniLab's stimulus generators can playback captured or edited signals.

■ At the heart of the 9240 is SELECT triggering, the most straightforward and complete solution **ever** to triggering dilemmas. It's one system, operating with synchronized analog and digital views of your data. By combining conventional oscilloscope and analyzer triggering with powerful RAM truth tables — plus min/max time qualification as needed — SELECT triggering helps you analyze hardware, debug software, and integrate systems more easily.

■ OmniLab™ is a generation ahead of conventional digital scopes that often hide rarely occurring faults because they only show you a few cycles out of millions. With its continuous monitoring, you can use SELECT triggering to quickly catch every occurrence of rare events like metastable states, bus contentions, missing pulses, and buried noise glitches.



OmniLab display demonstrates capture of an imbedded analog glitch (in top trace) with time-aligned presentation of the waveform's digitized bit values (center) and numeric states.

■ The 9240 is like having a complete benchtop of instruments integrated with your PC/AT or compatible. Which you can easily customize for digital development, analog development, or a combination of both.

■ With OmniLab, your productivity will soar. Because you achieve results with fewer instruments. And in fewer steps than ever before. By no means least, the 9240 delivers the best price/performance you'll find anywhere, costing just $8900 fully outfitted. And most importantly, without compromising a single high-performance spec. Not a one.

NO-COMPROMISE 9240 SPECIFICATIONS

DIGITAL OSCILLOSCOPE		LOGIC ANALYZER	
Digitizers:	Two, 8 bit	Inputs:	48, timing and state
Bandwidth:	100 MHz	Asynchronous Clocking:	34 MS/s on 48 inputs; 204 MS/s on 8 inputs
Single-Shot Digitizing:	34 S/s to 204 MS/s		
Repetitive Sampling:	680 MS/s	Repetitive Sampling:	680 MS/s on 48 inputs
Scale Factor:	5 mV/div to 10V/div in 1-2-5 sequence	Synchronous Clocking:	0 to 34 MS/s
		Acquisition Memory:	4K samples (16K, 64K optional)
Record Length:	4K (16K, 64K optional)	Disassembly Options:	Over 150 microprocessors
ANALOG STIMULUS		**DIGITAL STIMULUS**	
Output:	8mV to 8 V peak-to-peak, 8 bit	Outputs:	24, 74F tri-state drivers
Cycle Length:	4 to 4K samples (16K optional)	Cycle Length:	4 to 4K samples (16K optional)
Clocking:	34 S/s to 34 MS/s	Timing:	34S/s to 34MS/s
Functions:	Record, edit and playback	Functions:	Record, edit and playback

■ For more information, call **toll free 800/245-8500.** In CA: 415/361-8883. Or write for complete literature.

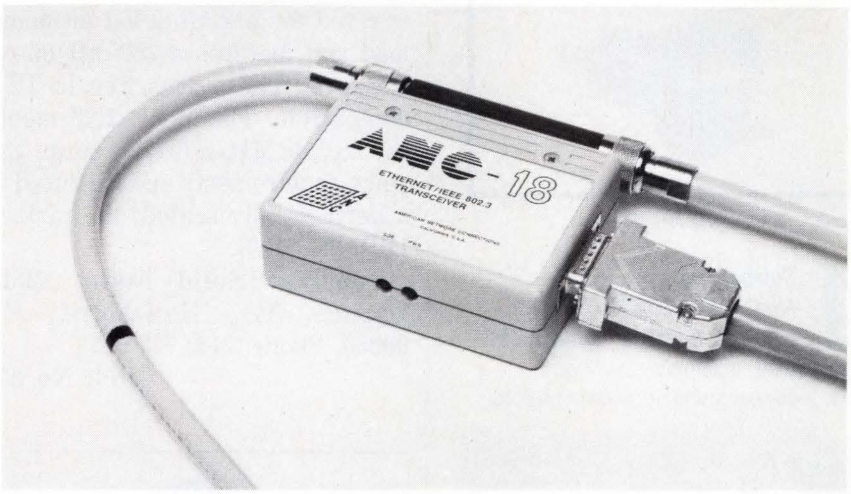
ORION INSTRUMENTS

702 Marshall Street, Redwood City, CA 94063
TELEX: 530942 FAX: 415/361-8970

Computer Integrated Instrumentation

*OmniLab, and SELECT are trademarks of Orion Instruments, Inc.

COMPONENTS & POWER SUPPLIES



TRANSCEIVER

- *Connects to a standard Ethernet coaxial cable*
- *Features proper operation and power indicators*

The ANC-18 transceiver connects standard Ethernet-coaxial (10-BASE5) or thin-coaxial (10-BASE2) cable with a choice of three taps—AMP piercing, N-type, and BNC-type. It is designed to comply with Ethernet V2/IEEE 802.3 transceiver specifications and 10M-bps Ethernet CSMA/CD operation. The unit features two indicators for operation and power statuses and is housed in a die-cast aluminum case. The units are UL, CSA, TUV, and FCC certified. $280.

American Network Connections Inc, 462 Oakmead Parkway, Sunnyvale, CA 94086. Phone (408) 737-1511. TWX 650-334-0732.

Circle No 370

LASER DIODES

- *Designed for long-haul applications*
- *Feature 0.2-nsec response time*

DFB laser diodes are designed for long-haul, high-speed communications applications. Available in hermetically sealed metal packages, the diodes feature a typical side-mode suppression ratio of 33 dB. They operate in a stable transverse mode and feature a 0.2-nsec pulse-response time. All six devices in the line have a 20-mA typ operating threshold current and output 5 mW typ. Three of the units—ML7912, ML7612, and ML7702—operate at a 1310-nm optical wavelength. The ML9912, ML9612, and ML9702 feature a 1550-nm output wavelength. $1787 to $2112.

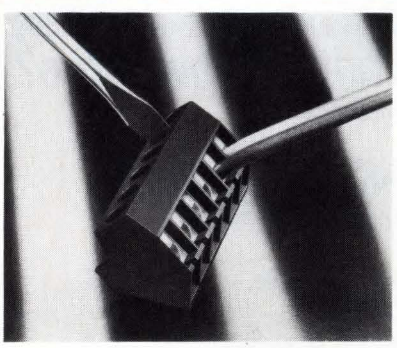
Mitsubishi Electronics America Inc, 1050 E Arques Ave, Sunnyvale, CA 94086. Phone (408) 730-5900.

Circle No 372

TERMINAL STRIPS

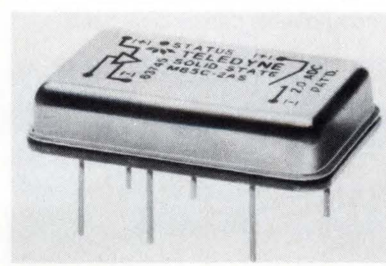
- *Save space on crowded pc boards*
- *Captive protectors hold wires securely in place*

With 0.197-in. contact spacing, Eurostyle 45° entry terminal strips save space while providing easy, safe access for wiring on crowded pc boards. In addition to a small footprint and easy wire access, the terminals have touch-proof recessed terminals and wire-ready captive screws that won't fall out and cause shorts. The terminal strips carry a 15A UL-recognized current rating and will accommodate voltages to 300V. Other features include a large wire-entry design that will accept 14 AWG wires, a closed side that acts as a wire stop, and thermoplastic insulator material that has a 130°C temperature index and carries a 94V-0 UL flame-retardant rating. $0.18/circuit (500).



Vernitron Corp, Beau Products Div, Box 10, Laconia, NH 03247. Phone (603) 524-5101. TWX 710-364-1843.

Circle No 371



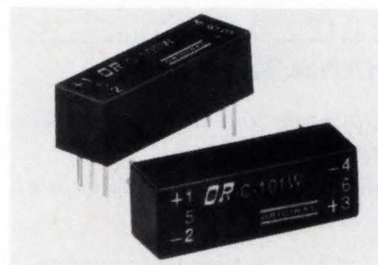
SOLID-STATE RELAY

- *Features output-status feedback*
- *Senses a short-circuit condition and shuts down*

The M85C-2AS solid-state relay features true output-status feedback as well as short-circuit and current-overload protection. An output-status pin indicates that the output is on and conducting current. The short-circuit protection provided will sense a short-circuit condition and initiate a shutdown within 5 μsec. The relay will block the short-circuit condition indefinitely until the short circuit is removed and the input control is recycled. The relay is rated for a 2.1A/60V continuous load and features a 280-mΩ on-resistance. The status line is TTL compatible. The M85C-2AS meets the 28V dc MIL-STD-704 surge and spike requirements and is housed in a hermetically sealed, militarized DIP. $90 (100).

Teledyne Solid State, 12525 Daphne Ave, Hawthorne, CA 90250. Phone (213) 777-0077.

Circle No 373



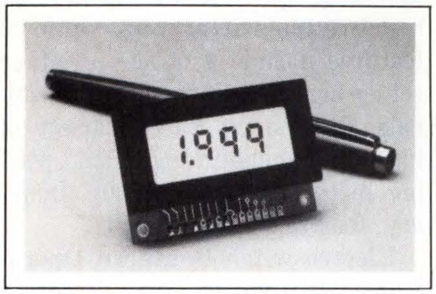
REED RELAY

- *Designed to meet high-density packaging requirements*
- *Features a −30 to +60°C operating range*

Measuring only 0.394×0.375×1.157 in. for a 1 Form A type, the OR-C Series reed relays meet the high-density packaging requirements of applications in instrumentation, audio and telecommunications equipment, and security and control systems. Contact configurations of 1B, 2A, 2B, 3A, and 3B are also available. The relays are available in both open and enclosed versions and operate over a −30 to +60°C range. Switching capability specs at 1A at 3 to 24V dc. Coil sensitivity ranges from 100 to 280 mW. The relays have a 2-million-operations lifetime at the rated load. $1.36 (1000) for 1 Form A relays.

Original Electric Mfg Co Inc, 123 Lincoln Blvd, Middlesex, NJ 08846. Phone (201) 271-5770.

Circle No 374



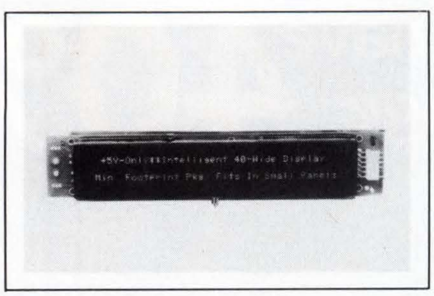
DIGITAL PANEL METER

- *Supports all 4- to 20-mA transmitters*
- *Adjustable for both the zero and full-range spans*

The DP-670 supports all 4- to 20-mA transmitters and interfaces directly to any 4- to 20-mA process loop. The meter draws operating power from the loop. The DP-670 features full differential input, 86-dB min CMR, and a dual-slope integrating A/D converter. As shipped from the factory, it is calibrated for a reading of 0 at 4 mA and 2000 at 20 mA. Both the zero and full-range spans are adjustable to permit users to fine tune the full-scale display ranges. You can momentarily freeze the display by strapping the hold-display pin to 5V dc. $95.

Acculex, 440 Myles Standish Blvd, Taunton, MA 02780. Phone (617) 880-3660. TLX 503989.

Circle No 375



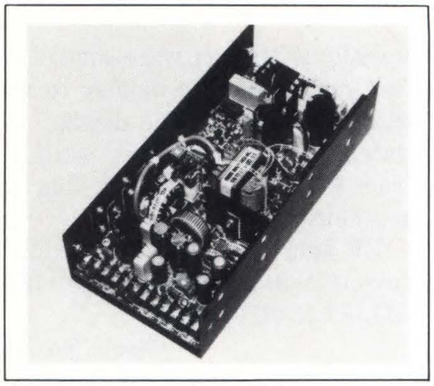
DISPLAY

- *Flicker-free operation under data-loading conditions*
- *Onboard μP controls all display functions*

The 3601-54-080 intelligent vacuum-fluorescent display provides two lines of 40 5×7 dot-matrix characters measuring 5.05 mm high. It offers flicker-free operation under all normal data-loading conditions. An onboard μP controls all the display functions and easily interfaces to an 8-bit parallel TTL data bus. The module displays the full 96-character ASCII font and additional European characters, scientific symbols, and user-programmable characters. The brightness level is typically 165 fL; software-control allows you to dim the display to approximately 50 fL. The display operates from a single 5V supply. From $177 (100). Delivery, four to six weeks ARO.

IEE Inc, 7740 Lemona Ave, Van Nuys, CA 91409. Phone (818) 787-0311. TLX 4720556.

Circle No 376



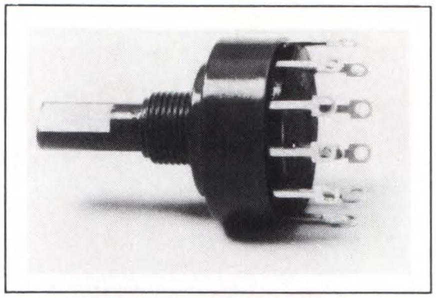
POWER SUPPLIES

- *Provide four fully isolated outputs*
- *Suitable for tight-space applications*

Having dimensions of 5×2.5×10.5-in., NQF-200 Series 200W switch-mode power supplies are suitable for enclosures where space is at a premium. The units provide four fully isolated outputs. The main output is preset to 5V at 25A and features a remote-sensing capability. Users can specify the three auxiliary voltages in any combination. Standard values are 5, 12, 15, or 24V, but custom voltages are also available. Outputs 1, 3, and 4 are fully regulated. Output 2 is semiregulated and features a 10A surge-current rating. All outputs are fully protected against overload and short-circuit conditions. The supplies are designed to meet VDE, UL, CSA, IEC, BS, and FCC safety standards and contain VDE-standard RFI line filters. $252 (50).

Intelligence Power Technology Inc, 2111 Howell Ave, Anaheim, CA 92806. Phone (714) 937-1301. TWX 910-591-1893.

Circle No 377



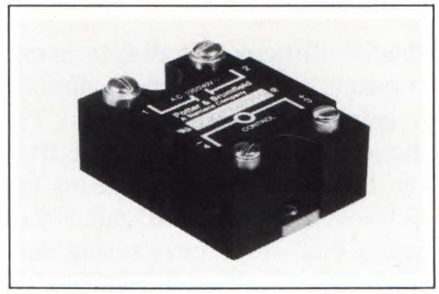
ROTARY SWITCHES

- *Molded silver-plated terminals lock out flux*
- *Will carry 5A*

Series 900A rotary switches are available in single-deck designs with 1- through 4-pole switching configurations. Standard features include a detent mechanism for a positive feel; insert-molded, silver-plated terminals for strength and flux lock-out; water-resistant housing-to-deck construction; 30° indexing; and an adjustable 2- through 12-stop position selector. The units will switch 1A at 125V ac resistive and will carry 5A. Optional features include a choice of either solder-lug- or pc-board-type terminals, fixed stops, and a variety of bushing and shaft lengths and plating materials. $0.90 (1000). Delivery, four to six weeks ARO.

Electroswitch Southern Operations, 2510 North Blvd, Raleigh, NC 27604. Phone (919) 833-0707. FAX 919-833-8016.

Circle No 378



RELAYS

- *Available in 10 and 25A versions*
- *Feature 4000V rms isolation*

SSRT Series solid-state relays feature an spst NO contact configuration and are available in 10 and 25A versions for loads on 120 and 240V ac lines. Housed in the traditional hockey-puck package, they use a triac for the output device. A dv/dt

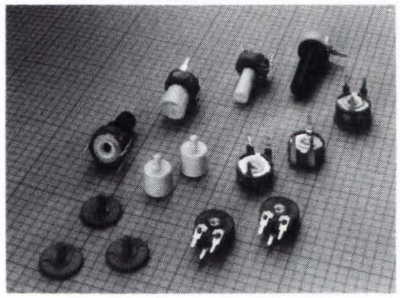
snubber network on the output protects against false triggering by restricting voltage-transient rise times. The zero-voltage-turn-on units are available with control voltage ranges of 3 to 32V dc or 90 to 280V ac. The relays employ optical coupling to develop 4000V rms input-to-output isolation. The relays are UL-recognized and CSA-certified. From $15. Delivery, stock to 10 weeks ARO.

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

Circle No 379

TRIMMERS

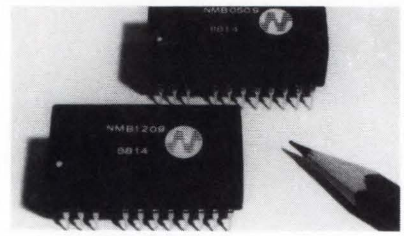
- *Incorporate carbon-ink or cermet tracks*
- *Available with a variety of adjustment arrangements*



The CP10 Series trimming potentiometers are available with either carbon-ink or cermet tracks. The carbon-ink versions use a Mylar film substrate that achieves a better humidity characteristic than conventional paper-phenolic materials. They are available with nominal resistance values between 100Ω and 10 MΩ, and have an end resistance of less than 3% of their nominal value. The cermet versions have a 0.5W power rating at 40°C, and a temperature coefficient of 100 ppm/°C. The nominal value tolerance is 20%, but tighter tolerance parts are available on special order. You can order versions with top, side, or underside adjustment controls. From £0.06 (1000).

Bicc-Citec Ltd, Westmead, Swindon, Wiltshire SN5 7YT, UK. Phone (0793) 487301. TLX 449112.

Circle No 380



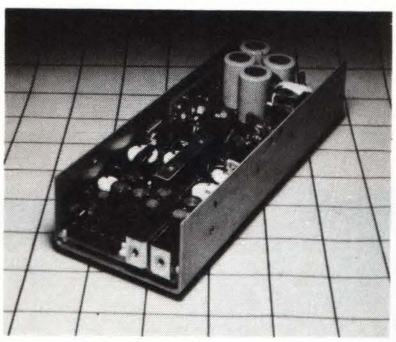
DC/DC CONVERTERS

- *Generate −9V from 5 or 12V dc inputs*
- *Suitable for use with Cheapernet transceivers*

Producing a −9V/250-mA output from a 5 or 12V dc input respectively, the NMB0509 and NMB1209 pc-board mounting dc/dc converters are designed for use in LAN equipment that conforms to the Ethernet or Cheapernet specification. They are suitable for use with a variety of transceiver chip sets. The converters have an input-to-output isolation of 500V dc, and an operating efficiency as high as 80%. They do not require additional heatsinking or derating over their operating temperature range of 0 to 70°C. The converters are housed in 24-pin DIPs with a height above the pc board of 10.8 mm. Around £8 (1000).

Newport Components Ltd, Tanners Dr, Blakelands North, Milton Keynes MK14 5NA, UK. Phone (0908) 615232. TLX 825621.

Circle No 381



POWER SUPPLY

- *Delivers 700W*
- *All outputs are user-adjustable*

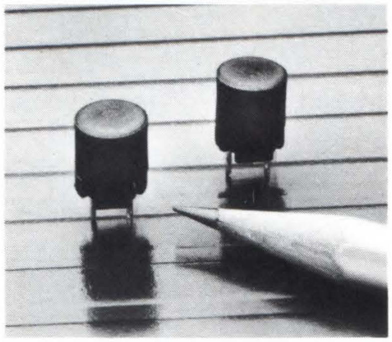
The MAX-704 delivers 700W and provides 100A at 5V for logic and memory applications. As many as three auxiliary outputs provide regulated 12 or −5.2V at 20A max. All outputs feature a ±5% user-adjustment range. Overload protection is provided on all outputs as is overvoltage protection on the 5V main output. Remote inhibit is standard, and power-fail is available as an option. MTBF specs at 80,000 hours. The supply meets international safety requirements such as UL 478, CSA 22.2, IEC 380 and 435, and the Class A RFI standards of FCC and VDE 0871. The supply features creepage and clearance distances of 4 and 8 mm, respectively, to meet SELV requirements. $549 (100). Delivery, stock to six weeks ARO.

Todd Products Corp, 50 Emjay Blvd, Brentwood, NY 11717. Phone (516) 231-3366. TWX 510-227-4905.
Circle No 382

INDUCTORS

- *Internal capacitor conserves pc-board space*
- *Can accommodate wave-soldering processes*

Model 8RBC fixed inductors are designed for noise-filtering and trapping applications. They feature an internal matched capacitor that provides a stable temperature coefficient, conserves pc-board space, and reduces design and assembly time. Inductance values range from 1 to 45 mH, and the operating frequency range spans 50 to 200 kHz. Values for the internal capacitor range



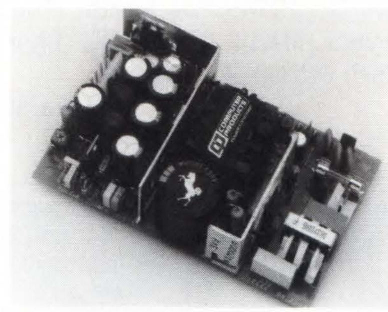
from 5 to 6800 pF. The inductor base features pedestals that protect the winding terminations during assembly operations. The base is molded from UL 94V-1-grade phenol for heat protection during wave-soldering processes. All terminals are presoldered to provide reliable pc-board bonds. $1. Delivery, six to eight weeks ARO.

Toko America Inc, 1250 Feehanville Dr, Mount Prospect, IL 60056. Phone (312) 297-0070.
Circle No 383

POWER SUPPLIES

- *Accept any input from 85 to 264V ac without jumpers*
- *Available in single- and triple-output versions*

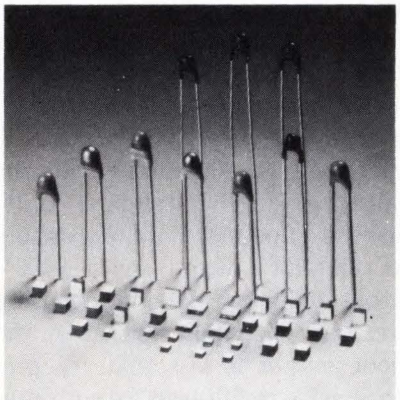
NFS40 40W switching power supplies will accept any input from 85 to 264V ac without the need for jumper wires or a switch. Versions are available with single outputs (5, 12, 15, or 24V) and triple outputs (various combinations of 5, 12 and 15V). The supplies will regulate down to zero output load and feature a



160,000-hour MTBF. Line regulation is ±0.5% max and efficiency specs at 70%. The supplies are approved by UL, CSA, and VDE, and provide sufficient line filtering to meet FCC limit B and VDE limit A line-conducted noise specs. Of the eight models making up the line, only the NFS40-7608 is stocked as a standard product. From $59 (1000).

Computer Products Inc, 2900 Gateway Dr, Pompano Beach, FL 33069. Phone (305) 974-5500. TWX 510-956-3098.

Circle No 384



THERMISTORS

- *Feature a 0.75% beta-value tolerance*
- *Provide low-thermal-conductivity leadouts*

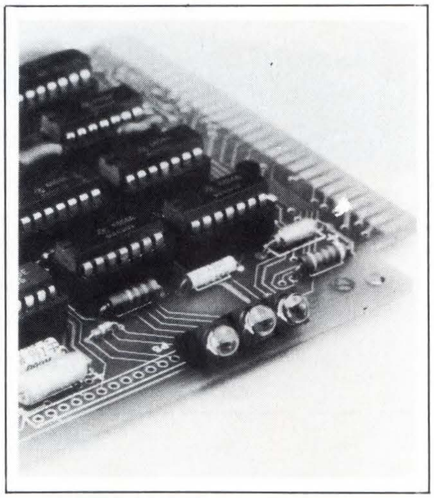
NTC thermistors in the 640-6 and 645-0 stable-line families have a 0.75% beta-value tolerance and a 25°C resistance (R25) with a 3% tolerance. These tolerances allow the units to achieve an accuracy of 1.5°C at 85°C. The 640-6 family comprises 16 devices with R25 values between 2.7 and 470 kΩ. The 645-0 family offers four devices with R25 values of between 5 and 10 kΩ and 38-mm low-thermal-conductivity nickel leads. The thermistors operate from −40 to +125°C. When operating at their maximum rated power of 250 mW, the units function over a reduced range of 0 to +55°C. Gld 0.38 (10,000) for thermistors with a 5% R25 tolerance.

Philips, Components Division, Box 523, 5600 AM Eindhoven, Netherlands. Phone (040) 757189. TLX 51573.

Circle No 385

Mepco/Centralab Inc, Box 760, Mineral Wells, TX 76067. Phone (817) 325-7871.

Circle No 386



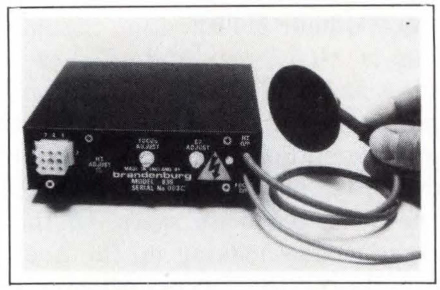
INDICATORS

- *Mount at a 45° angle for better visibility*
- *Meet UL94V-0 requirements*

PC45 Series LED indicators mount on pc boards with the LED at a 45° angle. This design makes the devices well-suited for applications requiring viewing from an elevated position. Designed for use on the edge of boards positioned low in a cabinet or rack, the LEDs are compatible with side-by-side or front-to-back mounting. The indicator housings meet UL94V-0 flammability requirements and are available in red, green, amber, and yellow, all with a choice of diffused or nondiffused encapsulation. Typical operating current and voltage drop spec at 20 mA and 2.1V, respectively. From $0.22 (1000). Delivery, stock to six weeks ARO.

Data Display Products, Box 91072, Los Angeles, CA 90009. Phone (800) 421-6815; in CA, (213) 640-0442.

Circle No 387



HV SUPPLY

- *Powers high-resolution CRTs*
- *Features full regulation*

You can employ the 836A shadow-mask supply for high-resolution monitors. The fully-stabilized dc/dc converter operates from a 20 to 30V input. The supply provides a 22 to 28 kV output voltage at currents as high as 1.2 mA for the final anode of the CRT; the adjustable output voltages for the CRT's focus and G2 grids; and a −200V output for the control grid. The standard model includes a floating, stabilized supply for the CRT's heater and a +400V output to power dynamic focusing circuitry. The ripple voltage on the anode output is less than 5V p-p. Static zero- to full-load output regulation on the anode output is 15V. Around £70 (1000).

Brandenburg Ltd, 939 London Rd, Thornton Heath, Surrey CR4 6JE, UK. Phone 01-689-0441. TLX 946149.

Circle No 388

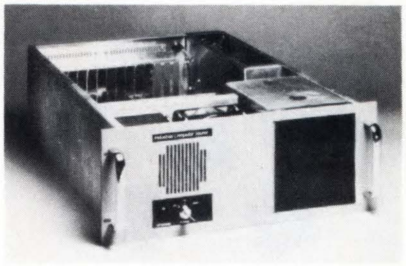
Astec (USA) Ltd, 2880 San Thomas Expressway, Suite 200, Santa Clara, CA 95051. Phone (408) 748-1200. TLX 6839191.

Circle No 389

CHASSIS

- *Delivers full PC/AT functionality*
- *Includes a filtered cooling system*

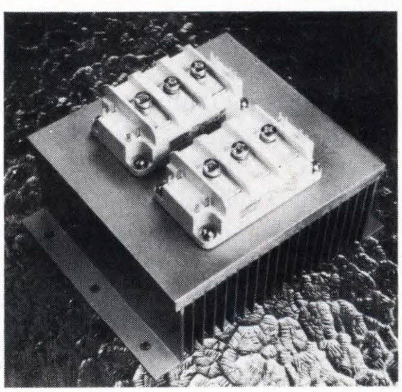
The 7515-24H chassis is designed for installation inside a standard 19-in. rack. When appropriately configured, the chassis can serve as a node, server, or gateway in a network. With its 15-slot backplane,



the chassis delivers full PC/AT functionality. The rugged steel enclosure includes a disk-carrier assembly that can hold as many as four half-height drives, a drive-area cover door, a system reset button, and a 200W power supply with a filtered cooling system. A positive-pressure buildup inside the chassis prevents dust particles from damaging any installed drives. From $1395.

Industrial Computer Source, 5466 Complex St, Suite 208, San Diego, CA 92123. Phone (619) 279-0084. FAX 619-541-1138.

Circle No 390



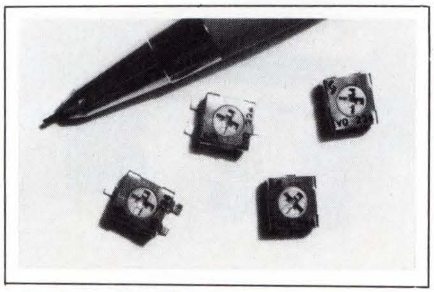
HEAT SINKS

- *For natural-convection and forced-air applications*
- *Achieve 0.024 to 0.08°C/W thermal resistance*

Series 6760 bonded-fin heat sinks are designed for both natural-convection and forced-air applications. Available in nine standard sizes, the heat sinks feature mounting-hole patterns that accept all standard-power-module packages. Forced-air models are designed to accept standard muffin fans with a 4.12-in.-square mounting hole pattern. These models are 5.25 in. high and have mounting surfaces ranging from 7×4.78 to 16×10.78 in. Thermal resistance ranges from 0.024 to 0.08°C/W. Natural-convection models are 3.130 in. high and available in 7- and 12-in. lengths. These units have a 7.375-in.-wide mounting surface and are available with or without mounting flanges. Thermal resistance ranges from 0.22 to 0.30°C/W. $39.37 (100) for the 7-in. natural-convection model. Delivery, eight to 12 weeks ARO.

Aavid Engineering Inc, Box 400, Laconia, NH 03247. Phone (603) 528-3400.

Circle No 391



TRIMMERS

- *Have a temperature coefficient of 50 ppm/°C*
- *Provide surface mounting*

The TS5Y-series single-turn, miniature, surface-mounting trimmer potentiometers feature automatic and manual adjustment. A clutch mechanism prevents damage to the trimmers. For nominal values of 100Ω or higher, the trimmers feature a ±50 ppm/°C temperature coefficient. They come with nominal resistance values between 10Ω and 1 MΩ with either ±10% or ±20% tolerance. The trimmers have a power rating of 0.2W at 85°C and an operating temperature range of −55 to +155°C. Housed in a sealed package, the trimmers can withstand vapor-phase or reflow soldering, and water cleaning. $0.20 (1000).

Sfernice, 199 blvd de la Madeleine, 06021 Nice Cedex, France. Phone 93446262. TLX 470261.

Circle No 392

Ohmtek, 2160 Liberty Drive, Niagara Falls, NY 14304. Phone (716) 283-4025. TWX 710-524-1653.

