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October 29, 1992

ELECTRONIC TECHNOLOGY FOR ENGINEERS AND ENGINEERING MANAGERS WORLDWIDE

PROCESSOR UPDATES PG 86

Special Report:
Craft basic connections between objects using C++
pg 112

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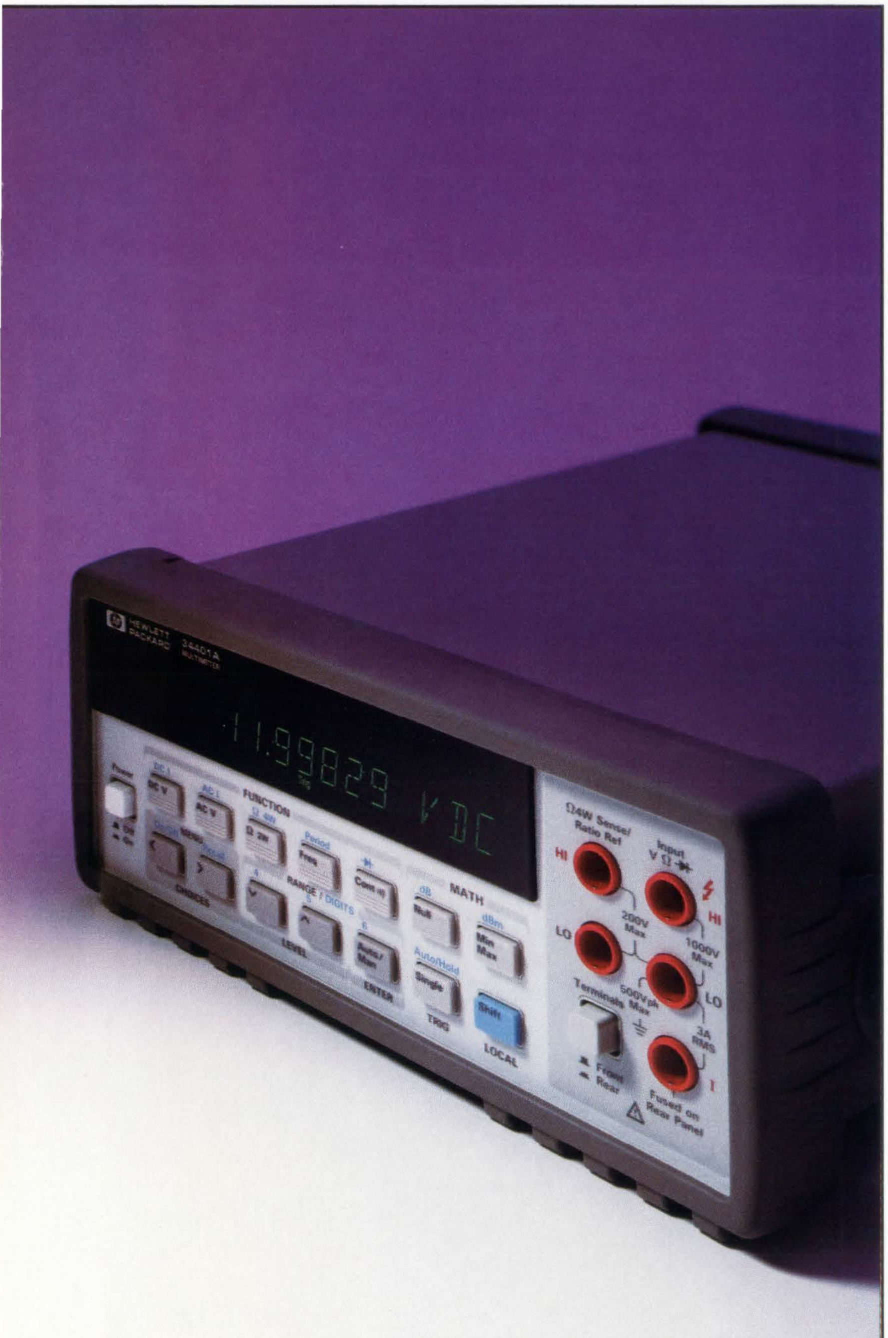

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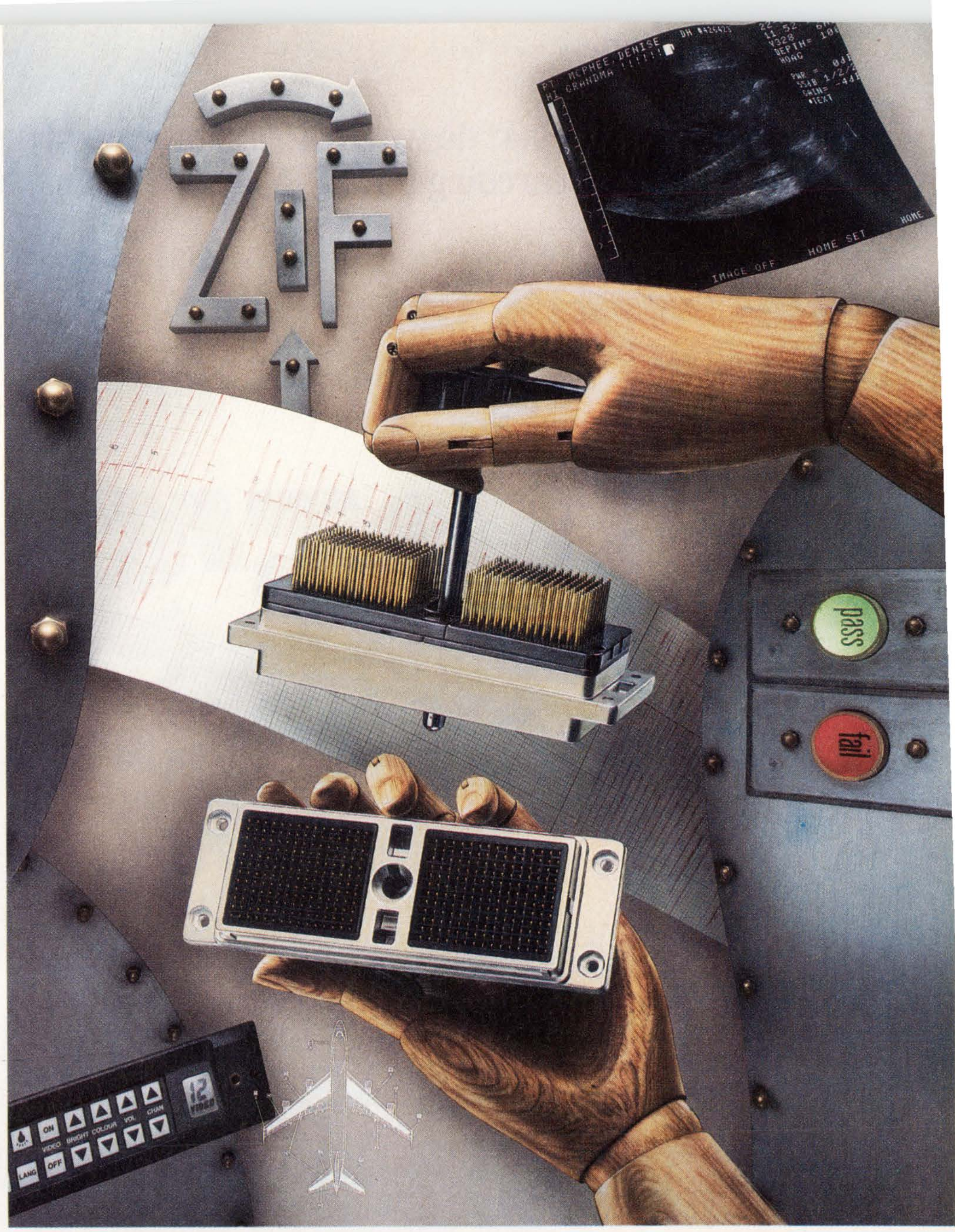

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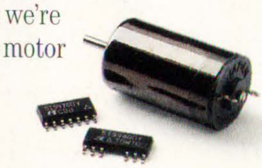

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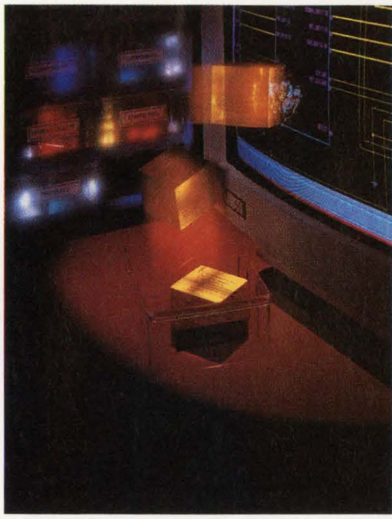
ELECTRONIC TECHNOLOGY FOR ENGINEERS AND ENGINEERING MANAGERS WORLDWIDE



On the cover: As you move from C into the world of C + +, you face many obstacles to a complete understanding. One way to ease the transition is to know how to use C + + to implement inheritance. Photo courtesy Mentor Graphics; our Special Report begins on . . **PAGE 112**

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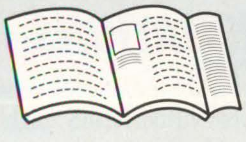
Foldout Contents

Turn to the last information-retrieval service card in the back of this magazine and you'll find a foldout table of contents. Now, instead of flipping back and forth from this table of contents to the articles you want to read, you can have the convenient foldout open at all times while you're reading EDN. Use the foldout contents to mark off articles you'd like your colleagues to read or to remind yourself to copy stories for your files.



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October 29, 1992

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TECHNOLOGY UPDATE

PRODUCT UPDATES

PROCESSOR UPDATES

NEW PRODUCTS

DEPARTMENTS

INSIDE EDN

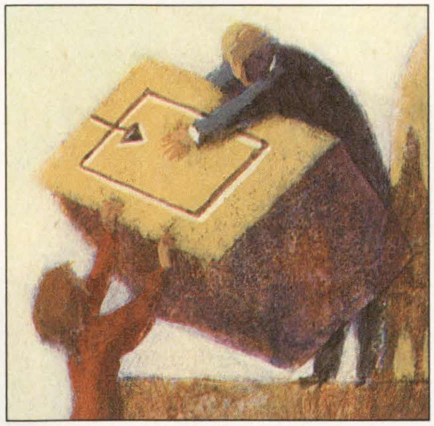
A summary and analysis of articles in this issue

In a software survey EDN conducted two years ago, C++ was nowhere in sight. Our latest survey indicates a tremendous surge in C++, for good reason: Because it's upwardly compatible, C++ lets people who are using C write object-oriented programs without having to throw away their old programs. So in this issue, we present the fourth article we've printed this year on this hot software topic. Put this issue's Special Report together with three other related articles we've run this year (see January 2, July 6, and August 6 editions), and you've got a complete package that thoroughly explains what C++ is and how to use it.

If you're already comfortable with the basics, take a look at John Napier's Special Report on **how to program with objects in C++.** He tells how to use C++ to implement the key OOP concept of inheritance.

"Until I did this article, I didn't understand exactly when and where to use 'dynamic binding' (an OOP term that C++ calls 'virtual functions')," says John. "It's hard to follow unless you're a software jock, so I went to great lengths to describe it in my article." To complement his words, John cooked up some diagrams to explain dynamic binding.

In one of our two Technology Updates, Rich Quinnell covers **PC chip sets for embedded control**. He had some challenges gathering the information for the article, though. "I found a few companies that recognized embedded control as an important area for them. But most of the chip-set folks didn't want to talk about embedded control. They're set up to service the large customer—the high-volume clone-maker type. They would rather deal with 10 customers who buy a million parts each rather than a million customers who buy ten each."



"Build a strong foundation to program in C++" is this issue's Special Report.

Rich delves into the enormous advantages of using the IBM PC architecture as the core of embedded designs and covers the problems that designing with PC chip sets can incur.

Gary Legg has got some good news and some bad news in our second Technology Update, which describes **PC cards**—plug-in peripherals for small computers. A ton of newly available PC cards that contain memory, modems, faxes, hard disks, and LAN adapters are making the computer-upgrading chore a nonproblem, even for the technically unsophisticated user. However, the PC-card standard from The Personal Computer Memory Card International Association (PCMCIA) is undergoing revisions, which makes for incompatibility problems.

Gary has been following the progress of the PCMCIA standard for some time. He says that with the cards you won't need to upgrade a system in the traditional manner. "Rather, you'll just have different cards that you plug in as you need them."

The PCMCIA committee met recently to hammer out revisions to the standard. Check News Breaks in this issue for Gary's coverage of what happened.

Joan Morrow Lynch
Managing Editor

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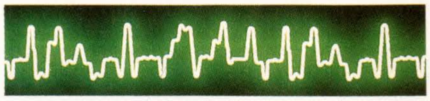

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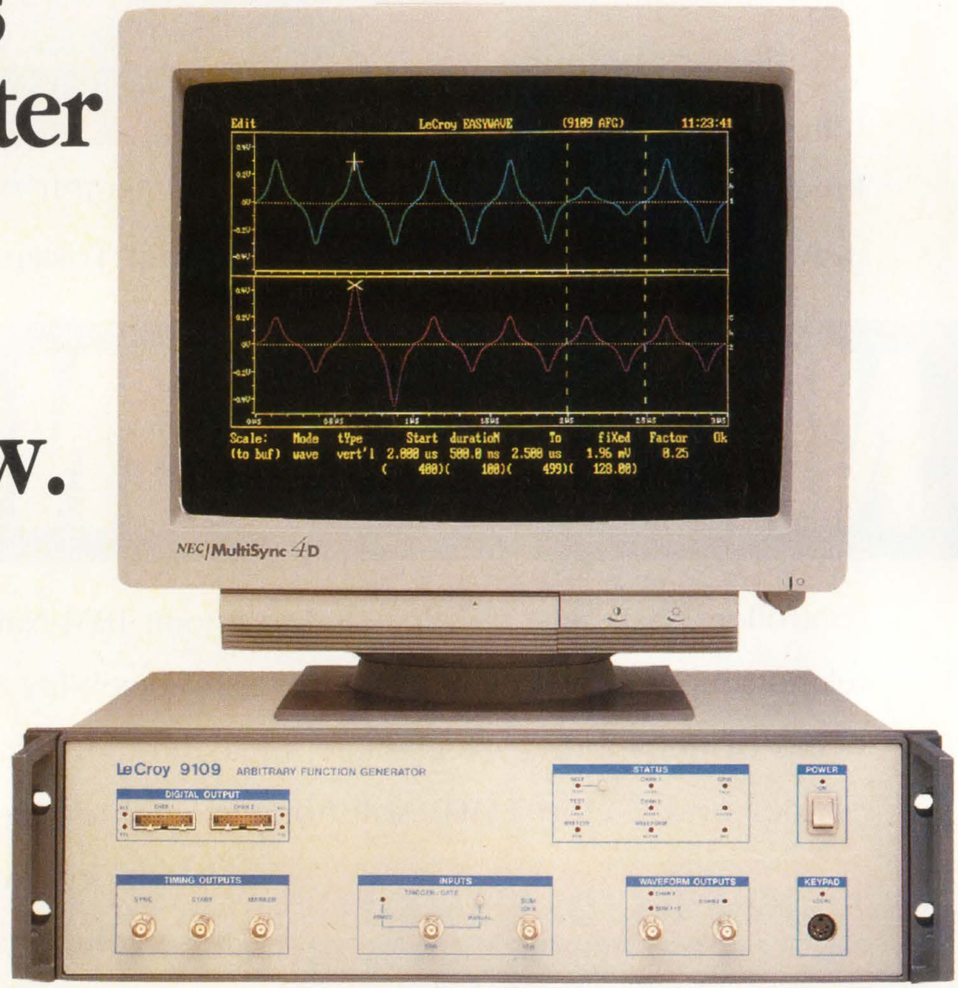

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CIRCLE NO. 39

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Innovators in Instrumentation

EDITED BY SUSAN ROSE

PCMCIA standard advances as PC-card products emerge

The Personal Computer Memory Card International Association (PCMCIA) has approved a long-awaited specification for Card Services, a key software module for systems that use credit-card-sized PC cards. Until now, computer designers have worked with a Card Services draft standard that was "very stable," according to the PCMCIA, but nevertheless incomplete (see related article, pg 49). The Card Services module helps make PCMCIA-compliant computers tolerant of users who have little or no technical expertise. Key features allow "hot swapping" of PC cards while power is on and the use of different types of cards in a common slot without need for system reconfiguration. A PCMCIA executive says the Card Services standard will be available in published form by the end of October. For more information, contact PCMCIA (Sunnyvale, CA, (408) 720-0107).

Adoption of the Card Services standard comes just as a trickle of PC-card products threatens to become a flood. A 9600-bps fax card and an Ethernet LAN card from Intel are among the vanguard; many more cards, not to mention computers that use PC cards, are expected at the upcoming Comdex exhibit. Samples of the two Intel cards are available now, although volume production won't begin until next month for the fax card and January for the LAN card. The fax card will cost $180 (1000); the LAN card will be $185 (1000). Intel, Santa Clara, CA, (800) 548-4725.

—by Gary Legg

Chip sets package serial data for fiber links

TriQuint Semiconductor is offering two serial-data chip sets that work with a variety of fiber-optic-communication standards. The sets have three components: a receiver, a transmitter, and an encoder/decoder. The receiver and transmitter chips are common to both sets. The encoder/decoders for the chip sets have identical pinouts and footprints, allowing a single design that is configurable to multiple applications.

The GA9102 receiver and GA9101 transmitter chips handle 10-bit TTL-level data at one port and optical signals at the other port. They need no external timing or filter components. Both are implemented in GaAs and can clock data at rates as great as 265 MHz with less than 244 psec of random jitter.

The encoder/decoder chips distinguish the sets. Both are CMOS devices that handle 8b/10b encoding and decoding, offer CRC (cyclic redundancy check) generation and checking, and detect loss of synchronization. The GA9104 meets the ESCON (Enterprise Systems Connection architecture) coding and control standards and offers parity generation and checking along with the 16-bit CRC. The GA9103 handles the Fiber Channel standard and uses a 32-bit CRC.

Parts are available either individually or as sets. Pricing for sets is $110 (100) for the ESCON chip set and $119.50 for the Fiber Channel chip set. Evaluation boards, incorporating the chip sets and necessary optics and connectors, are also available for either chip set for less than $3000. TriQuint Semiconductor, Santa Clara, CA, (408) 982-0900, FAX (408) 982-0222.

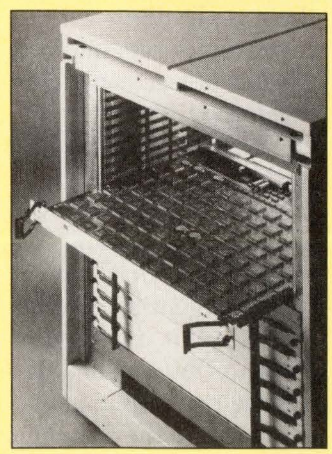
—by Richard Quinnell

Hardware emulator takes big step forward

Quickturn Systems Enterprise Emulation System is a hardware emulator that consists of up to 11 logic-emulation modules with a capacity of 30,000 emulation gates each. The system, therefore, lets you emulate up to 330,000 gates in a single system without interconnect cables. The larger your µP or ASIC design, the more likely you are to need hardware emulation. Above 100,000 gates, running design verification vectors on workstation-based simulators (at their usual 5 or 10 vectors/sec) can be impractical. Testing a large software component on a simulator takes even longer than design verification. Usually fabricating several rounds of prototype chips reveals errors that do not turn up in limited simulation. Another way to solve the problem of slow simulators is to pass your netlist to a hardware emulator.

The emulation system accepts your design in netlist form and partitions it to run efficiently on the system's Xilinx 3090 FPGAs (field-programmable gate arrays) and custom interconnect chips. Depending on the results of the mapping, running speeds range from 4 to 8 MHz. Software called the Automatic Design Partitioner maps netlists to clustered systems, letting you emulate up to 6 million gates of logic. Systems cost $388,000 for 120,000 gates or $798,000 for 330,000 gates. Quickturn Systems, Mountain View, CA, (415) 967-3300, FAX (415) 967-3199.

—by John Napier



Quickturn's Enterprise Emulation System

Electronica 92 show adds new sections

Electronica 92, one of the world's largest electronic components exhibits, will be held Tuesday, November 10 to Saturday, November 14, 1992, at the Messegelände in Munich, Germany. The show will have more than 2000 exhibitors and more than 500 additional companies represented. Approximately 110,000 trade visitors from 70 countries are expected to attend. On the exhibition floor, attendees will find semiconductor components; passive components; electromechanical, microwave, and optoelectronic components and subsystems; and equipment for development, quality assurance, and services.

In addition to exploring the exhibits on the show floor, registrants can attend a variety of programs on Wednesday and Thursday. There are three seminars on Wednesday, November 11. The 6th International Conference on Power Electronics and their applications will cover topics ranging from the use of semiconductor technology for switching and actuating applications to the aspects of high-power rectification, inversion, and conversion. "Intelligent sensors" covers the intelligent-sensor market, which is expected to grow to DM65 billion during the next eight years, according to the Intechno-Consult Market Research Institute in Basel (Switzerland). And, "Organic Semiconductors" will cover not only new materials, but also applications in selected sectors.

On Thursday, November 12, attendees can choose from two seminars. The first is a symposium on quality in electronics organized by the DGQ (German Society for Quality) in cooperation with the ZVEI German Electrical and Electronics Manufacturer's Association and Messe Müenchen. The symposium will focus on international standardization activities and will have as its central theme "TGM, ISO, CECC—Contradiction in Synergy?" Second is a seminar on the engineering experience with the latest GSM mobile radio networks (D-Networks) in public-sector applications. The seminar predominantly deals with metrological issues from the network-operator and maintenance point of view.

According to the show organizers, show attendees should expect to see the introduction of the first German-American 64-Mbit dynamic RAM, which will store 4000 typewritten pages. For more information about attending the show, contact Messe München International, (089) 51070, FAX (089) 51 07-506, Telex 5 212 086.

—by Raymond Boult, contributing editor

Manufacturing ATE detects open circuits with patented method

The 4200 in-circuit ATE from Marconi Instruments addresses problems of testing boards containing mixed ASICs, VLSI, and SMT devices. In addition to normal analog and digital in-circuit test and diagnostic facilities, the 4200 adds a patented technique, called Q-test, for detecting open circuits. Marconi maintains that open circuits are now the largest single fault area on pc boards, and result from widespread use of SMT parts. Faults arise due to component positioning, bent lead-outs, etching errors, and soldering failures. Marconi's Q-test locates open circuits with a sensor head mounted over the package to detect current flow within the device. The technique uses the parasitic diodes present between circuit elements and substrates of an IC to form a path for the test current.

Other tester features include bus emulation for testing bus-structured designs where in-circuit access is not possible, cluster testing for checking noncontactable areas of the board, and boundary-scan support in accordance with IEEE-1149.1.

The VME-based 4200 runs an OS-9 operating system to provide a real-time, multitasking environment, so that testing and programming can be concurrent. Hardware interfaces include Ethernet, X-terminal, and IEEE-488. Programs and fixtures for the company's earlier System 80 ATE are compatible with 4200. Price ranges from £40,000 to £100,000, depending on test-point capacity (128 to 2048 pins). Marconi will show the 4200 at Electronica in Munich, Booth 19F01. Marconi Instruments Ltd, St Albans, UK, 727-59292, FAX 727-47933. In US, Marconi Instruments Inc, Allendale, NJ, (201) 934-9050, FAX (201) 934-9229.

—by Brian Kerridge

Tone decoder chip suits international telecom systems

The FX613 IC from Consumer Microcircuits Ltd senses call progress tones used in a range of applications in international phones, faxes, modems, and telemetry systems.

The IC senses signal level and measures signal frequency in the ranges of 300 to 660 Hz (39.47 msec/reading) and 900 to 2150 Hz (13.16 msec/reading). The IC outputs the frequency reading as a 6-bit serial word to a system microcontroller (μC). You can program a μC to recognize the frequency, sequence, and cadence of input signals, and thus adapt your product to prevailing telecommunica-

Text continued on pg 20

Text continued from pg 18
tions standards and maintain compatibility as standards develop.

The FX613 consumes 1 mA max with a 3.3V supply and requires a 3.579545-MHz system clock or crystal network. The plastic package is 16-pin small-outline surface-mount (£2.44/1000) or 14-pin DIP £2.22 (1000).

The FX613 is one of several telecommunications ICs the company will announce at Electronica in Munich, Booth 25B03. Consumer Microcircuits Ltd, Witham, UK, 376-513833, FAX 376-518247. In US, MX-COM Inc, Winston-Salem, NC, (919) 744-5050.

—by Brian Kerridge

83-MHz PLD offers superset of 22V10 functions

If your design won't fit in a single 22V10, or if you need functions it doesn't offer, consider the CY7C335 from Cypress Semiconductor. The chip does everything a 22V10 will do, and quite a bit more, at speeds up to 83 MHz in registered pipelined operations. The chip has 12 instead of 10 I/O macrocells plus four additional buried macrocells. You can bury up to six of the 12 I/O macrocells without losing the associated input pins. The chip also provides 12 dedicated input pins with input registers.

Product terms range from 9 to 19 wide instead of the 8 to 16 on the 22V10. The 22V10 only provides D-type flip-flops. The CY7C335 includes an XOR gate after the sum-of-products to let you emulate T and JK flip-flops, reducing product term usage. The XOR gate also provides polarity control. You can select registered inputs, outputs, or bypass registers individually. Three clocks control the registers: one for input registers, one for output registers, and one additional clock you can use for either inputs or outputs. The ability to use two separate output or state clocks lets you create two asynchronous state machines in one device. The UV-erasable CMOS PLD is available in plastic or ceramic 28-pin 300-mil DIPs, LCCs, or plastic leaded chip carriers. The plastic version is $9.95 (100). Cypress Semiconductor, San Jose, CA, (408) 943-2600.

—by Doug Conner

Supercomputing dips to workstation pricing

MasPar Computer Corp, developers of the MP-1 1000-processor parallel computer, is introducing its binary-compatible second-generation system, the MP-2. This computer can incorporate as many as 4096 processors working in parallel, yet is programmable in Fortran or C. Along with the introduction of the MP-2, MasPar has lowered the price of its MP-1. Even though the MP-2 costs $260,000, the entry price of an MP-1 is $75,000. Contact MasPar Computer Corp, Sunnyvale, CA, (408) 736-3300.

—by Richard A Quinnell

Conference focuses on DFT

The International Test Conference (Baltimore, MD, September 21 to 24), focused on DFT (design for testability)—a favorite theme for several years. Although cynics decry the DFT field's low ratio of action to talk, there is evidence that the design community realizes it must pay attention to test needs during product development. For example, as ICs grow in complexity, just showing that they meet the design objectives requires using testability features.

ITC also saw the announcement of several multivendor alliances among IC, CAE, and ATE suppliers. The Design and Test Alliance—a group whose initial 9-firm membership includes Texas Instruments (TI) and Cadence—aims to spur cooperative efforts among vendors and users of design and test technologies and to raise management awareness of the need for integrating the technologies.

Tektronix has joined TI's separate alliance with Teradyne to promote boundary scan and to distribute hardware and software products that support the technique. More companies may yet join that alliance. TI also announced the release of V2.0 of its MS-Windows-based Asset scan-test tools (priced from approximately $11,000).

Since the 1990 approval of the IEEE-1149.1 standard, boundary scan has apparently become the one DFT technique that has taken the industry by something approaching a storm. The pervasiveness of fine-pitch, surface-mount devices severely restricts nodal access during board testing. Boundary scan permits testing a board's interconnections (and often more) without probing—or it would if scannable ICs existed for every need. Even as IC vendors work on new scannable parts, designs that mix scan and non-scan chips significantly reduce the need for nodal access.

Cadence announced the Test Intelligent Design Tools for use with its ASIC Workbench. These $175,000 tools combine synthesis and optimization of test features with logic synthesis. Cadence emphasizes that integrating the design of testability features with the synthesis of a device's primary functions results in better fault coverage, smaller die size, and fewer performance penalties than adding test features after the design is otherwise complete.

Crosscheck introduced V5.0 of the internal-scan-based Aida tool set that it acquired from Teradyne earlier this year. The Aida tools, which also require a designer to think about design and testability together, are priced from $90,000 and run on Sun and HP workstations. The Aida tools complement the firm's original test tools, which by embedding a proprietary observability matrix within an IC, impose a minimum of constraints on chip designers.

Cadence Design Systems Inc, San Jose, CA, (408) 943-1234. Crosscheck Technology Inc, San Jose, CA, (408) 432-9200. Design and Test Alliance, Los Gatos, CA, (408) 356-5119. Tektronix Inc, Beaverton, OR, (800) 426-2200. Teradyne, Boston, MA, (617) 422-3567. Texas Instruments Inc, (214) 995-6611, ext 3990.—by Dan Strassberg

Achieve software flexibility with hard-wired speed

You can reprogram RAM-based FPGAs (field-programmable gate arrays) an unlimited number of times to perform different functions at different times. For IEEE 1149.1 boundary-scan operation for board-level test and system self-test diagnostics, you can use a macro with Concurrent Logic's CLi6000 family to program the IC. After test, you can load the functional logic into the FPGA, eliminating any speed or area penalty associated with dedicated boundary-scan logic.

The family takes this a step further in reprogramming logic by offering dynamic reconfiguring of individual logic cells. Dynamically reconfiguring logic opens up some interesting design possibilities: You have the flexibility of software combined with the speed of hard-wired logic. The firm calls the concept cache logic. You load in blocks of logic as needed, writing over logic that is no longer in use.

As a simple case, consider an FPGA programmed with several counters. Instead of having the size of the counters fixed, you can reprogram the FPGA to have the appropriate size and number of counters at any given time. Because you can individually reprogram logic cells while the chip is operating, you can have some of the counters operate while reprogramming others. The net benefit of reprogramming logic to perform different operations at different times is less logic and lower power.

The boundary-scan macro is included in a $495 preliminary collection of macros, described in volume one of the company's application notes. The DCS2100 development system ($3995) also includes a library. Concurrent Logic Inc, Sunnyvale, CA, (408) 522-8700.—by Doug Conner

Vendors augment ASIC attributes

ASIC designers will soon have a broader range of choices for their base technology. Hitachi America, NEC Electronics, and VLSI Technology have announced their next-generation ASIC processes, with gate arrays to follow by early 1993.

Hitachi America is offering a 0.5-μm BiCMOS array with 250k-gate master slices planned. Each cell of the array contains both MOS and bipolar transistor types, creating an integrated BiCMOS product instead of the usual CMOS core with a ring of higher-drive bipolar transistors. The process was first described at CICC in 1989, but Hitachi delayed the technology's commercial introduction until a substantial (100+) macrocell library was available. Hitachi, Brisbane, CA, (415) 589-8300.

NEC's 0.5-μm offering is strictly a CMOS process, but it has been optimized for 3V operation. It can also incorporate Crosscheck's gate-level test technology, JTAG, or scan techniques at the user's option. The extra pins used for the built-in testing don't steal from the user's I/O pin availability, though, because the arrays use a staggered bond-pad pattern that lets them offer die sizes with as many as 1000 I/O pins. NEC Electronics, Mountain View, CA, (415) 960-6000.

VLSI's process incorporates Quicklogic's antifuses, adding programmability to the ASIC community. The company's first arrays will use the antifuses for programming an on-chip memory system. Subsequent products in the pFSB family will include field-programmable logic, taking away some of the risk in committing a design to ASICs and allowing field customization of ASICs. VLSI Technology, San Jose, CA, (408) 434-7520.

—by Richard A Quinnell

RAID systems proliferate

RAID (redundant array of independent disks) mass-storage systems seem to be gaining headway. New products for implementing the systems, which combine a special controller with multiple small disk drives, are available from NCR Corp, UltraStor Corp, and Sanyo Icon; previously, Ciprico Inc introduced a 8.4-Gbyte RAID subsystem (see EDN, Oct 15, pg 75). RAID systems allow vast amounts of data, fast data access, high transfer rates, and fault tolerance.

NCR's SCSI-2 controller, the ADP-92-06, lets you implement a RAID system on an ISA or EISA PC. The controller supports RAID 0 (data striping), RAID 1 (mirroring), RAID 3 (parallel disks with one drive devoted to parity storage), and RAID 5 (parallel disks with parity storage spread across all drives). It transfers data at 20 Mbytes/sec. The OEM list price is $1995. NCR Corp, Witchita, KS, (800) 334-5454.

The Ultra 124F RAID controller from UltraStor connects EISA computers to SCSI-1, SCSI-2, or Fast SCSI devices. It supports RAID 0, RAID 1, RAID 4 (data striping with parity), and RAID 5. A 3-channel version costs $1995; a 5-channel version is $2370. UltraStor will soon introduce a $2995 SCSI-to-SCSI RAID controller. UltraStor Corp, Irvine, CA, (714) 581-4100.

Sanyo Icon's RAID offerings are complete mass-storage subsystems for use on networks. The $30,000 base-model LANser MRX100 provides as much as 4.8 Gbytes of storage; the $75,000 MRX500, available later this year, can expand to more than 300 Gbytes. According to Sanyo Icon, the products will support 12 file servers, 105 disk drives, and "thousands" of PCs. The systems implement RAID 0, RAID 1, and RAID 5. They connect via SCSI ports to file servers having ISA, EISA, or Micro Channel Architecture buses. Sanyo Icon, Irvine, CA, (714) 263-3758.

—by Gary Legg

FORMERS

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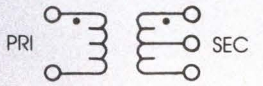
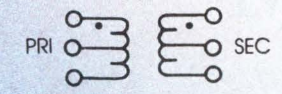
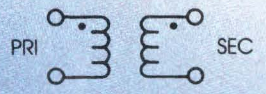
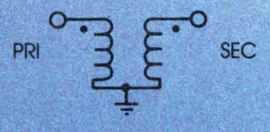
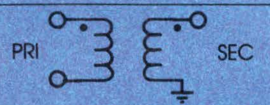
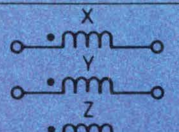
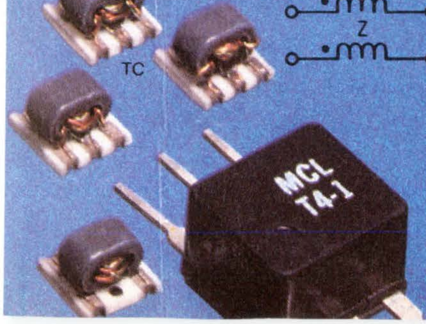
		MODEL NO.	Ω RATIO	FREQUENCY MHz	INSERTION LOSS 3dB MHz	2dB MHz	1dB MHz	PRICE $ Qty. (1-9)
A*  PRI SEC	T	T1-1T	1	.05-200	.05-200	.08-150	.2-80	4.45
		T1-6T	1	.015-300	.015-300	.021-150	.03-50	6.95
		T2-1T	2	.07-200	.07-200	.1-100	.5-50	4.95
		T2.5-6T	2.5	.01-100	.01-100	.02-50	.50-20	4.95
		T3-1T	3	.05-250	.05-200	.1-200	.5-70	4.95
		T4-1	4	.2-350	.2-350	.35-300	2-100	3.25
		T4-6T	4	.02-250	.02-250	.05-150	0.1-100	4.45
		T5-1T	5	.3-300	.3-300	.6-200	.5-100	4.95
		T8-1T	8	0.3-140	0.3-140	0.7-90	1-60	7.95
		T13-1T	13	.3-120	.3-120	.7-80	5-20	4.95
		T16-6T	16	.03-75	.03-75	.06-30	.1-20	5.65
	TH	T4-1H	4	10-350	10-350	15-300	25-200	5.95
	TMO	TMO1-1T	1	.05-200	.05-200	.08-150	.2-80	7.95
		TMO2-1T	2	.07-200	.07-200	.1-100	.5-50	8.45
		†TMO2.5-6T	2.5	.01-100	.01-100	.02-50	.05-20	8.45
		†TMO3-1T	3	.05-250	.05-250	.1-200	.5-70	7.95
		TMO4-1	4	.2-350	.2-350	.35-300	2-100	6.25
		TMO5-1T	5	.3-300	.3-300	.6-200	5-100	8.45
		TMO13-1T	13	.3-120	.3-120	.7-80	5-20	8.45
B*  PRI SEC	TT	TT1-6	1	.004-500	.004-500	.02-200	.1-50	6.95
		TT1.5-1	1.5	.075-500	.075-500	.2-100	1-50	5.95
		TT2.5-6	2.5	.01-50	.01-50	.025-25	.05-10	6.45
		TT4-1	3	.05-200	.2-50	.2-50	1-30	5.95
		TT4-1A	4	0.1-300	0.1-300	0.2-250	0.3-180	6.95
		TT25-1	25	.02-30	.02-30	.05-20	.1-10	9.95
	TTMO	TTMO25-1	25	.02-30	.02-30	.05-20	.1-10	11.95
		TTMO1-1	1	.005-100	.005-100	.01-75	.05-40	11.45
		TTMO4-1A	4	0.1-300	0.1-300	0.2-250	0.3-180	13.95
C  PRI SEC	T	T1-1	1	.15-400	.15-400	.35-200	2-50	3.25
		T1.18-3	1.18	0.01-250	0.01-250	0.02-200	0.03-50	5.65
		T1-6	1	.01-150	.01-150	.02-100	.05-50	5.65
		T1.5-1	1.5	.1-300	.1-300	.2-150	.5-80	4.45
		T1.5-6	1.5	.02-100	.02-100	.05-50	0.1-25	5.65
		T2.5-6	2.5	.01-100	.01-100	.02-50	.05-20	4.45
		T4-6	4	.02-200	.02-200	.05-150	.1-100	4.45
		T9-1	9	.15-200	.15-200	.3-150	2-40	3.95
		T16-1	16	.3-120	.3-120	.7-80	5-20	4.45
		T36-1	36	.03-20	.03-20	.05-10	.1-5	6.95
	TO	TO-75	1	10-500	—	10-500	40-250	6.95
	TH	T1-1H	1	8-300	8-300	10-200	25-100	5.95
		T9-1H	9	2-90	2-90	3-75	6-50	6.45
		T16-1H	16	7-85	7-85	10-65	15-40	6.45
	TMO	TMO1-02	1	1-800	1-800	2-500	—	9.45
		TMO1-1	1	.15-400	.15-400	.35-200	2-50	6.25
		TMO1.5-1	1.5	.1-300	.1-300	.2-150	.5-8	8.45
		†TMO2.5-6	2.5	.01-100	.01-100	.02-50	.05-20	7.95
		†TMO4-6	4	.02-200	.02-200	.05-150	.1-100	7.95
		TMO6-1	6	.3-200	.3-200	.5-150	5-50	7.95
		TMO9-1	9	.15-200	.15-200	.3-150	2-40	7.95
		TMO16-1	16	.3-120	.3-120	.7-80	5-20	7.95
D  PRI SEC	T	T2-1	2	.050-600	.050-600	.1-400	.5-200	3.95
		T3-1	3	.5-800	.5-800	2-400	—	4.45
		T4-2	4	.2-600	.2-600	.5-500	2-250	3.95
		T8-1	8	.15-250	.15-250	.25-200	2-100	3.95
		T14-1	14	.2-150	.2-150	.5-100	2-50	4.95
	TMO	TMO2-1	2	.050-600	.050-600	.1-400	.5-200	7.95
		TMO3-1	3	.5-800	.5-800	2-400	—	8.45
		TMO4-2	4	.2-600	.2-600	.5-500	2-250	7.95
		TMO8-1	8	.15-250	.15-250	.25-200	2-100	7.95
		TMO14-1	14	.2-150	.2-150	.5-100	2-50	8.45
	FT	FT1.22-1	1.22	.005-100	.005-100	.01-50	.05-25	35.95
		FT1.5-1	1.5	.1-400	.1-400	5-200	1-100	35.95
E  PRI SEC	FTB	FTB-1	1	.2-500	.2-500	.5-300	1-100	36.95
		FTB1-6	1	.01-125	.01-125	.05-50	.1-25	36.95
		■FTB-1-75	1	.5-500	.5-500	5-300	10-100	36.95
F  X Y Z	T	T-622	1	0.1-200	0.1-200	0.5-100	5-80	3.25
		T626	1	0.01-10	0.01-10	0.2-5	.04-2	3.95
		T2-613.1						



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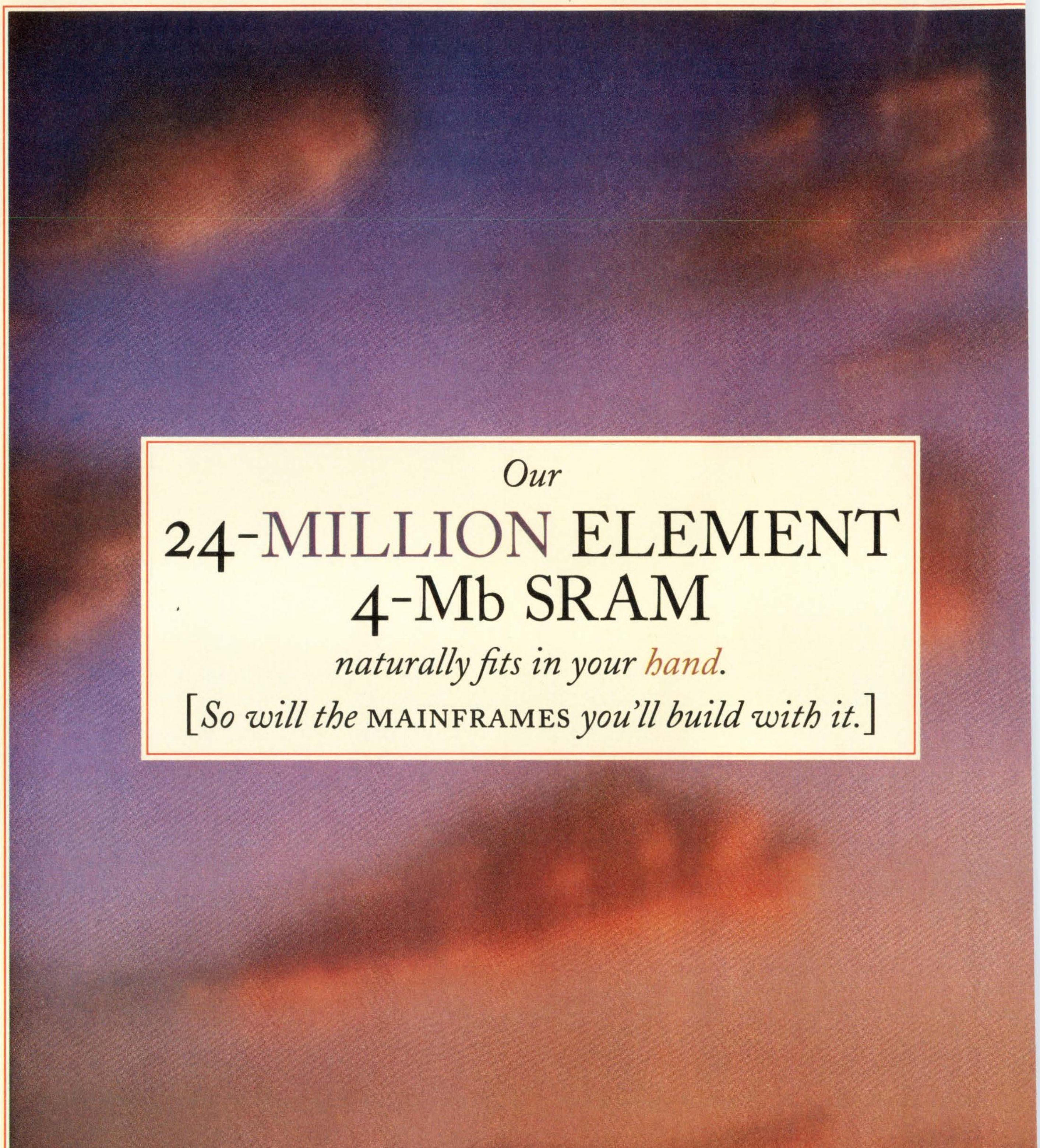

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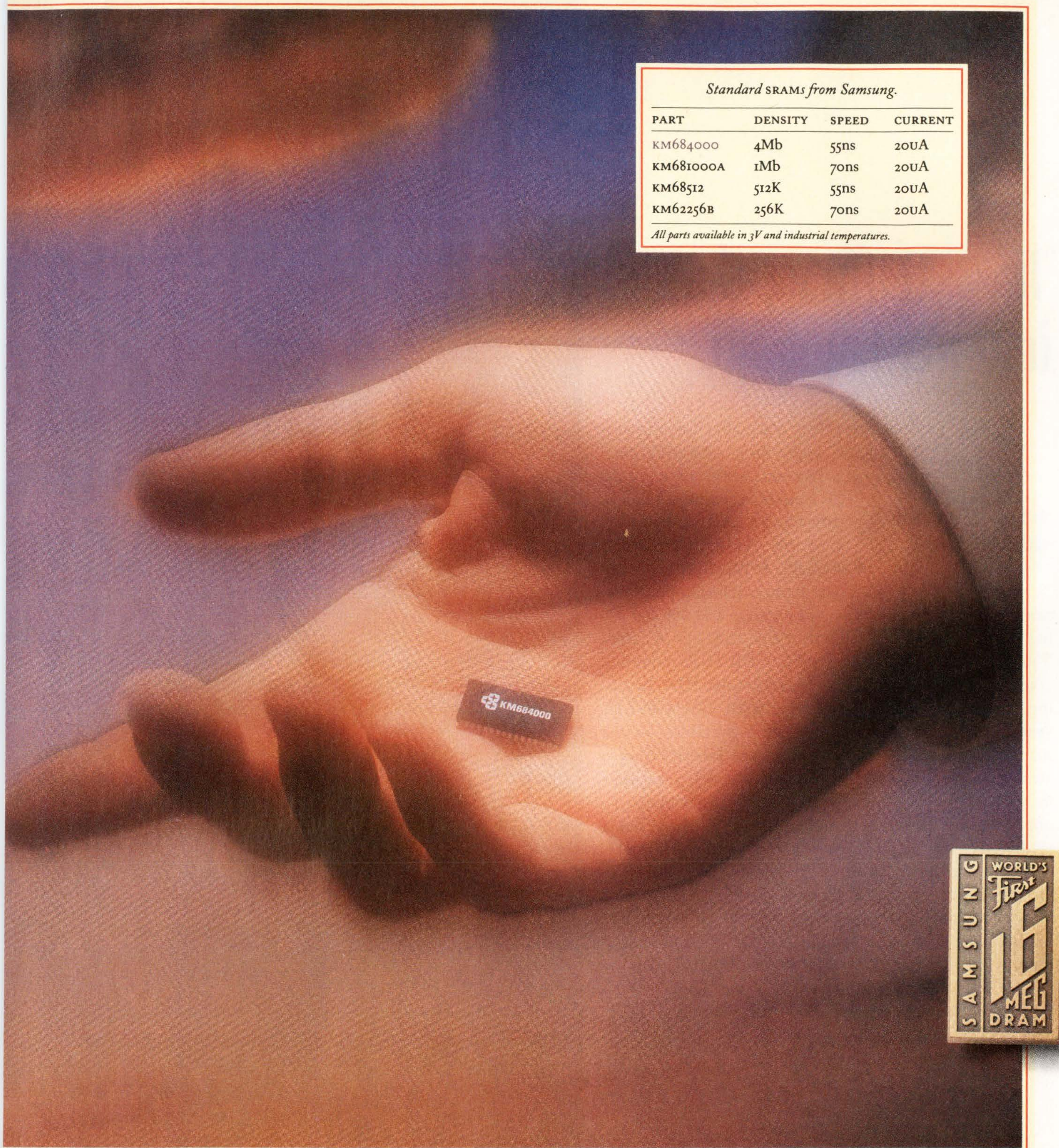

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He joins Shakespeare in asking, "What's in a name?"