Circle No 393

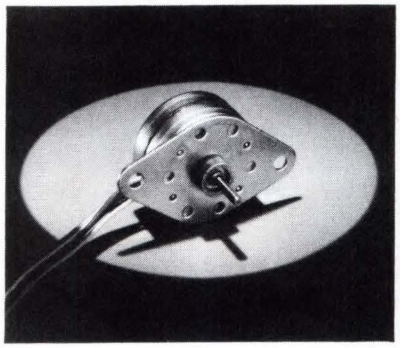
CIRCUIT BREAKERS

- *Address the problem of nuisance tripping*
- *Current ratings of 5 to 20A*

To address nuisance tripping problems, S Series circuit breakers incorporate a solenoid. To reset a remote breaker, you simply actuate the solenoid. The solenoids will operate from 24V ac, 120V ac, or 24V dc. The devices are available in 250V ac and 50V dc versions with current ratings of 5, 10, 15, and 20A. At 200% of rating, tripping time is 6 to 30 sec. Acceptable solenoid-actuation techniques range from a simple switch to a radio-receiver signal. $85 (10).

Casco/Maitland, Box 947, Roswell, GA 30077. Phone (404) 475-3192.

Circle No 394



STEPPER MOTORS

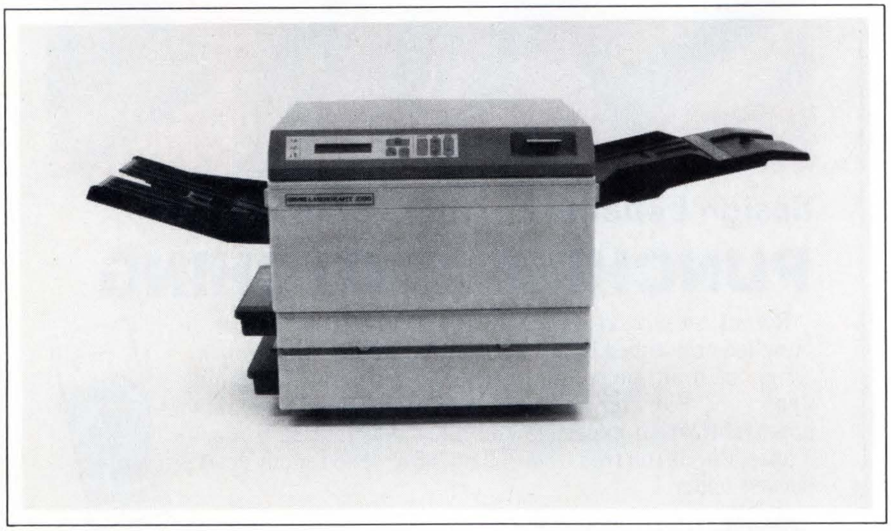
- *Operate from either 5 or 12V dc supplies*
- *Suitable for portable equipment*

With a housing that measures only 1-in. in diameter, Series M82100 and N82100 stepper motors are well suited for portable equipment where space is at a premium. The motors have step angles of 7.5 and 15°, respectively. Both operate from either 5 or 12V dc supplies and are available for unipolar or bipolar operation. The PM motors come equipped with permanently lubricated bronze sleeve bearings. Holding torques for unipolar or bipolar units spec at 1.3 and 1.5 oz-in. on 7.5° models, and 0.7 and 1.0 oz-in. on 15° models. M82100 motors have a 1.1×10^{-4}gm^2 rotor moment of inertia and a ±0.5° step-angle tolerance. These parameters equal 4.5×10^{-5}gm^2 and ±1°, respectively, for N82100 motors. Bipolar motor, $5.35 (500). Delivery, four to 12 weeks ARO.

Airpax Co, Box 868, Cheshire, CT 06410. Phone (203) 272-0301.

Circle No 395

COMPUTERS & PERIPHERALS



LASER PRINTER

- *Prints 22 pages/minute*
- *Offers 36 resident fonts*

The Lasergrafix 2200 laser printer prints at 22 pages/minute and can handle 11×17-in. paper. It offers 36 resident fonts and can support optional slim-card font cartridges. Using an HP-GL emulator, you can make B-size CAD drawings. The desktop printer has two 250-sheet letter-size paper cassettes and one 100-sheet ledger/letter paper cassette. The print engine includes a 16-MHz 68000 μP and 7M bytes of RAM. The engine can concurrently process two B-size pages of bit-mapped graphics at a 300×300-dot/in. resolution. An optional QMS 80-VE interface connects to a Versatec parallel interface on a CAD workstation to emulate the Versatec V-80 electrostatic printer. Another optional printer interface lets the printer attach to IBM 3276, 3274, or 3174 controllers for printing on the IBM 3270 network. $14,995.

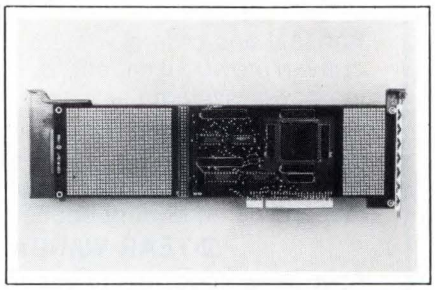
QMS Inc, 1 Magnum Pass, Mobile, AL 36618. Phone (205) 633-4300.

Circle No 351

PROTOTYPE BOARD

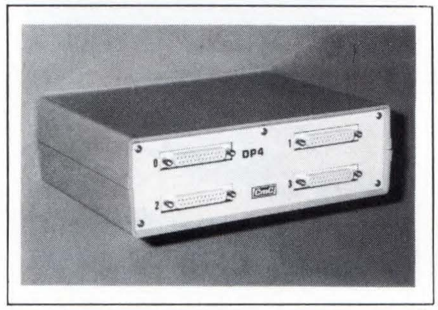
- *For the Micro Channel in IBM's PS/2 model 70 computer*
- *Features the One Chip Plus interface chip*

The One Chip Plus add-in prototype development board for the IBM PS/2 model 70 computer features the company's 88C01 interface chip for the Micro Channel. You can program the chip to decode addresses for extended memory, expanded memory, ROM, and multiple I/O ports. It also supports the Micro Channel DMA arbitration and burst-mode DMA. The chip supports all speeds of the model 70: 16, 20, and 25 MHz. The hardware kit includes the board with decoded memory and an interface for connecting a logic analyzer. The software kit includes the extended and expanded memory driver (LIM 4.0 specification), design utilities, and sample adapter-description files. An acquisition engine provides high-level programming commands for data acquisition and I/O control. Kits range from $495 to $995.



Capital Equipment Corp, 99 S Bedford St, Burlington, MA 01803. Phone (617) 273-1818.

Circle No 352



MULTIPLEXER

- *Adds four buffered ports to any RS-232C or RS-422 port*
- *Transmit and receive buffers*

The DP4 is a 4-port multiplexer for RS-232C or RS-422 interfaces. Each of the four ports contains a 4992-byte transmit data buffer and a 4992-byte receive data buffer. The unit lets the user simultaneously communicate with as many as four devices operating at the same or different baud rates from 75 to 38.4k baud. You can individually select the baud rates, parity, and word length. The unit supports XON/XOFF and hardware handshaking techniques. It is one of the company's CMCNet II system products and can create a system that supports as many as 6400 users via multidrop. Menu-driven control software for IBM PCs and compatible computers is included free of charge. $695.

Connecticut MicroComputer Inc, Box 186, Brookfield, CT 06804. Phone (203) 354-9395. TWX 710-456-0052.

Circle No 353

68030 - VME
The Real *Single* Board Computer

The TP32V from Tadpole

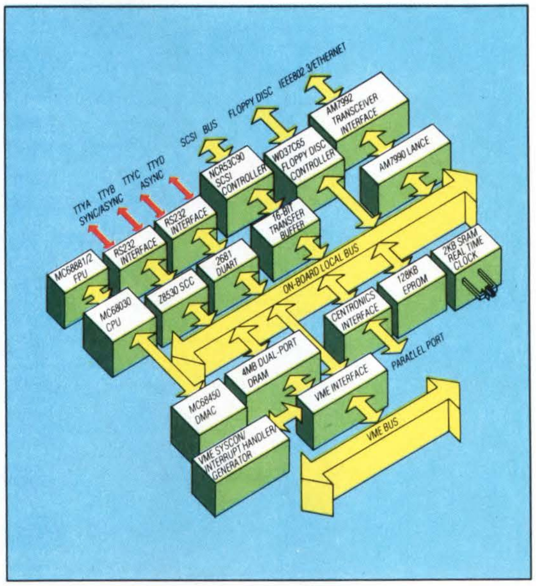
•The Philosophy•

Designed for optimum system performance from a single full IEE 1014 VME board, the TP32V needs no other cards, piggy-backs or mezzanines to deliver the full potential of the 16-33 MHz MC68030. To maximise overall throughput, all the on-board I/O facilities were designed to take advantage of hardware transfer buffers, DMA facilities and advanced DRAM arbitration techniques between competing resources.

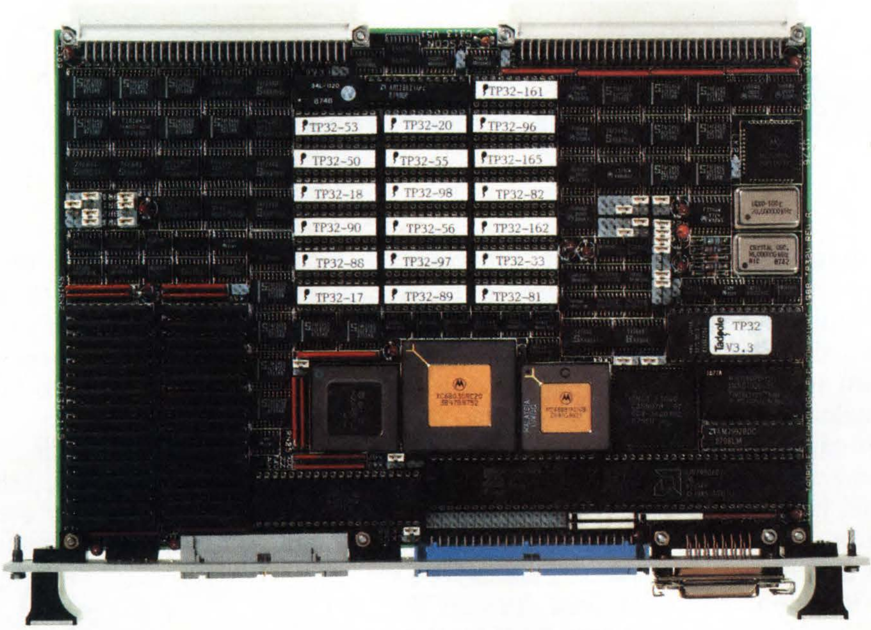
•The Specification•

- MC68030 16-33MHz
- MC68450 4-channel DMA controller
- 4Mb multi-ported nibble-mode DRAM
- AMD Lance IEEE 802.3 Ethernet with DMA
- Z8530 SCC giving two DMA-driven RS232 sync/ asynchronous ports and two further RS232 asynchrous ports
- NCR 53C90 DMA-driven synchronous or asynchronous SCSI interface • Floppy disk controller
- Full VME Rev C.1 IEEE 1014 interface
- 64-512Kb EPROM • Battery-backed RTC/SRAM
- Full debug monitor • Optional MC68881/2 FPU
- TP-IX/68K version of UNIX V.3.1* • NFS, RFS, TCP/IP

•The Design•



• The Evidence•



Tadpole Technology
the driving force in 32-bit design

Tadpole Technology plc
Titan House, Castle Park,
Cambridge, CB3 OAY, UK.
Tel: 0223 461000
Fax: 0223 460727

Tadpole Technology Inc
Reservoir Place,
1601 Trapelo Road, Waltham,
Massachusetts 02154, U.S.A.
Tel: 0101-617-890-8898
Fax: 0101-617-890-7573

2157 O'Toole Avenue,
Suite F, San Jose,
California 95131, U.S.A.
Tel: 0101-408-435-8223
Fax: 0101-408-435-8432

T A D P O L E

WORKSTATIONS

- *Six models for the VAXstation 2000 family*
- *Feature an 8-bit plane graphics coprocessor*

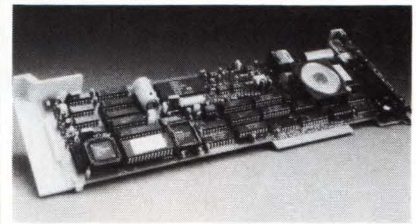
The VAXstation 2000 family has six new models of desktop workstations. They incorporate the company's MicroVAX II CPU and floating-point unit along with a choice of a 15- or 19-in. color monitor. A graphics coprocessor module supports 8-bit planes and offers 256 simultaneous colors from a palette of 16M colors. A 12M-byte memory-expansion module provides a total of 14M bytes of memory. The models are available with either a VMS or an Ultrix operating system. Optional main storage comes in 42M-, 71M-, or 159M-byte hard disks. Backup options include a 96M-byte streaming tape and a 1.2M-byte floppy-disk drive. Applications developed for the VAXstation II/GPX, 3200, and 3500 workstations are fully compatible with the new systems. A system with an 8-bit plane coprocessor, 6M bytes of memory, and a 15-in. color monitor costs $13,830.

Digital Equipment Corp, 146 Main St, Maynard, MA 01754. Phone (617) 493-4297.

Circle No 354

MODEM CARD

- *Allows microcomputer-to-mainframe communication*
- *Includes autodial and autoanswer facilities*



The Syncro-24-PS add-in synchronous modem for IBM-PS/2 computers or Micro Channel Architecture systems lets these systems access mainframe computers. The modem transmits at 2400 bps. It complies with CCITT V26-bis specifications. Another version, the Syncro-48-PS, operates at 4800 bps. This version conforms to V27-ter specifications. The modem's software indicates the condition of the modem-interface signals. Along with the modem's onboard speaker, the software provides information on call progress. In addition, the software provides autodial and autoanswer facilities using commands based on the AT and CCITT V25-bis standards. You can use the autodial software with synchronous communication packages that don't feature autodial functions. You enter dial commands via an independent control channel, which lets you monitor the call's status. A nonvolatile RAM stores

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A HIGHER LEVEL OF PERFORMANCE

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Higher Reliability: MTBF to 500,000 hours with conservative design criteria including NAVMAT guidelines.

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- Meets many provisions of Mil-Std-810D, Mil-E-5400 and Mil-E-16400.

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ARNOLD MAGNETICS CORPORATION

4000 Via Pescador, Camarillo, California 93010-5049
Phone: (805) 484-4221 • TWX 910-343-6468 • FAX: (805) 484-4113

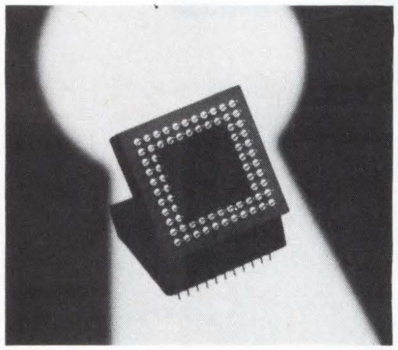
the modem's configuration data. Syncro-24-PS, £545; Syncro-48-PS, £645.

Mayze Systems Ltd, Delta 900, Great Western Way, Swindon, Wiltshire SN5 7XQ, UK. Phone (0793) 511789. TLX 445707.

Circle No 355

ENCRYPTION KEY

- *Protects against unauthorized access of data*
- *Meets NSA's communication security requirements*



The Smart Key encryption device prevents unauthorized data access. This key-like device provides eight pairs of redundant gold contacts that plug into a 16-pin socket. It contains a 12-MHz CMOS μP with ROM for program storage and a 16k- or 64k-byte EEPROM. With the key inserted in a system, you can initialize a new key number, write a record into memory, read a record from memory, read a status register, compute a checksum, read the key number assigned during initialization, and erase the data storage area. The unit measures 5.08×2.54×1.27 cm and weighs less than 12g. It meets NSA's communications security (COMSEC) requirements. $375 (OEM).

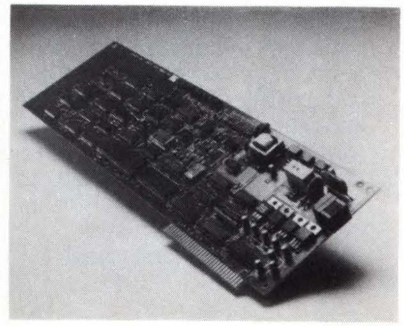
Tracor Inc, 6500 Tracor Lane, Austin, TX 78725. Phone (512) 926-2800.

Circle No 356

VOICE PROCESSOR

- *Has an 8k-sample/sec μ-law codec*
- *Compresses voice data 2 to 1, using 32k-bps ADPCM encoding*

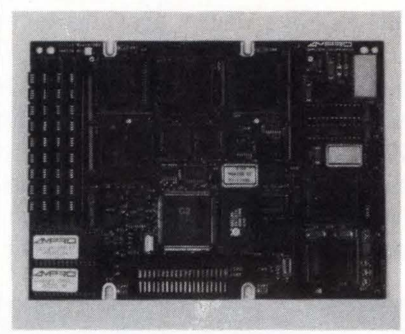
The AVA (Automated Voice Administrator) single-slot IBM XT and AT board for processing voice communications has an 8k-sample/sec μlaw codec; it compresses voice data 2 to 1, using adapative differential-pulse-code modulation (ADPCM) encoding. It compresses data further by deleting silent periods and



restoring them on transmission. A telephone interface has ring detection, DTMF reception and dialing, and call progress tones. Its features include an unattended answering routine, unattended directory assistance, personalized messages, call screening, and an information bulletin board. Customized software lets you adapt the system to user protocols. $1100.

Zymacom Inc, 2 Lyberty Way, Westford, MA 01886. Phone (617) 692-4500.

Circle No 357



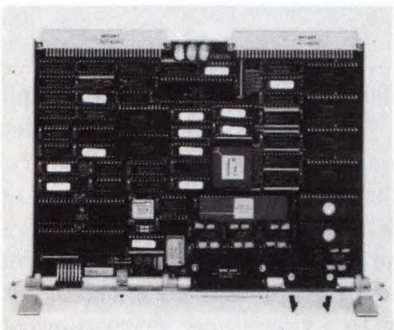
MOTHER BOARD

- *Performs IBM PC/AT motherboard functions in 46 in³*
- *Employs a 3-chip set and consumes 8W*

The Little Board/286 mother board performs the functions of an IBM PC/AT computer in 46 in³. It measures 8×5¾×1 in. The board employs a 3-chip set, called the 286 AT, which permits the integration of an AT-compatible system with 13 ICs. The board consumes 8W and operates from 0 to 70°C. It lets you substitute bubble memory, EPROM, and nonvolatile RAM for disk drives in embedded applications and harsh environments. The board comes with an 8- or 12-MHz 80286 CPU, an AT-compatible BIOS, a 512k- or a 1M-byte dynamic RAM, and a floppy-disk controller for two 5¼- or 3½-in. disk drives. In addition, it has two RS-232Cs serial ports, a parallel port, a keyboard port, three counter/timers with seven DMA channels, and 16 levels of interrupts. $739 (OEM).

Ampro Computers Inc, 1130 Mountain View, Alviso Rd, Sunnyvale, CA 94089. Phone (408) 734-2800. TLX 4940302.

Circle No 358



COMM BOARD

- *Provides X.25 communication over wide-area networks*
- *Implements layers 1 to 3 of the OSI communications model*

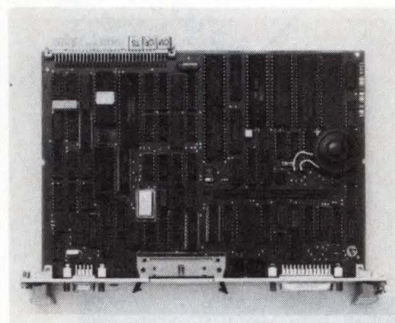
Simplifying the software that you have to write during systems integration, the CC-125 VME Bus X.25 communications card conforms to the X.213 specification for data transfer to layer 4 functions of the OSI (open systems interconnection) model. The board implements layers 1 to 3 of the OSI model. Layer 1 operates according to the X.21 bis (V.24/V.28) standard, and layer 2 to the LAPB (link access procedures balanced) protocol standard. The board's layer 3 software handles the X.25 packet-level protocol and imposes flow control to prevent the communications link from overloading. Messages are passed between the CC-125 and the VME Bus system's layer 4 functions via dual-port RAM on the CC-125. These messages, coded according to X.409 recommendations, are transferred to the dual-port RAM in the form of network-service data units that can be as much as 4k bytes long. The 68000-based board is suitable for transmitting packet-switched data over public or private data networks at bit rates as high as 64k bps. $3675.

Compcontrol bv, Stratumsedijk 31, 5600 AD Eindhoven, The Netherlands. Phone (040) 124955. TLX 51603.

Circle No 359

Compcontrol Inc, 15466 Los Gatos Blvd, Suite 109-365, Los Gatos, CA 95032. Phone (408) 356-3817. TWX 510-601-2895.

Circle No 360



INDUSTRIAL PC

- *Puts an IBM PC/AT-compatible in VME Bus systems*
- *Allows memory expansion to 16M bytes*

The PX4000 VME Bus module allows you to implement an IBM PC/AT-compatible computer in VME Bus systems. The 2-board sandwich runs an 80286 μP and an optional 80287 math coprocessor at 8 MHz. It includes all the ports you'd expect to find on a standard PC/AT—that is, a keyboard, a monitor, a printer, and floppy-disk interfaces—and runs the MS-DOS operating system. However, the module's video output provides an IBM CGA-compatible interface as standard. In addition to accessing the board's 512k bytes of onboard dynamic RAM, processor and DMA channels can transparently access additional memory via the VME Bus. If you use the μP's protected addressing mode, it can access as much as 16M bytes of memory. The onboard RAM is also accessible to other VME Bus masters. A hard-disk controller board that operates in conjunction with the PX4000 is also available. $2500.

Philips, Industrial and Electro-Acoustic Systems Div, 5600 MD Eindhoven, The Netherlands. Phone (040) 788620. TLX 35000.

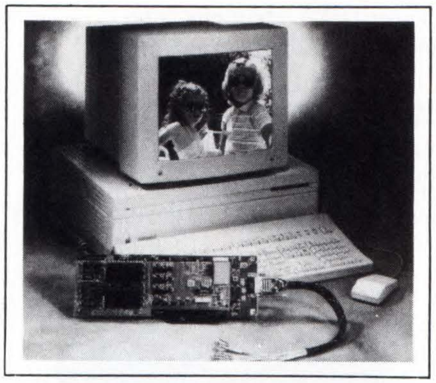
Circle No 367

Philips Electronic Instruments Inc, 85 McKee Dr, Mahwah, NJ 07430. Phone (201) 529-3800.

Circle No 361

FRAME GRABBER

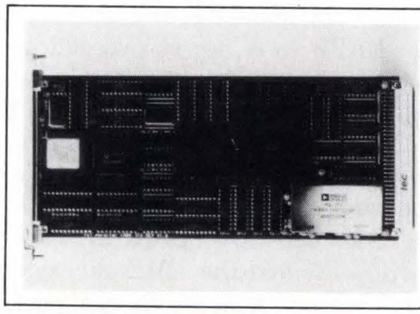
- *Displays color motion pictures on the Macintosh II*
- *Captures 640×480-pixel images with 32,768 colors*



The ColorCapture plug-in frame grabber board for the Macintosh II computer captures color images from video cameras, VCRs, or still-video equipment. It displays them in 1/30 sec (real time) on a video monitor. The board captures 640×480 square-pixel images and can display them in 32,768 colors. The board lets you edit images, add text or graphics to color video, output to a video tape, sharpen or soften edges, build multiple images, and perform animations. An external trigger lets you synchronize captured images with other events. A zoom, pan, and scroll controller provides real-time magnification. The 60-Hz DT2270 version comes with an NTSC composite output and outputs for the three RS-170 RGB signals. The 50-Hz DT2270 version provides PAL composite output and the three CCIRR RGB outputs. $2995.

Data Translation Inc, 100 Locke Dr, Marlboro, MA 01752. Phone (617) 481-3700. TLX 951646.

Circle No 362



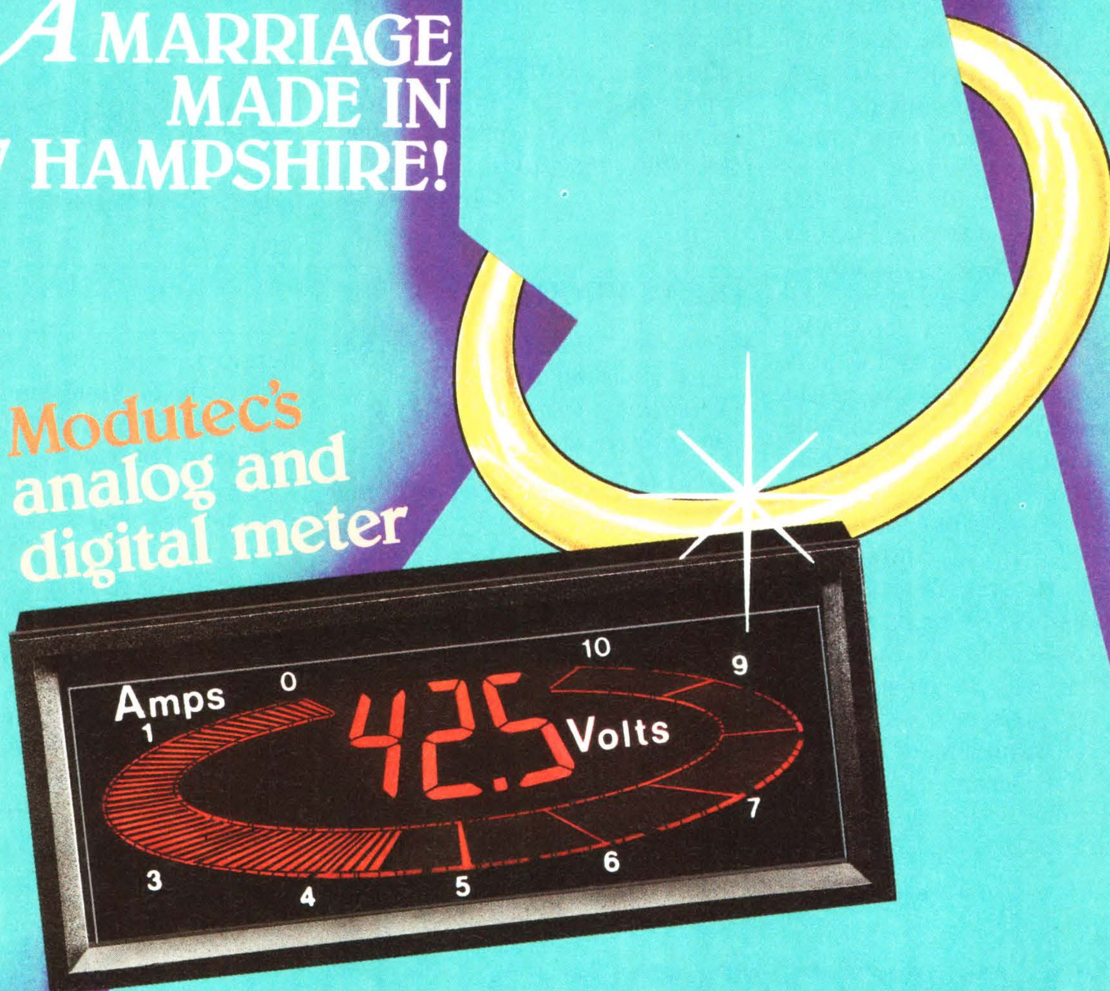
IMAGING BOARD

- *Digitizes up to 256 gray-scale levels*
- *Provides 768×512-pixel max resolution*

The TFG single-Eurocard image processing module includes a frame grabber, a frame store, a

A MARRIAGE MADE IN NEW HAMPSHIRE!

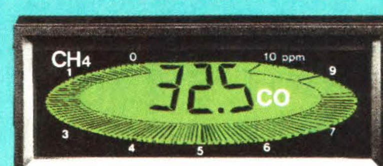
Modutec's analog and digital meter

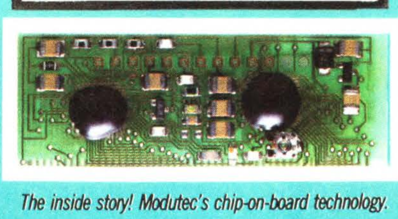


THE FIRST 2 IN 1 'BIG-LITTLE' METER BREAKTHROUGH!

All brides have a special glow as they walk down the aisle, but the new BGE Series meter gets its brightness from Modutec's exclusive Big-Little LCD, with LED backlighting. A big 0.34" digital readout and 101 segment, superfast 3½" bargraph provides 2 readings in one meter and the case is only 2.5" x 1" x 0.5" deep. Now that's a major breakthrough in analog and digital panel meter technology! Separate inputs to the numerical and bargraph displays; and customized scales and nomenclature, make it ideal for power supplies, UPS systems and all applications measuring either one or two parameters.

For power, choose 5V DC or a 9V battery. Bargraph is accurate to 1% typical and the digital reading is accurate to 0.1% typical. To get a perfect analog/digital marriage, all you have to say is "I do." You'll agree, Modutec's new BGE Series is a meter marriage made in...New Hampshire!





The inside story! Modutec's chip-on-board technology.

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MODUTEC

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603/669-5121. FAX: 603/622-2690. 1-800-METERS-1

CIRCLE NO 181

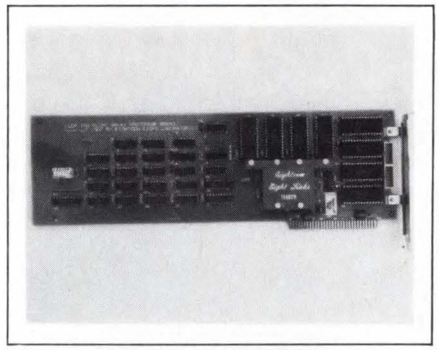
Transputer to process the image, a color look-up table, and video output. The board accepts CCIR and RS-170A video signals and digitizes them to 256 gray-scale levels with a 768×512-pixel max screen resolution. You can externally or internally synchronize the frame grabber and cascade boards to capture RGB color inputs. The board stores the image on a 0.5M-byte video RAM. It provides an additional 1M byte for the onboard T800 or T414 Transputer. The color look-up table lets you generate color images containing 256 colors from a palette of 262,144 colors. Four 20M-bps Transputer links allow the Transputer to communicate with other processors. By using adapter modules you can insert the board into an IBM PC, or couple it to a VME Bus, a Q bus, or a Nu bus. The vendor's software support includes compilers for Occam, C, Fortran, Pascal, Parallel Prolog, and the Helios Transputer operating system. DM 7800.

Parsytec GmbH, Juelicher Strasse 338, 5100 Aachen, West Germany. Phone (0241) 166000. FAX (0241) 1660050.