Perhaps the slow acceptance of fuzzy logic by Western engineers is due in part to the ambiguity inherent in the name, and not because Western engineers require a new mindset, as David Brubaker states in his article (EDN, June 18, 1992, pg 111). It's hard to believe that the Japanese equivalent of the words, "fuzzy logic," could conjure up so many ill-defined images.

Alan H Ostroff, Engineer
ELA Medical SA
Woerth, France

Don't abandon textual-programming methods

In Charles Small's article, "Windows and engineering software" (EDN, April 9, 1992, pg 122), perhaps he can tell me where his colleague got the "I Hate Windows" badge. I've just upgraded to V3.1, which is a bit more resilient, but still crashes to the extent that I need to switch off completely.

But my real concern is that its "look and feel" are not really suitable for CAE. His reference to engineers' abandoning textual-programming methods for diagrammatic programming is a point I don't accept. If true, [it] would give some merit for using Windows, if it were not for the fact that creating engineering diagrams with [diagrammatic programming] is tedious and frustrating.

Unlike text, engineering diagrams need to be larger than an A4 sheet and are not created from the top down (like typing) but grow in all directions. This requires fast screen handling and sensible drawing controls, which Windows doesn't have. My current DOS-based CAE packages are fast, probably because of the "undocumented features" Small mentions, but might be considered somewhat limited in capability. Windows might allow for more complex FPGA and EPLD (field-programmable-gate-array and erasable-programmable-logic-device) compilers, for example, but is there nothing else? Is Microsoft going to dictate the "look and feel" of all future CAE?

Colin R Woodbridge
Development Manager
Ego Computers Ltd
Borehamwood
Herts, UK

Defuzzing fuzzy logic

After reading the articles "Fuzzy-logic basics: intuitive rules replace complex math" and "Fuzzy-logic system solves control problem" (EDN, June 18, 1992, pgs 111 and 121, respectively), my suspicions are confirmed:

- Fuzzy logic is nothing but the multivalued logic first enunciated (I believe) by Alfred Korzybski in the 1920s(?).
- Fuzzy logic, as practiced today, is actually an attempt to do analog computation by digital means and, as a result, gives a limited number of discrete results rather than a continuum of results, such as a true analog system would.

It is unfortunate that the originator of the term, "fuzzy logic," didn't choose a more accurate name, such as "continuous logic," "analogic," or even the original "multivalued logic." This choice has undoubtedly led to a lot of reluctance to use—or even to investigate—fuzzy logic, because of the implications of imprecision.

A similarly unfortunate choice of a name was made in the case of the computer language, Lisp. When one stops to think about it, doesn't the word, "lisp," carry a connotation of immaturity ("All I Want For Chrithmuth Ith My Two Front Teeth")?

Afterthought: I wonder what the *literal* translation of the Japanese term for "fuzzy logic" might be?

Robert J Nedreski
Nedreski Industrial Service
Erie, PA

Executive-salary rate *can* affect the taxpayer

In response to Jon Titus's editorial, "Don't tread on me" (EDN, April 9, 1991, pg 39), I agree that in a free-enterprise economy, executives should be paid whatever the board of directors and stockholders can tolerate. But in the real world (these United States), we have a "cause and effect" society. Executives with inflated salaries (that is, compensation that doesn't correlate with the health of the business, especially when workers' salaries are depressed due to a "downturn in the business cycle"), bail out of failing companies with golden parachutes while the American taxpayer is left to pick up the tab for the increased burden on the social services that the displaced workers cause.

From the ethical, moral point of view, the human destruction through loss of ego, pride, and hope is intolerable. As the ranks of the homeless swell, and "discouraged workers" increase in number, the negative impact on the human equation as well as the economy, cannot be overlooked, especially by those who claim that the free-enterprise system is self-correcting.

If what Titus says is true, then not another family should face hardship and bankruptcy caring for a sick family member or loved one. The converse of this statement is also true: Not another failing business should be allowed to pay one penny for an executive's golden parachute before it compensates workers who will end up using tax-supported social services.

When poor business practices affect only that business, I consider that self-correcting free enterprise. When a failing company's actions start to touch my pocketbook, I demand a say in what that company does. In this country, we do this through legislation.

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3M Co,
St Paul, MN

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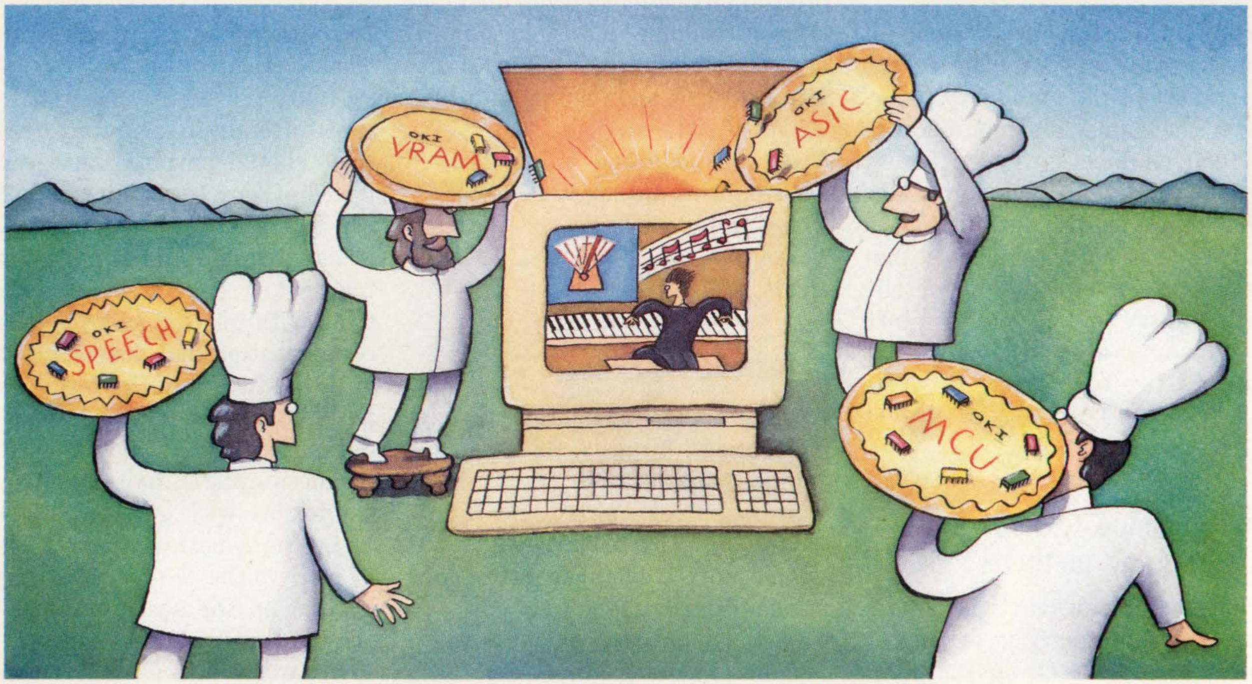

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EDITED BY JULIE ANNE SCHOFIELD

Check your stockroom for obsolete ICs

Matric purchased the RCA 1800 series Microboard line from RCA in 1985. Now our stock of obsolete CDP1866 and CDP1867 4-bit latch ICs is nearly depleted. Does anyone know of a replacement, or have, any of these parts that we can purchase?
Les Switzer
Technical Process Engineer
Matric Ltd
Franklin, PA

We checked the CAPS system, a CD-ROM-based IC and semiconductor database available from Cahners Technical Information Service Div, and found no upgrades, downgrades, or pin-for-pin replacements for the CDP1866 or CDP1867. Calls to several distributors proved fruitless also. If anyone has a stash of these parts, please contact Ask EDN.

LCD bar graphs available as display-driver pair or standard modules

In the May 21, 1992, Ask EDN, S Morris-Jones was looking for an LCD bar-graph module or a display-driver pair available in small quantities. Some years ago, TD Electronics developed a 256-element bar graph for a custom piece of equipment. The LCD is available from Crystalloid, and we used Motorola's MC145000 and MC145001 driver ICs. The drivers are based on a serial stream of pulses, but you can use analog conversion via a VCO or dual-slope ADC to derive the bit stream. At project time, the LCD was about $12 (100). I would estimate the circuitry at $18 (100).

Crystalloid Electronics Co
Box 628
Hudson, OH 44236
(216) 655-2429

Motorola Semiconductor Products Inc
Box 20912
Phoenix, AZ 85036
(800) 521-6274.

Robert B Bertolasi
TD Electronics Inc
Loves Park, IL

Thanks for the display-driver pair. Thanks also to Richard J Borstelmann of UCE Inc, Roger Williams of Matec Instruments (Middleborough, MA), and Craig Ogden of Heath Electronics (Glenns Ferry, ID) for pointing out three sources of LCD bar-graph modules:

UCE Inc
35 Rockland Rd
Norwalk, CT 06854
(203) 838-7500
FAX (203) 838-2566

Standish Industries
W 7514 Highway V
Lake Mills, WI 53551
(414) 648-1000
In UK, (0379) 64-4411

Modutec Inc
920 Candia Rd
Manchester, NH 03103
(603) 669-5121.

Does byte-oriented HDLC data-link protocol exist?

Is there a variant of the HDLC data communications standard (ISO 3309) that uses byte-oriented frame structures in conjunction with the CCITT frame-checking sequence? The ISO specifies a frame structure that, in general, ends up transmitting a non-integral number of bytes because it uses bit stuffing to achieve data transparency. This is awkward if you want to use it for asynchronous as well as synchronous data links.
David Cooper
Coherent Research Ltd
London, UK

By definition, HDLC data communications is bit oriented. In fact, this CCITT-specified data-link protocol is the foundation on which most other bit-oriented protocols are based. We haven't come across a byte-oriented derivative of this protocol and doubt that one exists. If any reader knows of some renegade variant, please let us know.

Singapore reader seeks electrifying engineers

I am a 1991 physics graduate from the National University of Singapore. I am certainly obsessed with electronics and lasers; however, in Singapore engineers are very boring and do boring jobs. Could you direct me to any electronics clubs in the US where I can get to know interesting people like the Free Software Foundation's Richard Stallman?
Chui Yeok Pong
Singapore

We have several suggestions for you. First, surely not all engineers in Singapore are boring—perhaps you could start your own laser-lovers club. Second, you could contact the Free Software Foundation, which may be able to put you in touch with some interesting people to correspond with. Third, try subscribing to an international electronics magazine. Two magazines geared for hobbyists are *Electronics Today International* ($56/year) and *Elektor Electronics* ($48/year). Also, you could contact EDN Asia's home office to start a subscription.

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MACH 120	1200	48	15ns	50 MHz	68	MASC 120
MACH 220	2400	96	15ns	50 MHz	68	MASC 220
MACH 130	1800	64	15ns	50 MHz	84	MASC 130
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CIRCLE NO. 47

Engineering heroes are a dime a dozen

It's a crisis! Something doesn't work. Purchasing can't obtain a sole-sourced part. Customers are burning up the phone lines enraged over late deliveries. Your adrenaline starts pumping; you roll up your sleeves and jump in. You can save the day!

And you *do* save the day. You burn the midnight oil for a couple of nights and make a few deft circuit modifications so that production can start up again. You grin at your skill, heave a sigh of relief, and shrug off the congratulations of your superiors. Perhaps even the general manager stops by for a handshake and a brief congratulatory chat.

"Everyone has his 15 minutes of fame," you tell yourself, and you hope that your boss will remember your skill and dedication at your next review. If past performance means anything, he or she will. "This is what engineering is all about. EEs have darned few chances to play hero." You feel fortunate to have had the opportunity.

On your next project, will you remember your moment in the spotlight and subconsciously make a couple of design decisions that, later on, will give you another chance to be a hero? Companies that reward engineering heroics without similarly rewarding engineers who do their utmost to *avoid* ever having to play hero are encouraging sloppy engineering . . . encouraging poor quality.

Quality experts often point out that no company can have good quality unless management is committed to it. Employees will figure out what management *really* wants and deliver it. If management wants heroes, then it will get heroes—at least for a while. By and large, customers don't care about your heroics. If your company makes a habit of late deliveries or provides products of questionable quality, business will suffer, and your job and your opportunities to play hero will disappear.

If management commits itself to quality, many acts of engineering heroics are seen for what they are: examples of poor engineering. Managers who think twice before they reward such engineering heroics are acting in their companies' best interests. And if they cause engineering heroes to change their ways, they are acting in the engineers' best interests, too. In the long run, having a job beats getting a hero's medal.

Dan Strassberg
Senior Technical Editor

Jesse H. Neal
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1987, 1981 (2), 1978 (2),
1977, 1976, 1975

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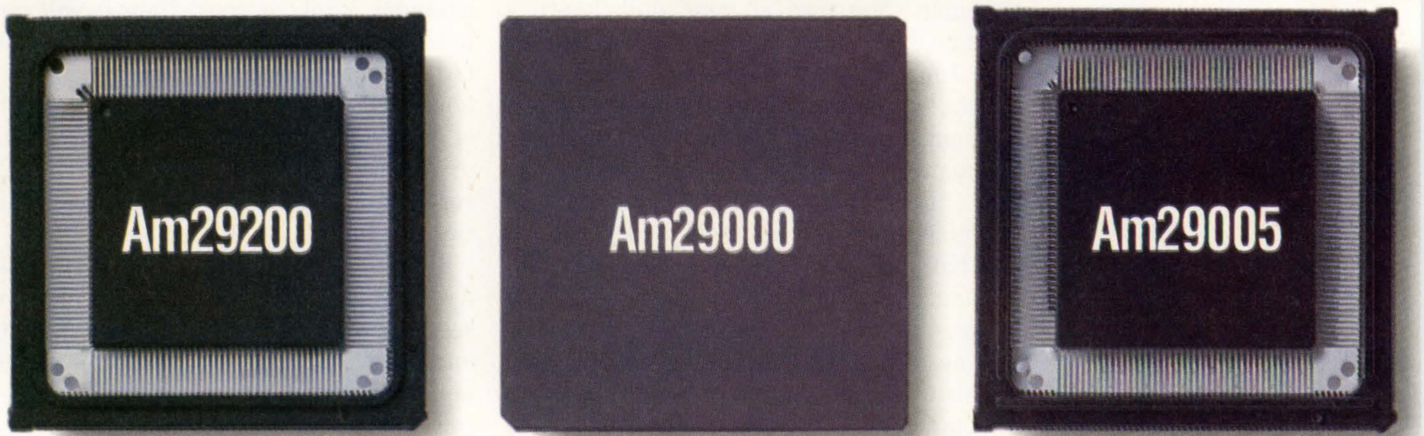

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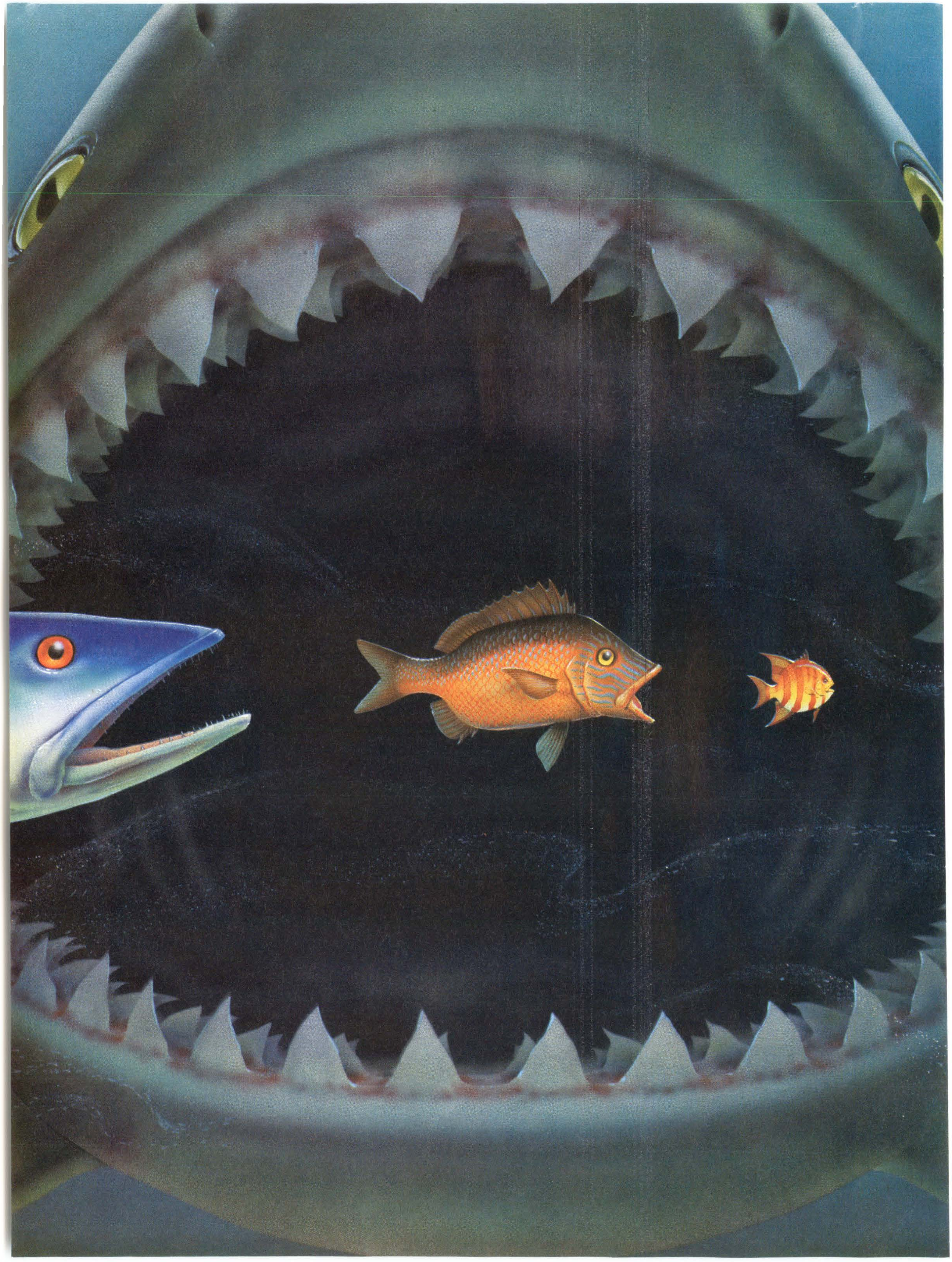
CIRCLE NO. 48



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MCM6706A	**MCM6705A**	**MCM6708A**	**MCM6709A■**	**MCM67082A▲**
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☐ 256K x 4	☐ 12ns	☐ 256K x 4	☐ 12ns	☐ 32K x 8	☐ 10ns	*10 &
☐ 128K x 8	☐ 15ns		☐ 15ns	☐ 32K x 9*	☐ 12ns	12ns Only

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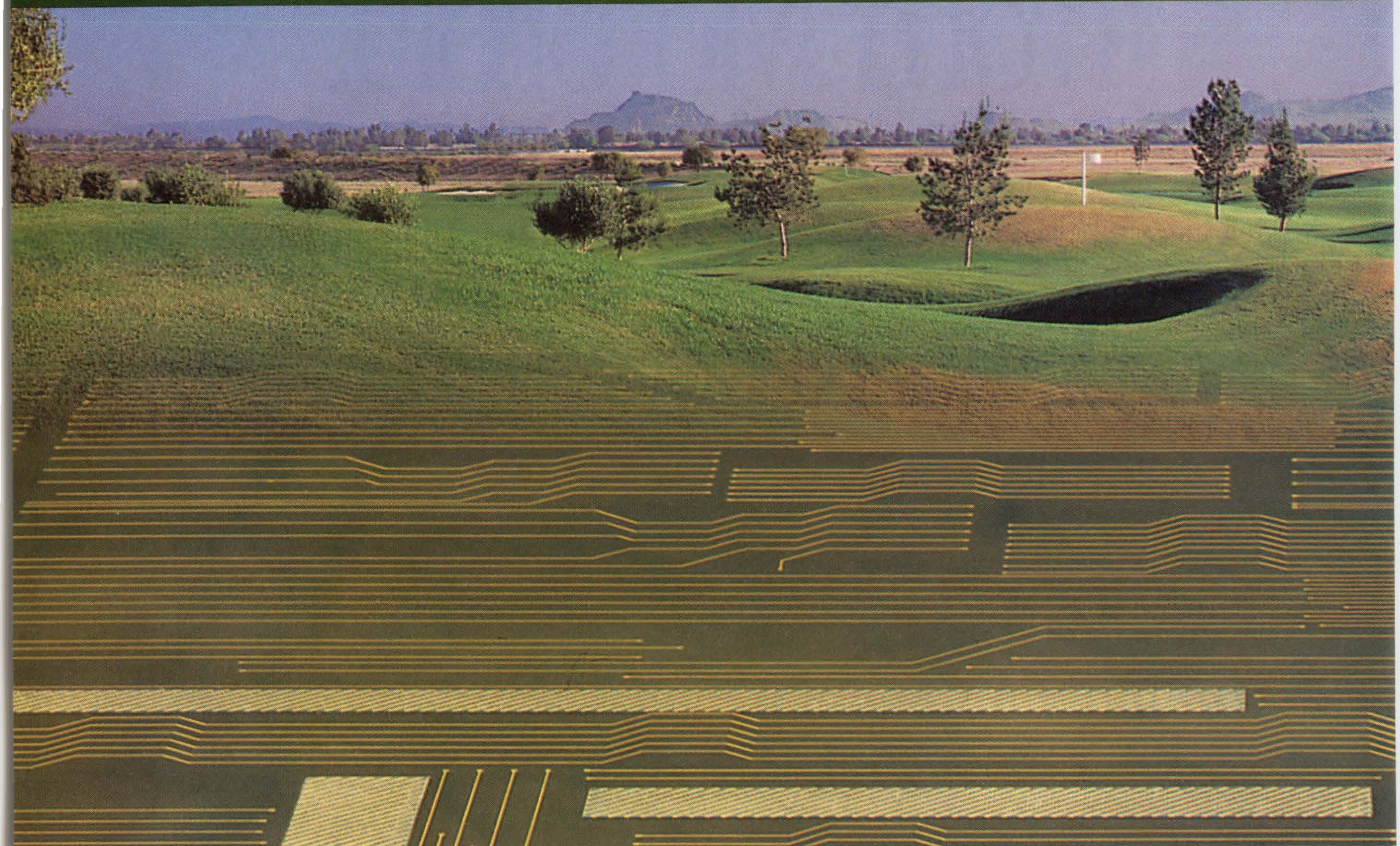

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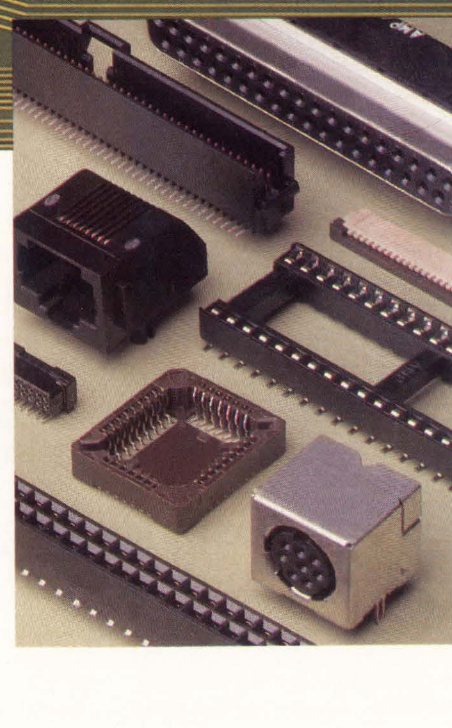

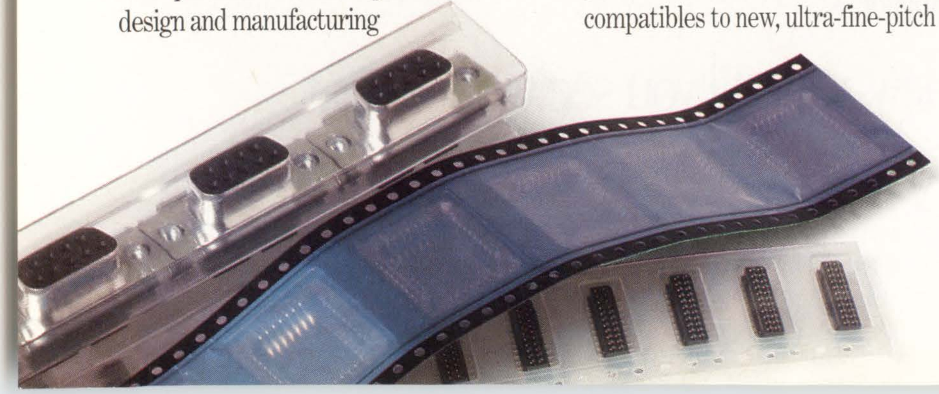

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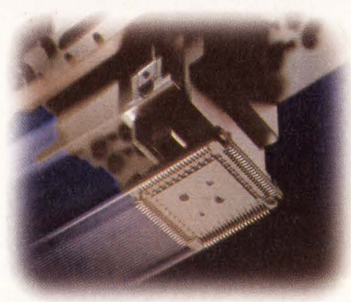

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CIRCLE NO. 51

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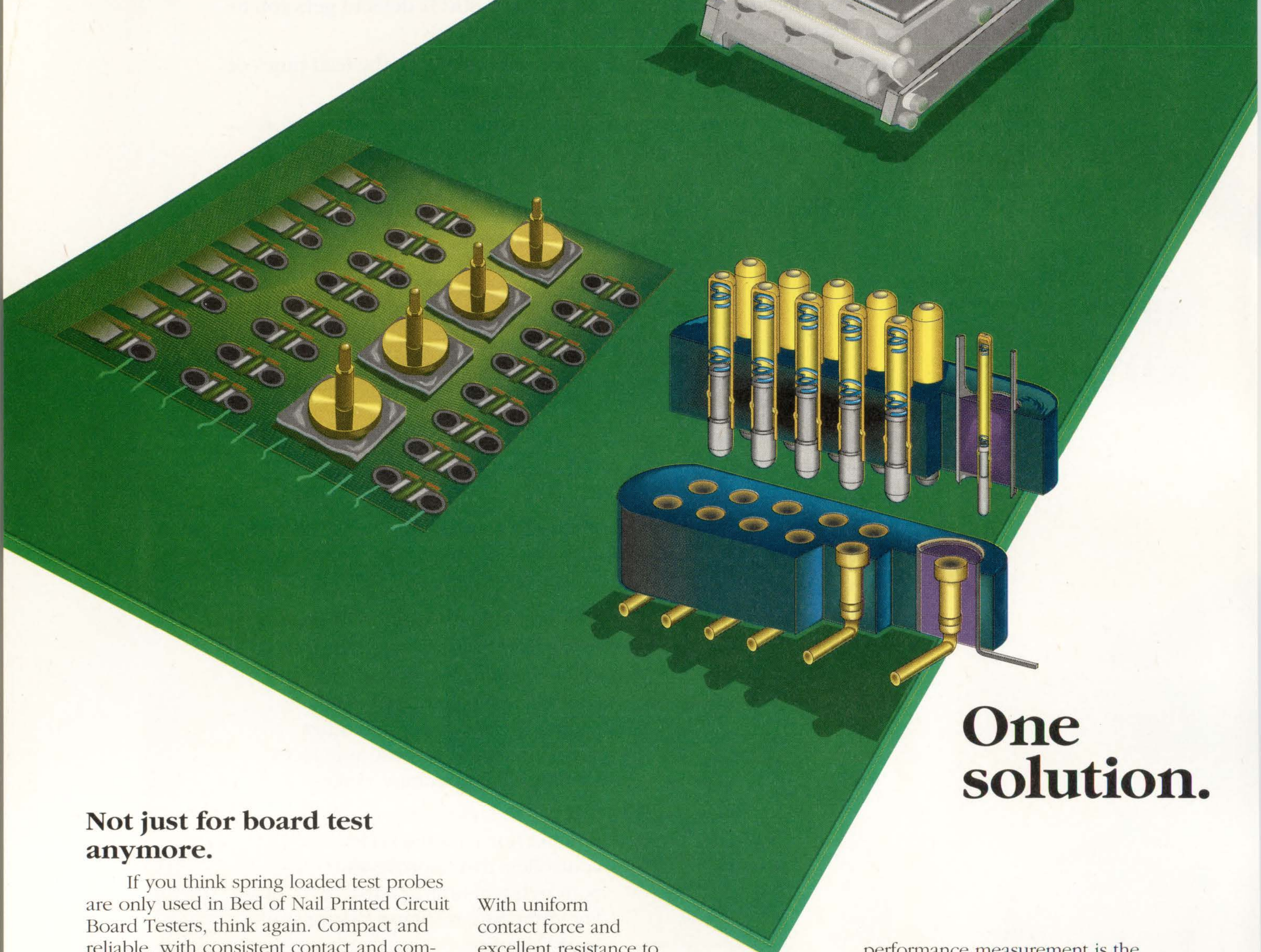

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CIRCLE NO. 54

Small, smart PC cards strive for compatibility

GARY LEGG, Senior Technical Editor

They're not just for memory anymore. PC cards—modules not much bigger than credit cards—now contain modems, faxes, LAN adapters, and even disk drives. Unfortunately, similar cards from different vendors aren't always interchangeable.

There's both good news and bad news about PC cards, a new category of plug-in peripheral devices for small computers. The good news is that PC cards are very small (like thick credit cards) and very smart (merely plugging a new card into a computer slot automatically reconfigures the system). The bad news is that definition of a PC-card standard has lagged product development, so some cards lack features that would make them interchangeable with similar cards.

Incompatibility problems stem from a major addition that the Personal Computer Memory Card International Association (PCMCIA) made to the PC-card standard. The original standard (Release 1.0) covered only memory cards; last year's revision (Release 2.0) provided for peripheral devices of all types in what the PCMCIA calls I/O cards. The ramifications of Release 2.0 are so enormous that many of the technical details have yet to be specified.

A flood of new products, now being introduced before the PCMCIA standard is fully defined, threatens to exacerbate the situation. Manufacturers are so eager to tap a growing market, they simply can't wait for a final PCMCIA standard. Some even hope their products will set the standard's future direction.

New PC cards containing modems, faxes, LAN adapters, hard disks, and flash memory that emulates a hard disk will appear at next month's Comdex, joining the few I/O cards and the numerous memory cards already on the market. There will also be new computers that use the cards and new ICs that help implement both cards and systems (see **box**, "The anatomy of a PCMCIA system"). Some key system software that provides special PC-card services will also be making its debut.

Many of the Comdex products will be interim implementations that conform to the PCMCIA's goals but obviously not to every detail that will end up in a final PCMCIA specification. Other products—some hard-disk drives, for example—will take the physical form of PCMCIA cards without attempting PCMCIA compatibility. In those products, manufacturers believe, small size is benefit enough; attempting PCMCIA compliance would just delay market entry.

Eventual PCMCIA compliance, however, will be important in products for

As much as 20 Mbytes or more of flash memory will fit in a 3.3-mm-thick PCMCIA Type I card. Intel is the price leader in flash cards, selling its 20-Mbyte version for around $600.

nontechnical consumers. In subnotebook and palmtop computers and in handheld products known as personal digital assistants (PDAs), ease-of-use features that are key PCMCIA goals will be essential. Such features provide what is essentially "plug-and-play" capability.

Plug-and-play features make PCMCIA-compliant systems virtually goof-proof. For example, you can insert or remove a PC card while a system is running, and no damage will occur either to the system or the card. You can even plug any kind of PC card—containing disk drive, modem, memory, or whatever—into any card slot that will physically accept it. System software recognizes the card type and reconfigures itself appropriately. It also passes information about the card to the application program that is running, allowing the program to "gracefully" halt instead of proceeding with dire consequences.

The capabilities for hot insertion and removal of PC cards result from special requirements in the PCMCIA specification. For example, the pins on each PC card are of three different lengths. Power pins

The anatomy of a PCMCIA system

A computer designed to accept PC cards—plug-in modules specified by the Personal Computer Memory Card International Association (PCMCIA)—has special hardware and software features that let it make use of those cards. The tiny cards, each having their own special features, get most of the attention though.

PC cards are the size and shape of thick credit cards. They come in three thicknesses—3.3, 5.0, and 10.5 mm—and each has a recessed 68-pin connector. A card can contain either memory or a peripheral device.

A PCMCIA-compliant memory card can contain any type of memory (and combinations) except dynamic RAM (DRAM). The PCMCIA views DRAM as better suited for fixed system memory than for removable cards.

Peripheral cards, which the PCMCIA calls I/O cards, can contain any kind of device. Modem and hard-disk cards will be most prevalent for the near future, primarily because they're in demand for subnotebook computers. Flash-memory cards having a standard hard-disk interface will go in applications where size and weight are critical and cost is not.

Within a PCMCIA-compliant computer, most of the capability for using PC cards comes from software (**Fig A**). A BIOS-level module called Socket Services provides very basic capabilities. A higher-level module called Card Services provides special features that make PC cards easy to use. For example, Card Services recognizes different types of inserted cards and configures the system software accordingly.

Adapter IC connects bus to socket

An IC called a host adapter connects a PCMCIA-compliant computer's bus to one or more card sockets. Host adapters are hardware-dependent; each works with a specific processor type. Each adapter also needs a hardware-dependent version of Socket Services.

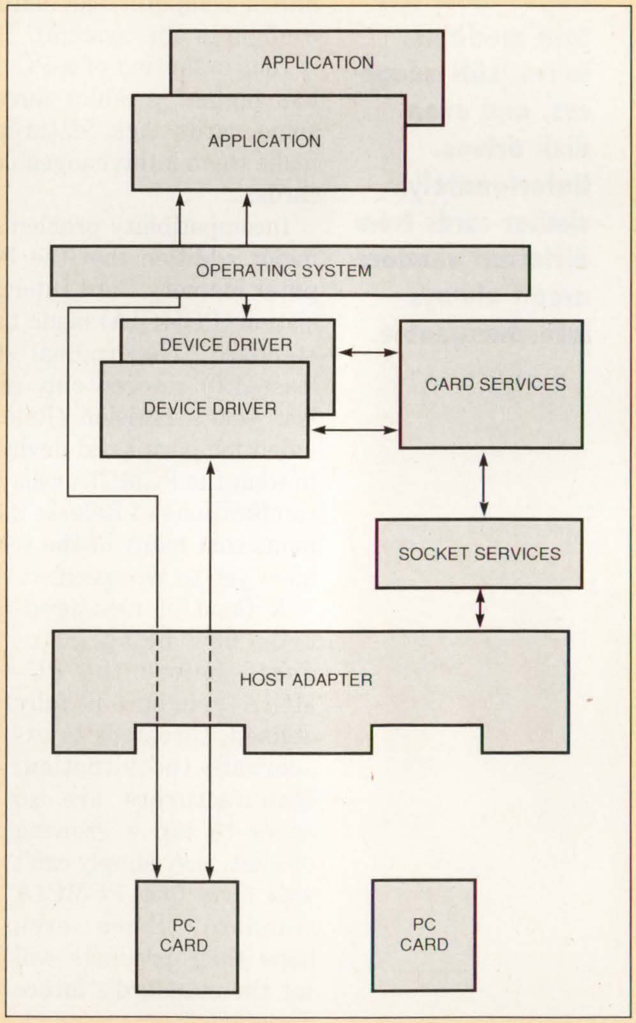

Fig A—Two software modules, Socket Services and Card Services, provide a standard software interface to PC cards. A host-adapter IC connects a computer bus to one or more card sockets.

are longest, so they make contact first and break contact last. Control-signal pins are intermediate in length; data and address pins are shortest. The different pin lengths, in combination with a specified electrical sequence and special system software, ensure that a system will not attempt to access a card that is in a power-up or power-down transition.

To avoid use of an inappropriate card, a PCMCIA-compliant system interrogates inserted cards to determine their functions and characteristics. Each card contains a description of itself in a memory table.

The system software that interrogates cards and takes appropriate action is just now becoming available. It is part of a software module known as Card Services that the PCMCIA outlined, but did not define, with Release 2.0. PCMCIA has defined a lower-level module, Socket Services, which is already available from several software companies.

Work-around solutions

The delay of Card Services has fostered a variety of interim approaches to PCMCIA product de-

Existing host-adapter ICs reflect a changing PCMCIA standard. Some implement only the requirements of PCMCIA's Release 1.0; recent introductions, however, also cover Release 2.0.

Recently introduced adapter chips are register-compatible with Intel's 82365SL, the first adapter to comply with PCMCIA 2.0. Intel introduced the 82365 last year, along with an Exchangeable Card Architecture, the company's own specification for implementing PCMCIA systems on 80x86 processors.

Existing PCMCIA host-adapter chips are necessarily similar because virtually all PCMCIA implementations are on 80x86 systems. IC manufacturers differentiate their products, however, by adding certain features. Databook's DB86082, for example, implements a PCMCIA Release 2.0 interface and adds a standard hard-disk interface. Fujitsu, Databook's manufacturing partner, sells the same chip under its own name.

Other distinguishing features of adapter ICs include on-chip line buffers, advanced power management, and versions for either one or two card sockets. One-socket versions are slightly cheaper and smaller, important for handheld consumer products. Two-socket versions can link to give a system more than two sockets.

Most host-adapter chips currently sell for around $25 and will eventually drop to about $10, sources say. In addition to Intel, Databook, and Fujitsu, Cirrus Logic and Vadem manufacture the chips. Vadem's product ($38 in OEM quantities) is a 1-chip PC that includes a PCMCIA 1.0 socket interface for memory cards. The company is also working on a stand-alone Release 2.0 adapter chip.

The two key software modules for PCMCIA systems, Socket Services and Card Services, are closely tied to system BIOS software. Socket Services, in fact, becomes a part of BIOS in most PCMCIA systems. Because Socket Services is hardware dependent, it allows higher-level software to be hardware independent.

Card Services, more than any other part of a PCMCIA system, provides the intelligence that makes PC cards so easy to use. It must recognize any inappropriate card, for example, so that a system can reject the card and halt gracefully instead of crashing. It must also dynamically reconfigure a system for any newly removed or newly inserted card. As part of dynamic reconfiguration, it must monitor and allocate all system resources, such as I/O ports and interrupt levels.

To recognize an inserted card, Card Services reads the Card Information Structure (CIS) that each card contains in a section of on-card memory. A CIS can contain very basic information, such as interface and electrical characteristics, or extremely detailed information. The more detailed information might specify the logical organization of data on a card or even include details of specific card applications. Card Services must know how to process whatever information it may find in a CIS.

By allocating system resources to a newly inserted card, Card Services spares computer users the complicated task of specifying interrupts and I/O locations. It also allows each card slot to accept any type of card without the need for setting switches or jumpers.

Because Socket Services and Card Services are closely tied to BIOS software, most implementations of the two modules are from companies that are also BIOS vendors. One exception is Databook, which offers its own software with its host-adapter chip. Other companies that provide Card Services include SystemSoft, Phoenix, American Megatrends, and Award Software, which licenses software from Databook.

PC CARDS

velopment. Most system implementations, in keeping with PCMCIA's intentions, use a version of Card Services that is essentially complete, but which may require revision when the Card Services specification is formally released. Another approach uses card-specific software drivers instead of Card Services. Many developers of PCMCIA products say that such work-around solutions will exist for an interim period of at least a few months and possibly much longer.

Hewlett-Packard's 20-Mbyte, 1.3-in. Kitty Hawk disk drive ($250 in OEM quantities) will soon be appearing in PCMCIA-compliant PC cards. PCMCIA Type III cards, which are 10.5 mm thick, can hold either a 1.3-in. or a 1.8-in. drive.

Some of the difficulties in pinning down the PCMCIA specification come from trying to satisfy present needs while providing for long-term flexibility. For example, the existing market for 80x86-based computers running DOS is strong, but the PCMCIA doesn't want to undermine card portability by limiting its specification to a particular type of processor or operating system. So, while the PCMCIA struggles to define a specification that is sufficiently general, manufacturers grow impatient for a specification that addresses their immediate, specific concerns.

In some cases, manufacturers object to the added difficulties and costs of flexibility. For example, PCMCIA allows both normal operating voltage (5V) and a reduced operating voltage (3.3V) in cards. However, to ensure that cards won't get damaged in any slot, PCMCIA requires that all cards be ca-

For more information . . .

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

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CIRCLE NO. 55

PC CARDS

pable of initialization at 5V. Reduced-voltage operation is permissible only after initialization and after the system determines by interrogation that a card is capable of 3.3V operation.

The requirement for cards to accept, and for systems to provide, both 5 and 3.3V is especially objectionable to manufacturers of small, cost-sensitive consumer products. Many of them would like to see a 3.3V-only provision.

Details to be worked out

Other issues—controversial or simply difficult—will be PCMCIA concerns for some time to come. All the details of implementing an 80x86 protect mode, for example, have yet to be worked out; real-mode DOS-based systems comprise most of the market and thus have attracted most of the attention. A PCMCIA working group is even investigating ways to expand the PCMCIA interface from its present 8- and 16-bit operation to a 32-bit bus.

But whatever direction or directions the PCMCIA standard takes, it is still likely to become a major standard for connecting peripheral devices to small computers. The need for peripherals that are small, physically interchangeable, and foolproof is clear; the PCMCIA, for all its immediate problems, is addressing that need. EDN

References

1. *PC Card Standard*, Release 2.0, Personal Computer Memory Card International Association, Sunnyvale, CA, 1991.

2. *Socket Services Interface Specification*, Release 1.01, Personal Computer Memory Card International Association, Sunnyvale, CA, 1991.

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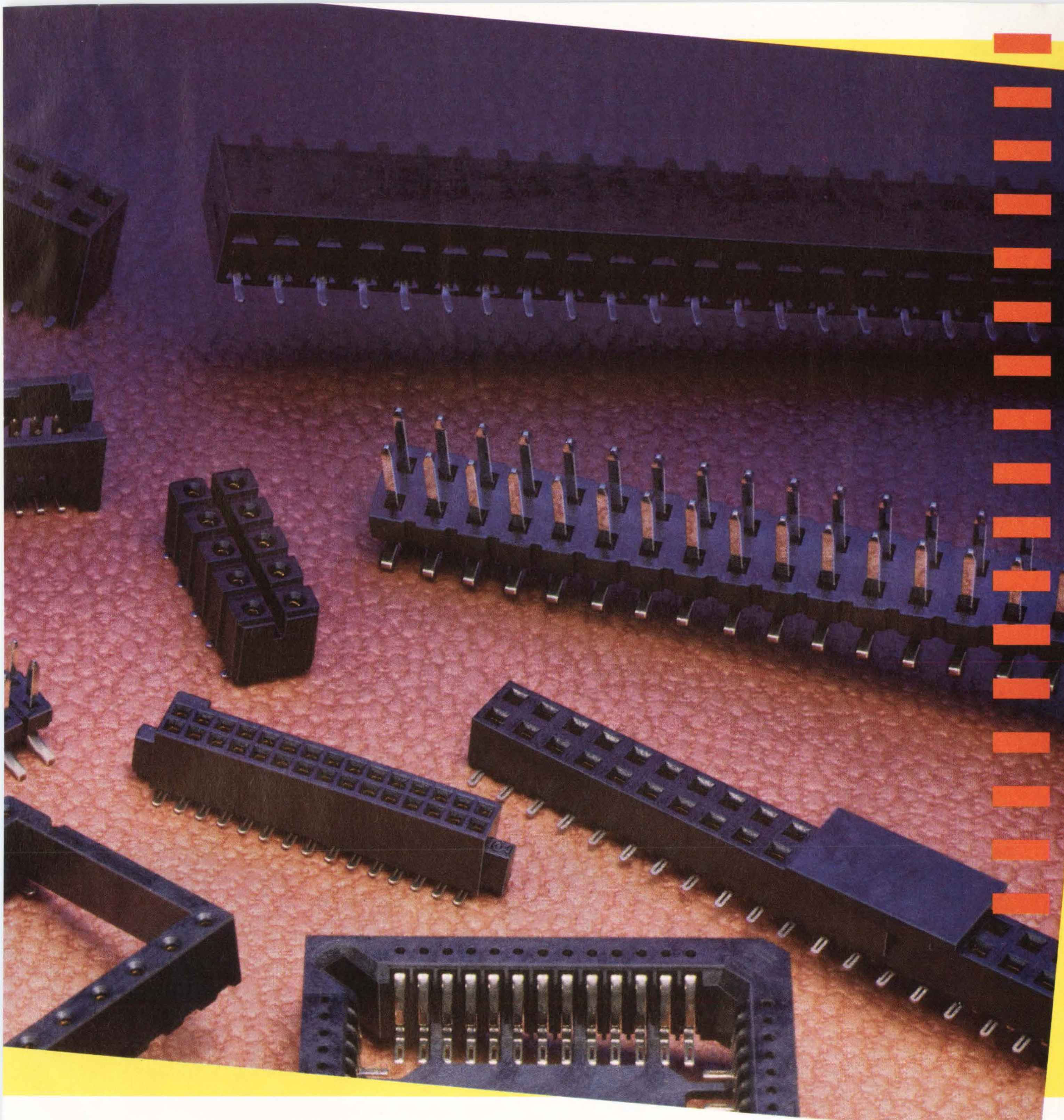

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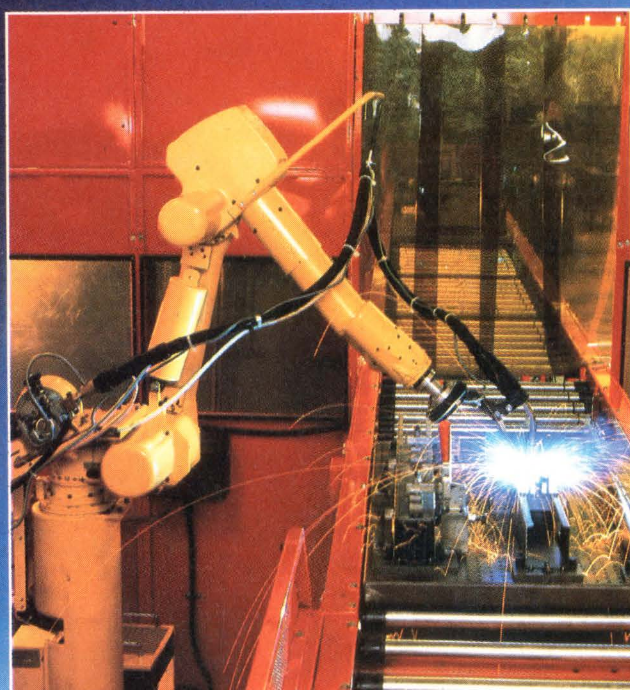