Circle No 363

ARRAY PROCESSOR

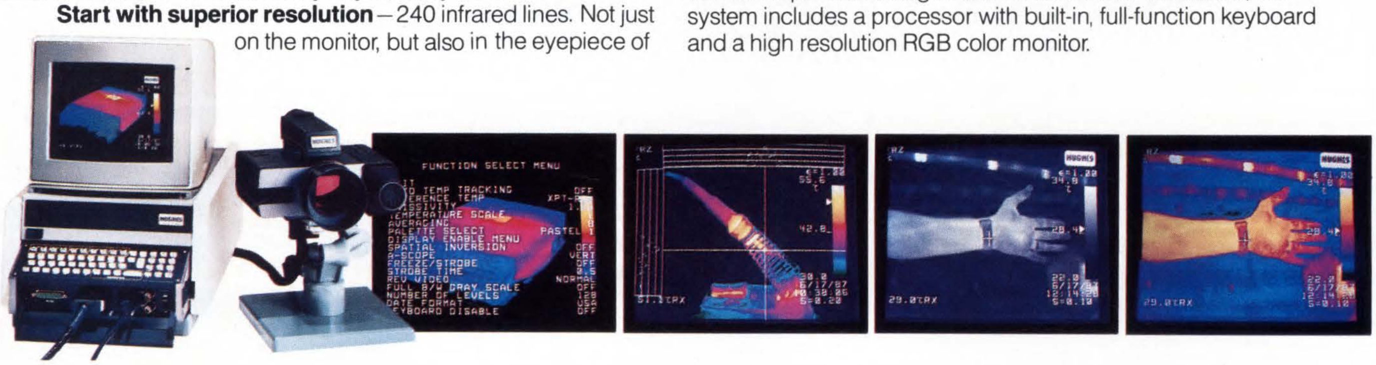
- *Provides 8M 32-bit flops on IBM PCs and compatibles*
- *Contains a 60k-byte cache for program and data*



The PL800 is an array-processing board for the IBM PC, PC/XT, PC/AT, and compatibles. A floating-point engine contains a 32-bit floating-point multiplier, a 40-bit ALU, and four 40-bit accumulators. The multiplier and ALU are in a pipeline and operate in parallel. This combination can perform 8M 32-bit flops. The board also contains a 16-bit RISC (reduced instruction set computer) Integer Processor, a 60k-byte cache for program and data, a host interface processor, and an auxiliary interface processor. A 32-bit instruction fetch, two 32-bit data fetches, and a 32-bit store occurs within 244 nsec. You can use from one to eight boards by writing control programs in Fortran, C, or Pascal. PL800 with support software, $1995.

Eighteen Eight Laboratories, 771 Gage Dr, San Diego, CA 92106. Phone (619) 224-2158.

Circle No 364



VME BUS SBC

- *Features a 33-MHz 68030 CPU and a VSB interface*
- *An 8-bit extension bus lets you add plug-in modules*

The 68-31 single-board computer for the VME Bus in a single-slot, double Eurocard form factor features a 33-MHz 68030 CPU and the VME Subsystem Bus (VSB) interface. The additional interface lets you dedicate different operations to either the VSB or the VME Bus for optimum bus utilization. The board contains 4M bytes of dual-ported dynamic RAM, an optional 68882 floating-point coprocessor, a cache capable of burst fills with zero wait states, two synchronous or asynchronous serial ports, mailbox interrupts, and a Processor EXtension bus (PEX). The PEX bus is an 8-bit asynchronous bus linked to the CPU that lets you add more functions via plug-in modules. Modules with SCSI or floppy-disk interfaces are available. The board complies with the VME Bus IEEE-1014 standard and operates as a 32-bit address/data bus master. $4295.

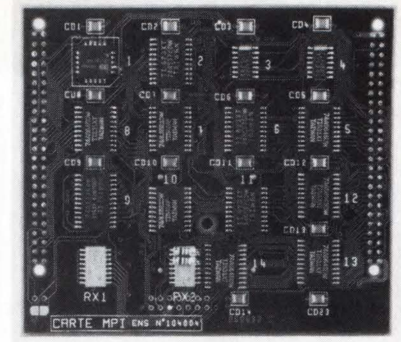
Radstone Technology, 1 Blue Hill Plaza, Pearl River, NY 10965. Phone (800) 368-2738; in NY, (914) 735-4661.

Circle No 365

INTERFACE MODULE

- *Lets you interface I/O boards to the iPSB bus*
- *Sends and receives iPSB messages*

The MPI module lets you interface I/O cards to the Multibus II iPSB. This 81.3×80×12.3-mm module needs two I/O card connectors. It occupies a single slot. The module's iPSB interface can send or receive normal or broadcast messages without data fields. In the I/O space, the



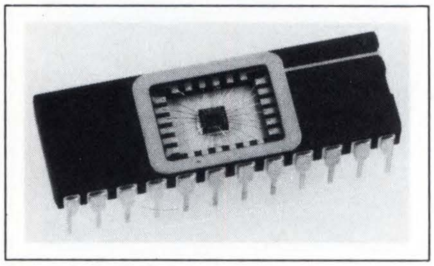
board provides for 8- or 16-bit data transfers and a 2k-byte board address region. In the interconnect space, the module provides 32 header registers, which you can program using an EEPROM. The interface module doesn't require I/O-board firmware. Approximately $220.

Centralp Automatismes, 16 rue Gabriel Pèri, 92120 Montrouge, France. Phone (1) 42533617. TLX 632380.

Circle No 366

NEW PRODUCTS

INTEGRATED CIRCUITS



GaAs DIGITAL ICs

- *Pin-compatible with 100K ECL*
- *Minimized propagation delay*

Fabricated in the company's depletion-mode GaAs process, the G100113 quad driver, G100141 8-bit shift register, G100179 carry-lookahead generator, and G100180 6-bit adder are all drop-in replacements for 100K ECL types. Typical propagation delays are 500 psec for the quad driver, 1150 psec for the 8-bit shift register, 1000 psec for the carry-lookahead generator, and 1450 psec for the 6-bit adder. All of these high-performance digital ICs are compatible with ECL single power supplies of −4.5V (100K systems) and −5.2V (10K systems). Each is fully compensated for voltage and temperature variations. Samples are available now in 24-pin DIPs; flat-pack versions will be available in the fourth quarter of 1988. $25 (G100113 and G100179), $26 (G100141), and $32 (G100180), (100).

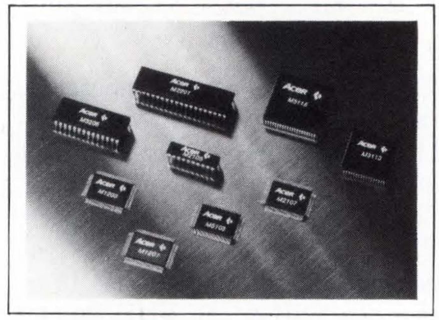
Microwave Semiconductor Corp, 100 School House Rd, Somerset, NJ 08873. Phone (201) 563-6300. TLX 833473.

Circle No 400

PS/2 CHIP SET

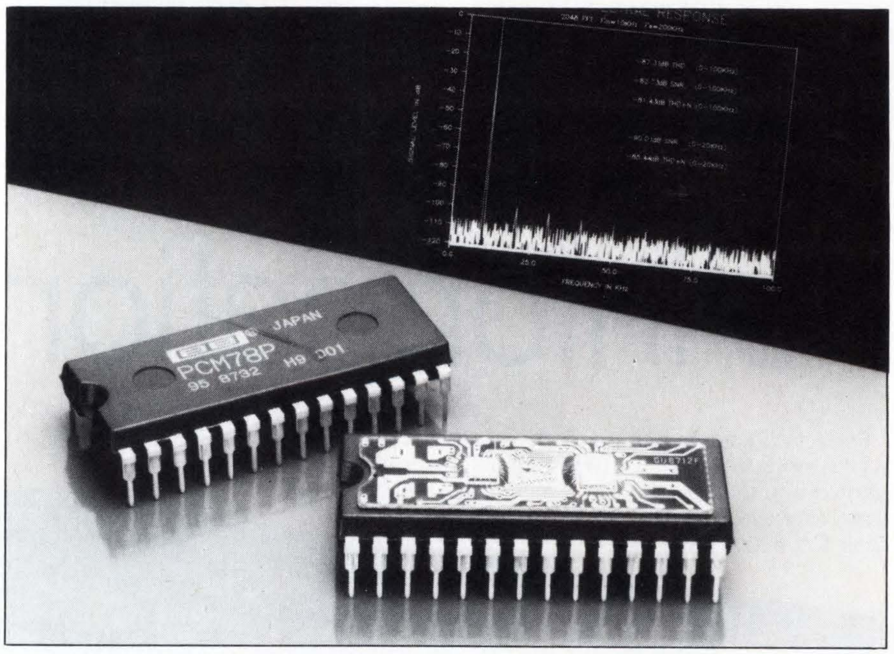
- *Contains 8 chips*
- *For IBM Models 25 and 30*

The PC86 chip set provides the system-, graphics-, and peripheral-control functions needed to build a fully compatible PS/2 Model 25 or 30. The chip set's architecture and partitioning simplify manufacturing and reduce costs by making it possible to use only a few chips to build a range of systems. The set consists of the M1201 system controller for the 8086 and V30; the M1203 address and data buffer; the M2107 input/output controller; the M3113 and M3115 MCGA and Hercules graphics controllers; the M3205 50-MHz, 256×18-color palette; the M2201A bidirectional printer interface; and the M5103 floppy-disk-drive interface. You can use the graphics-control and peripheral-control chips separately for PC/XT and PC/AT computers. A PC86 sample set costs $88; $77 (1000).



US Sertek, 926 Thompson Pl, Sunnyvale, CA 94086. Phone (408) 733-3174.

Circle No 401



16-BIT AUDIO ADC

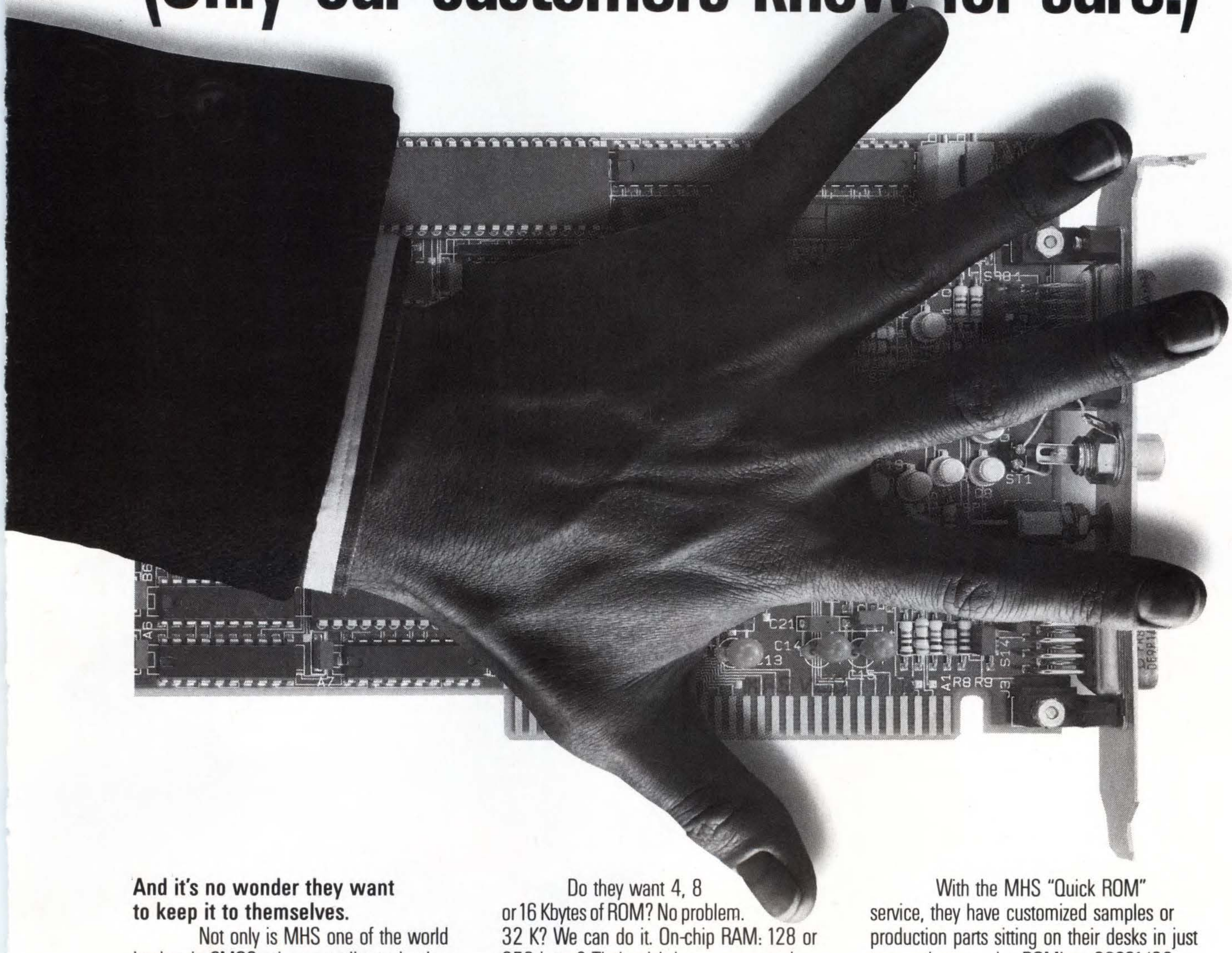
- *4-μsec conversion time*
- *Typical THD+N of −88 dB*

The PCM78P 16-bit successive-approximation A/D converter has a typical total-harmonic-distortion-plus-noise (THD+N) spec of −88 dB (−82 dB max) at full scale. The chip is designed and tested for dynamic applications. The chip uses bipolar circuitry for its precision analog portion and low-power CMOS for its logic and clock functions. It features a typical 4-μsec conversion time (5 μsec max). The PCM78P's ±3V input range interfaces to S/H amplifiers, and its two serial-output modes facilitate interfacing. The chip includes an internal clock and reference, is 100% tested to data-sheet specifications, operates from ±5 to ±12V supplies, and dissipates 600 mW. $39.90 (100).

Burr-Brown Corp, Box 11400, Tucson, AZ 85734. Phone (602) 746-1111. TLX 666491.

Circle No 402

What's so special about our 8 BIT microcontrollers? (Only our customers know for sure.)



And it's no wonder they want to keep it to themselves.

Not only is MHS one of the world leaders in CMOS microcontroller technology, with over 7 million units delivered to date. We're also one of the fastest suppliers, delivering both standard and customized parts to our customers' doorsteps – anywhere in the world – in no time flat.

It would seem that they appreciate it. Our customers have made us the No. 3 supplier of 80C51 microcontrollers worldwide. In Europe, they've made us No. 1.

That's not all. The MHS product line gives our customers unrivalled freedom of choice.

Do they want 4, 8 or 16 Kbytes of ROM? No problem. 32 K? We can do it. On-chip RAM: 128 or 256 bytes? Their wish is our command.

Part-number	ROM (Kbytes)	RAM (bytes)	Timers	Special features
80C51	4	128	2	Quick ROM 18 MHz
80C52	8	256	3	Quick ROM 18 MHz
83C154	16	256	3	Extra modes
83C158	32	256	3	Extra modes
80C752	4	128	2	Keyboard controller

They can also choose from a range of operating clock speeds from zero all the way up to 18 MHz, or from our full choice of packages and temperature ranges. Not to mention low-voltage (down to 2.7 V!) or "Secret ROM" versions.

With the MHS "Quick ROM" service, they have customized samples or production parts sitting on their desks in just two or three weeks. ROMless 80C31/32 parts are there before they even know it.

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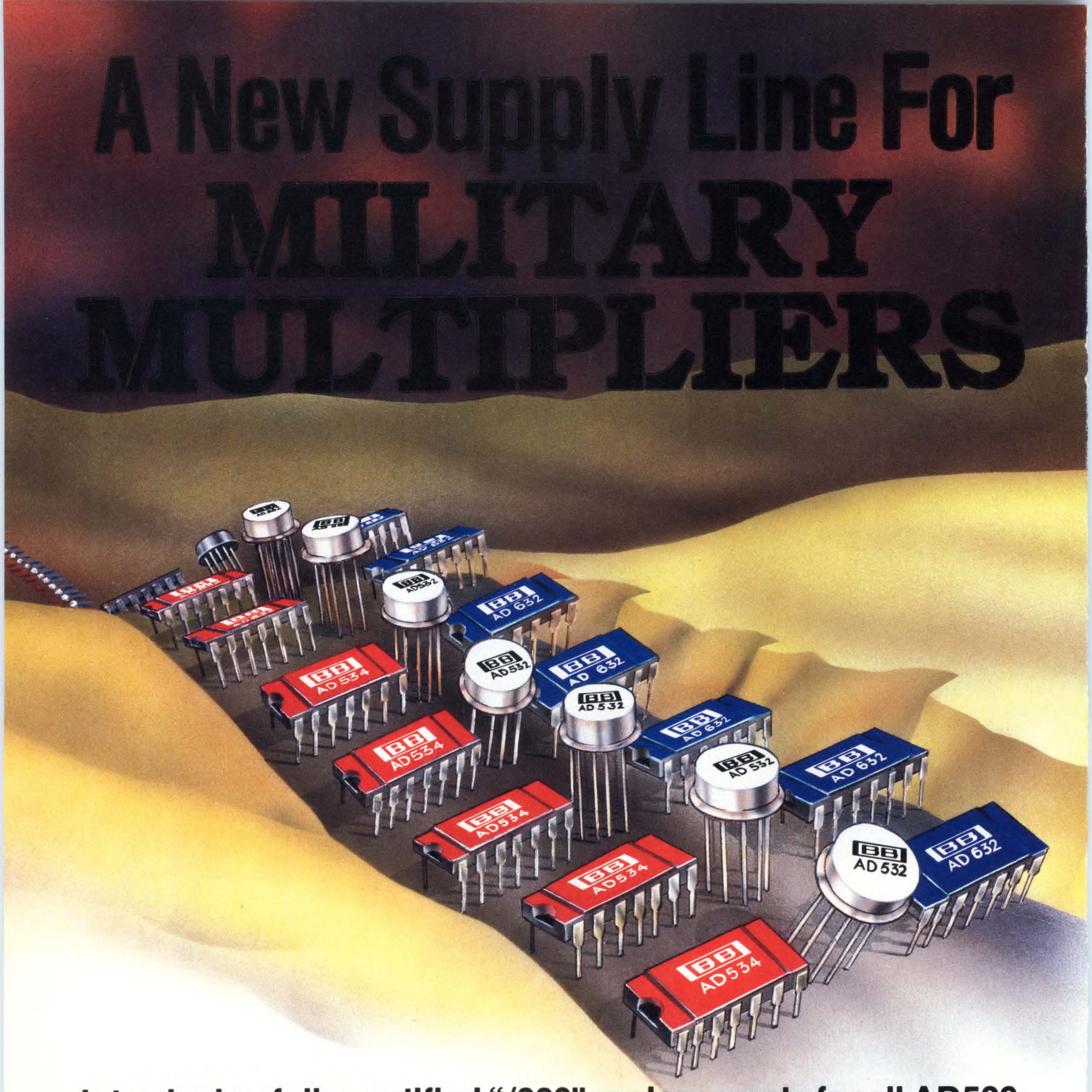
CIRCLE NO 183

A New Supply Line For MILITARY MULTIPLIERS



Introducing fully-certified "/883" replacements for all AD532, AD534, and AD632 analog multipliers.

Now you can get popular AD532, 534, and 632 analog multipliers from Burr-Brown's Military Products Division. These drop-in replacements are manufactured in our DESC-certified facilities and meet all requirements of MIL-STD-883C. Key features include:

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- 1MHz min bandwidth (3MHz typ);
- choice of two performance grades in metal TO-99 or 14-pin ceramic DIP packages;
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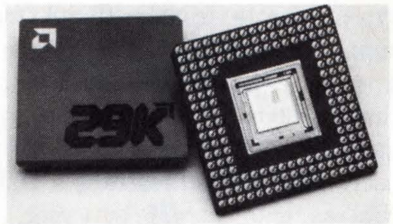
CIRCLE NO 184



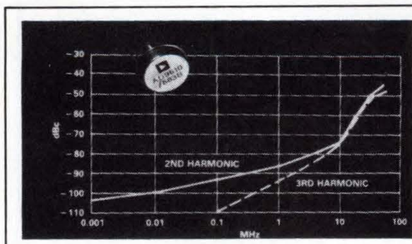
32-BIT RISC μP

- *16- to 25-MHz versions*
- *11- to 17-MIPS performance*

The Am29000 32-bit, RISC μP is now available in three different speeds: 16 MHz (11 MIPS), 20 MHz (14 MIPS), and 25 MHz (17 MIPS). The company is also supplying samples at beta sites of a 30-MHz (20-MIPS) version. The 25-MHz version delivers 36,000 dhrystones, using the V1.1 benchmark with 8k bytes of instruction and data cache. It delivers 15 MIPS at 24,000 dhrystones using V1.1 with an inexpensive video RAM. The dhrystone benchmark represents the typical mix of instructions anticipated for large-integer applications. 16-MHz version, from $174 (100).

Advanced Micro Devices Inc, Box 3453, Sunnyvale, CA 94088. Phone (408) 732-2400.

Circle No 403



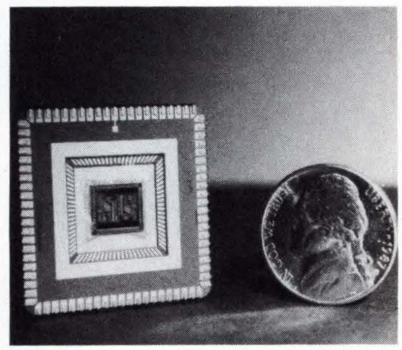
100-MHz OP AMP

- *Conforms to MIL-STD-883B*
- *Has 3000V/μsec slew rate*

The AD9610 current-feedback operational amplifier is now available in a MIL-STD-883B version that is specified over the −55 to +125°C temperature range. The AD9610TH/883B offers a minimum −3-dB bandwidth of 80 MHz and a maximum total-harmonic distortion of −50 dB with a 20-MHz input tone. Rise- and fall-times are <4 nsec with a 5V step; the settling time is 25 nsec (max) to 0.1%. A minimum slew rate of 3000V/μsec is guaranteed. Maximum dc specifications at 25°C include: ±1-mV offset voltage, ±15-μA inverting-node bias current, and ±50-μA noninverting-node bias current. The AD9610TH/883B operates from ±15V supplies and comes in a TO-8 metal can. $125 (100).

Analog Devices Inc, Box 9106, Norwood, MA 02062. Phone (617) 329-4700. TLX 924491.

Circle No 404



SYNTHESIZER

- *Has a resolution of 0.01 Hz*
- *30-MHz input reference*

The Q2334 single-chip digital frequency synthesizer provides a μP interface to control variable frequency and phase signals that are synthesized from a master reference. It includes two independent frequency synthesizers for use in full-duplex systems, spread-spectrum analysis, or quadrature oscillator applications. The chip provides a resolution of more than 0.01 Hz with an input signal clocking the phase accumulator at 30 MHz. Signal-to-noise ratios are 72 dB for quantization noise and 76 dB for phase noise. The Q2334 is available in 68-pin packages. $98 (1000).

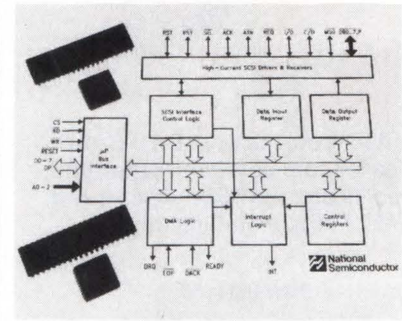
Qualcomm Inc, 10555 Sorrento Valley Rd, San Diego, CA 92121. Phone (619) 587-1121.

Circle No 405

CMOS SCSI ICs

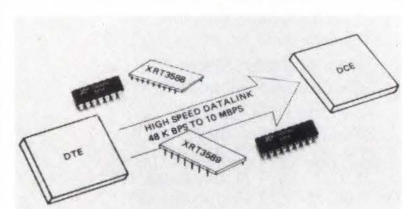
- *Pin-compatible with NMOS types*
- *10-mA max supply current*

Targeted at new and upgraded system designs, the DP8490 and DP5380 are CMOS devices that comply with the SCSI standard and are pin-compatible with the NMOS NCR5380 device. The DP8430/5380 types operate from a 10-mA max supply current. The devices feature a typical acknowledge-to-request time of 60 nsec, and a typical request-to-acknowledge time of 30 nsec. The DP8490 features a DMA rate as high as 4M bytes/sec. It powers up as a 5380 device until an enhanced mode opens three registers. Two registers control interrupts, and a third register, Extra Mode, has a sophisticated arbitration scheme that controls the use of the SCSI bus; μP polling, as used with 5380 devices, is not required. A loop-back test mode allows users to fully test the device's functions, including DMA operation. The DP8490 also includes a phase-mismatch interrupt that detects a phase mismatch in any information transfer, decreasing dead-time on the SCSI bus. For users not making software changes, the DP5380 is available; it has the same speed and power features as the DP8490. The devices are available in 40-pin DIPs and 44-pin PLCCs. DP8490, $8; DP5380, $7.50 (100).



National Semiconductor Corp, Box 58090, Santa Clara, CA 95052. Phone (408) 721-4960. TLX 346353.

Circle No 406



INTERFACE CHIP SET

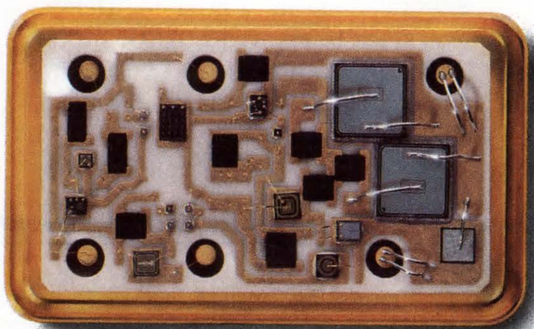
- *CCITT V.35/Bell 306 compatible*
- *Data rates to 10M bps*

The XR-T3588 (driver) and XR-T3589 (receiver) provide a communications link between data-terminal and data-communications equipment at rates from 48k bps to 10M bps. The XR-T3588 contains three independent drivers; the XR-T3589

SOLID STATE RELAY

Short Circuit Protection and True Output Status

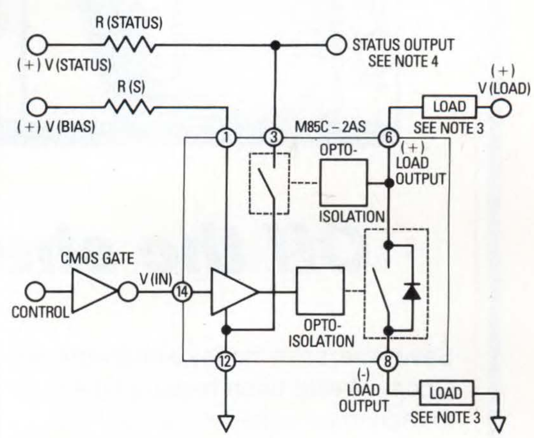
- Current Overload Protection
- Optical Isolation
- TTL & CMOS Compatible Control
- DESC Drawing Number Pending



PART #M85C-2AS

ELECTRICAL CHARACTERISTICS (−55°C to +105°C unless otherwise noted)	Min	Max	Units	
Bias Voltage (V_{BIAS})	3.8	32	V_{DC}	See Note 1
Bias Current (I_{BIAS})		15	mA	$V_{BIAS} = 5 V_{DC}$
Control Voltage (V_{IN})	0	18	V_{DC}	
Control Current (I_{IN})		250	µA	$V_{IN} = 5V_{DC}$
Turn-Off Voltage	3.2		V_{DC}	−55°C to +25°C
$V_{IN (OFF)}$	2.8		V_{DC}	+25°C to +105°C
Turn-On Voltage		0.5	V_{DC}	−55°C to +25°C
$V_{IN (ON)}$		0.3	V_{DC}	+25°C to +105°C
Continuous Load Current		2.0	A	−55°C to +25°C
I_{LOAD}		400	mA	+105°C
Output Trip Current (I_{TRIP})	8 (TYP.)		A	+25°C, 100 ms
Continuous Load Voltage (V_{LOAD})		60	V_{DC}	
Output Leakage Current (I_{LEAK})		2	mA	
On-Resistance (R_{ON})		0.28	Ohms	
Turn-On Time (T_{ON})		3.0	ms	
Turn-Off Time (T_{OFF})		1.0	ms	
Status Voltage (V_{STATUS})	1	18	V_{DC}	
Status Current (I_{STATUS})		0.6	mA	See Note 2

Notes: 1. Series resistor is required for bias voltages above $6V_{DC}$. $RS = (V_{BIAS} - 5 V_{DC})/15$ mA
2. A pull up resistor is required for the status output. $R_{STATUS} = V_{STATUS}/600$ µA
3. Output will drive loads connected to either terminal (sink or source).
4. Status output is low when the load output is off.



TELEDYNE SOLID STATE
A Division of Teledyne Relays

For immediate application assistance call 1-800-284-7007.

Teledyne Solid State, 12525 Daphne Avenue, Hawthorne, California 90250.

contains three independent receivers. Both ICs are TTL compatible and feature a power-down mode for each of the drivers and receivers. According to the company, the chip set is the first monolithic version to fully meet the CCITT V.35 requirements. The XR-T3588 comes in a 14-pin ceramic DIP; the XR-T3589 in an 18-pin ceramic DIP. $4.18 (5000).

Exar Corp, Box 49007, San Jose, CA 95161. Phone (408) 434-6400. TWX 910-339-9233.

Circle No 407

18-BIT AUDIO DAC

- *Includes deglitcher and reference*
- *Features 4× oversampling*

Serving as the back-end of a digital audio system, the ZDA1801A 18-bit D/A converter includes a built-in deglitcher circuit and a voltage reference. The chip's guaranteed

front-to-back total harmonic distortion plus noise (THD+N) is 98 dB over the full 20-Hz to 20-kHz audio range. The ZDA1801A operates at a 4× oversampling rate. The DAC module comes in an electrostatic- and electromagnetic-shielded package with dimensions of 3.0×1.6×0.45 in. $99 (100). Delivery, stock to six weeks ARO.

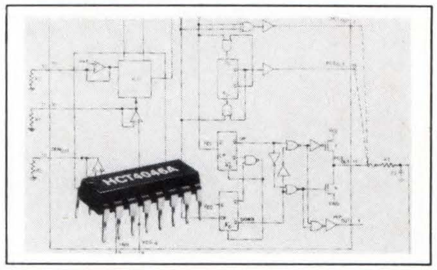
Analog Solutions, 85 W Tasman Dr, San Jose, CA 95134. Phone (408) 433-1900.

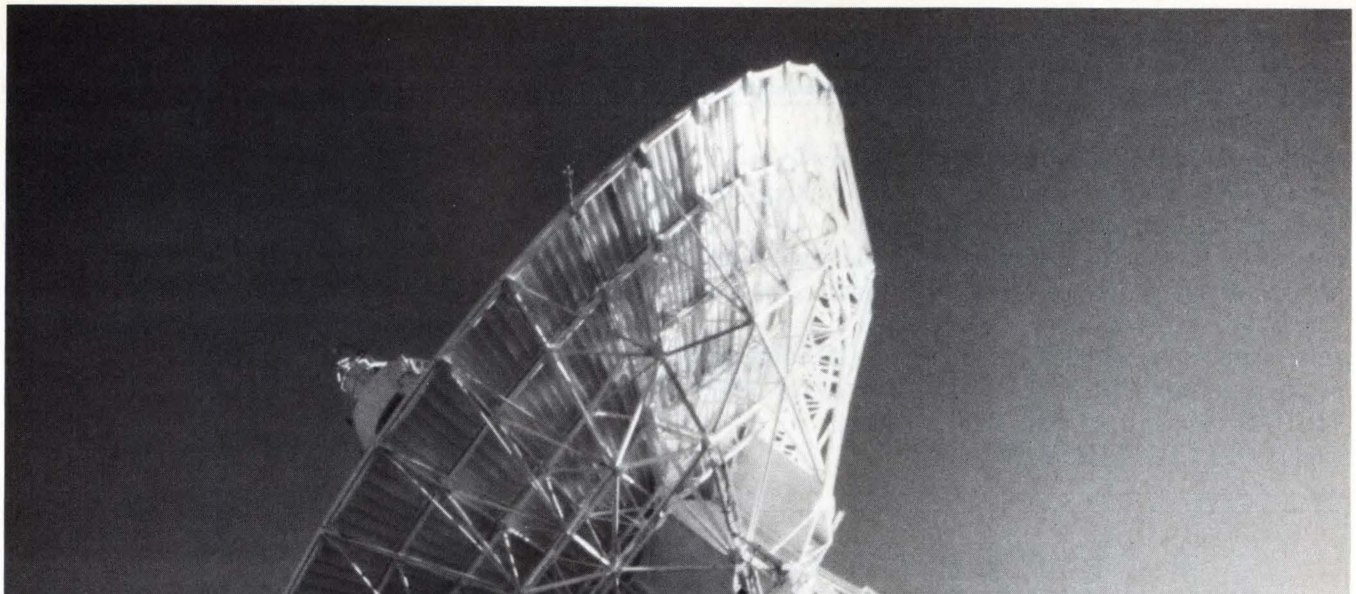
Circle No 408

PLL IC

- *Has three phase comparators*
- *0.4% frequency linearity*

The CD54/74HC/HCT4046A PLL IC contains three different phase comparators—an exclusive OR gate, a J-K flip-flop, and an R-S flip-flop. Its VCO characteristics include a frequency linearity of 0.4% and a typical frequency stability of 0.11%/°C. The VCO operates at frequencies as high as 38 MHz, and a VCO-inhibit pin provides on/off control and limits power consumption when the PLL is in standby mode. A signal input and a comparator

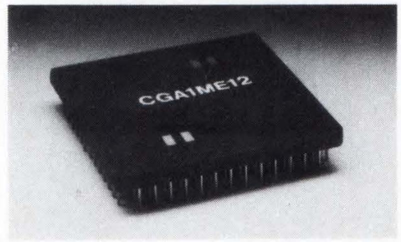




input are common to all three phase comparators. You can couple the signal input directly to logic-level voltages or indirectly to millivolt-level signals through a series capacitor. The chip's self-bias circuit keeps small signals within the linear range of the input amplifiers. The CD54/74HC4046A operates from a 2 to 6V supply; the CD54/74HCT4046A operates from a TTL-compatible 4.5 to 5.5V supply. Available packages include 16-pin ceramic and plastic DIPs and a 16-pin surface-mount version. In 16-pin plastic DIP, $1.62 (100).

GE Solid State, Box 2900, Somerville, NJ 08876. Phone (201) 685-6562.

Circle No 409



ECL GATE ARRAY

- *4584 equivalent gates*
- *3.5-nsec typical access time*

Featuring a typical access time of 3.5 nsec, the CGA1ME12 ECL gate array contains 4584 equivalent gates max, 1280 bits of configurable RAM, and 120 I/O cells. Interfaced among the I/O cells are 34 dedicated power pins. The gates are laid out in 12 contiguous rows with each row containing 1320 transistors and 1320 resistors. For the typical gate, the propagation delay is 300 psec, and the power consumption is 300 μW. The RAM megacell consists of four separate blocks of 320 bits each. You can configure the RAM blocks independently or combine them to form larger memory blocks. Commercial versions of the device are specified for operation over the 0 to 70°C temperature range. Depending on gate utilization, quantity, and test requirements, prices start at $150. Nonrecurring engineering costs range from $40,000 to $60,000.

Raytheon Company, Semiconductor Div, 350 Ellis St, Mountain View, CA 94043. Phone (415) 966-7639.

Circle No 410

CHIP SET

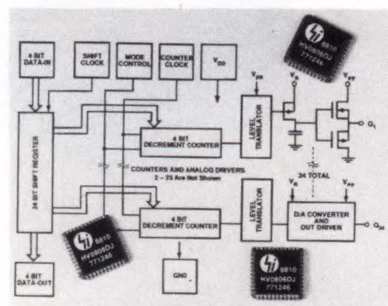
- *Includes multiplier and ALU*
- *Performs 60M flops*

The B3110A-50 floating-point multiplier and B3120A-25 floating-point ALU comprise an ECL 10KH-compatible chip set that offers double-precision (64-bit) multiply operations in 50 nsec and add or subtract operations in 25 nsec. TTL-compatible versions are also available

(B2110A-50 multipler and B2120A-25 ALU). The set offers a combined performance of 60M flops and support DEC's F and G formats and IEEE-STD-754. The multiplier performs single-precision (32-bit) or double-precision (64-bit) floating-point multiply, divide, square-root, and 32×32-integer operations in a single cycle. Worst-case multiply times are 40 nsec for single-precision and 50 nsec for double-precision. Worst-case division times are 180 and 300 nsec for single- and double-precision, respectively. The ALU performs add, subtract, integer-shift, rotate, arithmetic, and Boolean operations on 32- or 64-bit integers. Integer operations execute in 12 nsec. Packaging is in 169-lead pin-grid-arrays. $565 (ECL), $490 (TTL) (100).

Bipolar Integrated Technology Inc, 1050 NW Compton Dr, Beaverton, OR 97006. Phone (503) 529-5490. TLX 263097.

Circle No 411



TFEL BIDIRECTIONAL DISPLAY DRIVER (16 Shades of Gray)

DISPLAY DRIVER

- *Column driver for TFEL displays*
- *Provides 16 shades of gray*

Designed for high-resolution thin-film electroluminescent flat-panel displays, the HV08 column driver can provide 16 shades of gray. The chip includes four 24-bit shift registers, 24 4-bit counters, and 24 high-voltage S/H circuits to perform D/A conversion for any one of the 16 voltage levels that define the shades of gray. The HV08 is compatible with all general-purpose EL display applications, including IBM PC and PS/2 formats. The chip is available in either plastic or ceramic 44-pin J-lead packages. Plastic package, $9.96 (1000).

Supertex Inc, 1225 Bordeaux Dr, Sunnyvale, CA 94088. Phone (408) 744-0100. TLX 6839143.

Circle No 412

BUFFER AMPLIFIERS

- *125- and 200-MHz bandwidths*
- *1500V/μsec slew rate*

The EHOS-100 and EHOS-200 are high-speed, unity-gain buffer amplifiers with bandwidths (−3 dB) of 125 and 200 MHz, respectively. The EHOS-100 operates from ±15V supplies; the EHOS-200 from ±5V supplies. Included in each of the 2-stage amplifiers are bypass capacitors that improve the transient response. Both amplifiers feature a slew rate of 1500 V/μsec and can deliver 100 mA of output current. The buffer amplifiers come in TO-8 metal packages and are available in commercial and military versions. EHOS-100, $10.13 to $24.75; EHOS-200, $9.38 to $24 (100).

Élantec Inc, 1996 Tarob Ct, Milpitas, CA 95035. Phone (800) 821-7429; in CA, (408) 945-1323.

Circle No 413

PLDs

- *12-nsec propagation delay*
- *100 erase/write cycles*

The GAL16V8A-12 and GAL20V8A-12 are CMOS PLDs (programmable logic devices) with a maximum propagation delay of 12 nsec. As with all of the company's Generic Array Logic (GAL) products, these devices can replace any common 20-pin or 24-pin (PAL) device. The GAL16V8A-12 is a 20-pin device; the GAL20V8A-12 is a 24-pin device. The E²CMOS technology allows complete ac and dc testing during the manufacturing process. The company guarantees the devices for a minimum of 100 erase-write cycles; it guarantees data retention for more than 20 years. Available packages are plastic DIP and plastic leaded chip carrier (PLCC). In plastic DIPs, the GAL16V8A-12 costs $8.32; the GAL20V8A-12, $9.51 (100).

Lattice Semiconductor Corp, 5555 NE Moore Ct, Hillsboro, OR 97124. Phone (503) 681-0118. TLX 277338.

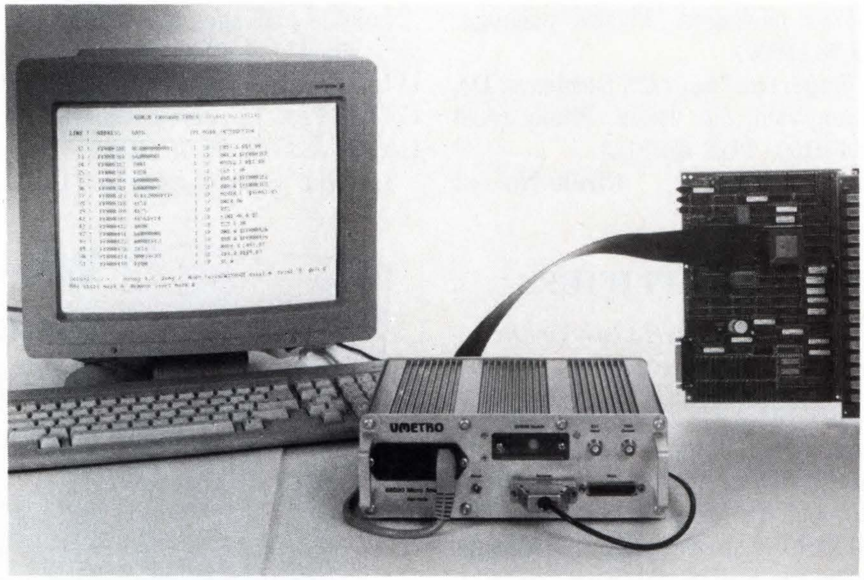
Circle No 414

NEW PRODUCTS

TEST & MEASUREMENT INSTRUMENTS

68020 ANALYZER

- *Disassembles code and traces program flow*
- *Measures cache hits and interrupt-level distribution*



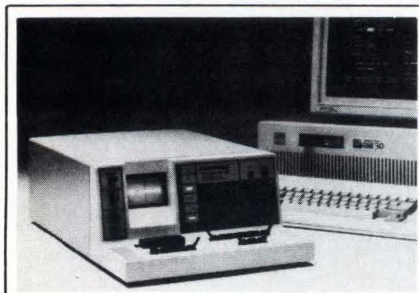
The PMA-020A microanalyzer stand-alone development tool tests, debugs, and evaluates 68020-based systems. A short cable connects it to the target μP socket. An RS-232C port links the analyzer to an ASCII terminal to provide the operator interface. A second RS-232C port lets you use the same terminal as the operator interface for the target system. The specialized 88-channel logic/software-performance analyzer was optimized for developing and debugging modules such as drivers and operating-system kernels. The analyzer disassembles 68020 code, traces program flow, and determines the cache hit rate and the distribution of interrupts on the μP's interrupt levels. $7900.

Vmetro A/S, Sognsvn 75, N-0855 Oslo 8, Norway. Phone 47 2 39 46 90. FAX 47 2 18 39 38.

Circle No 420

Vmetro Inc, 2500 Wilcrest, Suite 530, Houston, TX 77042. Phone (713) 266-6430. FAX (713) 266-6919.

Circle No 421



TROUBLESHOOTER

- *Memorizes analog signatures at good boards' circuit nodes*
- *Lets you compare unknown boards with good boards*

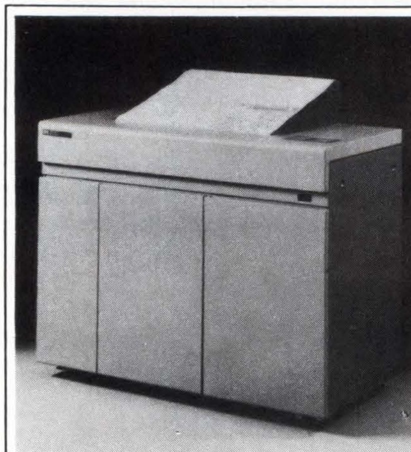
The Tracker 5100DS uses analog-signature analysis to help you troubleshoot analog and digital pc boards. You employ this PC-hosted instrument to force small ac currents into circuit nodes. It measures the ac voltages that appear at the nodes, digitizes them, and stores them on disk. You can recall the signatures from disk and display as many as eight on the PC's display. By recording the signatures from a good board and comparing the corresponding signatures from a board under test, you can find inputs with marginal-breakdown voltages, out-of-tolerance components, and gates and capacitors with high dissipation. $9500.

Huntron Instruments Inc, 15720 Mill Creek Blvd, Mill Creek, WA 98012. Phone (800) 426-9265; in WA, (206) 743-3171. TLX 152591.

Circle No 422

PLOTTERS

- *Use electrostatic imaging to resolve 406 dots/in.*
- *Produce D- and E-size drawings in under 1 minute*



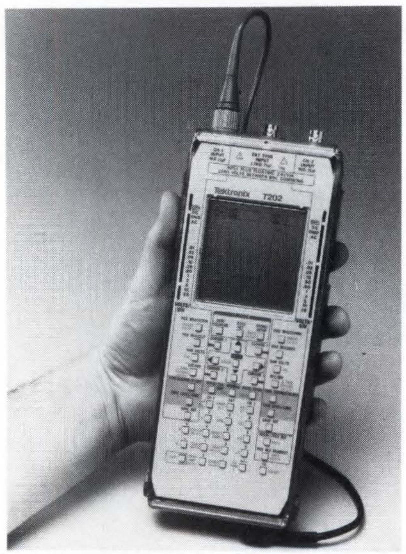
The HP 7600 Series Models 240D and E are electrostatic plotters that produce monochrome output on D- and E-size coated paper at a rate exceeding 1 page/minute. Though the plotters' only moving parts are the paper and the paper-drive mechanism, the plots, whose resolution is 406 dots/in., are as sharp as those produced by electromechanical pen plotters. The plotters incorporate a vector-to-raster converter and accept input in HP-GL/2, a superset of the vendor's earlier HP-GL (graphics language). Because of HP-GL/2's total compatibility with HP-GL and the wide support of HP-GL by vendors of CAD and CAE software,

CIRCLE NO 194

existing software packages already support these plotters. The vendor claims that you can simply plug in the electrostatic plotters in place of HP-GL-compatible pen plotters and start producing drawings in minutes. 24-in.-plot-width model, $22,900; 36-in.-plot-width model, $27,500. Delivery, four to six weeks ARO.

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

Circle No 423



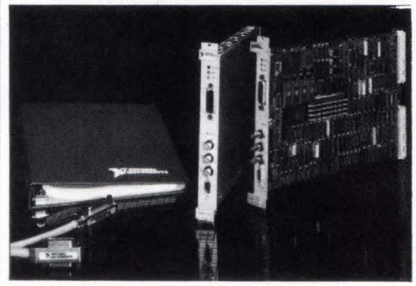
PLD TEST GENERATOR

- *Allows in-circuit testing of devices on pc boards*
- *Supports devices that you can't initialize*

Version 2 of the vendor's ATG (automatic test generation) software runs under MS-DOS and creates test routines for PLDs, including those already mounted on pc boards. According to the vendor, the tests provide very-high-fault coverage during in-circuit testing where you can't preload initial conditions into devices. The software models ICs the way you actually use them—with some pins connected together or to V_{CC}. It also lets you enter information on constraints imposed by the circuitry that surrounds the device under test. The vendor will upgrade existing installations at no charge. $4950.

Anvil Software, 427-3 Amherst St, Suite 341, Nashua, NH 03063. Phone (603) 891-1995. TWX 910-250-3381.

Circle No 424



GPIB/VXI INTERFACE

- *Plugs into VXI bus and links it to the IEEE-488 bus*
- *Transparently routes messages between the two buses*

The GPIB-VXI circuit card plugs into the VXI bus (VME Bus extension for instrumentation). With its two backplane connectors, this "C-size" board conforms to the VXI standard. The card edge opposite the backplane supports an IEEE-488 connector; a 9-pin, D-subminiature connector used for an RS-232C port; and BNC connectors for triggering input, output, and an external clock input. A 32-bit 68070 µP has 512k bytes of dual-ported RAM that you can increase to 4M bytes. The µP runs under a firmware-resident version of the pSOS operating system and makes the board and all the IEEE-488 devices connected to it appear to the VXI subsystem as a VXI device with its own command set. The µP manages the VXI bus resources; controls communication between the VXI and IEEE-488 buses; and lets you download custom instrument-control software modules. $3000.

National Instruments Corp, 12109 Technology Blvd, Austin, TX 78727. Phone (800) 531-4742; in TX, (800) 433-3488. TLX 756737.

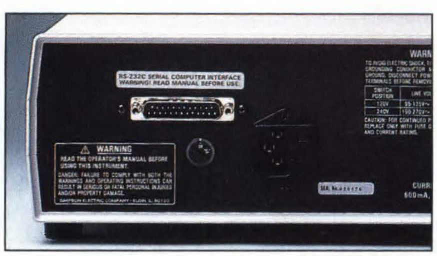
Circle No 425

THE SIMPSON 560 MENU DRIVEN MULTIMETER.

SOMETHING NEW ON THE MENU.

From microvolt transducer measurements to high voltage work, Simpson's new *Professional Series* Model 560 Digital Multimeter is designed to quickly give the answers you need—without elaborate signal conditioning.

Diagnostic functions such as MIN/MAX Hold and Peak Hold let you find and display transient amplitudes, while the bar graph continues to monitor the incoming signal. Programmable data logging on any range or function and a built-in 500 KHz frequency



counter, further expand the acquisition capabilities of the Simpson 560.

What's more, it's now possible to speed up routine tests—saving only the measurements of interest—because the 560 offers real-time comparison to stored test limits. Permanent records of the captured data can be generated by computers or printers connected to the optional interfaces (Centronics, RS-232 or IEEE-488). Displayed menus make it quick and easy to set the measurement parameters. And ultra-fast autoranging inputs instantly calculate the proper scale.

Order from our menu. The Simpson 560 Menu Driven DMM. You'll agree that it's done quite tastefully.

Simpson Professional Series products are made in USA.

simpson

Simpson Electric Company 853 Dundee Ave., Elgin, Illinois 60120-3090 312/697-2260 FAX: 312/697-2272

FFT ANALYZER

- *Has a bandwidth of 20 kHz*
- *Is battery powered and portable*

Weighing 4 kg and measuring 256×250×82 mm, the battery-powered PL21 single-channel and PL22 dual-channel FFT analyzers are suitable for a variety of field and lab test applications in mechanical, structural, acoustic, and electrical engineering. The instruments analyze frequencies in the range of 0 to 20 kHz and produce frequency spectrums with as many as 1600 lines and a resolution as high as 62.5 mHz. They have input voltage ranges between ±5 mV and ±5V, which you can autorange or manually range in a 1-2-5 sequence. An accelerometer input allows you to connect the instrument to accelerometers with built-in charge amplifiers without a separate accelerometer power supply. Eight input frequency ranges, between 100 Hz and 20 kHz are provided, and the analyzers have a data record length selectable between 256 and 4096 points. Triggering facilities allow pre- and post-trigger recording. The instruments have 256k bytes of nonvolatile memory in which you can store as many as 250 measurements. Signal-processing functions include autospectrum, cross-spectrum, autocorrelation, cross-correlation, transfer function, coherence, and averaging functions. You can dump measured data through the RS-232C interface. PL21 $5900; PL22 $8900.

Diagnostic Instruments Ltd, 264 W Main St, Murraysgate Industrial Estate, Whitburn, West Lothian EH47 0LB, UK. Phone (0501) 43031. FAX (0501) 43933.

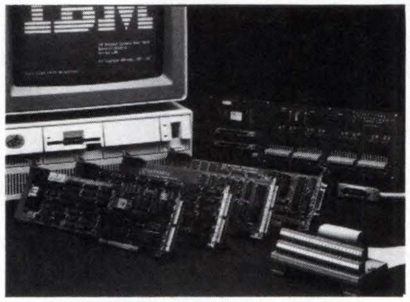
Circle No 426

PS/2 I/O CARDS

- *Plug into Micro-Channel bus*
- *Provide analog and digital I/O capability*

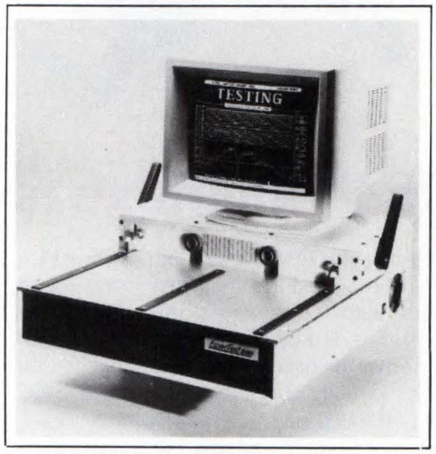
The MC-MIO-16 is an analog, digital, and timing I/O board for the IBM PS/2 Micro-Channel bus. The MC-DIO-32F is a 32-bit parallel digital I/O interface card for the same bus. It achieves high speed by implementing DMA. The MC-DIO-24 is a lower-cost and lower-speed 24-bit parallel digital I/O card for interrupt-driven applications. The MC-MIO-16 incorporates a 12-bit A/D

converter preceded by an amplifier that provides software-controlled gain and an analog multiplexer with 16 single-ended inputs. The board also contains a pair of 12-bit D/A converters with double-buffered digital inputs, eight TTL-compatible digital I/O lines, and three 16-bit counter/timer channels. Other features include a FIFO buffer for A/D conversion results, an automatic channel sequencer for the analog multiplexer, and a timer and interrupt generator. You can obtain the board in three A/D-conversion speed grades: 9, 15, and 25 μsec/conversion. The fastest grade permits a throughput of 100k conversions/sec. MC-MIO-16, from $1195. MC-DIO-24, $245. MC-DIO-32F, $595.



National Instruments Corp, 12109 Technology Blvd, Austin, TX 78727. Phone (800) 531-4742; in TX (800) 433-3488. TLX 756737.

Circle No 427



BOARD TESTER

- *Performs time-phased analog and digital generation*
- *Can sample at equivalent of 1 GHz*

The Expertest 2000 automatic test system is hosted by an 80386-based PC. The system tests loaded pc boards. It runs the vendor's diagnostic expert system software and uses a bed-of-nails fixture. The unit generates coordinated, time-phased, analog and digital patterns. Its high-speed channels can sample continuously at 200 MHz or can achieve an effective 1-GHz sample rate on repetitive waveforms by programmable edge shifting. According to the vendor, you don't have to write any code. The artificial-intelligence-based test-generation software tests with 1000 channels and, the vendor maintains,

thousands of diagnostic messages. From $17,985 to $49,985. Delivery, 30 to 45 days ARO.

Array Analysis, 200 Langmuir Lab, Brown Rd, Ithaca, NY 14850. Phone (607) 257-6800. TWX 490-000-1912.

Circle No 428

TEST GENERATOR

- *Generates device- and board-test programs*
- *Uses waveform database derived from simulator output*

The VectorBridge software package produces device- and board-test programs. It uses files generated by logic-simulation programs in the vendor's standard-events format. The test programs created comply with restrictions imposed by the target tester's hardware. The software's programs are compatible with Hewlett-Packard's 3065 and 16500, Integrated Measurement Systems' Logic Master, and Schlumberger and Semiconductor Test Solutions' systems that use the Factor language. The package runs on workstation platforms that support the vendor's other software products. Starts at $10,000 for upgrades; $15,000 for new installations.

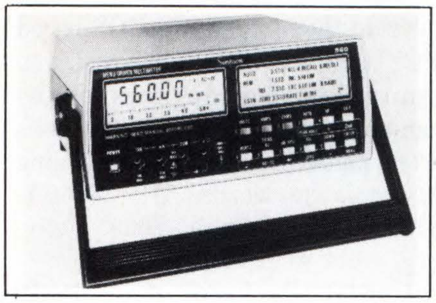
Test Systems Strategies Inc, 8205 SW Creekside Pl, Beaverton, OR 97005. Phone (503) 643-9281.

Circle No 429

5-DIGIT DMM

- *Incorporates 52-segment bar-graph display*
- *Includes 500-kHz frequency counter*

The model 560 digital multimeter makes dc-voltage measurements with a basic uncertainty of 0.0035%. It measures dc voltage from 10 μV to 1 kV, ac voltage from 10 μV to 750V, resistance from 10 mΩ to 50 MΩ, dc and ac current from 10 nA to 10A, and frequency from 5 Hz to 500



kHz. It can also compute voltage ratios in dBm and power ratios in dBW, determine diode function, and provide both an audible and visual indication of continuity during go/no-go testing. The unit sports a pair of LCDs. One provides both numeric and 52-segment bar-graph readouts. You use the other, an alphanumeric panel, to display menus during programming of the instrument. $2195; with RS-232C or Centronics interface, $2395.

Simpson Electric Co, 853 Dundee Ave, Elgin, IL 60120. Phone (312) 697-2260. TLX 722416.

Circle No 430

ELECTRONIC LOADS

- *Impose static and dynamic loads to 2 kW*
- *Sink 300A and can withstand 150V*

The Autoload Series of electronic loads checks for overvoltage, overcurrent, overpower, overtemperature, and reverse-polarity conditions. The line includes models that can continuously absorb a maximum power of 0.5, 1, and 2 kW. The 2-kW model sinks 300A. When sinking 150A or the maximum-specified current, whichever is smaller, the units operate normally at 3V min. The loads behave as programmable, constant or time-varying, multirange resistances or current sinks. A remote-sensed, 12-bit measuring system withstands 150V max. The loads are ohmically isolated from the chassis and from their IEEE-488 interfaces. You can connect either of the loads' terminals to the ground. When you use the units as time-varying loads, you can control the low- and high-current levels, the duty factor, the slew rate, and the frequency. The units can store five programmed waveforms and can rapidly switch between any pair. From $6250.

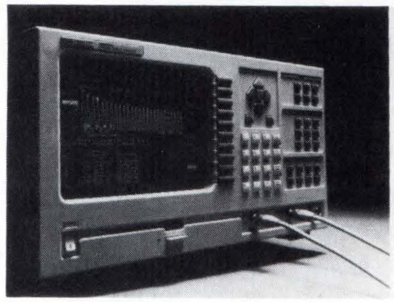
Analogic/3H, 1289 Hammerwood Ave, Sunnyvale, CA 94089. Phone (408) 734-5970. FAX 408-734-5139.

Circle No 431

SIGNAL ANALYZER

- *Performs spectrum analysis from dc to 102.4 kHz*
- *Performs network analysis from dc to 51.2 kHz*

The HP 35660A FFT-based low-frequency spectrum/network analyzer performs spectrum analysis from dc to 102.4 kHz and network analysis from dc to 51.2 kHz. Its 3½-in. disk drive can load signal-analysis programs developed by third parties into the internal computer. These programs utilize the vendor's disk-based HP 35680A Instrument Basic language interpreter; they customize the analyzer for specialized applications such as diagnosis of electric-motor problems from vibration spectra. You can write your own programs in Instrument Basic and



develop them on an MS-DOS-based PC. Using an ASCII keyboard, you can type in your programs, or you can enter them from the analyzer's front panel by keystroke recording of Basic keywords. HP 35660A, $12,500; HP 35680A, $500. Delivery, eight weeks ARO.

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

Circle No 432

CIRCLE NO 205

IN-CIRCUIT EMULATOR

- *Supports 80C196, 8096-90, and 8096-BH µPs*
- *Shares memory with host PC at 12 MHz max*

The EMS96 in-circuit emulator supports the 8096-90 and 8096-BH microcontrollers. It allows multiple hardware breakpoints on instruction fetch, data read, write, address or pattern matching. The emulator plugs into the IBM PC bus and provides full-speed emulation. You place the 8096 code and data in the PC's memory, where both the PC and the 8096 can share it. The emulator maps this RAM space to shared or user memory in 64-byte blocks. It allows your PC-resident programs to access, display, and modify variables without affecting the microcontroller's operating speed. The unit supports the host processor's speeds from 4.77 to 12 MHz and the 8096's speeds from 3 to 18 MHz. It allows for symbolic debugging in ASM96, PL/M96 and C96. $2995.

Annapolis Micro Systems Inc, 612 3rd St, Suite 301, Annapolis, MD 21043. Phone (301) 269-8096.

Circle No 433

DESIGNED TO TAKE ON THE WORLD'S TOUGHEST ASSIGNMENTS.

Mallory designs and manufactures a broad line of high-reliability, wet tantalum capacitors to meet your specific design needs.

The CLR-79 and CLR-81 hermetically sealed, all tantalum wet slug capacitors meet MIL-39006 requirements with low DC leakage, low ESR, high ripple current ratings and 3 volts reverse voltage capability. These high and extended range capacitors maintain quality approval up to failure levels R (CLR-79) and P (CLR-81).

For your next assignment, go with the leader. Contact your local authorized Mallory distributor or Mallory today. Mallory Capacitor. Stronger Than Ever.