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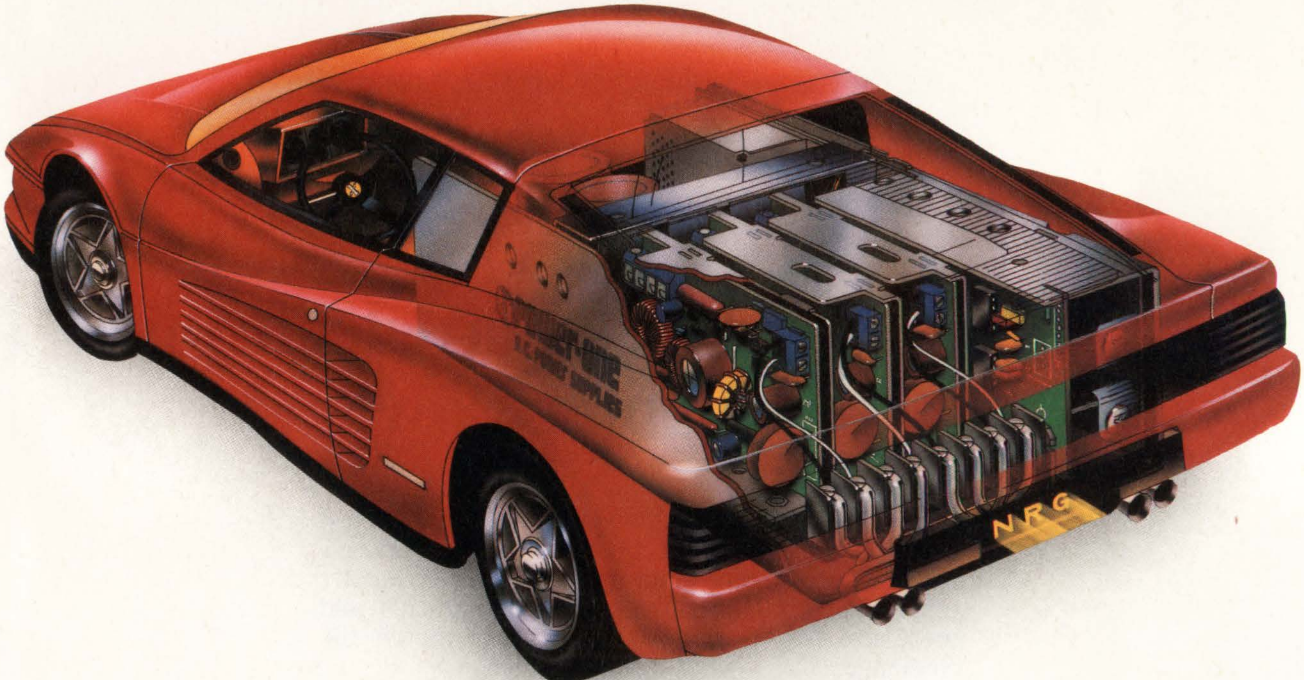

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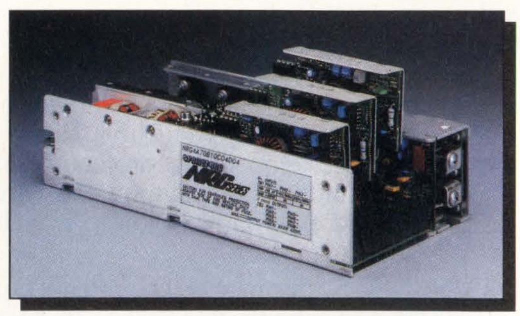

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CIRCLE NO. 62

Chip sets help bring PC architectures to embedded control

RICHARD A QUINNELL, Technical Editor

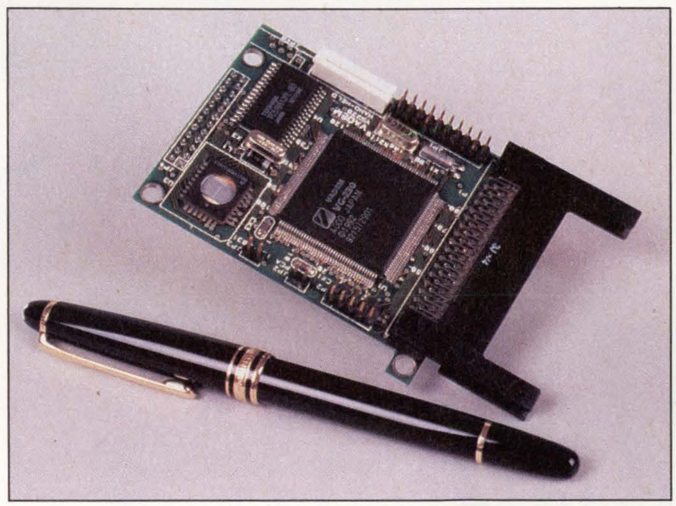
The IBM-PC architecture offers many advantages as the core of an embedded-control design. However, unless you have special needs, designing with PC chip sets can be more trouble than it's worth.

In the face of shrinking product-development cycles, one option available for embedded-control system designers is to use an industry-standard architecture as the product's processing engine, rather than designing the engine from scratch. Using a ready-made architecture lets you focus your development efforts on your most important system component—software. The IBM PC/XT and PC/AT are good candidates because their core-logic design has already been captured in PC chip sets, further shortening design time. Unfortunately, suppliers of these sets are geared toward high-volume applications, not embedded control.

The PC architectures offer numerous advantages as core processors for embedded-control systems, not the least of which is ease of software development (**Refs 1** and 2). Tools for software development on MS-DOS computers are legion, and virtually every engineer already has, or has access to, a PC-compatible computer to work on. In addition, many software designers are already familiar with programming the PC, so your people probably won't have to spend time learning a new system.

If your system's core is fully PC and MS-DOS compatible, you'll be developing the software in your system's native environment, eliminating the need to port your software from host to target. You'll also have numerous hardware peripherals available. These include networking, graphics display, mass storage, telecommunications, and data-acquisition cards, which you can add to your system without any design effort.

The existence of inexpensive (as low as $12) PC chip sets is another hardware bonus of the PC architectures—most of the logic design is already done for you.



All-in-one PC chip sets let embedded-control designers incorporate PC compatibility even with the most demanding space constraints. This example uses Vadem's chip set to provide a PC/XT with one PCMCIA card slot.

The chip sets sweep together many of the PC's key LSI components, as shown in **Fig 1** for the PC/AT, and eliminate some buffers and glue logic.

Many chip sets also go beyond the original PC/AT structure to include cache controllers that boost system performance. Some, such as the Chips and Technologies F8600, the NEC V41 and V51, and the Vadem VG-230 are nearly complete PC/XT systems on a chip.

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CIRCLE NO. 63

PC CHIP SETS

They include the CPU along with the system logic, needing only RAM, BIOS (basic I/O system) ROM, and some buffers.

If you want to design with PC chip sets, however, you have some significant logistics problems to overcome. PC-chip-set vendors evolved in response to the dynamic and competitive standard-computer marketplace. As a result, they aren't structured to meet the individualized needs of embedded-control applications.

Further, as an embedded-control customer, you'll have trouble getting the attention of many PC-chip-set vendors. Several vendors are small, with less than 100 employees, and concentrate their efforts on new product design, not design assistance. Some of the larger vendors, such as Siemens, are not interested in the embedded-control business. Others, such as Motorola and National Semiconductor, are not accepting any new business.

Vendors offer limited help

Even if they're interested in your business, most PC-chip-set vendors are unprepared to offer significant technical support. Instead, they are organized to provide turnkey computer designs (including schematics, parts lists, and pc-board artwork) to a handful of large customers. In most cases, you'll have to depend instead on distributors or sales representatives for your support.

Continued availability of the chip set can be another concern. To keep pace with their primary market, chip-set vendors continually pursue the leading edge of PC performance. As a result, chip sets have market lifetimes of 12 to 18 months. After that, the chip sets go out of production unless you are a large-enough customer to make continued production worthwhile. Even so, given the competition occurring in the chip-set market, the vendors themselves may start to disappear.

In addition to the problems of supply and technical support, designing with PC chip sets places heavy demands on your manufacturing capabilities. Chip sets all come in surface-mount packages (see **Table 1**), some of which are large and dense. If your production line isn't set up to handle fine-pitch surface-mount, you may not be able to use a chip set.

Further, the chip sets themselves may not be adequate for your needs. Because they are intended for computer use, most chip sets are only rated for operation over 0 to 70°C. Applications with harsher temperature requirements may not be feasible. Even if you can accept the 0 to 70°C range, several experienced chip-set users have found that the temperature ratings are sometimes optimistic. They suggest you run temperature tests on all

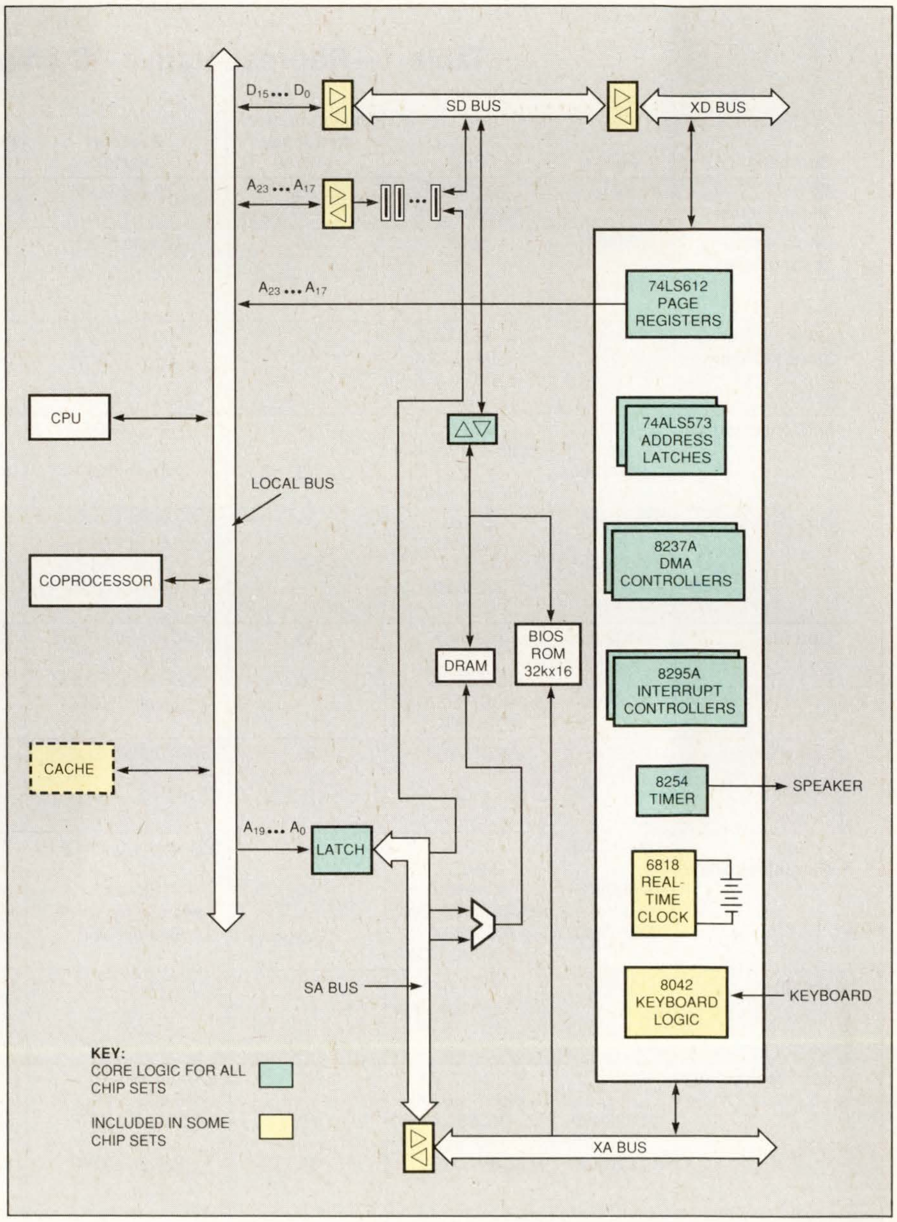

Fig 1—Many key elements of the original PC/AT architecture, shown here colored, have been swept into logic chip sets. In some cases, the real-time clock or keyboard controller are also incorporated.

candidate chip sets to weed out marginal designs.

Another challenge to face when designing your own embedded-PC core involves something the chip sets don't include: the BIOS ROM. The BIOS ROM is potentially the biggest hurdle for embedded-control designers to clear because it controls your design's software compatibility with standard PCs, yet it assumes your system configuration is that of a general-purpose computer.

Standard BIOS ROMs are available from a number of sources, including the chip-set vendors, at relatively low cost. Unfortunately, the standard BIOS is unsuitable for most embedded-control applications. You may, for example, want to boot your system from ROM instead of a disk drive. You also might want a custom power-up message on the display device to conceal the existence of a PC inside your system. You might want to use a custom key panel, or have no keyboard at all.

A standard BIOS may cause your system to fail if you don't use a standard keyboard. The BIOS will check that the keyboard is functioning during a power-up self-test sequence. If the test fails, the BIOS will halt execution. In an AT sys-

Table 1—Representative PC chip sets

Company	Part #	CPU	Maximum clock frequency (MHz)	Package size(s)	Price (1000)	Special features
ACC Microelectronics	2046	80386DX 80486SX/DX	50	208-pin PQFP	$50	Includes dynamic-RAM controller, clock generators.
Chips and Technologies	F8680	8086	14	160-pin PQFP	$35	Single chip includes CPU and system logic, LCD controller, PCMCIA interface, and serial port. Offers system-management software mode.
Eteq Microsystems	Cheetah Jaguar	80486SX/DX 80386DX 80486SX/DX CY486DLC	50 50	160-pin PQFP 184-pin PQFP	$12 $15	VESA local bus interface. VESA local bus interface, write-back cache controller.
NEC Electronics	μPD70270 (V41) μPD70280 (V51)	V20HL (8088-compatible) V30HL (8086-compatible)	16 16	160-pin PQFP 160-pin PQFP	$25 $25	Single chip includes CPU and system logic. Runs 8 MHz at 3V. Single chip includes CPU and system logic. Runs 8 MHz at 3V.
Oak Technology	OTI-020 OTI-040	80286 80386SX 80286 80386SX	33 33	144- and 160-pin PQFPs 144- and 160-pin PQFPs	$25 $60	Nine programmable bidirectional I/O pins. Local-bus VGA chip interface. Power management independent of operating system. Local-bus VGA chip interface.
Opti Inc	82C283/ 82C206 82C498/ 82C206	80386SX 80386DX 80486SX/DX/DX2 CY486DLC	33 50	160-pin PQFP and 84-pin PLCC 208-pin PQFP and 84-pin PLCC	$18 $28	Includes dynamic-RAM controller. Includes cache and dynamic-RAM controllers.
Symphony Laboratories	SL82C460 (Haydn)	80486SX/DX	66	Two 160-pin PQFPs	$50	VLbus, flash memory, x36 dynamic-RAM interaccess. Includes posted-write cache controller with built-in write buffers and tag RAM.
United Microelectronics	UM82C330 UM82C480B M82C490	80286 8386SX 80386DX 80486SX/DX/DX2 80386DX 80486SX/DX/DX2	20 50 50	100- and 160-pin QFPs 100- and two 160-pin QFPs 208-pin QFP	$12 $20 $20	Offers sleep mode. Includes cache and dynamic-RAM controllers. Runs 33 MHz at 3.3V. Runs 33 MHz at 3.3V. Available first quarter of 1993.
Vadem	VG-230	V-30HL (8086-compatible)	16	160-pin QFP	$84	Single chip includes CPU and system logic, CGA LCD controller, serial and parallel ports, PCMCIA interface, keyboard scanner, and pen-ink plane.
VLSI Technology	Scamp II VL82C480 VL82C486	80386SX/DX 80486SX/DX 80386DX 80486 80486SX/DX	33 40 33	208- and 160-pin MQFP and 100-pin TQFP 208-pin MQFP 208-pin MQFP	$73 $35 $30	3.3 or 5V operation. Integrated write-back cache control can use VL82C113A for I/O control. 32- or 64-bit dynamic-RAM interface, can use flash memory for BIOS, can use VL82C113A for I/O control.

Note: PQFP=plastic quad flatpack; PLCC=plastic leaded chip carrier; QFP=quad flatpack; MQFP=metric quad flatpack; TQFP=thin quad flatpack.

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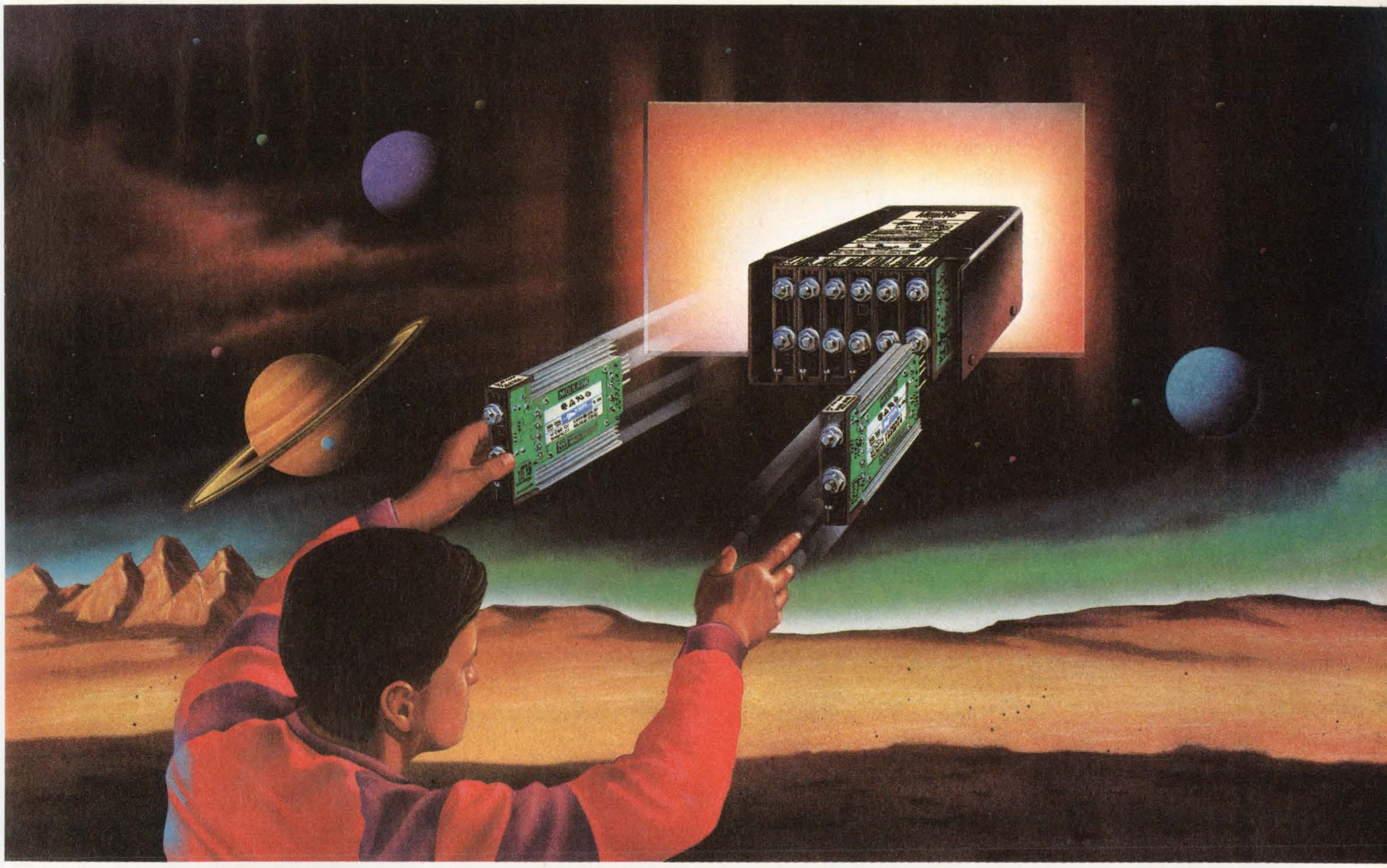

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PC CHIP SETS

tem, the standard BIOS will also stop if the system-configuration data, stored in the battery-powered real-time clock IC, is faulty. A dead battery, then, can cripple your entire system.

Modifying the BIOS can be an expensive proposition. To obtain the source code for a chip-set-optimized BIOS used in mass-production computers, expect to pay as much as $25,000 to $50,000. Once you have the source code, you'll have to be careful that your modifications don't change the BIOS's compatibility with the standard. Otherwise, you'll lose most of the software advantages that the PC architecture promises.

You may also want to modify MS-DOS to meet your needs. This may involve paring it down to its essentials by eliminating device drivers and file handlers your system doesn't need (**Ref** 3). It could also mean augmenting DOS with a real-time operating system to handle multitasking and time-critical functions. As with the BIOS, you'll need to take care to maintain strict compatibility with standard DOS.

One way to sidestep all of the

Your production line must be able to handle large, fine-pitch surface-mount devices, such as these from VLSI Technology, if you're going to design your own embedded PC.

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problems with designing in PC-chip sets is to buy ready-made PC-compatible modules. A number of vendors, including Ampro and Radisys, offer such modules in a variety of configurations. You can buy full MS-DOS computers on modules that fit VME, STD, VXI, and other buses.

You can also find compact modules, as small as 14 in.^{2}, that incorporate the core CPU, interface logic, and memory of a PC. The PC/104 Consortium, for example, has defined a series of stackable 3.6× 3.8-in. modules (**Ref 4**) that offer a range of PC-compatible computers and peripheral functions.

The advantage of using a module rather than designing with a PC-chip set is that the module vendors have tackled all the logistics problems for you. They provide the necessary technical assistance, have already modified the BIOS for embedded use, and serve as a buffer for chip-set obsolescence. The module vendor often provides several pin-compatible designs, so that you have an alternative CPU core if a given chip set is suddenly discontinued. You can also use such modules to provide a painless performance upgrade path for your system.

Chip sets have some advantages

Still, there are circumstances in which you would want to do your own design rather than use a module. You may, for example, need an unusual shape for your controller's pc board. Building your own design may also be more cost-effective. If your production volumes are greater than 1000 units/year, for example, your own design may be cheaper to produce.

A chip set may also offer special features that are not available in modules. The Oak Technology OTI-040, for example, offers power-management functions that don't depend on your choice of operating system. Vadem's VG-230 has a built-in CGA display driver with an additional bit plane for the "ink" data of a pen-based user interface. Several chip sets incorporate a PC-MCIA (Personal Computer Memory Card International Association) 2.0 interface; others offer 3V operation.

If you do decide to tackle an embedded-control design with a PC-compatible core, several sources of help are available. When looking for a chip set, for instance, you may want to invest $1495 in a copy of *PC Chip Sets* by Microdesign Resources, publishers of the newsletter *Microprocessor Report*. This document includes discussions of the PC/XT and PC/AT architectures, main and cache memory structures, peripheral interfaces, and power management. It also offers detailed technical information on virtually every PC chip set available, including system block diagrams and performance benchmarks. Further, it provides business details for each chip-set vendor, so you can estimate the likelihood that your supplier will remain in business.

Further training available

If you want more information on how to adapt the IBM PC architectures for embedded control, Radisys Corp offers free half-day seminars on the topic from the viewpoint of a module supplier. For greater technical depth, you can take a course in embedded-PC design from Annabooks. This $1195 3-day course includes discussion of the BIOS, ROM-based DOS, chip-set selection, and bus protocols.