WET SLUG TANTALUMS

Style	Mil Spec (or description)	Mallory Type
CLR-79	M39006/22	TLT
CLR-81	M39006/25	W18
CLR-65	M39006/09	TLX
CLR-69	M39006/21	TXX
CLR-10/14/17	Mil-C-39006/18/19/20	XT
CRL-01/02	Mil-C-83500	W13
	Silver Tubular	MTPH
	All Tantalum Module	TMX

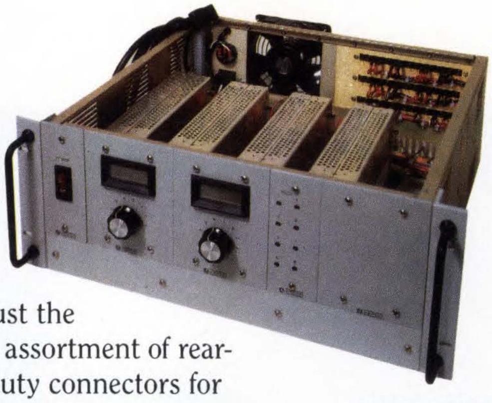
Mallory Capacitor Company
4760 Kentucky Avenue
P O Box 1284
Indianapolis Indiana 46206
Telephone 317 856 3731

MALLORY

EMHART MALLORY

 CIRCLE NO 206

Get your custom Power Assembly with all the trimmings, from KEPCO, your power supplier.™



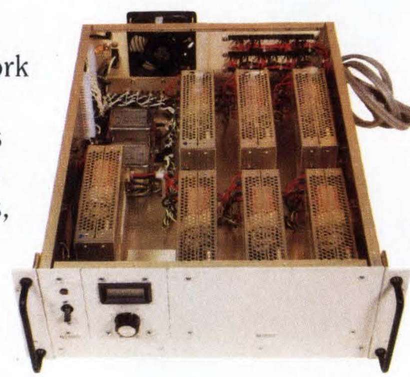
TYPICAL ASSEMBLY

OUTPUTS
+28 VOLTS & 2.15 AMPS
+28 VOLTS & 2.15 AMPS
−28 VOLTS & 2.15 AMPS
−28 VOLTS & 2.15 AMPS
±15 VOLTS & 0.4 AMPS
±15 VOLTS & 0.4 AMPS

We'll help you create a custom power assembly professionally constructed and wired and tested to your specific system requirements. With Kepco's selection of digital voltmeters and ammeters, LEDs, test points, trimmers, circuit breakers and switches, you can create a multi-output power assembly with just the control and monitoring facilities you need. Kepco offers a large assortment of rear-panel options, too: a-c and d-c inlets, barrier strips and heavy duty connectors for high current service. If you like, we can even incorporate custom connectors of your choice.

All at surprisingly low cost.

Our expert engineers will work with you to layout a custom assembly to your specifications choosing from power modules that span 3 Watts to 1500 Watts, 2 Volts to 48 Volts — a-c and d-c inputs. An easy-to-use template and layout grid system enables you to determine what combination can be fit into our five (5) basic housings that range 16″ to 24″ deep, 5¼″ or 7″ high in a standard 19″ configuration.



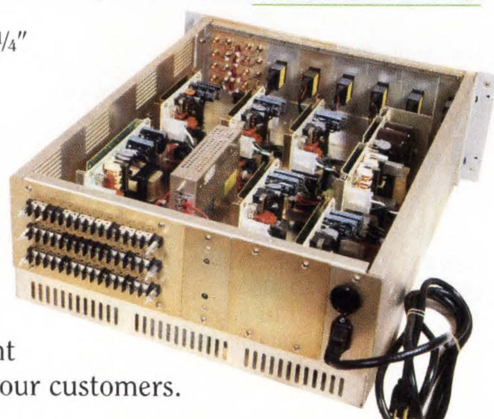
TYPICAL ASSEMBLY

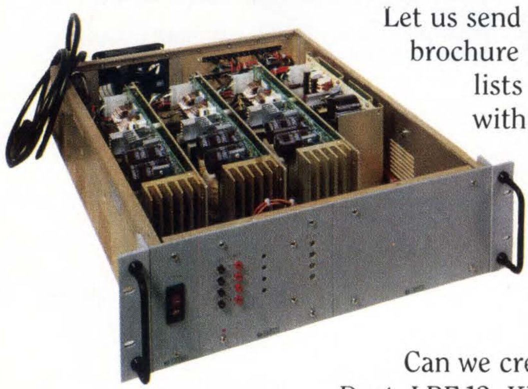
OUTPUTS
+5 VOLTS & 24 AMPS
+5 VOLTS & 6 AMPS
+5 VOLTS & 6 AMPS
−5 VOLTS & 6 AMPS
−2.1* VOLTS & 0.25 AMPS

*Modified Standard Unit

TYPICAL ASSEMBLY

OUTPUTS
+5 VOLTS & 10 AMPS
+5 VOLTS & 10 AMPS
−5 VOLTS & 10 AMPS
−5 VOLTS & 10 AMPS
+28 VOLTS & 2.15 AMPS
−28 VOLTS & 2.15 AMPS





Let us send you a colorful 6-page brochure that tells you a lot more. It lists suggested power modules with prices that allow you to estimate cost on the spot. These photos illustrate custom power assemblies showing the variety of front and rear layouts chosen by our customers.

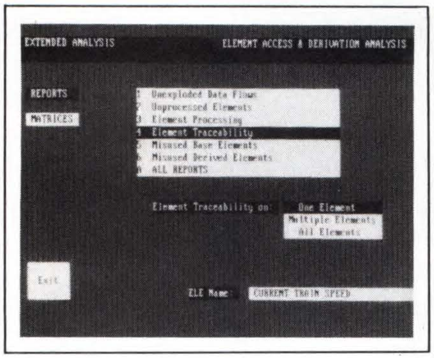
TYPICAL ASSEMBLY

OUTPUTS
+24 VOLTS & 10 AMPS
−24 VOLTS & 10 AMPS
+5 VOLTS & 48 AMPS
+12 VOLTS & 10 AMPS

Can we create one for you? Call or write Dept. LBF-12, KEPCO, INC., 131-38 Sanford Avenue, Flushing, NY 11352 USA • (718) 461-7000 TWX #710 582 2631 • FAX (718) 767-1102.

KEPCO®
THE POWER SUPPLIER™

CIRCLE NO 207



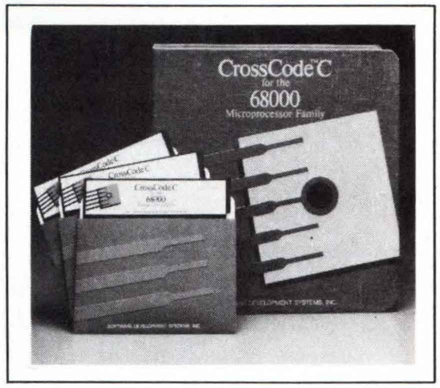
CASE TOOL

- *Analysis and workbench tools for real-time systems*
- *Semantic and syntactic validation of specifications*

Excelerator/RTS version 1.8A software lets you develop specifications for embedded and real-time systems. It works with the IBM PC/XT, PC/AT, PS/2, and compatibles. The software supports the Ward-Mellor and Hatley techniques for system design. You can adapt graphics and a central dictionary using the vendor's customizing software. The software provides semantic and syntactic validation of specifications. Its new features include 33 analysis reports with 25 matrices that let you check system design. An element-trace report lets you find logic errors in the design. The software's graphical-analysis facilities match your system design against 50 specified rules. $8400. If you own a prior version of the software and have a warranty or maintenance plan, the upgrade is free; the upgrade is available to other users for $500.

Index Technology Co, 1 Main St, Cambridge, MA 02142. Phone (617) 494-8200. TWX 910-380-7014.

Circle No 435

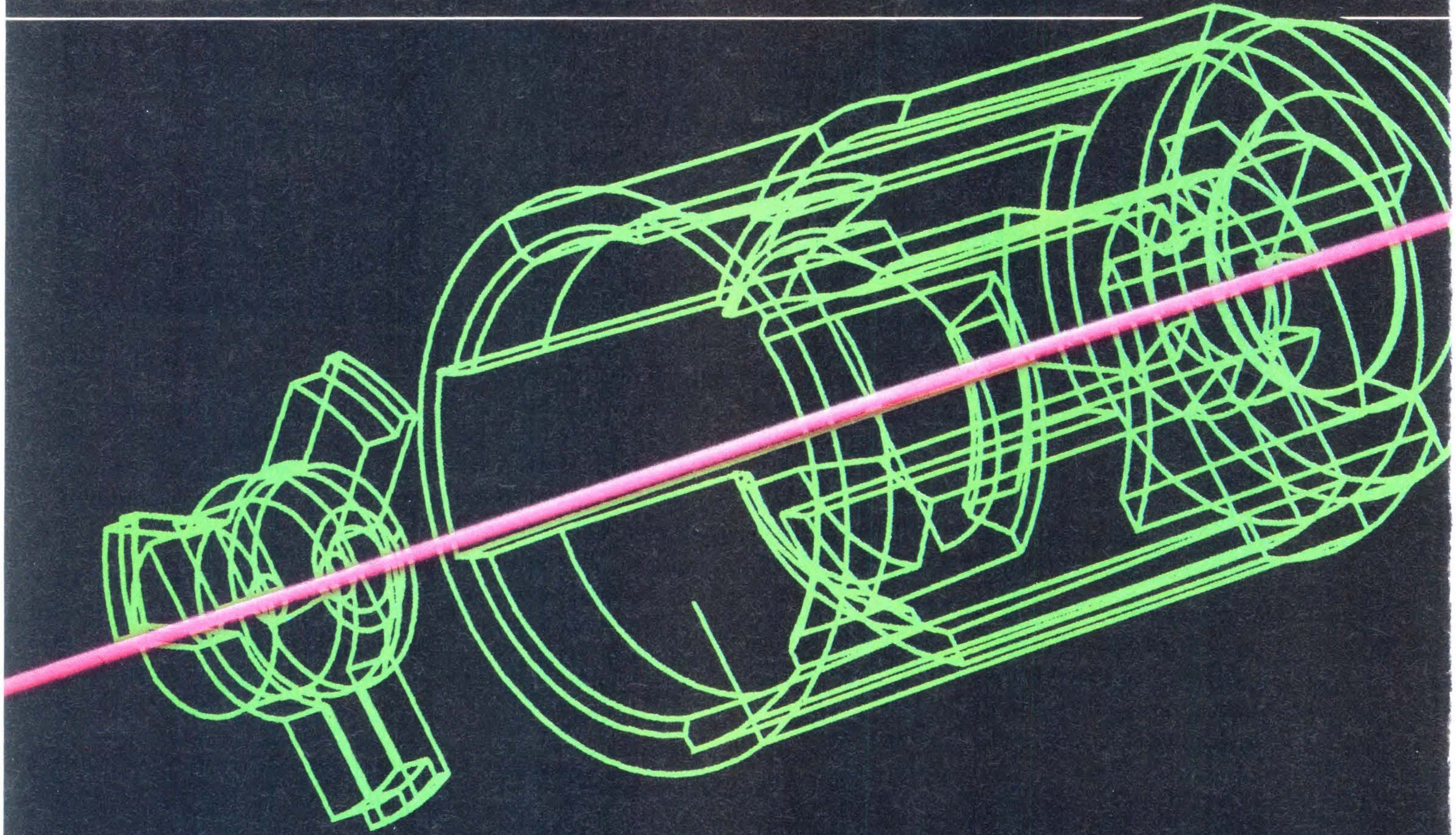


C COMPILER

- *Generates ROMable code for the 68000 μP family*
- *Can split output code into five memory sections*

The CrossCode C compiler generates ROMable code for the 68000 μP family and conforms to the ANSI C standard. The compiler package comprises a macro assembler, a

BREAK T H R O U G H



New microlasers are expanding and refining laser applications through advanced diode-pumped, solid-state technology.

Amoco Laser Company's microlaser technology represents a quantum leap forward for laser light sources. Finally, a low noise, highly efficient, compact laser is available with operating voltage and lifetime characteristics that make microlasers a practical solution for many applications.

Consider the following line of infrared microlasers. They are available for immediate shipment for a wide range of uses in testing and inspection, optical alignment, materials characterizations, metrology, process monitoring, spectroscopy, micromachining, and microsurgery.

Product	Wavelength	Power
ALC1064-50	1064nm	50mw
ALC1064-150	1064nm	150mw
ALC1320-25	1320nm	25mw
ALC1320-75	1320nm	75mw

All of the above lasers have a diffraction limited, TEM_{00} mode and are offered with linear or random polarization. A line of precision collimators is also available.

Want to learn more? Write for our videotape which more thoroughly explains Amoco's microlaser and its uses.

Amoco Laser Company, 1809 Mill St., Naperville, IL 60540, or phone: 312-369-4190.

AMOCO

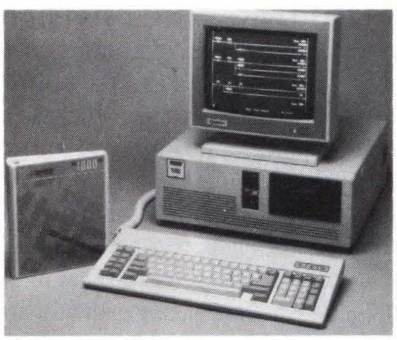
Amoco Laser Company

CIRCLE NO 210

linker, and a C library. Using the compiler, you can split output code into five RAM or ROM sections and define integer and pointer sizes over a 16- to 32-bit range. The linker lets you partition and allocate the required memory. The compiler's C library provides the source for more than 47 functions. The package also features a downloading utility that communicates with EPROM programmers, allowing you to convert compiled code into Motorola S records and other file formats. This utility also allows you to create binary images. The compiler lets you use a maximum of 64 characters for symbol names. MS-DOS or Xenix version, $1595; Unix version, $4795.

Software Development Systems Inc, 3110 Woodcreek Dr, Downers Grove, IL 60515. Phone (800) 448-7733; in IL or outside USA, (312) 971-8170. FAX 312-971-8513.

Circle No 436



SOFTWARE PACKAGE

- *Lets you design and run process-control functions*
- *Includes PLD and stepper-drum functions*

The PCI-20073S-1 software package is an enhanced version of the industry-standard RD1000/PC relay-ladder software. In conjunction with the vendor's PCI-20000 data-acquisition system, the software simplifies the design of process-monitoring and -control functions. You can use the PC first as a development system to configure a data-acquisition and -control algorithm, and then as a controller that runs the algorithm. A screen editor displays conventional and enhanced relay-ladder symbols that you can select and enter with single keystrokes. You can at any time access an on-line help screen. The editor allows you to perform forward and backward searches for rungs, and you can delete or insert rungs. You can monitor, and even modify, a running program. The software also provides password-security protection. The enhancements include the ability to program the logic equivalent of as many as 32 16×16 stepper drums; each drum can step 16 times and selectively open or close as many as 16 contacts at each step. $995.

Burr-Brown, 1141 W Grant Rd, #131, Tucson, AZ 85705. Phone (602) 746-1111.

Circle No 437

FORTRAN FOR 80386

- *Makes full use of 32-bit architecture for speed*
- *Lets you compile programs as large as 4G bytes*

The F77L-EM/32 full implementation of the ANSI Fortran 77 standard includes a number of popular extensions, which makes it easier to adapt minicomputer and mainframe applications to the 80386 architecture. The compiler can use both 80287 and 80387 math coprocessors, and a future release will also work with the Weitek 1167; it will run in protected mode. The package comes with a source-level debugger, a library manager, and a 32-bit linker. To run the compiler, you need an 80386-based machine, PC-DOS 3.0 or higher, at least a 1M-byte extended memory, and either OS/386 or Developers' Kit OS/386—the two DOS-extender systems from AI Architects (Cambridge, MA). $895.

Lahey Computer Systems Inc, Box 6091, Incline Village, NV 89450. Phone (702) 831-8123. TWX 910-240-1256.

Circle No 438

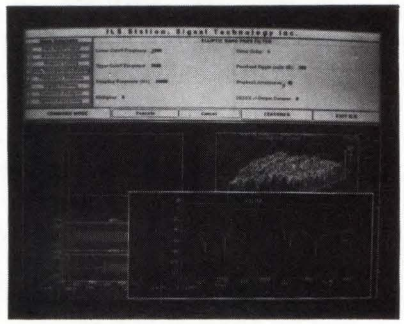
CAD SOFTWARE

- *Features 3-D polyline with five types of surfaces*
- *Works simultaneously with 2-D and 3-D elements*

The AutoCAD software package, release 10, now runs on the Apple Macintosh and uses pull-down menus and icons to guide you. Featuring a 3-D polyline with five types of surfaces, the software performs simultaneously with 2-D and 3-D elements. A coordinate-system icon provides visual feedback. The software's interactive viewing lets you display multiple on-screen views. Its standard features include zoom, clip, pan, and project facilities. The software employs a proprietary version of Lisp for programming. A graphics exchange facility lets you communicate with other CAD systems. $3000.

AutoDesk Inc, 2320 Marinship Way, Sausalito, CA 94965. Phone (415) 332-2344. TLX 275946.

Circle No 439



SIGNAL ANALYSIS

- *Performs DSP analysis of time-series data*
- *Supports Apollo user-interface and graphics standards*

The ILS (Interactive Laboratory System) signal-analysis package is now available for the Apollo 3000 and 4000 workstations. The software operates on digitized signal data stored in computer files. It lets you analyze the data using DSP techniques such as frequency analysis, digital filtering, numerical analysis, speech processing, and other forms of data manipulation. This version uses the Apollo Domain/Dialogue user-interface design and management system to provide a menu-driven operation for most DSP functions. You can easily modify and customize the menus. The multiple-window facility lets you view several different analysis steps simultaneously. The software conforms to the Apollo GMR (Graphics Metafile Resource) standard, which allows you to direct graphics output to any Apollo-supported output device. If you store graphics in a metafile, you can edit the file, share the file with other applications, or view the file on any Apollo workstation on the Domain local-area network.

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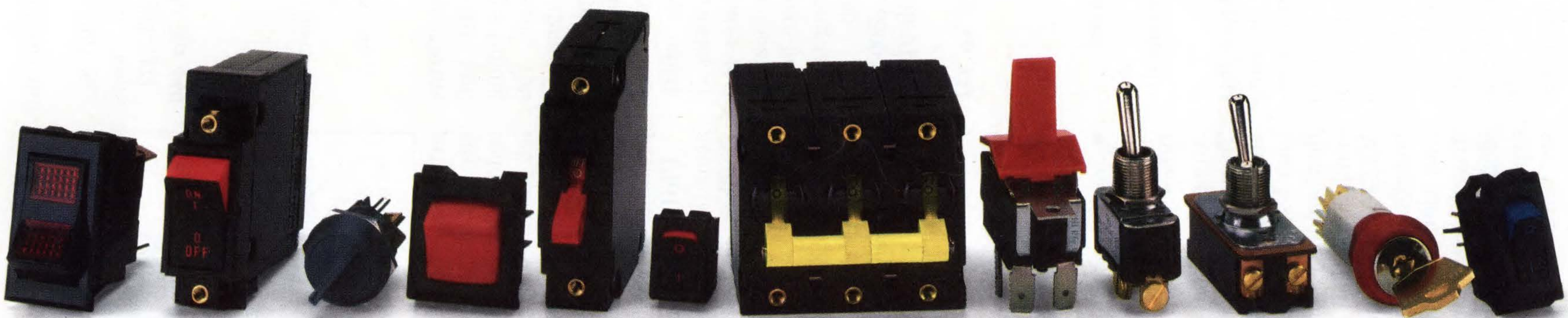

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Signal Technology Inc, 5951 Encina Rd, Goleta, CA 93117. Phone (805) 683-3771. TWX 910-334-3471.

Circle No 440

TIMING ANALYZER

- *Performs worst-case analysis on ASIC and board designs*
- *Displays timing problems on schematic designs*

The QuickPath analyzer performs worst-case analysis on ASIC and board designs, and displays timing problems on the schematic. You don't have to create vector stimuli in order to find setup and hold problems. The analyzer calculates path delays, then compares them to clock specifications. It supports multiphase and multifrequency clocks. In addition, the analyzer locates fast and slow components on pc boards. Its algorithm works with gate-level, functional, behavioral-language, and hardware models. $9900.

Mentor Graphics Corp, 8500 SW Creekside Pl, Beaverton, OR 97005. Phone (503) 626-1231.

Circle No 441

CASE TOOL

- *Lets you develop structured programs for PLCs*
- *Runs on an industry-standard PC*

The PDS5 software package lets you develop programs for the company's PC20 and MC30 programmable logic controllers (PLCs) on an industry-standard PC. The package supports the graphic Sequential Function Chart (SFC) language. SFC employs embedded ladder-diagram and functional-block diagram languages. In addition, you can program using text coding. The SFC language obtains the program structure from a flow chart of the main control functions. This feature lets you develop structured pro-

grams at shop-floor level. For on-site test purposes, you can download code to a PLC. The debug facilities let you monitor program execution at any level. The package includes pull-down menus, on-screen help, and documentation facilities. Approximately gld 5000.

Philips, Industrial & Electro-acoustic Systems Div, 5600 MD Eindhoven, The Netherlands. Phone (040) 788620. TLX 35000.

Circle No 442

Philips Electronic Instruments Inc, 85 McKee Dr, Mahwah, NJ 07430. Phone (201) 529-3800.

Circle No 443

CAE TOOL

- *Checks pc-board designs for environmental reliability*
- *Analysis conforms to MIL-STD-217 standards*

When combined with the vendor's Allegro pc-board design system, ThermoStats provides environment analysis. It allows you to analyze board-spacing, part-selection, airflow velocity, noise, and thermal conditions. The tool indicates the MTBF of a pc board by checking the board's conduction, convection, and radiation effects. By examining driver/receiver pin pairs, the tool identifies components that are susceptible to noise. The tool takes 30 sec typ to process an analysis and display the results on a color-coded line graph, and provides a library with 1200 thermal models. The reli-

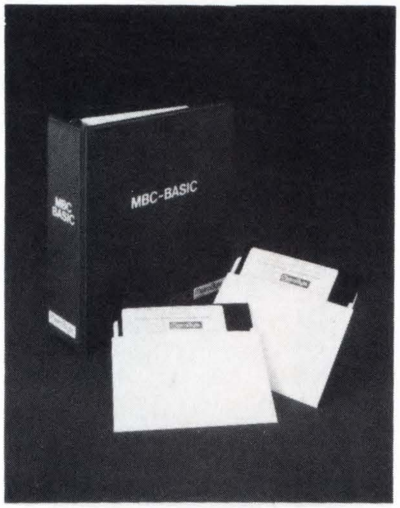
ability analysis conforms to the requirements of MIL-STD-217. The ThermoStats package runs on Sun 3, 4, and Digital 3000, GPX II workstations. $15,000.

Valid Logic Systems, 2820 Orchard Parkway, San Jose, CA 95134. Phone (408) 432-9400. TLX 3719004.

Circle No 449

STRUCTURED BASIC

- *Includes statements for data acquisition*
- *Provides structured-programming format*



The MBC-Basic high-level programming language is compatible with GW Basic and BasicA. However, the language has extensions that let you tailor programs to the needs of a specific data-acquisition and -control application. New control-flow keywords let you create structured procedures and functions similar to those of C or Pascal. You can declare variables as either global or local to a procedure. You can create libraries of pretested, error-free code for repeated use. The language also lets you create your own keywords, and the package comes with a number of these special keywords that are created specifically for the vendor's Metra-bus family of process-control and data-acquisition devices. Unlike other Basic implementations, which are restricted to 64k bytes of memory, MBC-Basic allows you to access the full 640k bytes available to DOS. $195.

MetraByte Corp, 440 Myles Standish Blvd, Taunton, MA 02780. Phone (508) 880-3000. TLX 503989.

Circle No 444

NUMBER GENERATOR

- *Generates double-precision random numbers*
- *Lets you select various probability distributions*

The RanGen software package performs high-speed generation of double-precision random-number sequences with uniform, Gaussian

(normal), lognormal, weibull, exponential, and other probability distributions. The only limit on the size of the sequences is the amount of disk space available to store them. The software lets you select the specific quantity of random numbers that you require. You can scale the numbers to a desired range and sum them. You can specify key parameters such as the mean and the variance of the distribution needed; if you don't specify these parameters, the program uses the defaults of zero-mean and unit variance. $29.95.

Signal Analysis Research, 8301 Thomas Ave N, Minneapolis, MN 55444. Phone (612) 560-8166.

Circle No 445

DEBUG TOOL

- *Provides hardware and software debug facilities*
- *Runs in real time without speed problems*

The Adapt29K, a RISC (reduced instruction set computer) μP development tool, provides both hardware and software debug facilities. According to the vendor, it runs in real time without encountering speed problems. The tool supports a 29k-byte max development project and provides ROM-resident software with an assembler. The software allows you to set eight breakpoints; to read from and write to I/O lines; to trace code execution; and to download files. Running on ASCII terminals and host computers, the tool catches bus signals at 40 MHz max. It plugs into the CPU socket and runs directly on the target processor. $8500.

Step Engineering, Box 3166, Sunnyvale, CA 94088. Phone (800) 538-1750; in CA, (408) 733-7837. TWX 910-339-9506.

Circle No 446

CAE SYSTEM

- *Lets you design and simulate in an interactive mode*
- *Allows you to work on more than 30,000 gates*

The Workview 3000 provides an ASIC design system for 386-based computers that lets you design and simulate in an interactive mode. The schematic capture lets you use the mouse, the keyboard, or macros for your instructions. The system provides 60 primitives that operate at

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gate, switch, and functional levels. Timing simulation facilities let you check setup, hold, skew, pulse-width, and recovery violations. In addition, the system allows you to work with more than 30,000 gates. The vendor offers design kits with design-rules checkers and bidirectional interfaces for analog and pc-board designs. From $10,000.

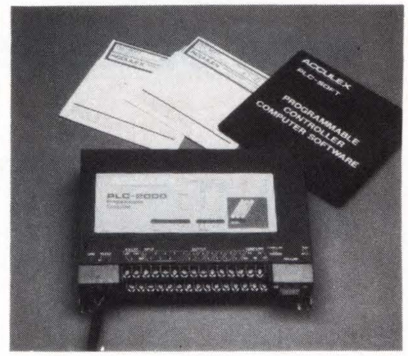
Viewlogic Systems Inc, 275 Post Boston Rd W, Marlboro, MA 01752. Phone (617) 480-0881. TLX 174242.

Circle No 447

PLD

- *Features ladder-logic software with an interactive mode*
- *Has a battery-backed RAM with eight inputs*

The D100 PLD provides a controller with interface modules and ladder-logic software. The software runs on the IBM PC, PC/XT, PC/AT, and compatibles. The controller comes with a battery-backed RAM with eight inputs. The device's features include six 24 to 240V ac/dc outputs; a 2-kHz max counter with 32 presets; and two 8-bit A/D channels with 12 presets/channel. The ladder-logic software lets you make interactive programming changes. A graphics-oriented interface provides visual feedback of your code. Controller and software, $325 each; RS-232C converter and cable, $55; interface card, $180.



Acculex Co, 440 Myles Standish Blvd, Taunton, MA 02780. Phone (617) 880-3660. TLX 503989.

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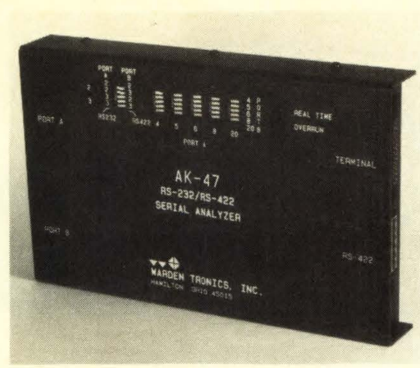

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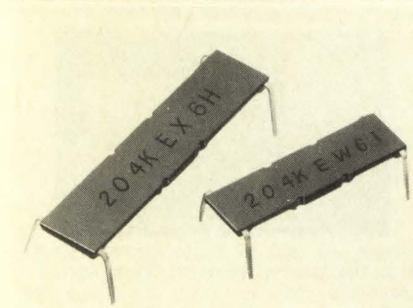

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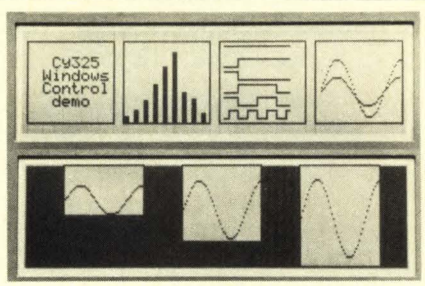

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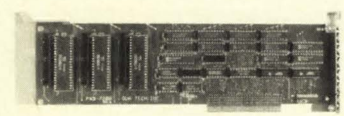

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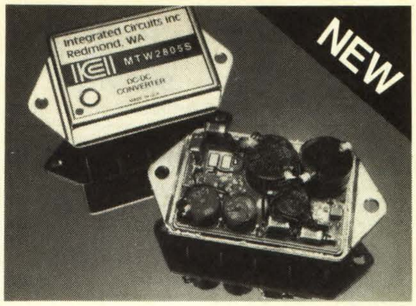

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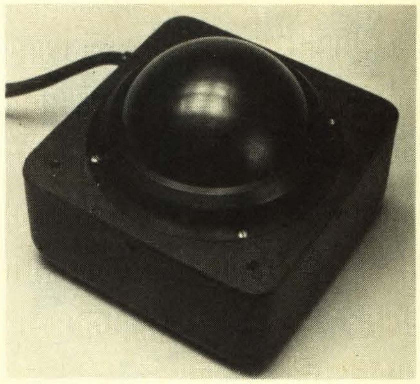

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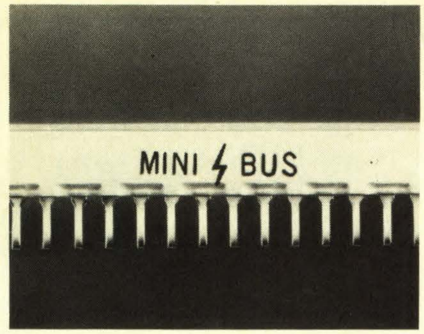

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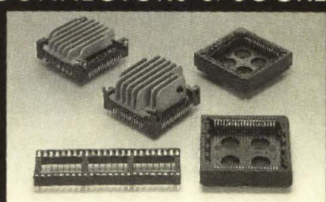

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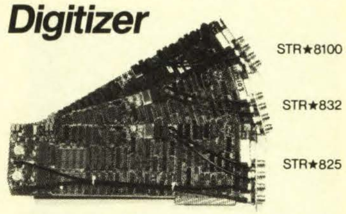

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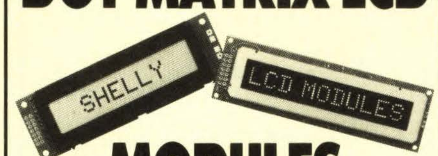

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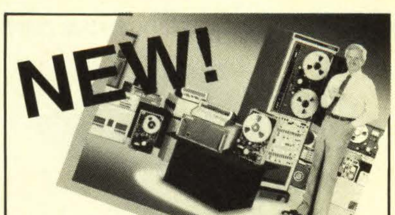

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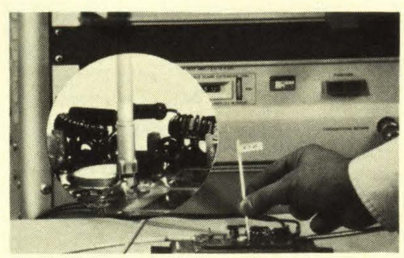

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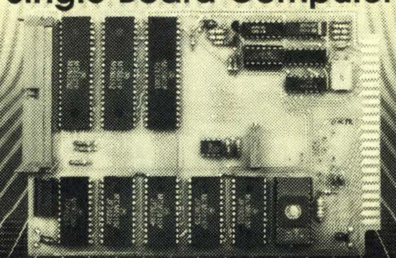

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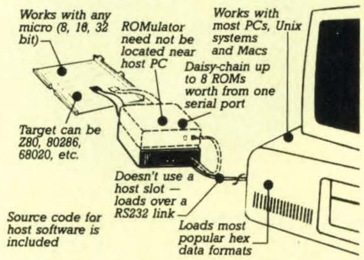

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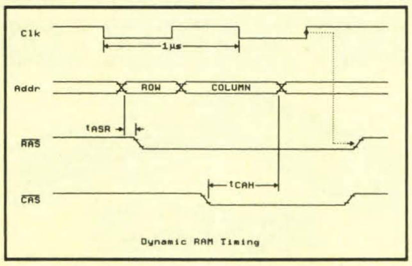

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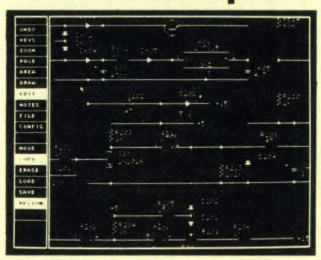

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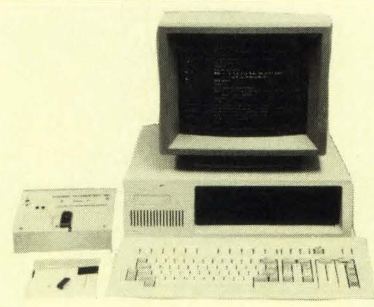

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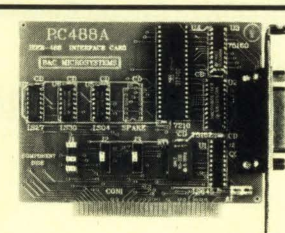

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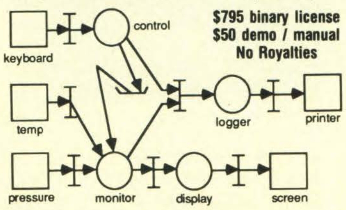

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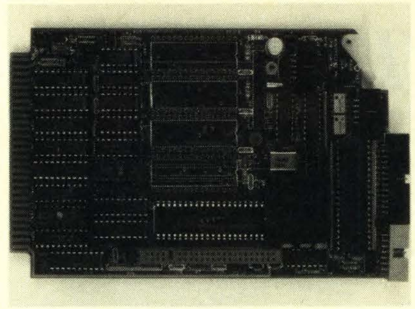

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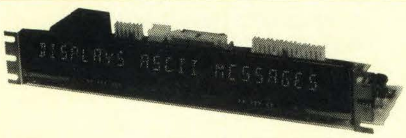

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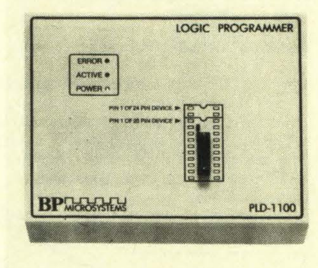

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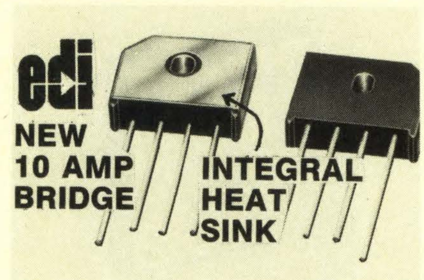

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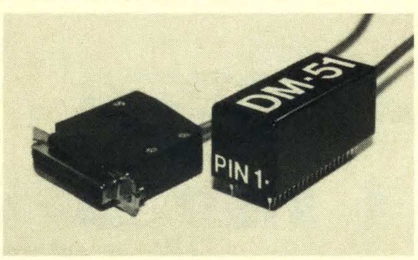

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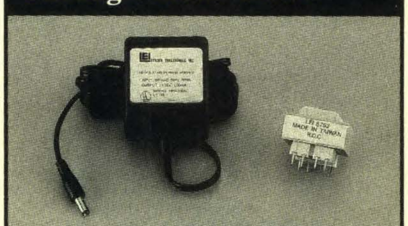

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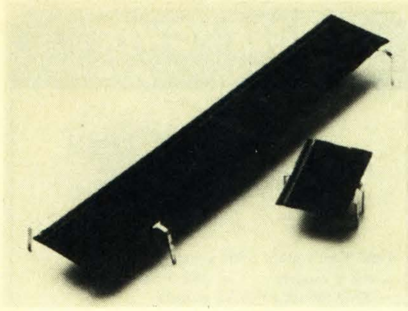

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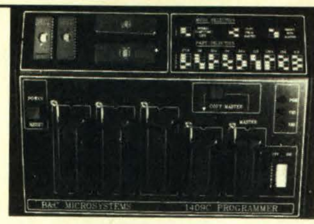

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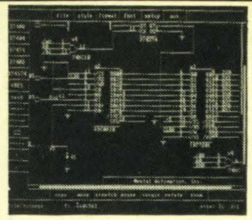

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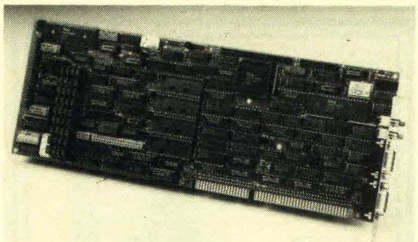

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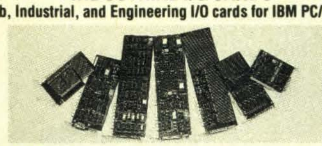

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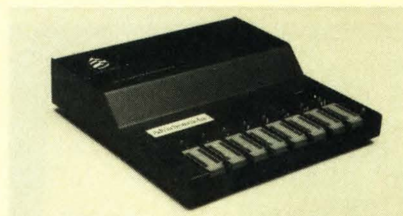

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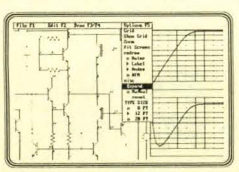

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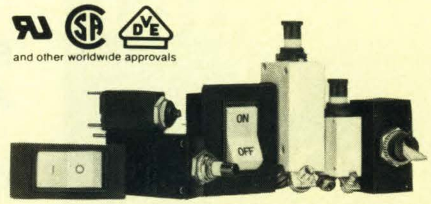

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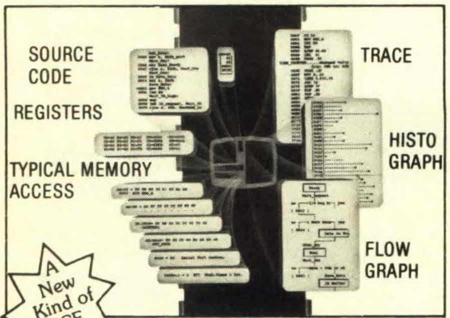

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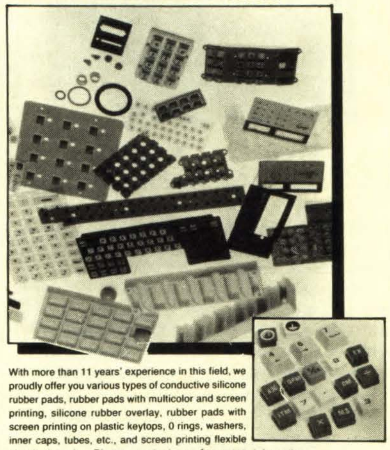

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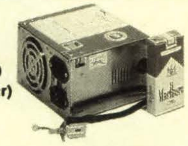

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Tlx: 10862 LEADYEAR Fax: 886-2-7857852

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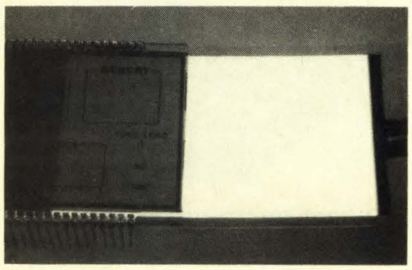
CIRCLE NO 787



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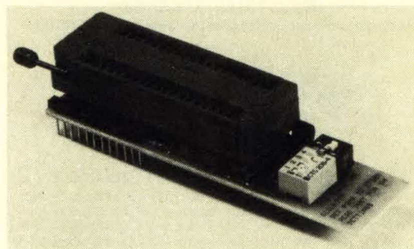

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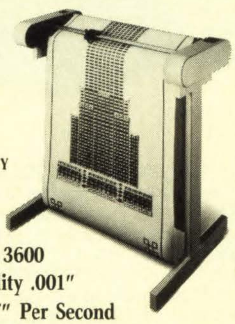

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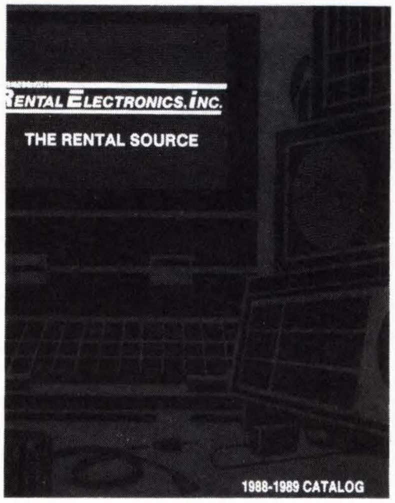


Listing of electronic test equipment for rent

This 1988-89 Rental Catalog presents electronic test equipment that's available for rent. The 36-pg listing includes products from major instrumentation manufacturers, such as Hewlett-Packard, Tektronix, Intel, and Fluke. The instruments for rent fall into 26 categories, including analyzers, meters, generators, oscilloscopes, desktop computers, and telecommunications. Rental terms and conditions, illustrations, and a product index complete the publication.

GenStar Rental Electronics Inc, 6307 DeSoto Ave, Suite J, Woodland Hills, CA 91367.

Circle No 450

Catalog unveils software for VAB and HP-UX

The vendor's 200-pg Publication 5951-6794 deals with software for value-added-business (VAB) and proprietary-software solutions for its HP-UX operating system. The catalog lists more than 400 technical and commercial software packages for the vendor's HP-9000 workstations and servers. Using the market keyword index, you can look for products in specific application areas. A range of application areas are available, from aerospace simulators to water-utilities operation. Business application areas include financial management, sales analysis, and accounting packages. The 200 VAB software packages listed in the publication are part of the HP Plus Program that assists third-party software suppliers with marketing the products.

Hewlett-Packard Co, Customer Information Center, Inquiry Fulfillment Dept, 19310 Pruneridge Ave, Cupertino, CA 95014.

Circle No 451

Survey analyzes repair record of personal computers

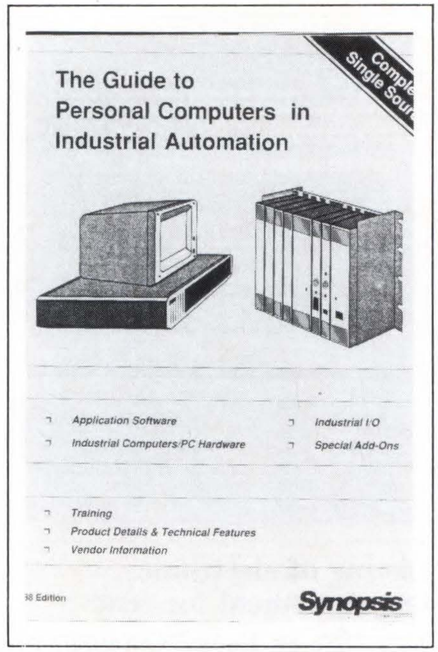
The report, *Opportunities in Personal Computer Servicing: A National Survey of Malfunction and Repair,* is the second in a series of analyses outlining the personal-computer industry. It provides an overview of personal-computer hardware and its failure rate, and evaluates the responses of almost 500 business-oriented respondents, concerning product failure, repair, and service contracts. $299.

Business Products Consulting Group, 24 Fort Salonga Rd, Centerport, NY 11721.

INQUIRE DIRECT

Guide to personal computers

The 2nd edition of *The Guide to Personal Computers in Industrial Automation* is a comprehensive single-source reference for the use of IBM-compatible and Macintosh personal computers. The 102-pg guide lists 700 products from 300 vendors, representing major applications and



technology. Entries include application software, PC hardware, industrial computers, industrial I/O devices, and peripherals. The guide also provides applications in process monitoring and control, data acquisition, PLC (programmable logic controller) programming/documentation, statistical quality control, manufacturing resource planning, operator interface, and cell control. A training section provides application training and technology reviews that include charts, photos, and diagrams. $39.95.

Synopsis Corp, 2708 Salisbury Plain, Raleigh, NC 27612.

INQUIRE DIRECT

IC data book

This company's 1988 data book presents all of the information found in the 1987 issue, as well as technical specifications and application notes for all the company's products released during the past year. It also features previews of many products to be released during 1988. New sections describe electrostatic discharge sensitivity and provide information about the sale of products in die form.

Elantec Inc, 1996 Tarob Ct, Milpitas, CA 95035.

Circle No 452

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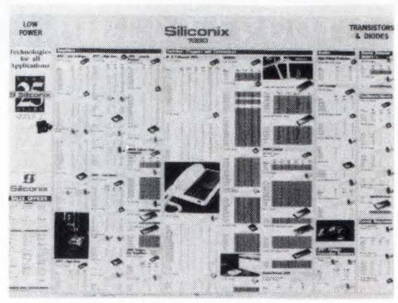
CIRCLE NO 225

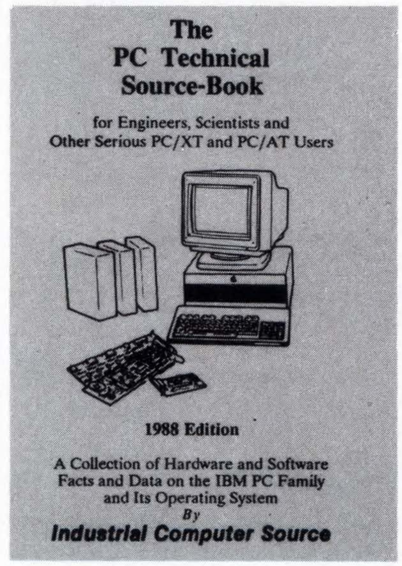
Visual aid helps you choose the best FET



This 22×32-in. wall chart helps you in the selection of the most suitable FET for your design—whether it's a low-leakage/low-noise JFET, an ultrahigh-speed DMOS FET, or a low-power MOSFET. The chart also includes specifications for the vendor's most popular low-power discrete FETs. For easy reference, the chart is organized by major circuit categories, such as amplifiers, switches, choppers, commutators, diodes, current regulators, oscillators, mixers, and voltage-controlled resistors. Within each application area, the parts are sorted according to selection criteria—for example, amplifier FETs are sorted by critical parameters and by package options.

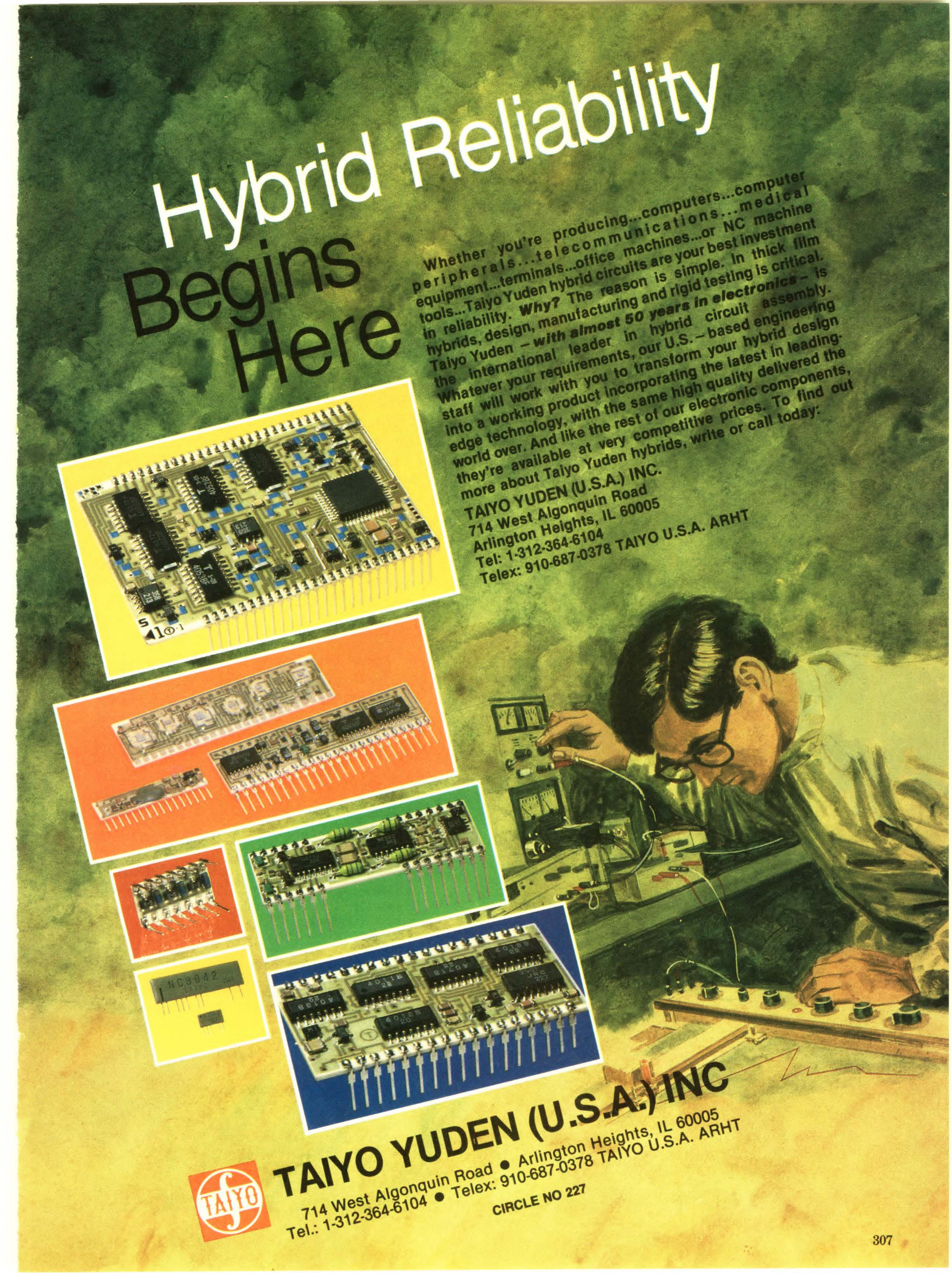
Siliconix Inc, 2201 Laurelwood Rd, Santa Clara, CA 95054.

Circle No 453



Manual targets IBM PC/XT and PC/AT users

Aimed primarily at engineers, scientists, and other professional IBM PC/XT and PC/AT users, *The 1988 PC Technical Source-Book* is a collection of hardware and software facts and data about the IBM PC family and its operating system. The 76-pg manual provides an introduction to the IBM PC for the beginner and a ready reference for the experienced user. It includes among its topics: I/O Bus 62-Pin Connectors, Bus Signal Summary, Memory Map, I/O Map, DMA Channels, Switch Settings, and DOS Commands. Further topics are AT CMOS Memory, 8237 DMA Controller, Keyboard Scan Codes, IBM PC/XT and PC/AT I/O Card Dimen-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CIRCLE NO 227

sions, and Hex and Decimal Equivalents.

Industrial Computer Source, 5466 Complex St, Suite 208, San Diego, CA 92123.

Circle No 454

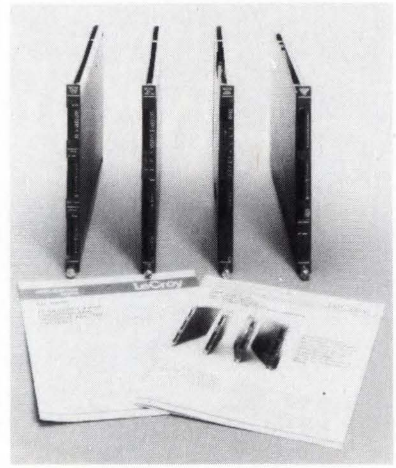
Studies deal with AI in electronics manufacturing

These three case studies discuss the use of artificial intelligence in electronics manufacturing. The 336-pg *Artificial Intelligence Applications in Manufacturing* presents more than 200 commercial expert systems and case studies for specific applications such as CAD/CAM, maintenance, production scheduling, and energy management. The 198-pg *Artificial Intelligence in the Computer/Electronics Industry* explains the aspects of AI used for in-house applications: expert systems, artificial vision, voice recognition, and intelligent robots. Finally, the 176-pg *Artificial Intelligence in the Semiconductor Industry* discusses the research being done by major manufacturers in the design of VLSI circuits. Each publication costs $135.

Lion Publishing, Box 1869, Los Gatos, CA 95031.

INQUIRE DIRECT

Publications clarify ADC and TDC systems



This technical data sheet and application note explain the FERA/FERET fast-encoding and readout data-acquisition systems. The 4-color, 8-pg data sheet details the features of these modular systems and describes units for fast A/D conversion (Model 4300B), time-to-digital conversion (Model 4303), and fast access memory (Model 4302). It also reports on modules that provide logic decisions based on analog and time information. The application note, *FERA/FERET-Fast Encoding and Readout ADC/TDC Systems (AN 4004A)*, presents the systems, using text, tables, and diagrams, and discusses several configurations.

LeCroy Corp, 700 Chestnut Ridge Rd, Chestnut Ridge, NY 10977.

Circle No 455

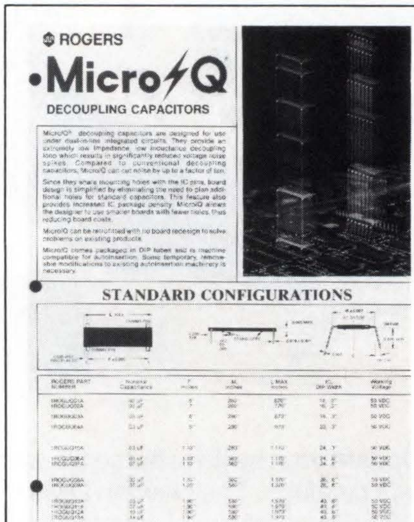
Document examines dc/dc converters and amplifiers

This 32-pg booklet of application notes defines technical terms for dc/dc converters. It includes a users' guide that tells you how to make accurate measurements; and about the effects of regulation, input noise, common-mode noise, and load-induced noise. Notes on *input ripple rejection* provide instructions for building a low-power noise test fixture and thermal-design calculations. Other sections, which include illustrations of 25 performance-type curves and 45 diagrams, instruct you in the use of a dc/dc converter as an ATE supply; in the use of a dc/dc converter in parallel for more power; in using instrumentation am-

plifiers, and in grounding and shielding amplifiers.

Calex Mfg Co Inc, 3355 Vincent Rd, Pleasant Hill, CA 94523.

Circle No 456



Data sheet deals with decoupling capacitors

This data sheet examines the vendor's Micro/Q decoupling capacitors. It gives you product specifications, standard and special configurations, and electrical performance. Finally, it provides installation and ordering information.

Rogers Corp, Circuit Components Div, 2400 S Roosevelt St, Tempe, AZ 85282.

Circle No 457

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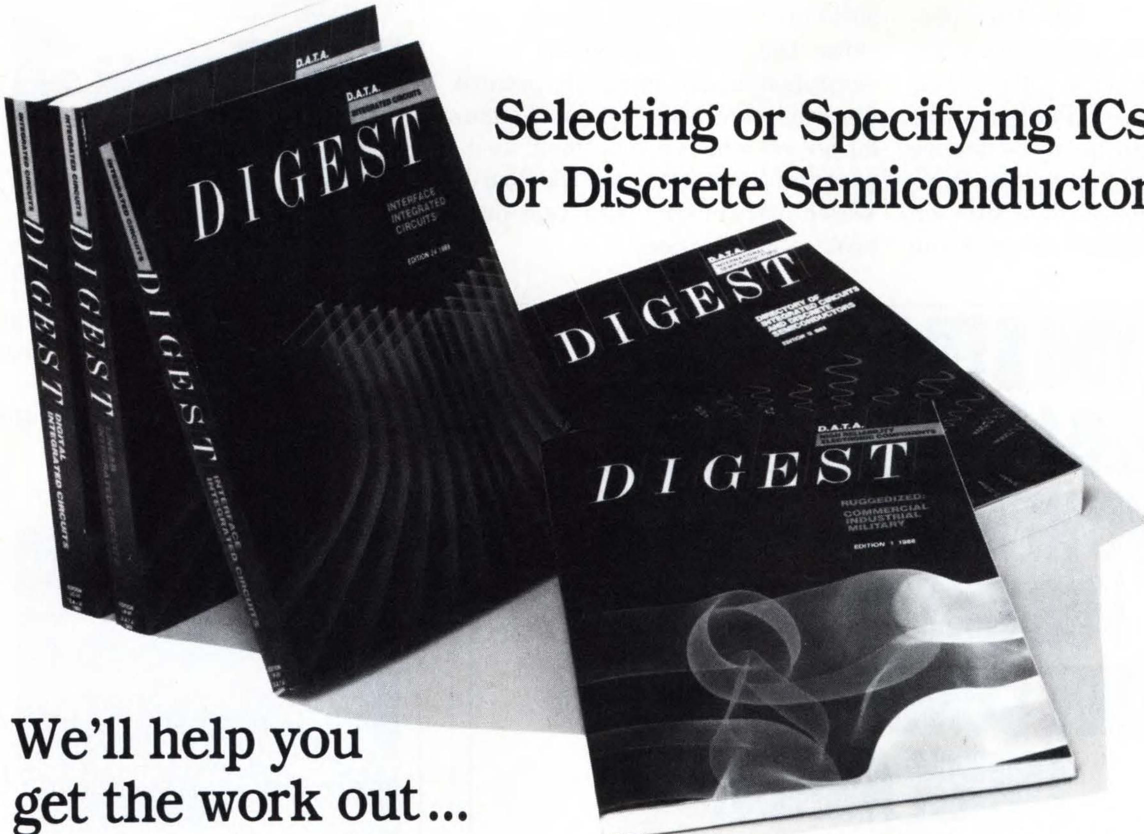

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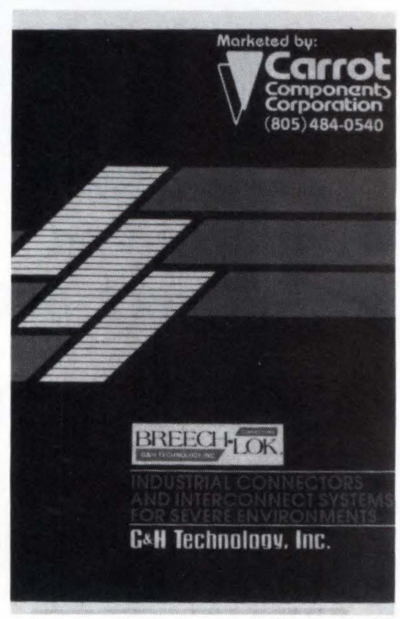
CIRCLE NO 231

Brochure surveys VLSI board-test systems

This 12-pg, 4-color brochure provides an overview of the five members of the vendor's L200 VLSI board-test systems. Discussing the features that provide cost-effective solutions to individual test requirements, the brochure elaborates on the modular architecture and the use of the VAX/VMS platform. Further, the pamphlet describes the software support for all the systems: the L200 test-development environment and in-circuit pattern libraries, the Lasar Version 6 simulation system for functional test-program generation, and the Board-Watch networking and test-data management system.

Teradyne Inc, Inquiry Systems & Analysis, 25 Drydock Ave, Boston, MA 02110.

Circle No 458



Listing of connectors

The vendor's 12-pg catalog of BLC Breech-Lok connectors features specifications, mechanical drawings, contact arrangements, and information about backshell accessories, crimp contacts, and service tools. Also included is information about straight plugs; mounting, in-line, and jam-nut receptacles; and protective covers.

Carrot Components Corp, 750 W Ventura Blvd, Camarillo, CA 93010.

Circle No 459

Filter-design package offers a variety of filter types

Filter Design and Analysis System. *Momentum Data Systems, 1666 Newport Blvd, #115, Costa Mesa, CA 92627. Phone (714) 548-3257. Version 2.0, $895; code generation, $200.*

Designing filters is easier when you don't have to calculate filter coefficients. It's even easier when you can try various filters and view plots of their characteristics. The Filter Design and Analysis System allows you to design, evaluate, and create code for a variety of digital filters. The system is well documented, easy to use, and very flexible.

The package runs on IBM PC, PC/XT, PC/AT, PS/2, and compatible computers. It supports most popular graphics interfaces, printers, and plotters. The graphs displayed on the CRT and the hardcopy devices provide a higher quality than most filter-design packages—high enough for use in reports and manuals. You can use a graphics-interchange file that lets you incorporate the plots in various desktop publishing systems. The software is easy to install; the manual provides easy-to-follow instructions. Operating the system is also easy—its menu-driven operation guides you. Also, the system checks your input for errors while you're entering it.

The main menu lets you design an infinite-impulse-response (IIR), finite-impulse-response (FIR), or equiripple filter; analyze a digital system; or read a filter-specification file. After you've made selections from the menu, the program accepts the screen when you press function key F10.

For IIR filters, you can employ a bilinear-transformation or impulse-invariance design method to design a lowpass, highpass, bandpass, or bandstop filter. You enter the characteristics of the filter by filling in blanks. The system then calculates the estimated order for four types of filters: Butterworth, Chebyshev, elliptic, and Bessel. You then select the filter type and order.

Next, the output-options screen is displayed. This screen allows you to select from a wide variety of plots on the screen and on the hardcopy. You can "zoom" by selecting start and stop ranges. The plot options include magnitude, log 10 magnitude, poles and zeros, impulse and response, group delay, phase, and step response.

In addition, the output-options screen allows you to quantize the filter coefficients over the 8- to 32-bit range. All of the internal calculations provide 64-bit, floating-point precision. The quantization option allows you to vary word sizes and determine the effects of the

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resolution. Other options allow you to create files for code generation, for future use, and for graphics interchange.

The FIR-filter design option works in a similar way. It supports lowpass, highpass, bandpass, bandstop, and differentiator filters with rectangular, triangle, Hanning, Hamming, Blackman, and Kaiser window functions. Once you've entered the filter characteristics, the system gives an estimated number of taps for each filter type. As in the IIR option, an output-options screen controls the output; however, it supports only magnitude, log-10-magnitude, impulse-response, and step-response plots.

The equiripple FIR-filter design is based on the Parks-McClellan algorithm; it helps you design lowpass, highpass, bandpass, bandstop, differentiator, multiband, Hilbert-transform, and arbitrary-magnitude filters. The use of this section is similar to that of the FIR option, except that in the equiripple option, you have to enter each band. The characteristics you use should be realistic: If your band transition is too steep, the system will not produce a result.