Annabooks also offers several textbooks on PC design issues, many of which contain the necessary software. These include books on ROM-based disk emulators, resident debugging routines, and BIOS development. The BIOS books contain a complete plain-vanilla BIOS in C, including source code and detailed description, for less than $200. Royalties for production use of the BIOS run $2 to $4 per system shipped. Further, Annabooks offers an MS-DOS developer's kit and handles licensing of Microsoft's MS-DOS 5.0 ROM version for small-quantity (<1000 copies) users. EDN

Acknowledgment

The author wishes to thank John Choisser of Annabooks and Michael Slater of Microdesign Resources for their generous contributions of time and materials for this article.

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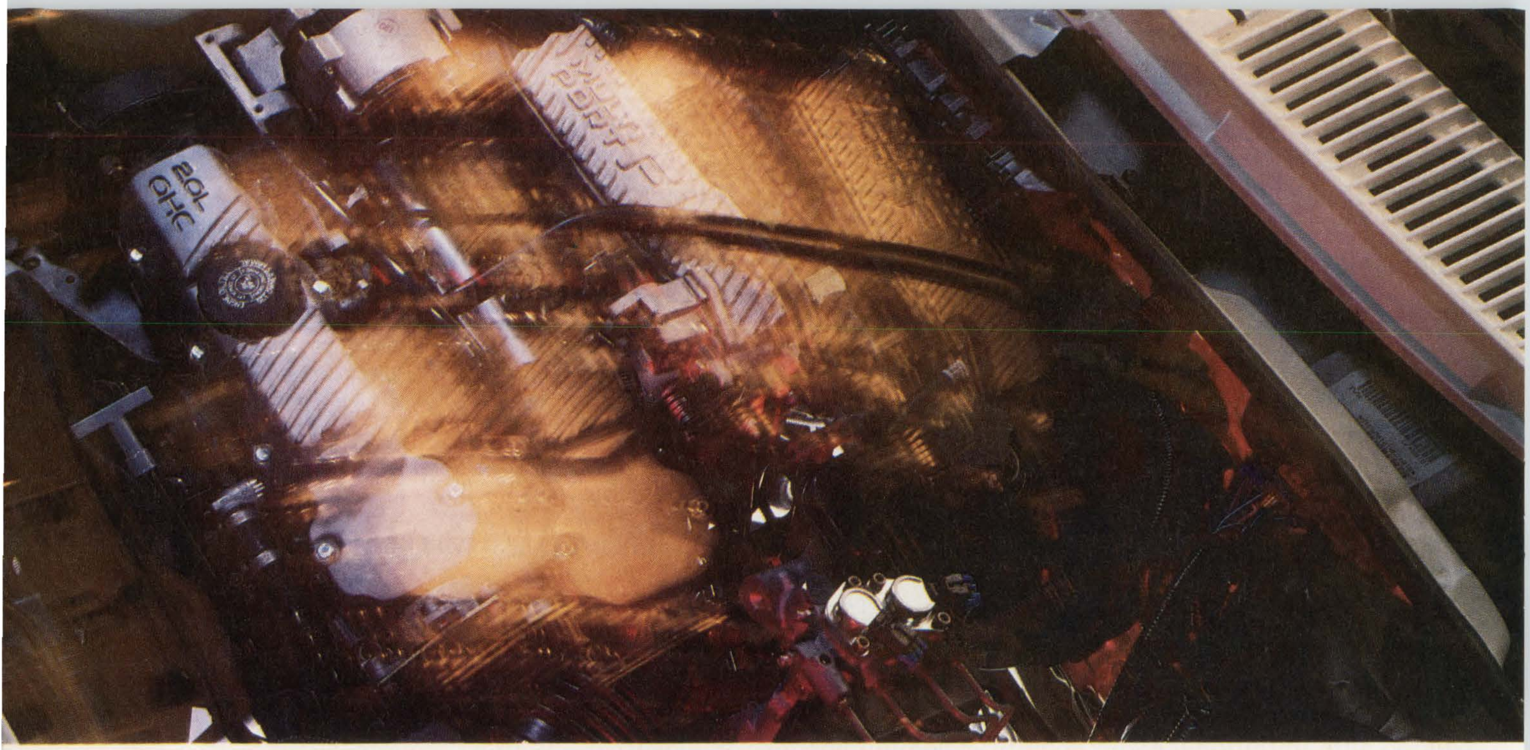

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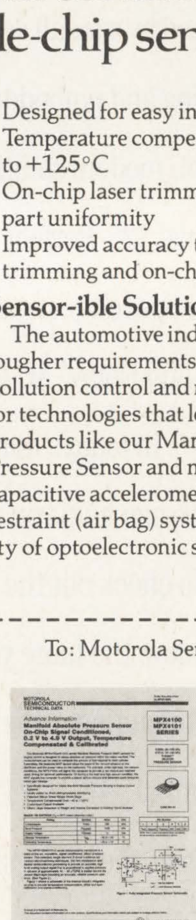

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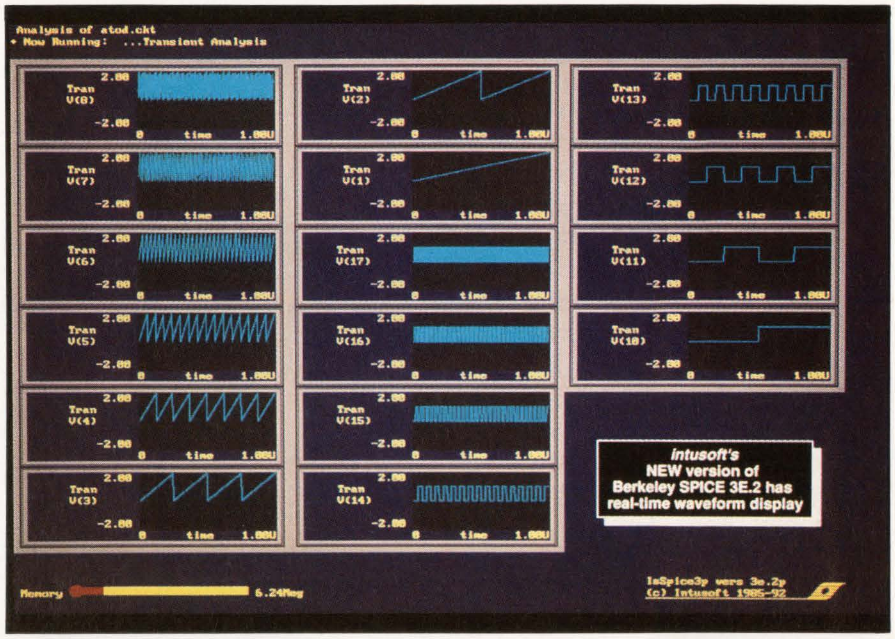
PC-compatible simulator enhances latest Berkeley Spice version

IsSpice3 from Intusoft is based on the latest Berkeley Spice 3E.2 version and includes a number of enhancements. The simulator performs ac, dc, transient, noise, distortion, Fourier, pole-zero, temperature, sensitivity, and mixed-mode analyses on most circuits operating from dc through microwave frequencies. The company has utilized—and spent considerable effort debugging—the entire 3E.2 kernel in this simulator; other Spice vendors have added portions of the Spice 3 code to their Spice 2G-based versions or based their simulators on previous versions of Spice 3.



The IsSpice3 simulator from Intusoft is based on Berkeley Spice 3E.2. The simulator includes all the abilities of Spice 2G.6 and enhances its analysis and modeling features. The simulator provides backward compatibility to all vendor-supplied op-amp model libraries.

Unlike earlier Berkeley Spice 3 versions, Spice 3E.2 includes all the capabilities of Spice 2G.6 and enhances its analysis and modeling features. New analysis abilities include an improved distortion analyzer, pole-zero analysis, and allowing you to change the temperature of any individual element in the simulation (Spice 2G.6 only let you change the temperature of the entire circuit). New models include a MESFET, three MOSFETs (BSIM 1 and 2 and Level 6), lossy-transmission lines, and current- and voltage-controlled switches.

On top of these features inherent to the Berkeley code, IsSpice3 adds the following features: an interactive waveform display that draws waveforms from the dc, ac, noise, and transient analyses as the simulation runs, letting you decide whether to continue with the simulation; the ability to use Boolean logic expressions for if-then-else statements, mixed-mode simulations and analog behavioral statements, such as in-line equations; and user-adjustable memory allocation and control. The simulator is compatible with the I/O syntax of 2G.6-based simulators. One catch with Spice 3E.2 is that the code doesn't recognize the dependent-source polynomial syntax, and instead uses a new nonlinear dependent source called the B element. IsSpice3 includes additional code that automatically converts the polynomial syntax to this new element, providing backward compatibility to all vendor-supplied op-amp model libraries.

The simulator runs on 386- and 486-based PCs and compatibles, Macintosh, and NEC 98-series computers. Upgrades from previous versions of IsSpice are available. You can also purchase the program as part of the ICAP/4 simulation system, which includes a schematic-entry program, model libraries, the simulator, analog behavioral modeling, Monte Carlo analysis, and a graphics post processor for $695 or as part of ICAP/4, $1575.—**Anne Watson Swager**

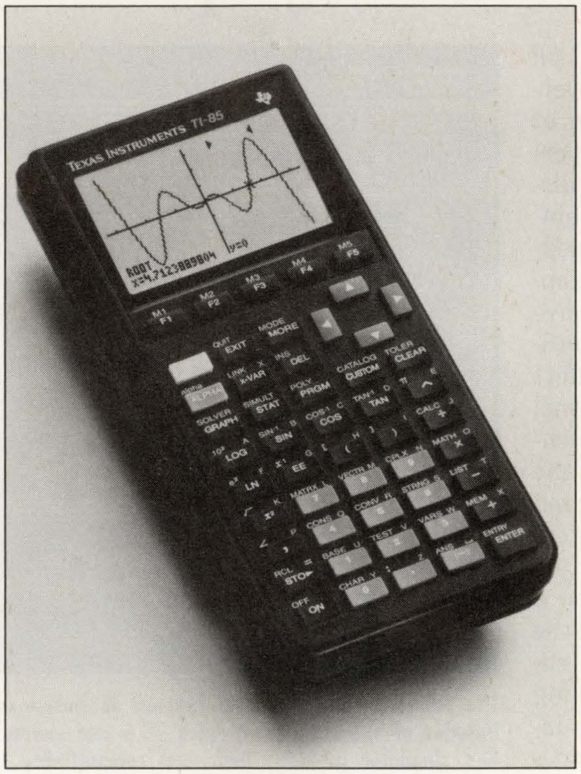
Intusoft, 222 W 6th St, Suite 1070, San Pedro, CA 90731. Phone (310) 833-0710. FAX (310) 833-9658. **Circle No. 386**

Graphing scientific calculator solves equations for you

The TI-85 scientific calculator has four features that set it apart from less-capable scientific calculators: graphics, an equation "solver," easier programming, and simple connectivity to personal computers.

The calculator's LCD can show eight lines of 21 characters each or a 128×64-pixel graph. In text mode, you can enter equations or entire programs in FORTRAN-like syntax.

In graphical mode, the calculator allows you to analyze a graph, or graphs, even as you view them. Graphing functions include zooming, taking a derivative at a point, integrating between two limits, and obtaining intercepts. Cursor keys allow you to select the portion of the graph you want to analyze.



The TI-85's graphics display, cursor keys, and built-in functions allow you to perform numerous analyses on a graph as you view it.

You can access many of the calculator's built-in functions, or functions you have programmed in yourself, using menu selections displayed along the bottom of the LCD. You make your selections with five dedicated hot keys. The menus-and-hot-keys approach permits the calculator to have a large number of functions without having a corresponding number of keys.

The equation "solver" is a key feature that sets top-of-the-line scientific calculators apart from low-cost, "student" models. The well-known time-value-of-money equation provides examples of the solver's power. First, the equation has five variables. You can punch in one version of the equation, enter values for any four variables, and the solver will solve the equation for the fifth variable. Less-capable calculators would require you to solve the equation for each variable and enter a version of the equation for each solution, wasting precious memory and your time.

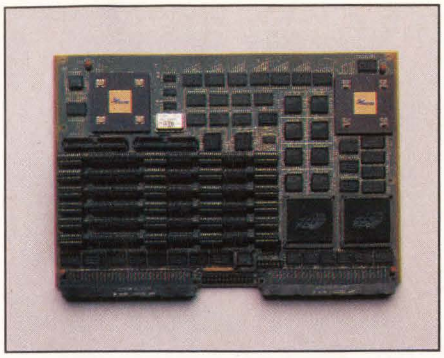
Second, in the time-value-of-money equation, no closed-form solution exists for rate of return. The solver will use numerical methods to obtain a solution. Calculators without a solver would require you to program an iterative solution. If your scientific calculator lacks a solver and is not programmable, you would be reduced to making manual iterations to determine the rate of return.

"Ease of programming" is easy to claim but hard to document. The calculator's programming language resembles high-level-language function calls more than it does a series of key presses. A typical programming step (for the "sinc" function) looks like y1 = fnint(sin t/t,t,0,x). This step integrates (sin t)/t between 0 and x.

The calculator can solve as many as 30 simultaneous, complex equations or find the roots of a 30th-order polynomial, and it can manipulate complex matrices of up to 30×30 elements. The unit has 32 kbytes of fixed RAM and no provisions for extending RAM or ROM.

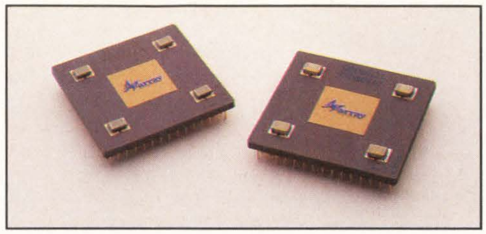
A built-in I/O port allows the calculator to exchange data and programs with an IBM PC or a Mac. The calculator runs off of four primary AAA cells and has an internal lithium cell for backup. The calculator measures $6.9 \times 3.2 \times 0.8$ in. and weighs half a pound. Instead of a soft holster, it comes with a clever, slide-off plastic hardshell case. The list price for the TI-85 is $130; calculators are heavily discounted, so expect the street price to be less.—**Charles H Small**

Texas Instruments, Consumer Relations, Box 53, Lubbock, TX 79408. Phone (800) 842-2737. FAX (806) 741-2146. **Circle No. 382**



400 MOPS FOR 6U VMEbus SYSTEMS

This 6U VMEbus board performs 400 million operations per second and is optimized for frequency domain processing such as FFTs and finite impulse response (FIR) filters using fast convolution. The FDaP features a private 32-bit, 20 MHz high-speed data I/O bus and extensive double buffering for continuous processing of real-time data. An additional 32-bit complex output provides phase/magnitude data. The a66540 is available in 25 MHz and 40 MHz versions. A single 40 MHz version can execute a 1K point FFT in 132.7 µs and a 64K point FFT in 13.1 ms. These times are nearly halved for real input. Multiple FDaPs can be cascaded to achieve almost linear improvement in FFT performance. Plug 400 MOPs into your system by calling **array** Microsystems' Hotline: 719-540-7999.



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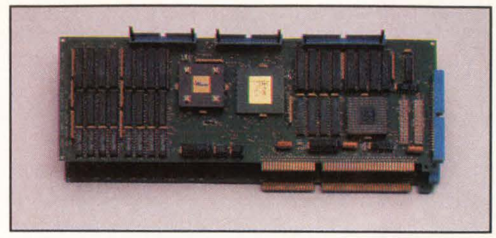
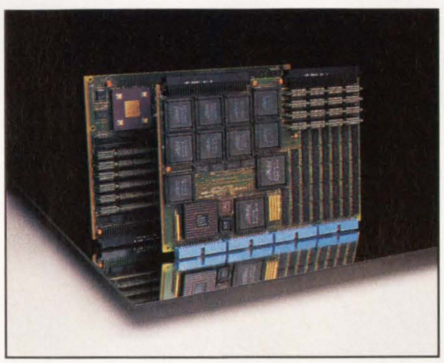
The Digital array Signal Processor (DaSP) executes 16 high-level instructions, including FFT butterflies, windowing, complex multiplies, and general-purpose functions. The Programmable array Controller (PaC) manages the entire system, including address generation for the DaSP and memory, and I/O up to 80 MHz. Using a single chipset, for example, a 1024 point FFT requires only 12 instructions and can execute in only 131 µsec; a complex FIR filter, using 28 instructions, processes at a 2.3 MHz rate. For even higher performance, you can cascade the chipset. Both utilize a 144-pin PGA format and are available in 30 and 40 MHz versions. To receive complete technical information, call **array** Microsystems' Hotline: 719-540-7999.



PC-FDaP PERFORMS 250 MOPS!

The a66550 Frequency Domain array Processor (FDaP) brings high performance FFT processing to any PC-AT compatible computer. The two board set will fit into two full size PC-AT slots, operate on the 16 bit PC-AT (ISA) bus, and allow real or complex input from either the high speed connectors on the back panel or from the PC-AT bus. The FDaP accommodates an optional complex I-and-Q to magnitude-and-phase converter for post-FFT processing. Available in two memory configurations, the a66550 handles complex FFTs up to 32K points and real FFTs up to 64K points. The a66550 can compute a 1024 point complex FFT in just 210 µs. For complete technical information, call **array** Microsystems' Hotline: 719-540-7999.



CORNERTURN PROVIDES QUANTUM LEAP IN 2D IMAGE PROCESSING PERFORMANCE

The a66545 Cornerturn™ board, used in conjunction with the a66540 FDaP board for real-time two-dimensional image processing, is the first capable of processing an entire 256 x 256 pixel frame of image data in 15.2 milliseconds. This equates to a continuous, real time rate of 65 frames per second. For 512 x 512 images, the board set transforms images in 71 milliseconds, or 14 frames per second. Designed for medical imaging, radar, sonar, machine vision, and other real-time 2D image processing applications, the board set features performance of 400 MOPS at a clock rate of up to 40 MHz. The Cornerturn accepts 32-bit complex I/O data through 10 MHz double-buffered external I/O connectors or through the VMEbus and stores it in one of four on-board frame store memory buffers. For technical assistance, call **array** Microsystems' Hotline: 719-540-7999.

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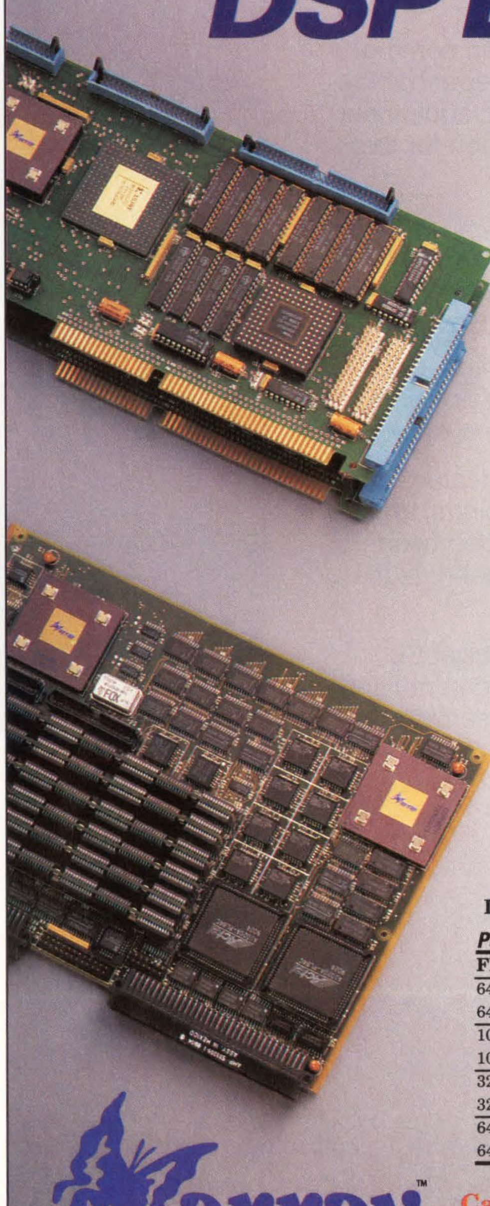

PC-AT DSP

1K FFT/126µs

DSP engine for the 16-bit PC-AT Industry Standard Architecture (ISA) bus

Performance Benchmarks

FFT size	a66550/32K @25MHz
64 Real	7.2 µs
64 Complex	10.9 µs
1024 Real	125.9 µs
1024 Complex	209.9 µs
32K Real	5.90 ms
32K Complex	10.49 ms
64K Real	15.73 ms
64K Complex	N/A

VME DSP

1K FFT/79.6µs

DSP engine for industry-standard VMEbus

Performance Benchmarks

FFT size	a66540A @40MHz	a66540A Cascade Sys.
64 Real	5.1 µs	2.9 µs
64 Complex	5.0 µs	3.7 µs
1024 Real	79.6 µs	29.6 µs
1024 Complex	132.7 µs	59.1 µs
32K Real	3.69 ms	0.91 ms
32K Complex	6.56 ms	1.82 ms
64K Real	7.37 ms	1.82 ms
64K Complex	13.11 ms	3.64 ms

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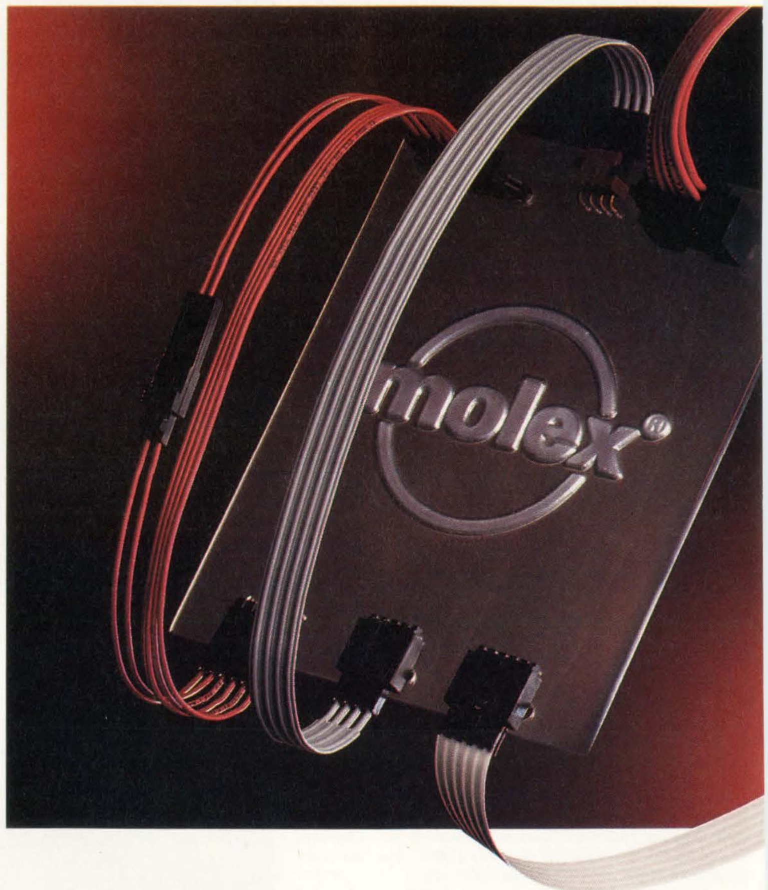

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CIRCLE NO. 67

Physical design libraries let you choose foundry

Compass Design Automation claims a first from an EDA company by offering a foundry-flexible family of physical layout libraries that also work with multiple EDA environments. Named the Liberty Series, the product and its associated services gives IC designers a single source for libraries that work with the CMOS process of their choice. The libraries also help semiconductor manufacturers make new CMOS processes that you can use within EDA environments more quickly than developing libraries one at a time for each new process.

The software retargets a base set of components to reflect the chosen set of design and electrical rules. The libraries include a set of circuit views, such as schematic descriptions, functional models, physical layouts, physical footprints, simulation models, and icons. The retargeting service generates timing models and power information that, with the previous views, make up a complete custom library.

The library takes a 2-tier approach to component organization. The lower-level components include memory blocks, standard cells, and gate-array macros that are ingredients in the higher-level components. The higher-level components include memory compilers, ALU and datapath compilers, functional system blocks, and application-specific standard products. The combination of the two lets semiconductor manufacturers avoid repeatedly developing low-level components for each new process, thereby freeing up time for developing the unique higher-level components.

Although Compass is a wholly owned subsidiary of semiconductor manufacturer VLSI Technology, the layout part of the libraries is not based on VLSI's process technology. Test marketing customers include ES2/US2, Evans & Sutherland, Hitachi, Hyundai, Matra MHS, National Semiconductor, Raytheon, Rockwell, Sierra Semiconductor, Thomson Consumer, TSMC, and VLSI Technology. Many of these customers accept designs incorporating the libraries for production in their processes.

The library works with products of more than a dozen EDA vendors including Mentor, Valid, Dazix, Viewlogic, Racal-Redac, ZyCAD, Genrad, and Synopsys. You can use the library for work with either two or three layers of interconnect. The library is available immediately; prices start at $100,000.

—John C Napier

Compass Design Automation, 1865 Lundy Ave, San Jose, CA 95131. Phone (408) 433-4880. FAX (408) 434-7820.

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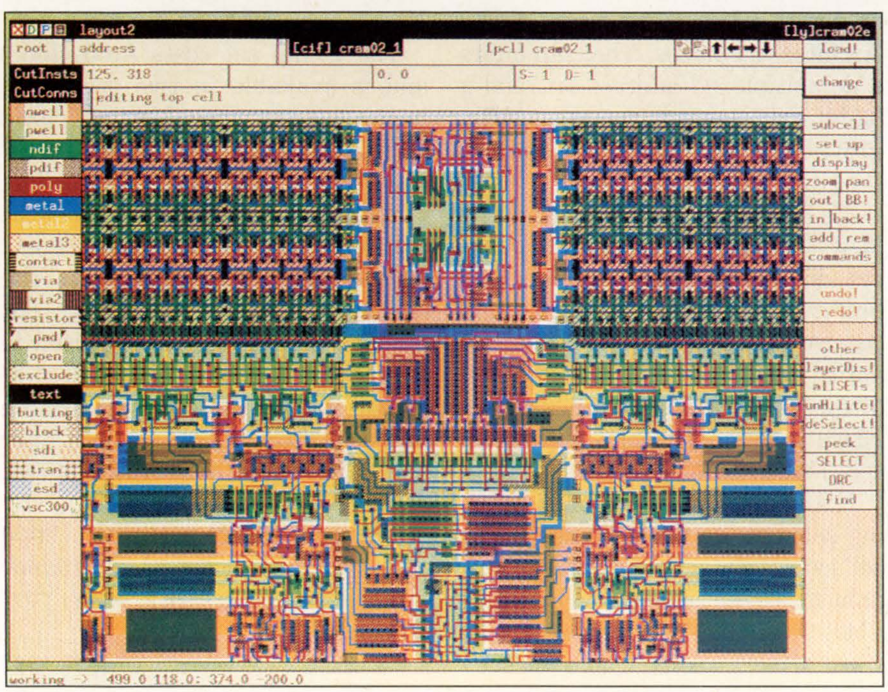
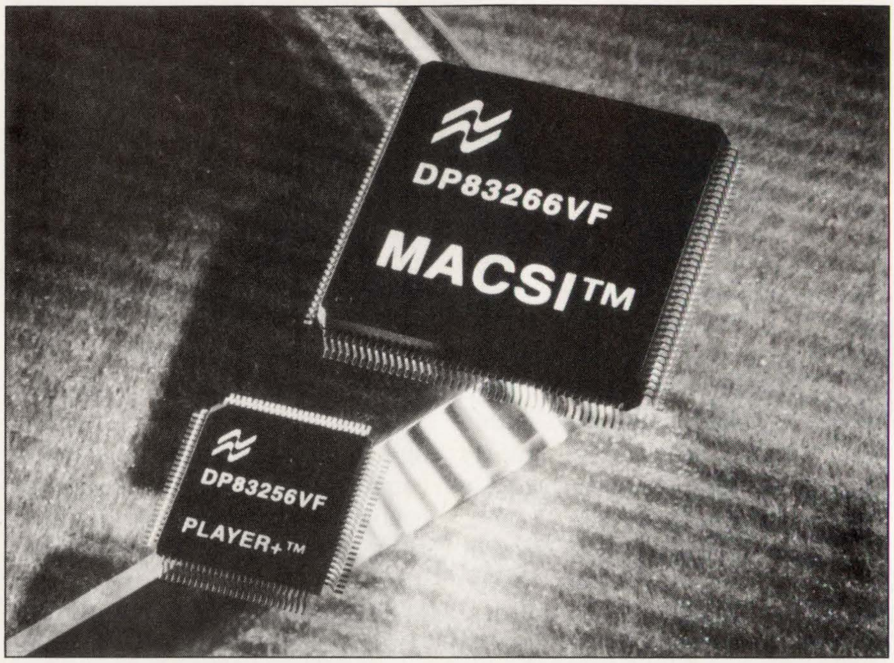


The RAM compiler in the Compass Liberty Series of libraries and compilers automatically generates RAM layouts.

2-chip set for FDDI cards handles fiber optics or twisted-pair wire

National Semiconductor has reduced its 5-chip FDDI (Fiber Distributed Data Interface) chip set to two chips, eliminated the need for external filter and timing components, and simplified the set's bus interface. Along the way, the DP83200 chip set acquired some additional features to relieve software overhead and to facilitate use of twisted-pair wire instead of optical fiber. The result is that FDDI adapter boards can be made smaller and less costly.



The DP83200VF chip set squeezes FDDI into just two chips, simplifying adapter-board design.

One chip (DP83256VF) in the set combines the physical-layer interface, clock recovery, and clock distribution functions that previously required separate devices. The other chip (DP83266VF) handles the system interface, memory control, and the media access control (MAC) protocol.

The physical-layer chip (Player+) incorporates all the necessary filter and timing components for data transmission and recovery on chip. It uses digitally controlled phase-locked loops, so the only external components needed are two loading capacitors, two power-supply decoupling capacitors, and an optional 12.5-MHz crystal.

The Player+ chip connects directly to fiber-optic transmitter and receiver modules for FDDI networks. It also offers some additional signals to simplify its use with unshielded twisted-pair wires. It provides, for example, a 125-MHz data clock. It also allows access to its clock-recovery circuitry for use by the data scrambling and unscrambling circuits that help control EMI in the twisted-pair wire link.

The system interface chip (MACSI) is designed for direct connection to the SBus used in Sun SPARC workstations. It is also usable with EISA and Micro Channel Architecture buses. The chip offers a demultiplexed address bus and a 32-bit data bus that run at 33 MHz, providing a data rate to memory of >1 Gbit/sec.

To help reduce bus latency, the MACSI incorporates two independent 4608-byte FIFO buffers. The buffers handle both transmit and receive data and can each hold one entire data frame. The buffers also allow the device to operate in FDDI's optional "Copy-All" multicast mode.

National Semiconductor is offering software to facilitate use of the set's station management (SMT) capabilities. The software conforms to SMT Version 7.2. Examples of software drivers are available for such network operating systems as Netware, LAN Manager, and the TCP/IP interface protocol.

The 2-chip set costs $165 (1000) and is available in two styles. In both cases, the MACSI chip (DP83266VF) is a 160-pin PQFP (plastic quad flatpack). The Player+ chip, however, comes as a 160-pin PQFP (DV83257VF) or a 100-pin PQFP (DP83256VF). The smaller pin-count device does not offer the additional signals used in twisted-pair wire networks. National is also offering evaluation boards (DP83200MK) for both fiber and twisted-pair networks at a cost of $3995.—**Richard A Quinnell**

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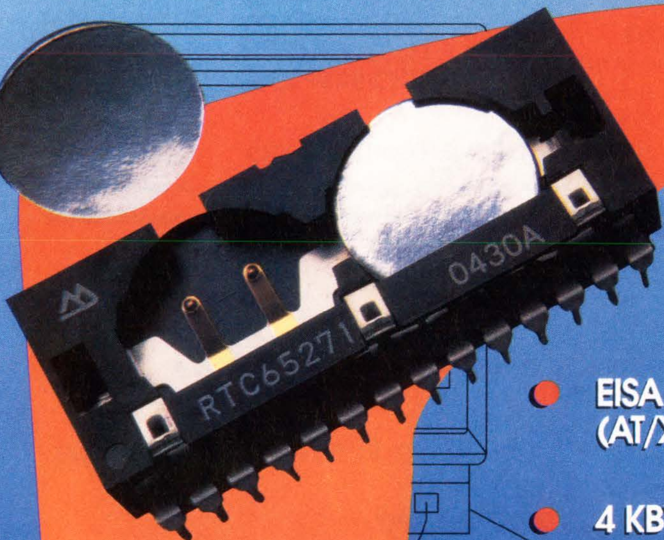

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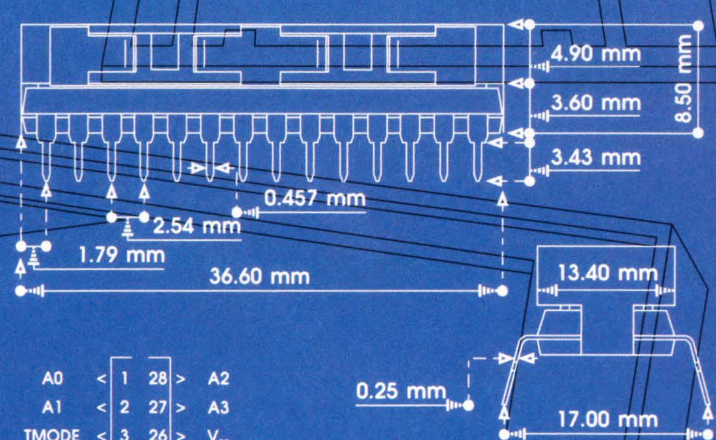

A0	1	28	A2
A1	2	27	A3
TMODE	3	26	V_{DD}
TCLOCK	4	25	SQW
$\overline{STBY}$	5	24	A4
D0	6	23	A5
D1	7	22	N/C
D2	8	21	$\overline{IRQ}$
D3	9	20	$\overline{RESET}$
D4	10	19	$\overline{RD}$
D5	11	18	N/C
D6	12	17	$\overline{WR}$
D7	13	16	$\overline{XRAM}$
V_{SS}	14	15	$\overline{RTC}$

SPECIFICATIONS

RATING		VALUE	UNIT
OPER. VOLTAGE		5 ±0.5	V
OPER. TEMPERATURE		-10 TO 70	°C
CURRENT CONSUMPTION	OPER.	15 (MAX)	mA
	STAND-BY	2 (MAX)	μA
	BACK-UP	0.5 (TYP)	μA

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CIRCLE NO. 68

12-bit DACs operate from 5V, provide 4.095V output swing

Despite all the hoopla surrounding the introduction of 3V parts—both digital and analog—plenty of 5V systems are still in need of better-performing 5V analog components. DACs are a case in point. Most existing DACs require an external reference and an external op amp to provide close to a 5V output swing.

The 12-bit DAC-8562 and DAC-8512 voltage-output DACs best this status quo. In addition to voltage-switched 12-bit D/A converters, both devices have internal bandgap references and rail-to-rail output amplifiers. Using a BiCMOS process, the DACs combine low-power CMOS for the logic parts of the design with complementary bipolar transistors for analog accuracy.

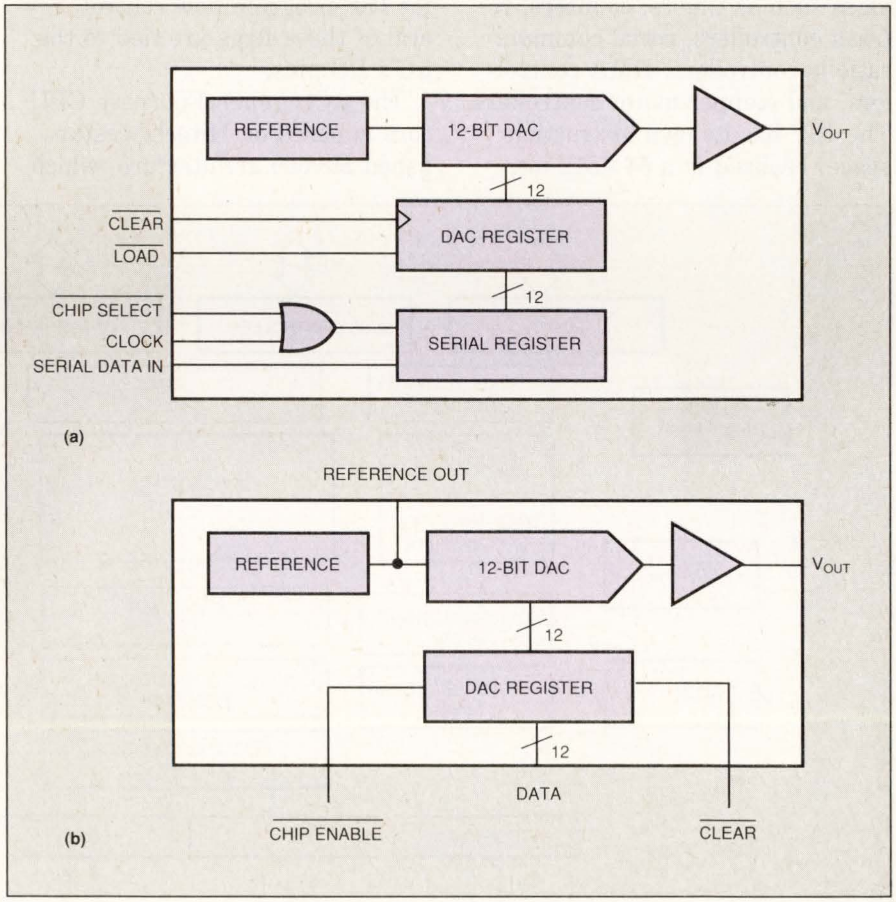
The company laser trims the reference to 2.5V. The op amp amplifies this voltage to provide an accurate full-scale output of 4.095V for a resolution of 1 mV/bit. (Performance curves in the data sheets indicate that the 0-to-4.095V output swing holds for loads approximately greater than 500Ω.) The amplifier can source and sink ±5 mA.

Even with higher integration, the 8512 serial-input version is extremely small—it fits in an 8-pin DIP and SOIC. The serial interface comprises three wires and features a 20-MHz data-loading rate. The 8562 is a parallel-input device. The simple parallel interface requires one $\overline{\text{CE}}$ (chip enable) signal. Because the 8562 has more output pins, it makes the internal reference available on a pin; the 8512 does not. The 8562 comes in a 20-pin SOIC and DIP.

When you drive the 8562 with TTL logic, typical power dissipation is 11 mW. When using CMOS logic, and when all inputs equal zero, the typical power dissipation drops to 3 mW. The typical power dissipation under the same conditions for the 8512 are 7.5 and 2.5 mW, respectively.

Two performance grades are available for each DAC. The E grades of the 8512 ($10.95) and 8562 ($12.50) feature maximum integral nonlinearity and differential nonlinearity of ±1 LSB. Typical E-grade integral nonlinearity specifications are ±1/2 LSB. The F grades, costing $6.95 and $8.95 (100) respectively, feature a maximum of ±2 LSB for both specifications. The company guarantees no missing codes for each grade of each device. The company specifies both DACs over a temperature range of −40 to +85°C.—**Anne Watson Swager**

Analog Devices Inc, 181 Ballardvale St, Wilmington, MA 01887. Phone (617) 937-1428. FAX (617) 821-4273. **Circle No. 381**



You need only a 5V supply to operate the serial 12-bit DAC-8512 (a) and parallel DAC-8562 (b). Both devices include an internal reference and output amplifier, which provides an output swing of 0 to 4.095V. The 8512 comes in an 8-pin SOIC or DIP.

μC teams CPU and 64-bit I/O subprocessor with abundant I/O hardware

Although microcontrollers (μCs) are used routinely in I/O-intensive applications, you often need to expend heroic programming efforts to attain the speed your application needs. The Hitachi H8/570 μC attempts to give you far more I/O horsepower than you can possibly use by teaming a microprogrammable, 64-bit I/O subprocessor with a general-purpose CPU. The chip also incorporates a variety of memory and I/O hardware (see **Table**).

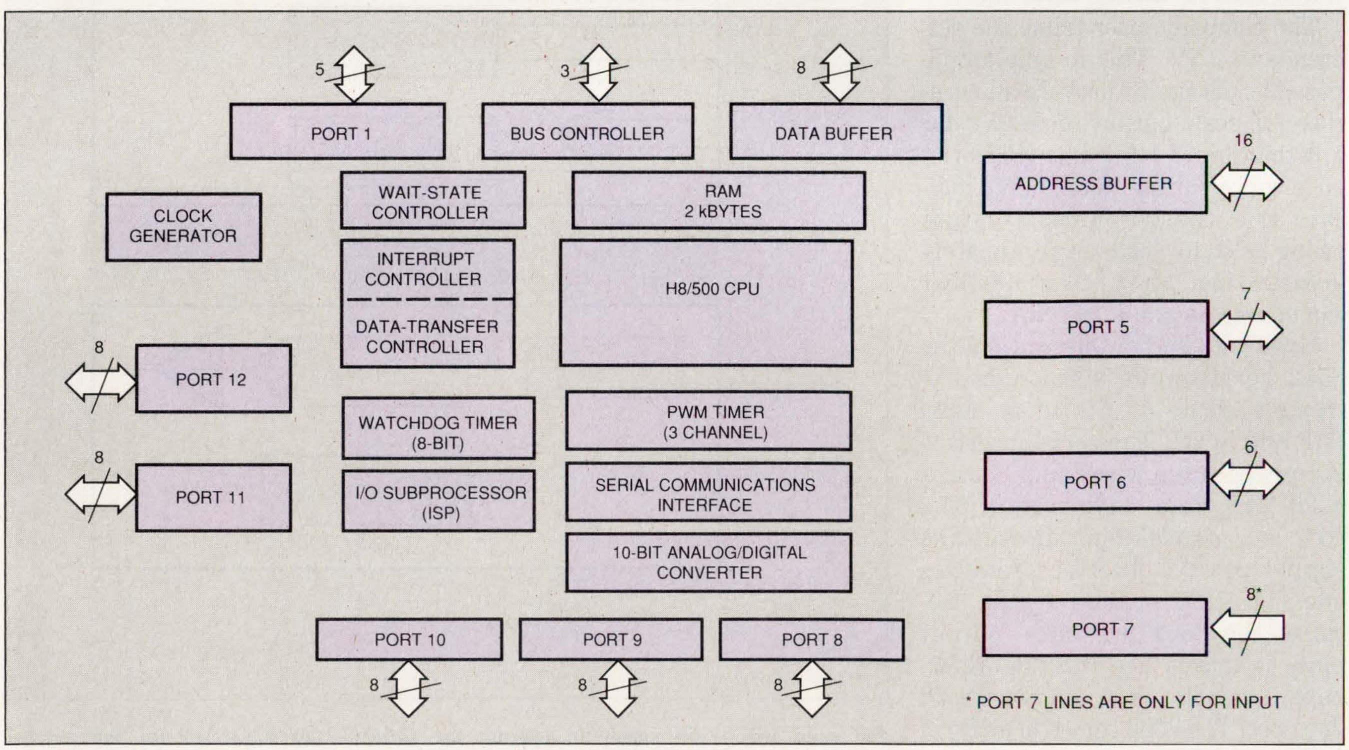
The I/O subprocessor's (ISP) 83 ⅓-nsec instruction cycle lets you create microprogrammed I/O devices such as timers, counters, refresh controllers, serial communications controllers, DMA controllers, and stepper-motor controllers. The ISP has its own instruction space, realized in a 64×512-bit, one-time-programmable, on-chip EPROM. A built-in time-slice sequencer and round-robin real-time operating system manage the ISP's operation through 12 program counters, allowing 12 ISP programs to operate concurrently.

The ISP and CPU exchange data through the ISP's 32 dual-ported data registers. These data registers also exist in the CPU's address space, and the dual-port register interface arbitrates access contention between the two processors. The ISP can generate general-purpose CPU interrupts and can read a number of flags that you can use for ISP-program flow control. Several of these flags are tied to the μC's I/O pins.

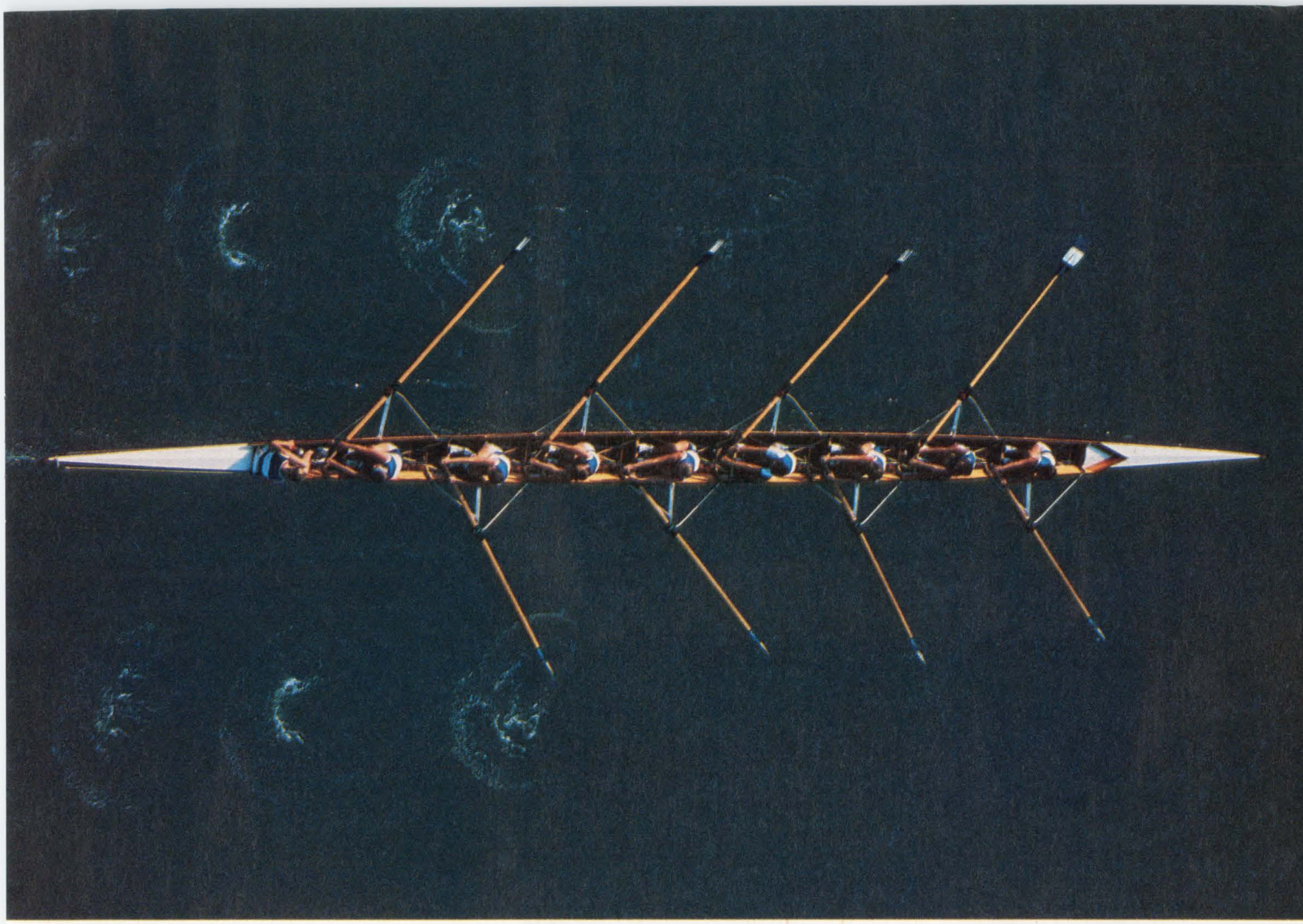
The μC's general-purpose CPU core is based on Hitachi's established H8/500 architecture, which has eight general-purpose 16-bit registers (two registers serve double duty as frame and stack pointers) and a 16-bit program counter. This particular member of the H8/500 μC family operates in either the "expanded minimum mode" with a 64-kbyte address space or the "expanded maximum mode" with a 1-Mbyte address space. (Other H8/500 μCs can address up to 16 Mbytes.) Five additional page registers (code, data, extended, stack, and base) boost the address space to 1 Mbyte. In either mode, the μC can operate with an 8- or 16-bit data bus, so you can tailor it for maximum system performance or minimum cost.