The analysis system also lets you analyze digital systems. You enter the transfer function in either the s or the z domain. You can then use an output-option screen similar to the one the IIR filter provides.

Two code generators take the filter you designed and convert it to source code. One generator creates code for the Motorola DSP56000, and the other produces code for the Texas Instruments TMS32010, TMS32020, and TMS320C25.

—***David Shear***

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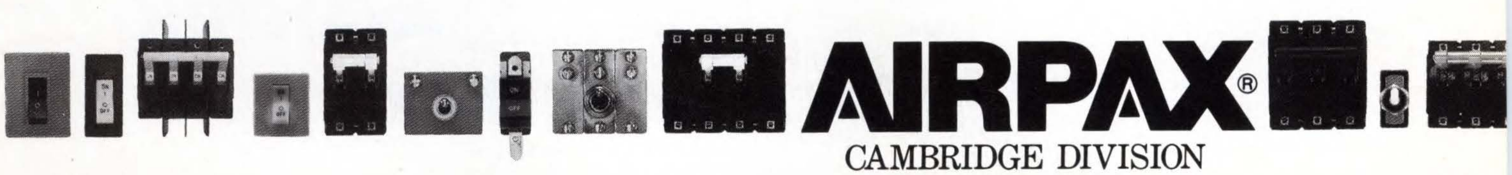

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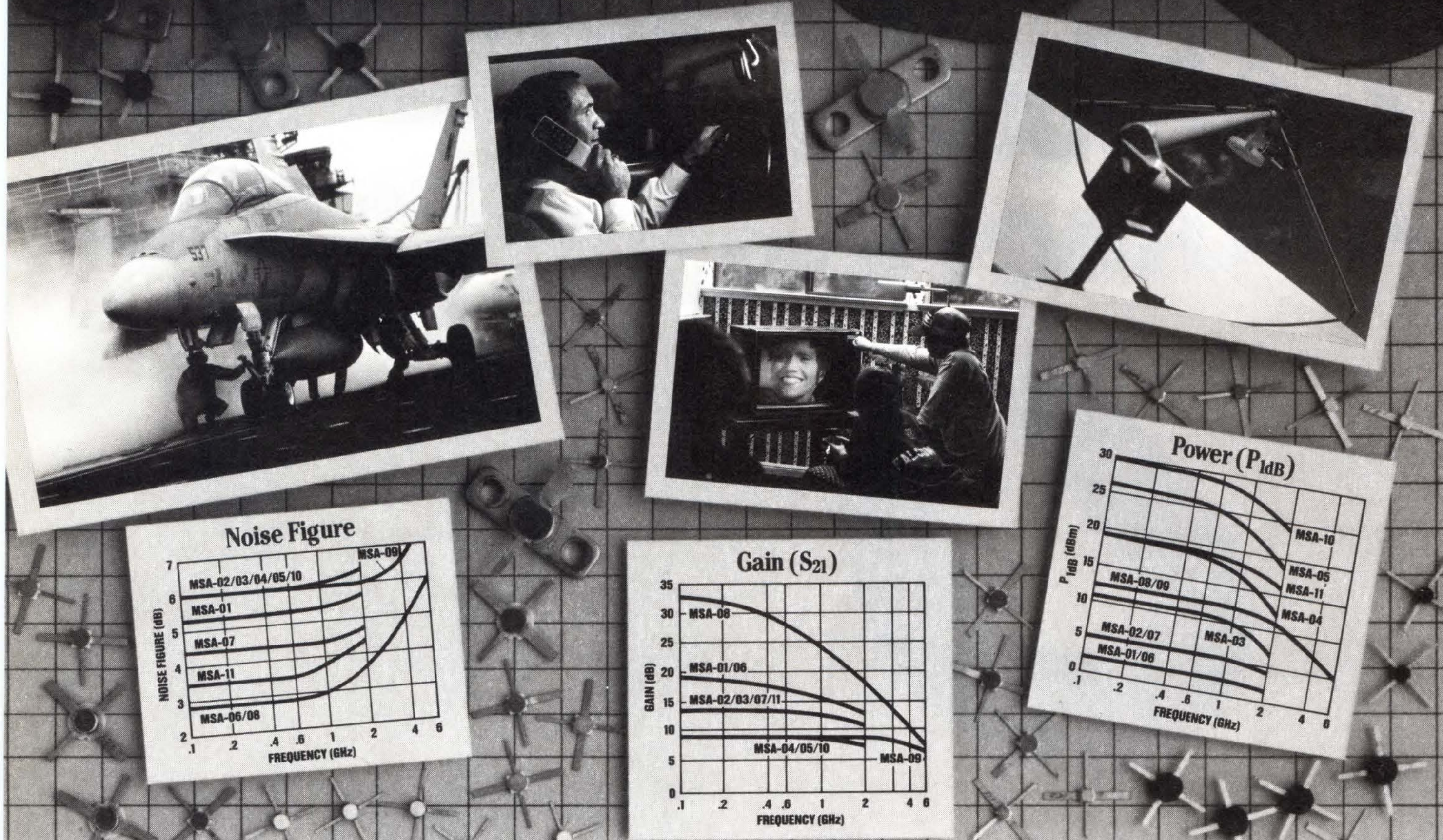

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- SOT-143 Plastic
- 4-Pac Plastic
- 85-Mil Plastic
- 85-Mil Plastic Surface Mount
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- 230 Mil Flange

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AVANTEK

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Santa Clara, California 95054-3292

CIRCLE NO 236

A "civilized" look at the engineering profession

The Civilized Engineer, *by Samuel Florman. 258 pgs; $15.95. St Martin's Press, 175 Fifth Ave, New York, NY 10010.*

Richard Simonelli,
Engineering Consultant

Are you a civilized engineer? Do you know something about the history of our profession? Do you know what motivates us as professionals? Have you thought about the profession's strengths and weaknesses?

Samuel Florman raises these prickly questions and many more in his controversial book, *The Civilized Engineer.* If you missed the book when it was first published in 1987, then read it now. Florman, a practicing civil engineer, provocatively discusses engineering's place in modern society and our values. He covers the ethics, the responsibilities, and the risk-taking issues posed by the Challenger disaster.

The author's arguments are direct—neither pedantic nor abstract. His tone expresses a deep pride in the profession, but at the same time, acknowledges that something is amiss.

Metaphorically, Florman argues, engineers are "uncivilized." To Florman, civilization refers to a broadening of horizons and a deepening of cultural awareness. Are we too narrowly educated and focused on our work to be effective as well-rounded citizens in the complex future?

The author traces the roots of engineering back to toolmaking. He follows the trail through ancient Greece and Rome, on to the Middle Ages and the Renaissance. Finally, he places modern engineering's origins in the tradition of Western craftsmanship.

During the industrial revolution of the 17th and 18th centuries, the British took a hands-on approach to engineering, while the French and continental approach emphasized polytechnic education and cooperation among government, industry, and academia. However, both approaches are alive today in North American engineering.

Florman points out that the term "ethics", as it applies to engineering, means something quite different from its meaning in other contexts. He writes: "A conscientious engineer, by definition, can not falsify test reports or intentionally overlook questionable data, cannot in any way evade the facts." As engineers, our ethics and viewpoints result from the black-and-white nature of our products: Things must work.

Florman always renders criticism with respect. His purpose is not to shock or denigrate the engineering profession, but to ask the unaskable. But some of his conclusions are grim:

- As engineers, our interests are narrow, and our specialties are all-consuming; we can't afford to be curious about areas outside our work.
- We are often insensitive and indifferent to human relations, finding them to be too much of a gray area.
- Compared with other professions, we are poorly educated in the humanities, and we are contemptuous of such learning.

As a result of these shortcomings, Florman contends, we fail to comprehend the cultural and social implications of our work, preferring to look the other way. As psychological types, he adds, we are often wooden, rigid in areas outside of technology. Florman maintains that we're easily manipulated as a group, and that we contribute less than our share to community and national leadership. It is courageous and timely of Florman to air this subject.

Florman encourages us to improve the humanities education available to those engineering students desiring it. Current accreditation standards require engineering students to take 12.5% of their courses in liberal-arts areas, yet, Florman says, most students show disdain for such studies. "Most of the young engineering students I meet these days want to take technical courses that will maximize their chances in the job market," he laments. "They don't want to spend a day or a dollar more than necessary in pursuing their degrees, and they are not at all convinced that the humanities are relevant to their concerns."

Florman believes that a better grounding in the humanities and social sciences would prepare more students for an engineering career involving leadership and communication skills. The idea of encouraging some students, and not others, to prepare for a leadership role naturally leads to cries of elitism. However, he argues that each person should have the opportunity to rise to the full extent of his or her abilities.

An engineer will come away from this book with both a sense of pride and a challenge not to rest on his or her laurels. It places the profession in perspective and makes concrete proposals for changes that will benefit the individual engineer, the profession, and our society. **EDN**

Richard Simonelli is an engineering consultant in Boulder, CO.

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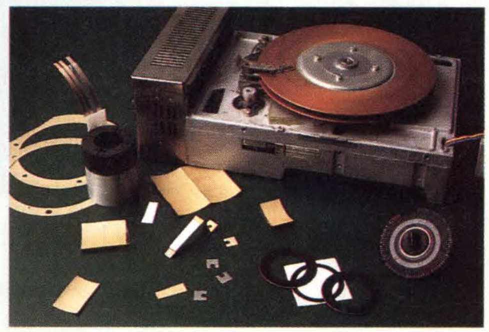

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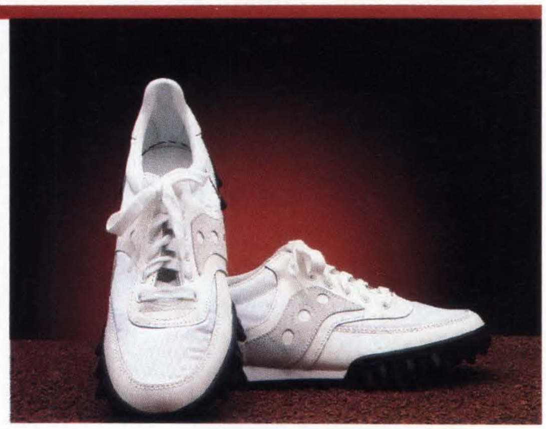

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CIRCLE NO 239

Design firms: A little bit of engineering heaven

Deborah Asbrand, *Associate Editor*

Independent design firms differ from traditional manufacturing companies in many ways. For one thing, they don't require engineers to perform product-support tasks or to prepare voluminous amounts of paperwork. They're strictly no-frills environments—no thickly carpeted, color-coordinated offices. Instead, the emphasis is on engineering. When clients are footing the bill, designs that are "good enough" aren't good enough. A client-driven, deadline-oriented environment isn't for everyone, but for engineers who enjoy that atmosphere, it can be a little bit of engineering heaven.

Engineer Bernard Daines founded Tidewater Associates, a Union City, CA, design house, in 1984. After having worked for two years as an independent consultant, Daines was anxious to take on meatier assignments. "I had a hunger to do bigger projects than I could on my own," he says. In 1981, he invited his younger brother, Nolan, to join his consulting practice, and three years later, they incorporated to form Tidewater.

The concept of a "full-service development firm," as Bernard Daines likes to call it, is new. Independent consultants and job shoppers are fixtures in the electronics industry. But the idea of a service company that maintains its own facilities and equipment and uses them to develop products for other companies is a new twist. Many people, Daines admits, aren't sure quite what to make of this recent addition to the electronics sector. To help remedy the situation, Daines recently hired a public-relations firm to promote not only Tidewater's services but also simply the idea of a full-service development firm.

Consulting companies such as Tidewater are sometimes referred to as "hired guns." Daines doesn't appreciate the

"All we have to offer is hard work and interesting projects."

Tim Davis

Bernard Daines, Founder, Tidewater Associates

"Clients' engineers need to support and manufacture a product. They want to maintain a close link with the designers."

comparison. The company emphasizes that its working style is cooperative. "Clients' engineers need to support and manufacture a product," sales and marketing director Mike Gifford asserts. "They want to maintain a close link with the designers."

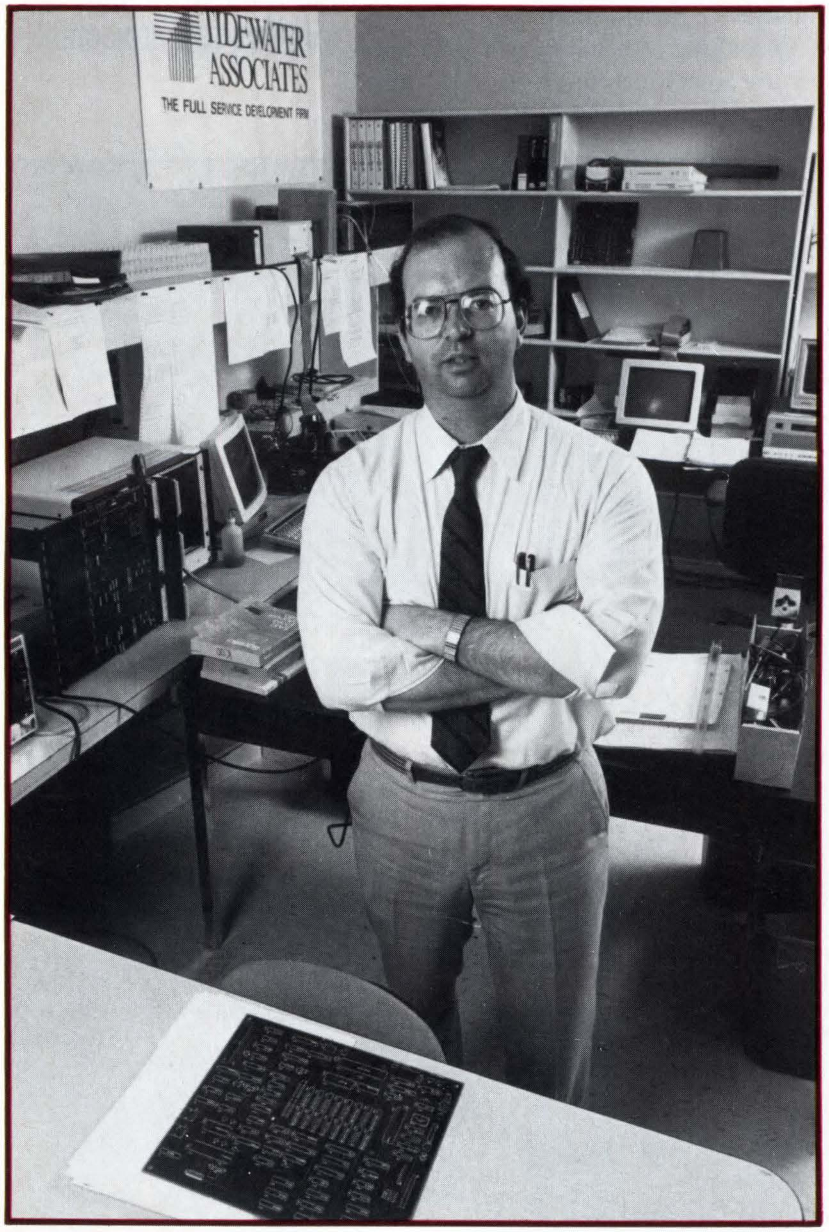
Tidewater's perseverance as a full-service development firm has paid off—its business is booming. In the company's early days, a $150,000 contract was a large one. Now, says general manager Larry Heaton, that's about the smallest contract the company will accept. This year, the company expects to pull in $8 million in revenue.

Tidewater's Union City location typifies its no-nonsense attitude. Union City is short on local color; it got its inauspicious start 20 years ago when area townships filled in the marshy, southernmost tip of San Francisco Bay. Today, it's a city made up largely of industrial parks. Work is the order of the day.

The firm currently occupies 15,000 square feet of space, which it has leased since 1981, when the Daines brothers moved their operation out of their garage. The space, once mostly vacant, is now nearly filled, as a result of the company's growth. The company's quarters feature few of the usual corporate props. Instead of finding the typical roomy lobby with floor plants, couches, and an oversized version of the company logo behind a receptionist's desk, visitors to Tidewater squeeze into a small, plain waiting area. In contrast, generous amounts of space have been set aside for design, assembly, and manufacturing. Four cavernous bays, allow ample room for work on clients' products.

Notably absent from the structure are the ubiquitous modular cubicles that pass for office space in most companies. Tidewater maintains genuine offices for its engineers and technicians alike. Individual work spaces are walled off, and incandescent lighting softens the interior atmosphere. Also noticeably missing, however, are doors to each office. Bernard Daines chose to keep the offices doorless as "a compromise between openness and privacy."

Clients retain Tidewater, and other design houses like it, for a number of reasons. Some engineering departments, for example, have come up with new ideas, but are too busy with existing projects to undertake the new ones. In other companies, the development of a



Tim Davis

Mike Gifford, Sales and Marketing Director

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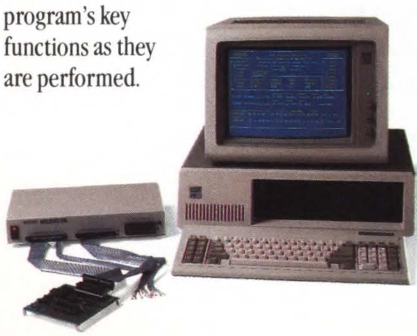

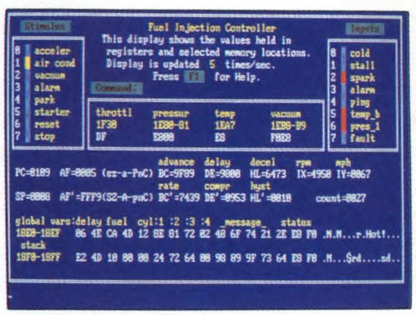

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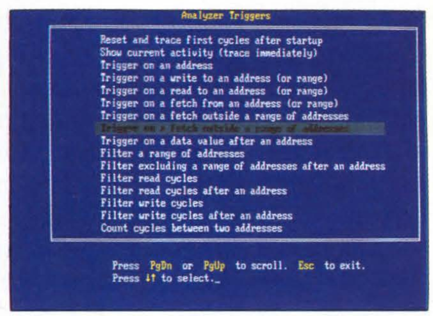

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CIRCLE NO 240

new product requires engineering expertise in an esoteric area, and rather than recruit and hire an engineer with the necessary knowledge, the company turns to a service company. Start-up companies that as yet lack their own engineering departments are also customers.

For some companies, the decision to approach a design firm for assistance can be gut-wrenching, particularly for firms that have gone to great expense to hire talented engineers only to load them with so much work that they're unable to proceed with the development of a new-product idea. "We may talk to a vice president of engineering who feels guilty about coming because he's got a staff full of engineers," says Gifford. "He also may be wrestling with the not-invented-here syndrome."

For the engineers who work at Tidewater, the client-driven atmosphere can be a pressure cooker. At any given time, Tidewater's engineers are working on 20-odd projects of varying sizes. The company bills its clients for its engineering services, and each engineer must keep meticulous track of the time spent on various projects. With clients footing the bill, deadlines take on new meaning. Says general manager Heaton: "At most companies, you have a deadline you don't make and you go in and ask for another six weeks. Here you can't do that."

Like employees of any service-oriented business, Tidewater's engineering staff must acquire a certain amount of finesse in working with their clients. "We once ran into a 3-week delay while a client decided on the color of a keyboard," sighs Heaton.

With each engineer juggling several projects at once and facing constant deadline pressures, there's little time for conversations at the water cooler. Tidewater's growing business keeps the engineers' between-project time to a minimum. Paul O'Connor, who joined Tidewater in 1987, says that his previous jobs with defense contractors always included a cooling-off period between contracts. It's not so at Tidewater, he says; there's always a new project to be tackled.

That kind of intensity isn't for everyone. Tidewater has lost several talented engineers who simply felt that the required level of involvement was too much for them. Mukesh Patel had similar thoughts when he joined the company in 1985. Battle weary from years of negotiating Silicon Valley's congested freeways, Patel's criterion for a new job had been reduced to one simple requirement: He wanted a commute of no longer than 15 minutes. Tidewater, located just a short distance from his home, fit the bill. Though he loved the short commute, he had originally planned to stay just one year. "I thought this place would be a sweatshop," he concedes. Since joining the company, he's worked on a project in video imaging, one in voice synthesis, and Project Victoria, an ISDN project. Now, he enthuses, there are few engineers in Silicon Valley who can match his resume. Agrees Nolan Daines: "We get to do the stuff that really raises the hair on the back of your neck."

The charged atmosphere results from Bernard Daines' business savvy rather than any desire to create an engineering utopia. "It wasn't structured to be a mecca for engineers, because all we have to offer is hard work and interesting projects," explains Daines, who is himself a veteran of Hewlett-Packard and IBM. "The thing that makes working here interesting is that the engineers don't have to live with a project for three years. I'm not knocking that, but I think there are a lot of really creative people who are banging out logic designs and feeling very frustrated."

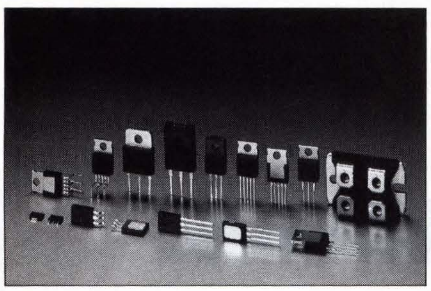
Indeed, a single recruitment ad for Tidewater typically produces 50 resumes. Tidewater is selective, and not everyone makes the grade. Heaton estimates that 20 to 25 of the inquiries are from qualified applicants, and of those,

A client-driven, deadline-oriented environment isn't for everyone, but for engineers who enjoy that atmosphere, it can be a bit of engineering heaven.

High Performance N-Channel PowerMOS Transistors

A new family of nearly 200 n-channel PowerMOS transistors from Philips Components offers the highest performance available, yet costs no more than existing devices. The BUK family of transistors spans low, medium and high voltages (up to 1000 V), and includes devices for use in such applications as automobiles and inverters.

The low-voltage transistors have cell densities of 1.6 million cells per square inch, which results in drain-source on-resistances as low as 25 mΩ. This feature is a key measure for PowerMOS devices, and corresponds to drain currents up to 56 A. Philips' new BUK family includes 14 low-voltage logic-level devices for 12 V battery operation in automotive and industrial applications, and 13 high-voltage FREDFETs for bridge or half-bridge applications in motor control, uninterruptible power supplies and inverters.



There are 74 low-voltage transistors with crystal sizes between 6 mm^2 and 20 mm^2, and with maximum drain-source voltages between 50 V and 200 V. Even the lowest voltage transistors in the family, such as the 50 V BUK453-50A, can carry up to 22 A drain currents because of $R_{DS(ON)}$ values as low as 80 mΩ.

There are 72 medium-voltage devices with drain-source voltages between 400 V and 600 V. These devices include 400 V transistors with $R_{DS(ON)}$ values of 400 mΩ and maximum drain-source currents of 14 A, and 600 V devices with $R_{DS(ON)}$ values of 800 mΩ, passing currents of 10 A.

Thirty-eight high-voltage transistors withstand between 800 V and 1000 V. These include 800 V devices with $R_{DS(ON)}$ values down to 1.5Ω and corresponding drain-source currents above 8 A, and 1000 V transistors with $R_{DS(ON)}$ values of 2Ω, passing currents of nearly 7 A.

Switching times are in the low tens of nanoseconds, allowing the transistors to operate at frequencies up to 10 MHz in resonant power supplies, for example. The devices are available in a choice of five packages, from the SOT-186 – a fully isolated version of the TO-220, which dissipates up to 30 W – to the SOT-93 (TO-218), which dissipates up to 250 W. Devices in other packages are in development.

CIRCLE NO 259

Range of SensorFETs Provides "Loss-less" Load Protection

By dedicating a few of its cells to current sensing, this range of SensorFETs from Philips Components provides "loss-less" overcurrent, or short-circuit, protection for a wide variety of automotive and industrial applications.
Unlike most power MOSFETs, which detect load currents using a high-power resistor, these new SensorFETs use some of their current-carrying cells to direct a proportion of their current – a few milliamps – to an external control-regulation circuit.

The four SensorFETs that make up the BUK700 series can be used whenever current limiting is needed to protect equipment – such as motor drives – from damage. The BUK793 and BUK795 have maximum drain-source voltages of 50 V or 100 V.

These SensorFETs have densities of 1.6 million cells per square inch, the highest in the industry for these types of devices. This density cuts the drain-source on-resistance to between only 40 mΩ and 800 mΩ, depending on the device, and leads to current-handling capacities of up to 40 A for the 50 V devices and up to 25 A for the 100 V devices.

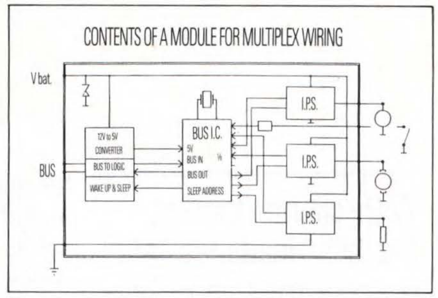
The SensorFETs come in TO-220 Pentawatt packages. Samples are available.

CIRCLE NO 260

11 A High-side Switch for Automotive Applications

A new MOS Intelligent Power Switch has a drain-source, on-resistance $R_{DS(ON)}$ of only 33Ω, four to eight times lower than that of other such devices. Called the BUK196-50, the new device from Philips Components passes a drain-source current of only 11 A and its $R_{DS(ON)}$ matches the low contact resistance of mechanical relays, making it a suitable replacement for such relays in a variety of automotive and industrial applications.

The BUK196-50 is an n-channel transistor that fits on the battery-side (high-side) of the load. It incorporates short-circuit and thermal protection, and features current-sensing circuits. An integral charge pump boosts the car-battery voltage to ensure that the MOSFET saturates fully, even when the battery voltage falls to 6 V. A status indicator signals that the device is functioning, thus closing the feedback loop between the drive and switch.



The device connects directly to the industry standard decoders for the multiplexed bus systems that will appear in the next generation of automobiles.

The low on-resistance comes from the high cell density – 1.2 million cells per square inch – of the BUK196-50. The high cell density also leads to the device's 11 A rated current, which is maintained even with a case temperature of 85 °C and battery voltage as low as 6 V. The low on-resistance also leads to low losses – the device has a low quiescent current of less than 10 μA.
The transistor also has a maximum drain-source voltage rating of 50 V. Its projected MTBF is as good as the standard Philips MOSFET.

The BUK196-50 comes in a TO-220 Pentawatt package. Samples will be available in November.

CIRCLE NO 261

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PHILIPS

CIRCLE NO 263

With clients footing the bill, deadlines take on new meaning. Says general manager Heaton: "At most companies, you have a deadline you don't make and you go in and ask for another six weeks. Here you can't do that."

no more than six make the second cut and are interviewed. "We get people who come in and say they've been doing 68000 work for 15 years," says Heaton. "But their involvement has been taking a small segment and passing it on. Those people don't have the global understanding of the product that we need here."

John McGinnis is an industry veteran and specialist in image recognition. He's now director of engineering for Tidewater. He characterizes the company's environment as "very, very different" from the other companies he's worked for. In the engineers he hires he looks for "a willingness to take chances—not someone who wants to analyze something forever."

Despite the breadth of his managerial responsibilities, Bernard Daines manages to remain an active team member on about four projects at a time. He enjoys the thrill of the new-product chase, he says, and he looks for that same enthusiasm in the engineers he hires. "I'm excited about every new project that we start. If the same enthusiasm to build things and make things work isn't there, then the person isn't suited to this thing." **EDN**

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Sept. 29	Sept. 8	DSP, Graphics, Optoelectronics	
Oct. 13	Sept622	Test & Measurement Special Issue, Instruments, Computers & Peripherals	Closing: Sept. 29 Mailing: Oct. 20
Oct. 27	Oct. 6	CAE, Computers & Peripherals, Integrated Circuits, Wescon '88 Show Preview	
Nov. 10	Oct. 20	Programmable Logic Devices, Integrated Circuits, Test & Measurements, Wescon '88 Show Issue	Closing: Oct. 27 Mailing: Nov. 17
Nov. 24	Nov. 3	Microprocessor Technology Directory Graphics, CAE	
Dec. 8	Nov. 16	Product Showcase—Vol. I, Power Sources, Software	Closing: Nov. 21 Mailing: Dec. 15
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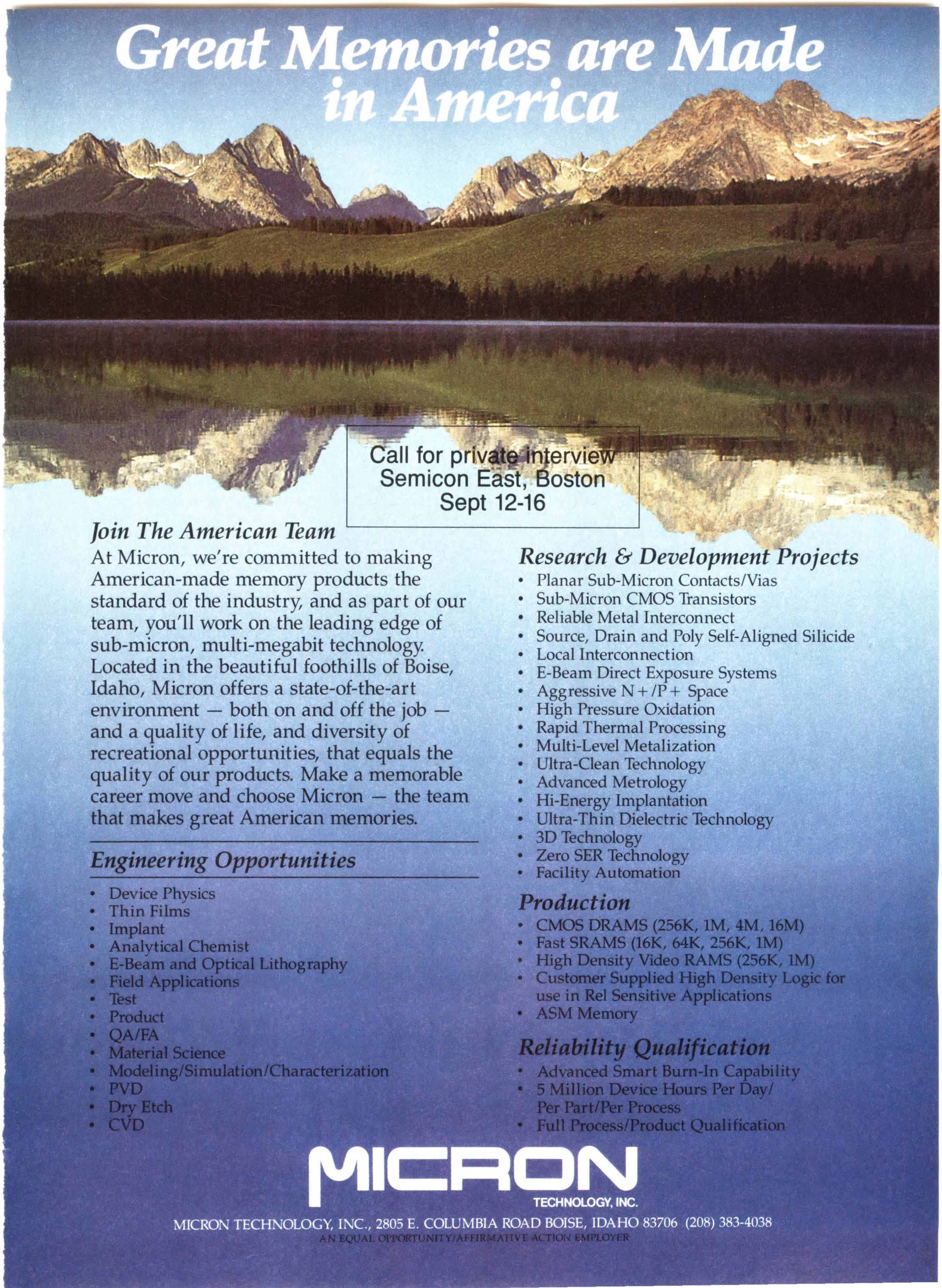
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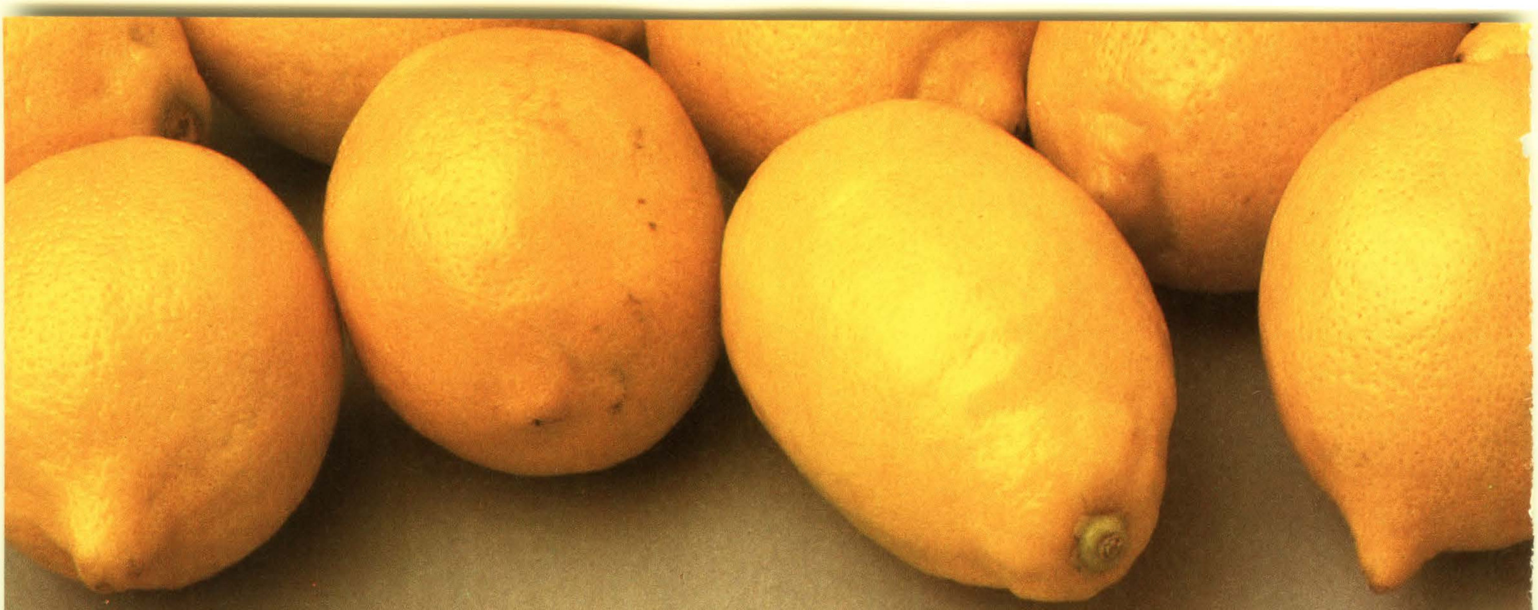

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test instrumentation, and noise and vibration control is required. This senior position requires seven years experience in testing and digital signal analysis, and a PhD in ME is preferred. U.S. Citizenship is required.

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Qualified candidates for this position must have a BS in Computer Science in addition to three to five years experience in Systems Management. Knowledge of VMS is helpful — three to five years experience in C and FORTRAN is a must.

RAMIS Programmer
Seeking qualified candidates with two to five years experience developing systems with RAMIS. Experience also required in IBM MVS, JCL, CLIST, and SQL. Candidates must have experience in development of internal and external file structures as well as menu based systems.

CV/ CADD System Administrator
This position is responsible for the operations and support of Computervision CADD4X Systems. BS in Computer Science with at least 3 years experience with CV/CADD System Management, knowledge of CADD4X/CGOS environment is required. SUN/UNIX systems knowledge is desired.

MANUFACTURING

(When writing in response to the career opportunities listed in this category, please use address listed below, attention: MANUFACTURING)

Industrial Engineer
B.S. degree in Industrial Engineering or Industrial Technology. Substantial knowledge of manufacturing processing in at least one of the following areas: forming and bending, machining, welding, heat treat, chemical processing and painting. Analyze and interpret engineering drawings and specifications for production application. Estimate all standards for bids and production floor operations. 2 to 3 years experience required.

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B.S. degree in Engineering, Industrial Technology, or Quality Assurance. Five years minimum experience in a Quality Engineering function with a strong working knowledge of MIL-Q-9858 and MIL-STD-1520. Involves extensive investigation of failure analysis and problem resolution. Must possess good verbal and written communication skills in interactions with customer representatives.

FMC offers an excellent salary and a comprehensive benefits package. For prompt consideration please send resume, including your salary history and requirements addressed to either Engineering, Technical Computing or Manufacturing at: FMC Corporation Ground Systems Division, 328 W. Brokaw Road, P.O. Box 58123, Dept. 17-88-05, Santa Clara, CA 95052. We are an Equal Opportunity Employer.

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- **Autonomous Underwater Vehicles**
- **Advanced Lightweight Sonar**
- **Remotely Piloted Air Vehicles**
- **ASW Research & Technology**
- **Surface Weapons Systems**
- **Combat Systems Engineering**
- **Robotics**

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- Cutter Specialist

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- Interface Integration

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- Mission Analysis
- Sensor Performance

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- State Table Design
- Test and Evaluation
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- Manipulator Design

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Please send your resume to: Martin Marietta Aero & Naval Systems, Employment Dept. SourceX293, 103 Chesapeake Park Plaza, Baltimore, MD 21220. An equal opportunity employer m/f/h/v.

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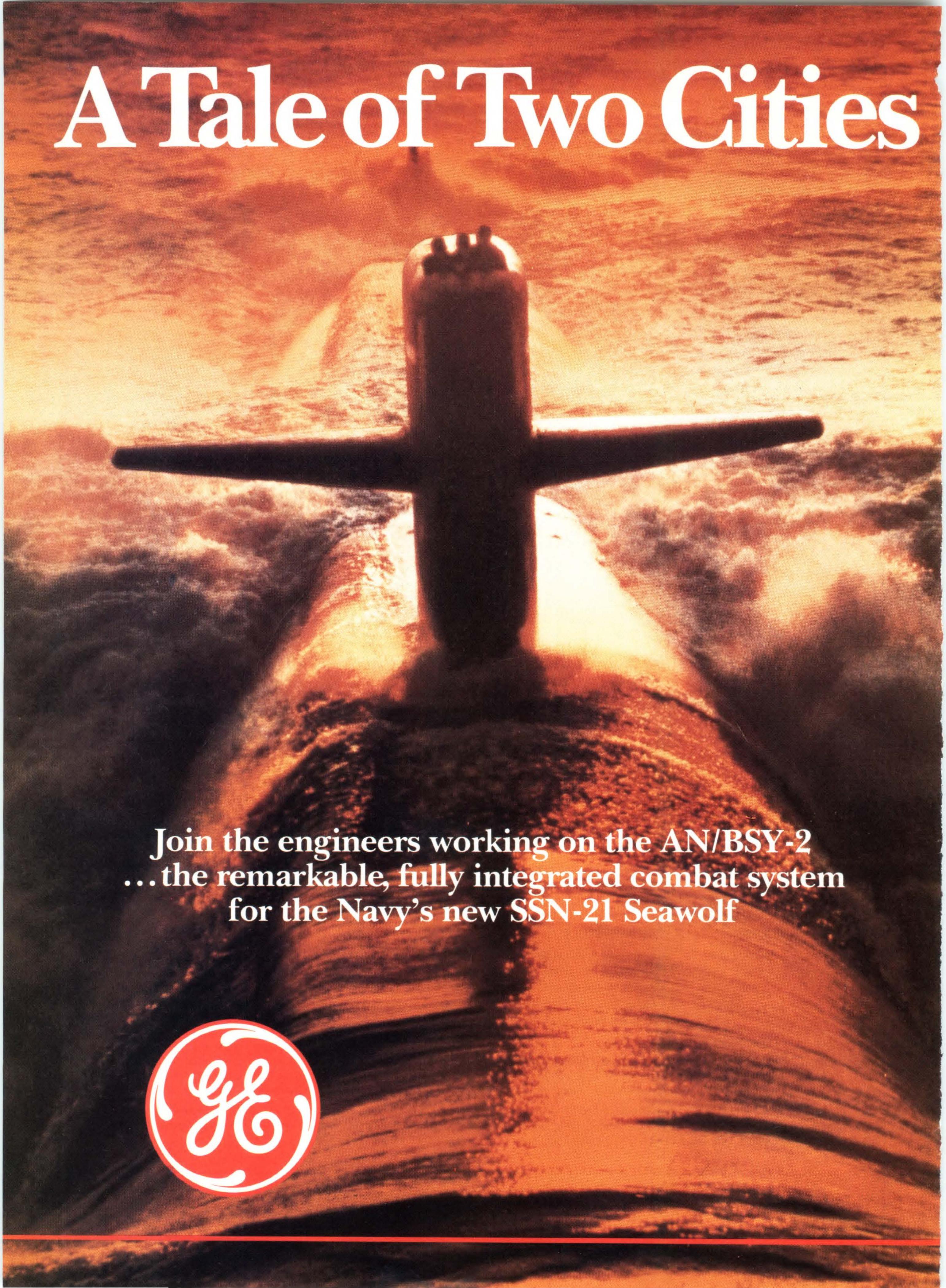
A Tale of Two Cities
Join the engineers working on the AN/BSY-2
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for the Navy's new SSN-21 Seawolf

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At GE Government Electronic Systems Division in Syracuse, we're taking undersea technology to new heights. And you can be part of it.

Exciting positions are now available to work on the SSN-21 Seawolf submarine project...developing systems architecture and providing overall program management for the AN/BSY-2. This marvel of sensor, processing and command hardware and software is our greatest achievement yet, confirming our position as a world leader in sonar and ASW.

Surface ship acoustic technology is another area of GE leadership in which we have a whole range of challenging opportunities.

To be part of this tremendous effort, see if you qualify for one of the following positions.

Software Architecture

Requires 7+ years experience in large systems design involving embedded programmable processors (68000 or similar processor). Familiar with top down structured design in ADA or Fortran.

Combat Systems Engineering

Requires 5+ years in analysis, design and development of large scale shipboard ASW systems. Must be knowledgeable in weapons control systems engineering, reliability/maintainability and human factors.

Acoustics/Signal Processing

Systems engineers with 5+ years design experience involving towed and remote sonar arrays. Sensor systems design and algorithm development are key requirements, also target motion analysis.

Sonar Array Hardware

Project engineers with 8+ years experience in advanced architecture and design of sonar hardware. Will lead a development team in all related functions: wide aperture array design, transmitter design, electronics packaging, cabinet design, simulation and modeling, etc.

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Must have 10+ years in-depth experience in ASW systems development. Broad ranging software/hardware knowledge. Experience in large program prime contractor environment. Subcontractor management experience.

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- BSEE
- 5+ years in Combat Control performance definition, design and test for real time Combat Control Systems.
- Knowledge of U.S. Navy systems, preferably submarine systems.

Senior Digital Design Engineers

BSEE, with 5+ years experience in the digital/firmware design of digital sub-systems. Should also have experience in the design of special purpose digital processors with strength in current custom design and simulation techniques.

Senior Software Design Engineers

BSEE or BSCS with 5+ years direct experience in the design and development of large real time Command and Control Systems which utilize sensor data input. Experience with the following:

- Fault location/fault detection with a plus for automatic configuration design experience.
- Real-time data base design experience with Ingress or Oracle.
- Motorola 68020 assembly language, and/or real time operating system experience.

Senior Engineers, Command & Decision

BSEE with 5+ years in Command and Control performance definition, design and test for real time Command and Control Systems. Should have knowledge of U.S. Navy systems, preferably submarine systems.

At RCA your engineering foresight and technological expertise are rewarded with an outstanding salary and benefits package including dental, tuition, and two on-site master's degree programs. Our location in Moorestown, NJ is a pleasant suburban environment just 15 miles outside of Philadelphia with close proximity to leisure activities of the shore and mountains. For confidential consideration, forward your resume to: **Mr. Herman C. Ford, RCA ESD, Bldg. 127-102, Moorestown, NJ 08057. U.S. Citizenship Required.**

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Develop systems and subsystems, test requirements, and design validation. Requires specialization in anti-armor launching, fire support or target acquisition and the ability to communicate requirements to design engineering. BSEE and 5 years in optics, electro-stabilization, electronic design, or real-time software are desirable.

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Perform environmental and functional test planing, preparation, and conduct tests; design test fixtures, setups, and write test plans; and have lead responsibility for test programs. Position requires 5 years related experience with MILSPECS and formal documentation in analog, digital and RF systems.

SENIOR STAFF ENGINEER (POWER)
Generate, implement and monitor EMI, NEMP, ESD plans for electronic programs. Provide source data for filter procurement specs. MSEE or Applied Physics and 10 years specialized experience with MILSTD-461 and 462 EMI Control required. NEMP and nuclear effects experience desired.

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Requires BSEE and 5 years experience either designing control units, or working with real-time computerized signal processor and image processing with radar interfacing. Design experience with VHSIC and/or ASIC desirable.

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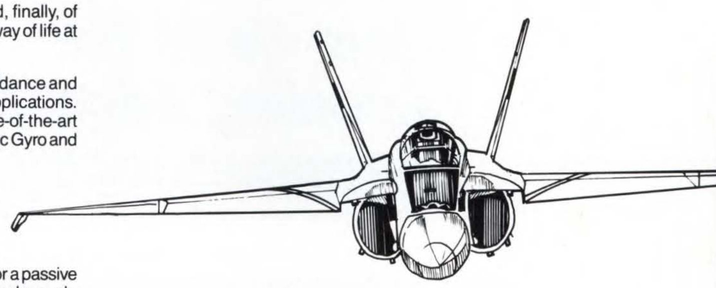
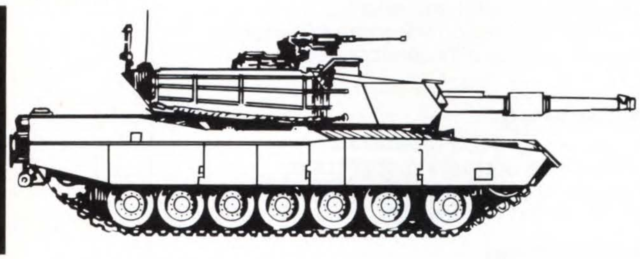
We are one of the world's premier manufacturers of aircraft instruments, guidance and navigation systems and flight data recorders for commercial and military applications. Building on a 40+ year history of leadership, we are today involved in state-of-the-art attitude heading reference systems technology (AHRS), including a Fiber Optic Gyro and Strapdown Inertial Navigation Systems.

Join us at our Grand Rapids Operation in one of the following challenges:



Guided Wave Optics Engineer

Senior position responsible for augmenting optical rate sensor development for a passive Fiber Optic Gyro. Requires solid hands-on development experience in single-mode guided wave optics. Proven leadership, communication, organizational and analytical abilities are a must. MSEE or MS Physics with applied electro-optic orientation required; PhD preferred.



Reliability Group Manager

You will manage reliability design engineering and product support activities, as well as failure analysis lab functions. Requires a minimum of 7 years related experience, including some at the supervisory level. BSEE or BS Physics expected.

Senior Reliability Engineer

Project coordination responsibilities in engineering and product support. Requires a minimum of 5 years related experience, and strong leadership and communication skills. You must be familiar with FMEAS, MIL-Specs, and reliability modeling, predictions and testing. BSEE or BS Physics necessary.

Mechanical Engineer

Your challenges will demand at least 6 years experience in the design, development and testing of dynamically tuned gyros, with an orientation toward project responsibility. BSME required.

Staff Engineer

Sales support engineering will be among your challenges. Requires systems project technical experience in the design, development and testing of Strapdown Inertial Navigation Systems. Strong math and analytical skills are a must. BSEE necessary.

Materials Engineering Section Manager

Requires 7+ years experience, to include some at the supervisory level. Materials engineering experience in an aerospace instrument or electronic systems environment is preferred, with knowledge of printed wiring board fabrication and assembly, metal finishing, heat treatment and general metallurgy. BS in Metallurgy, Chemistry or Materials Science expected.

Senior Data Systems Engineer

Qualifications include a minimum of 5 years experience in military avionics system design, with strong hardware and software experience. You must be familiar with MIL-490 and MIL-2167 system requirements documentation; background in structural analysis is preferred, as is the ability to formulate interface control documents, white papers, proposals, etc. BSEE or equivalent.

Senior Software Engineer

Requires 5+ years experience in real-time, embedded, computer-based system development, involving system requirements specification, architecture design, function design and programming. Knowledge of formal development methods and the DEC VAX/VMS environment is essential. Familiarity with CASE tools is preferred, as is teaching/ training experience. Advanced degree in Computer Science or Electrical Engineering desired.

DTS Engineer

You must possess at least 5 years experience with data transfer systems, and a strong digital hardware background involving microprocessors. You must be able to write software requirement specifications, and to analyze system software/ hardware trade-offs. Presentation and communication skills are essential. BSEE or equivalent.

Process Engineer

You will be instrumental in improving yields and capabilities in circuit board assembly. Requires an Engineer with process experience (wave solder, touch-up, coating, etc.)

Electromechanical Manufacturing Engineer

Your responsibilities in our dynamically tuned gyro area will demand strong electromechanical skills.

Producibility Engineer

Our producibility improvement/cost reduction team will make full use of your expertise.

Logistics Engineer

Requires a minimum of 3 years logistics planning experience for avionics equipment, with knowledge of the LSA process, MIL-STD-1388 LSAR database, and military logistics/acquisition or USAF concepts. BSEE or equivalent.

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Manager of Technical & Professional Staffing
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Grand Rapids Operation
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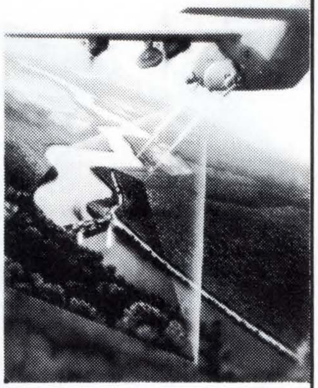

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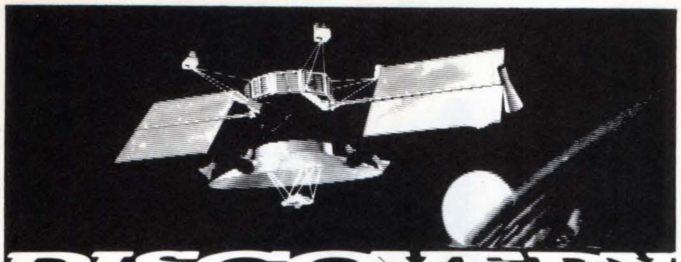

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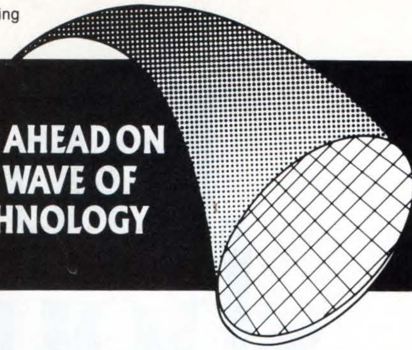

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☐ WILL RELOCATE ☐ WILL NOT RELOCATE ☐ OTHER ______

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Circulation
Denver, CO: (303) 388-4511
Sherri Gronli, Group Manager
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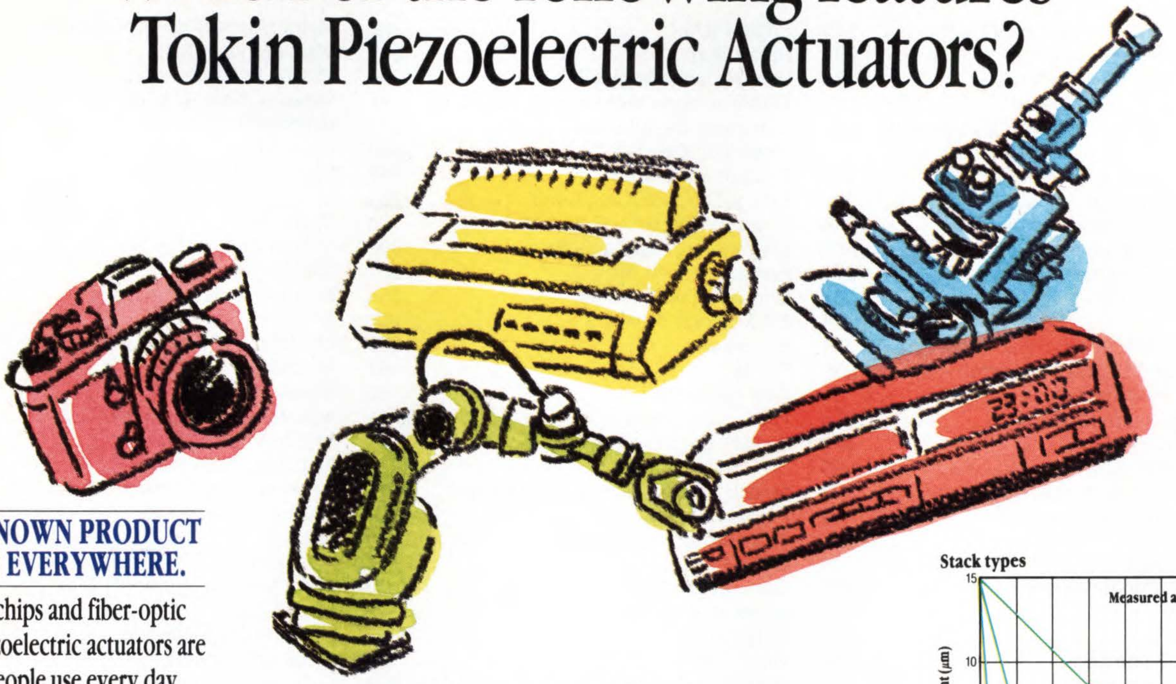
Reprints of EDN articles are available on a custom printing basis at reasonable prices in quantities of 500 or more. For an exact quote, contact Joanne R Westphal, Cahners Reprint Service, Cahners Plaza, 1350 E Touhy Ave, Box 5080, Des Plaines, IL 60018. Phone (312) 635-8800.

50th Anniversary

Which of the following features Tokin Piezoelectric Actuators?



They all do.

AN UNKNOWN PRODUCT THAT'S EVERYWHERE.

Like microchips and fiber-optic cables, piezoelectric actuators are products people use every day without even knowing it. They make camera shutter releases more accurate, and electronic microscopes more precise. They enable greater accuracy in robot positioning, VCR head tracking and printing head driving. In applications from fine-displacement elements for sub-micron positioning to fast-response, compact solid element motors, the piezoelectric actuator is an intrinsic part of daily life.

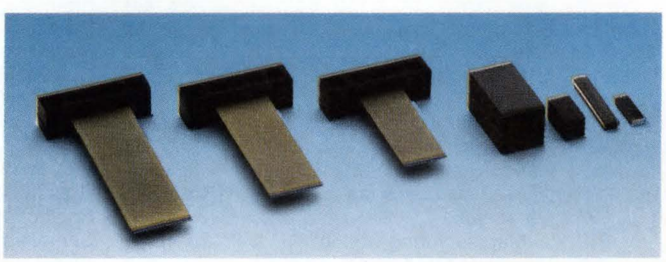
HOW TOKIN MAKES IT BETTER.

What's special about Tokin piezoelectric actuators is our unique manufacturing method: *solid-sintering* without adhesive material, using the thick-film multilayer technology. Combined with the HIP (hot isostatic press) process, it delivers the utmost in mechanical strength, with negligible variation from repeated compression and expansion.

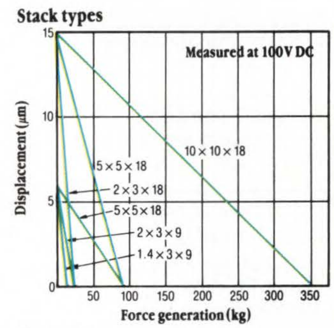
CAN YOU AFFORD TO BE WITHOUT TOKIN PIEZOELECTRIC ACTUATORS?

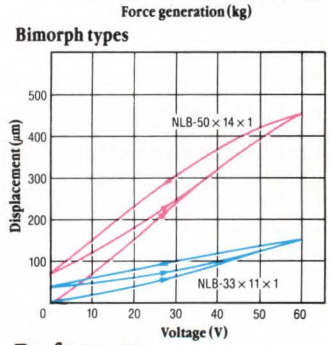
Tokin breakthroughs in piezoelectric actuators enhance the operation of many kinds of products. And the list of potential applications is rapidly expanding.

Couldn't a piezoelectric actuator enhance or improve your product? Call us today and find out more about the product and the company that's making a big difference in a multitude of products.



Now that you know what they do, how many new applications can you think of for Tokin Piezoelectric Actuators?





Performance

	Dielectric displacement	Force generation
Stack types	(μm/100V) ±10%	(kg/100V) ±20%
NLA-1.4×3×9	6.5	14.0
NLA-2×3×9	6.5	21.0
NLA-2×3×18	15.0	21.0
NLA-5×5×9	6.5	87.0
NLA-5×5×18	15.0	87.0
NLA-10×10×18	15.0	350.0
Bimorph types	(μm/60V) ±20%	(g/60V) ±20%
NLB-33×11×1	150	30
NLB-40×12×1	300	30
NLB-50×14×1	450	48

Tokin

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LOOKING AHEAD

EDITED BY CYNTHIA B RETTIG

Manufacturers praise JIT logistics

In response to a survey recently conducted by Touche Ross (Chicago, IL), 90% of a group of manufacturers and distributors said just-in-time (JIT) logistics were strategically important to developing or maintaining a competitive advantage. Once companies have put JIT plans into effect, they can deliver products in a short period of time while investing minimally in inventory needs. Companies have found that producing just what is needed and delivering exactly the right quantity at precisely the right time not only lowers inventory requirements but also improves a manufacturer's or distributor's relationships with both vendors and customers. About 25% of the nearly 200 respondents already had operational JIT programs; another 50% or more are in the planning or start-up stages.

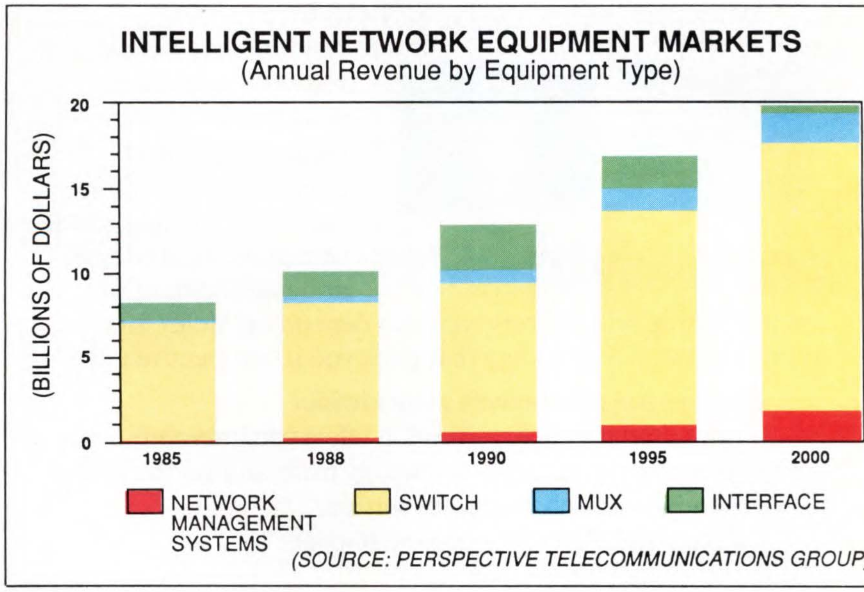
Operational JIT programs reduce the number of primary vendors any individual company deals with by an average of 42%, Touche Ross found. And when companies purchase more goods from fewer vendors, they have a better opportunity to influence those vendors' quality-control programs and to reduce purchase lead times. As companies thus reduce the number of vendors and improve their relations with them, the companies become much more satisfied with the quality of the goods and services received. Sixty percent of those with operational JIT programs stated that they were very satisfied with vendor quality; only 18% of those in the planning stages for JIT said they were as pleased.

Manufacturers with JIT programs also benefited from improved relationships with their customers. Those companies found they could reduce costs while providing better customer service—including more frequent, as well as more timely, deliveries.

Touche Ross found that implementing just-in-time programs is not without its obstacles, however. Some manufacturers, for example, faced internal organizational resistance, lack of systems support, and limitations in manufacturing facilities. Others encountered difficulties defining service levels, inadequate amounts of purchased goods, and generally poor implementation of JIT planning.

$20B market predicted for smart network equipment

Annual sales of equipment for intelligent telecommunications networks should reach $20 billion by the year 2000, according to the Perspective Telecommunications Group, a marketing research and management consulting firm specializing in telecommunications (Franklin Lakes, NJ). Prospective buyers will be looking for different qualities in different types of products. The extent to which intelligent switching gear improves system performance, for instance, will be critical to its success. On the other hand, customers will judge network management systems by ease of use. The market-research firm also points out that not all kinds of intelligent network equipment will flourish. Some products, like protocol converters, will actually decline in sales between the years 1990 and 2000.



Perspective also identifies specific areas where opportunities in public as well as private network development exist, including switch manufacturing, data-communication equipment, LANs, computer manufacturing, and other vendors of equipment, information, and services.