On-chip peripherals abound on this μC. A data-transfer controller moves data between memory and

Text continued on pg 91



A microprogrammable I/O subprocessor with an 83⅓-nsec instruction cycle on the H8/570 dual-processor μC allows you to create high-speed, custom I/O controllers. The chip also provides a number of standard peripherals.



Pull for total customer satisfaction. That's how you win three STACK awards in a row.

For the third consecutive year, STACK—the world's largest electronic component user group—has named Texas Instruments the recipient of its top Gold Award.

The members of STACK International collectively purchase more than $2 billion worth of semiconductor components every year. Their requirements for quality, delivery and service are the most demanding in the industry.

"I find it truly remarkable that TI has won the Gold Award every year since its inception," says Peter J. Savage, managing director, STACK International. "This is not a 'warm feeling' award—it's truly global and is based on hard performance data collected from our members."

The STACK award is a great honor, one of which the thousands of TI employees throughout Europe and the world can be justifiably proud.

But the award is also a great challenge—to continue to strengthen TI's efforts so that our partners and all of our customers realize the truest value from the semiconductor components we supply and our dedication to total customer satisfaction.

***The prestigious Gold Award** has been given to Texas Instruments by STACK International for the third consecutive year.*

STACK International consists of AG Communication Systems, British Telecom plc, Bull S.A./Bull HN, GEC Plessey Telecommunications, International Computers Ltd., Italtel SpA, NCR Corporation, Northern Telecom, Olivetti SpA, Siemens Nixdorf Informationssysteme AG and Siemens Stromberg Carlson.

 00-7271

TEXAS INSTRUMENTS

CIRCLE NO. 69

Hitachi H8/570

H8/500 8/16-bit CPU core
- 12-MHz clock rate
- 167-nsec min instruction cycle
- 8 16-bit general registers
- 57 instructions
- 16×16-bit multiply
- 32/16-bit divide

64-bit I/O subprocessor
- 1-cycle instructions
- 83⅓-nsec instruction cycle
- 32 16-bit data registers
- 64×512-bit program EPROM
- Simple real-time operating system
- Time-slice scheduler runs as many as 12 independent programs

Other features:
2 kbytes of RAM
Data-transfer controller
3-channel PWM timer
Watchdog timer
Wait-state controller
Serial communications controller
10-bit, 8-channel ADC
66 general-purpose I/O pins
122-lead PQFP package
$29.25 (10,000)

I/O devices without assistance from either of the on-chip processors. An on-chip wait-state controller inserts a programmable number of wait states in external bus cycles for the CPU, the ISP, and the data-transfer controller. The μC's 3-channel, 16-bit PWM (pulse-width-modulator) timer generates six independent waveforms simultaneously plus three CPU interrupts and two ISP transfer requests. A watchdog timer resets the μC if your program doesn't periodically clear the timer's counter. This feature prevents your program from permanently going out to lunch. You can also program the watchdog timer to generate periodic CPU interrupts instead of reset signals.

The μC's 8-channel, 10-bit ADC performs conversions in 13.4 μsec. There is an S/H circuit between the 8-channel analog multiplexer and the ADC. You can program the ADC to make one conversion or to take continuous readings of one to four channels. In continuous mode, readings appear in four 16-bit registers that the CPU can read.

Finally, the H8/570 includes traditional serial and parallel I/O ports. The serial communications controller operates either synchronously or asynchronously and has a built-in bit-rate generator. Although there is only one serial controller built into the μC's hardware, you can build several more using the ISP. The μC has 66 I/O pins divided into several bidirectional ports and one 8-bit input port. The 8-bit input port doubles as the ADC's analog input port. Many of the other port pins also have multiple uses depending on how you configure them.—**Steven H Leibson**

Hitachi America Ltd, 2000 Sierra Point Pkwy, MS-080, Brisbane, CA 94005. Phone (415) 589-8300. FAX (415) 583-4207. **Circle No. 387**

Enhanced PIC 16Cxx gets ADC and interrupts

Eight-bit microcontrollers (μCs) are taking over the low-cost, down-in-the-dirt, embedded-system world. Low-cost small pinouts, critical peripherals, and easy design-in are requirements in this tough design environment. Microchip Technologies' upgraded version of its PIC 16Cxx 8-bit μC line, the PIC 16C71, now has additional functions that include interrupt processing, an A/D converter, and high-current I/O for driving LEDs directly.

PIC μCs combine high processor-throughput rates with small pinouts (18 to 28 pins) and simple register-based architecture. PIC μCs evolved from an I/O controller for GE mainframes and have taken on distinct RISC-like features: a small number of fixed-length instructions and a pipelined operation (2 stage). Unlike RISC, PICs have an accumulator (working register) and handle dynamic data in registers, not RAM.

The 16C71 adds significant power to the PIC 16Cxx family. The instruction word is lengthened from 12 to 14 bits, which makes control easier; interrupts have been added (earlier chips required continual polling); and a 4-channel A/D converter (20 μsec) has been added, which eliminates the need for an off-chip converter.

Microchip PIC 16C71 8-bit μC
- 8-bit μC, 20-MHz clock
- 35 14-bit instructions
- 200-nsec instruction execution, 2-stage pipeline
- 36-byte RAM
- 1k-word (14 bits) ROM
- 4-channel, 8-bit A/D converter (20 μsec)
- Sleep mode with A/D wake-up
- 3 to 5V (2 mA at 3V, 4 MHz)
- $3.25 (10,000) in 18-pin DIP or SOIC

The PIC 16C71 runs at 20 MHz and executes most instructions in one pipeline cycle—200 nsec. Branches take two cycles, or 400 nsec.

The PIC 16C71 has four interrupt sources and an 8-level hardware stack. Interrupts or subroutine calls automatically push the 13-bit program counter onto the stack and pop it off on return. (Earlier PICs had a 2-level stack that could easily overflow.)

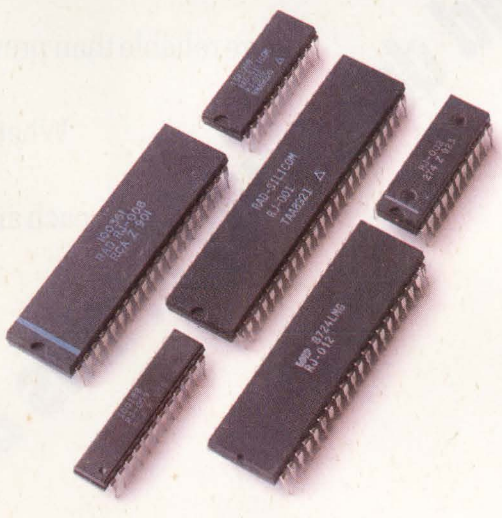
SLEEP mode cuts power by turning off the oscillator; the A/D converter can be turned off, too. The converter does conversions while the CPU is in SLEEP mode, waking up the CPU with a conversion-complete interrupt.

A more powerful version of the PIC family, the 17C42, adds interrupts, a larger instruction set, external-memory capability, and a wider, 16-bit instruction word.

—**Ray Weiss**

Microchip Technology Inc, 2355 W Chandler Blvd, Chandler, AZ 85224. Phone (602) 963-7373. FAX (602) 899-9210.

Circle No. 388



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RJ-008	V.54 DIAGNOSTIC GENERATOR
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RJ-010	ERROR CORRECTOR
RJ-013	BIT ERROR RATE TESTER (BERT)

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CIRCLE NO. 74

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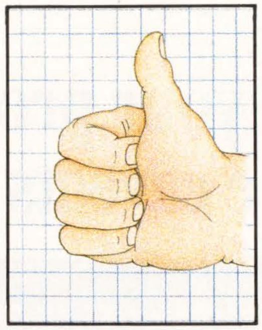
One with 75% fewer parts and far greater reliability. In fact, the TAS is three times more reliable than previous scopes.

What's more, each and every TAS

DESIGN IT RIGHT



PART 3

Leverage: Unconventional approaches lead to bigger, faster payoffs

Dan Strassberg, Senior Technical Editor

This third part of Design It Right covers leverage, or how to get the biggest bang for your R&D bucks. It tells the stories of three companies that took advantage of nontraditional resources and technologies to accomplish more in less time than conventionally possible.

In designing its 7200A modular high-performance digital-storage oscilloscope (DSO), LeCroy Corp replaced a proprietary μP board with a PC mother board and standard PC peripherals. The new approach resulted in a lower-cost, higher-speed product, but it also thrust some unexpected responsibilities on the designers.

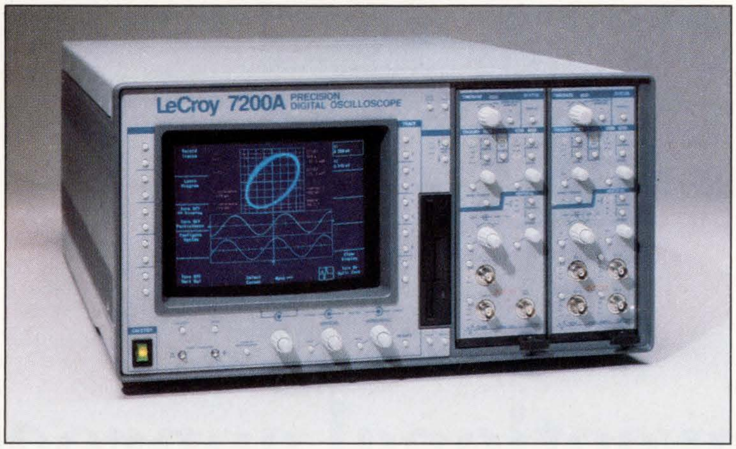
Quadtech, a new company with a 75+-year tradition, tapped a source of highly specialized knowledge—its suppliers. These companies recognized that by helping Quadtech become successful, they could contribute to their own success. As a result, the suppliers became, in effect, members of Quadtech's design team.

Finally, you'll learn how the VXI modular-instrumentation bus saved the day for a Tektronix design manager. VXI came to the rescue when, despite extensive customer contacts, team members discovered that they knew a little less than they had thought about customer requirements for a new signal source's user interface.

LeCroy Corp—7200A Modular DSO

Designing a PC into your product: Many benefits, some caveats

Test and measurement instruments that contain one or more µPs are the norm rather than the exception and have been so for years. Instruments on cards that plug into PCs are fairly common, too. But high-performance instruments built around complete PC mother boards are rather rare. LeCroy Corp's experiences with designing a PC mother board into a mainframe for a top-of-the-line, modular DSO reveal the many benefits of using PC components in a product that isn't a PC. However, those who believe that this approach will give them a free ride on PC technology had better think twice and read on.



From the front, the only difference you may note between LeCroy's 7200A DSO mainframe and its predecessor, the 7200, is the new unit's high-resolution color display. Internally, however, there are major differences. Although the same state-of-the-art acquisition modules plug into both mainframes, the new unit uses a PC mother board and other standard PC components.

LeCroy's new product is the 7200A. It is a DSO mainframe and is the successor to the 7200, which has been on the market a little over two years. Each unit includes a power supply, a display, some panel controls, hard- and floppy-disk drives, and much of the DSO's computing power. The mainframes accommodate plug-ins that house the scope's analog electronics, A/D converters, acquisition memories, and more panel controls. Both mainframes accept the same family of plug-ins, including those that acquire 1G sample/sec in real time and store 1M sample/channel. That combination represents state-of-the-art performance.

For many customers, the most important difference between the 7200 and the 7200A is the price. Configured as most customers will buy it, the 7200A is about $4000 less expensive. In addition, its high-resolution color display replaces the 7200's monochrome display. The 7200A is also faster. In performing an ensemble of tasks that LeCroy believes represents a typical use, the 7200A is from 2.5 to 5× as fast as the 7200; certain tasks run as much as 20× faster. Despite the reduced mainframe cost, the 7200A equipped with acquisition plug-ins carries a price tag that befits a top-of-the-line, state-of-the-art DSO. Systems cost from around $30,000 to over $50,000.

What made the 7200A's added features and lower mainframe cost possible was replacing a proprietary 68000-based dual-processor board with a standard 80386-based PC mother board and commercial I/O cards. LeCroy also designed an I/O card of its own. This card interfaces the backplane that accepts the acquisition modules to the mother board's ISA bus. On the card is firmware that, at startup, copies BIOS code from the hard disk into part of the mother board's 8 Mbytes (or more) of RAM. Bill Richardson, engineering director of LeCroy's Automated Test Division, points out that the 7200A's speed improvements are unique to its hardware. If you port one of your own designs from a 680X0 to an 80X86, you won't necessarily obtain similar results.

Unlike a standard PC, the 7200A does not run under MS-DOS or any other general-purpose operating system. Rather, the operating system (OS) for both the 7200 and 7200A is pSOS from Software Components Group (Santa Clara, CA). This OS, which in the LeCroy units loads from the hard disk into RAM at startup, was designed for embedded-processor applications. MS-DOS and pSOS are compatible to a certain degree. Systems that use either OS can read from and write to floppy disks formatted on systems that use the other OS. This feature allows users of pSOS-based systems to process acquired data on standard PCs.

Before making any changes, LeCroy took several months to study the idea of moving from its proprietary hardware to the PC architecture. Richardson admits that he resisted the move because he was convinced it would bring on problems nobody had predicted. What finally tipped the scales was the availability of an 'X86 version of pSOS. Because of the similarity between this version and the 7200's 68000 pSOS, software engineers could, simply by recompiling, try out 'X86 versions of 7200 code modules—at least ones not specific to the 7200 hardware (DSP routines, for example). When these modules ran immediately, Richardson became a champion of the PC approach. He says his subsequent experiences have only confirmed the wisdom of moving to PCs.

LeCroy had a long tradition of vertical integration; you might even call it a fear of anything it hadn't invented itself. But this approach created problems. Although the firm has annual sales of around $60 million, it competes with two instrumentation giants—Tektronix and Hewlett-Packard—and it has two DSO divisions. The division in Switzerland makes unitized scopes and the other, at corporate headquarters north of New York City, builds the modular 7200 series. LeCroy's key realization was that departing from vertical integration would let it compete more effectively. By buying components not directly related to acquiring high-speed signals, it can focus more resources on technologies that differentiate it from its competition.

Hidden costs

What was not immediately apparent either to Richardson or to LeCroy management was that, for all its benefits, the PC strategy isn't free; there are some hidden costs. The PC components marketplace changes as rapidly as any in electronics. Items

Gauge team performance by adherence to cost goals

Set product-cost goals, stick to them religiously, and revisit them regularly. Failure to regularly review how well the project team is adhering to its cost goals is an invitation to such ills as creeping elegance (the tendency to add features that "might be nice" but that, most of all, add unnecessary cost and complexity). You can make a strong case that adherence to cost goals is the single best gauge of whether a project is falling victim to these maladies because, unlike other measures, cost is quantitative.

Conform to industry standards wherever possible. By using the standard VGA resolution (640×480 pixels), the 7200A provides as clear a display as it could using a custom nonstandard-resolution video adapter, and it does so at much lower cost. Moreover, the VGA adapter can drive an industry-standard large-screen monitor in addition to the 7200A's built-in display. This capability opens up applications in classroom settings that are not accessible to most DSOs.

Always question contemporary thinking. The 7200A, which uses a single processor, is faster than the 7200, which used dual-processors. According to conventional wisdom, the single-processor scope should have been slower, but eliminating the interprocessor-communication overhead (and using a µP with a higher clock rate) saved enough time that the supposedly slower system turned out to be faster.

Use a universal power supply. Not having to build different versions of your product to accommodate the differing mains voltages and frequencies in different parts of the world will quickly pay for the cost of a universal supply. Moreover, if you use several types of supplies, there are additional hidden costs associated with spare-parts inventories.

Don't design portions of your product that you can buy. (See story.)

Don't mix assembly technologies on a pc board. An earlier version of the 7200 contained a board that mixed surface-mount and through-hole components. LeCroy found that the mixture required multiple insertion, soldering, and testing processes, which resulted in errors and necessitated rework that raised the product cost.

Don't blindly accept simulation results. Before it goes into production, any new design requires the scrutiny of smart engineers.

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that were introduced 18 months ago are now obsolete. A company that commits to using PC components must devote some resources to keeping abreast of what is available and tracking how prices shift to favor one component over another.

For example, to achieve fast video performance, the 7200A has a graphics-accelerator video-adapter card. LeCroy may soon be able to purchase mother boards that include video adapters that provide nearly equivalent performance. Using a mother board that doesn't require a separate video adapter would reduce the 7200A's cost. If such mother boards became popular enough, they might make graphics-accelerator cards like the one in the 7200A obsolete. Were these events to occur while LeCroy wasn't looking, shipping 7200As would become impossible.

Other consequences of the PC-component strategy relate to field service. Suppose LeCroy were to start using a mother board with an integrated video adapter, but a customer needed a replacement of an older 7200A mother board—one that used a (now obsolete) plug-in video adapter. The company would need to know that it should get the video adapter back; the customer would no longer need it after the replacement mother board arrived, but the card would be useful to LeCroy should someone else require a replacement video adapter.

Richardson says that to handle such situations, LeCroy's customer service group is toying with a concept developed by the military: the least replaceable unit (LRU). In this case, the LRU is a mother board whose video adapter takes either of two forms: a group of on-board components or a plug-in board.

These concerns notwithstanding, LeCroy is enthusiastic about the potential of building high-performance instruments around PC components. PC-based designs let companies that manufacture products in moderate volume take advantage of the low cost and high reliability of mass-produced subassemblies. Moreover, by letting designers focus on what differentiates their products from competing products, PC-based designs help companies squeeze the full value from their development dollars.

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Quadtech Instruments—1865 TΩ Meter

Using suppliers as members of the team

Dave Warnock is VP of engineering at Quadtech. You don't have to talk to him for very long to sense his enthusiasm for the new company, its products, or its people. And his excitement is contagious. You just have to believe that Quadtech can and will do what it has set out to do: become a major force in several segments of the precision-measurements market. One such area, and the focus of the company's first R&D program, is measuring very high resistances. Quadtech's no-nonsense, can-do approach is reflected in its premiere product—the 1865 TΩ meter. It measures to $10^{14}\Omega$, tests insulation quantitatively at voltages to 1 kV, and costs $3775.

Although Quadtech is a new kid on the block, it is also one of the oldest companies in the test-and-measurement field. Just 18 months ago, entrepreneur Phillip Harris, with venture-capital backing, bought what is now Quadtech from GenRad. Quadtech's product lines are the ones that were GenRad's core businesses until the late 1960s when the now-77-year-old firm shifted its focus to systems for automatic testing of pc boards.

With the exception of Harris, most of Quadtech's 78 employees came from GenRad. Nevertheless, essential elements of the new firm's operating style are quite different from GenRad's. Although some GenRad products do contain major elements purchased from outside, the company was known for its vertical integration. The firm's renowned quality resulted in part from its tight control over nearly every aspect of its products' manufacture. GenRad even ran the facility that made its well-known knobs. Quadtech simply couldn't afford such luxuries.

Nor could Quadtech afford the long cycles that, for decades, had been traditional in the development of the older firm's products.

Quadtech's answer was to turn to outside sources to supply key parts of its products, and to take maximum advantage of the suppliers' experience. Though the assemblies and software that Quadtech buys are significant, they don't relate to its instruments' basic measurement technology. The 1865 uses an 80186-based CPU card set—the PC104—from Ampro (Sunnyvale, CA) and a custom keypad assembly manufactured by Lucas Control System Products (Hampton, VA). The system runs under DR-DOS from Digital Research (Monterey, CA).

One measure of the 1865's complexity is the 128 kbytes the firmware occupies. Another index of the magnitude of the design task is the expected sales volume—roughly 3000 units. Despite the complexity and the expected volume, only five months elapsed between the program inception and the announcement. A problem obtaining a dot-matrix LCD caused a longer-than-planned interval between the announcement and the first customer shipments, but Quadtech still managed to deliver the initial units just 10 months after the project started. Of the 69 person-months invested, two-thirds were in design. The figures include replacing the original display. Differences in the new and old units' resolution and backlighting necessitated firmware and power-supply changes.

The speed with which Quadtech shipped its first product is all the more remarkable because of what was going on behind the scenes: the new company was extricating itself from GenRad. Besides relocating all

Quadtech's lessons: Keep your perspective and focus

Focus on the goal; learn to quickly dismiss ideas that don't differentiate the product from its competition. The differentiation is in the customer's eye, not the design team's. Make sure everyone knows the target and that every decision, conscious or subconscious, is based on that knowledge.

Take advantage of every available resource. Time is the project team's most expensive resource. Use it wisely. Reuse portions of other designs; adapt technology from other fields; draw on the expertise of suppliers.

Don't make unjustified changes. You will receive many suggestions to make such changes, but if you really understand your goal, figuring out which ones are "unjustified" should not be as difficult as it might at first seem to be.

Trust your designers and empower them to make decisions. If all team members truly are focused on the same goal, you can safely delegate decision-making authority. Doing so will save countless hours of meetings.

Don't design by committee. If all of the team members are focused on a single goal, you needn't second-guess their decisions.

Listen to your customers and hear what they mean—not what they say. Customers base their opinions on what they know. New technology changes customer needs. Customers who haven't yet been exposed to the new technology will describe what they need in terms of the products they know. In other words, when you change the rules, you must interpret what customers say they need in the light of the new rules.

In areas of your product that don't differentiate it from competition, rely on vendors to solve problems. Though purchased solutions may appear uneconomical, they can avoid hidden costs; hence, they often turn out to be the least expensive approach.

Be certain that new components you use really will be available. Even experienced designers can be fooled. In Quadtech's case, the vendor first selected to supply the 1865's LCD panel found that it couldn't obtain a key component of the panel and hence couldn't supply the panel. As a result, Quadtech had to find a new vendor and make several design changes to accommodate the new part.

Don't underestimate the cost of compressing schedules. Eliminating steps can increase scrap and rework.

Don't think that a design is complete just because you've shipped the product. As soon as customers learn what they can do with the new product, their requirements will change. (That is, the product's new capabilities will trigger new customer requirements.) Although beta-site evaluations can help you minimize the number of times you must make changes, the evolution should never end. Thinking that you have achieved perfection is dangerous to your competitive position.

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personnel to a facility about 15 miles from the group's former location, activities included setting up a new computer system and establishing new part-numbering and inventory systems. All the while, the new firm had to manufacture and support its older lines—former GenRad products.

Warnock credits two groups for Quadtech's ability to bring out the 1865 so quickly: the company's own people, who put in long hours and showed exceptional dedication, and the vendor personnel, who rolled up their sleeves and worked right beside them. In essence, the vendors became full-fledged members of the Quadtech team.

Thoughts are free

Of course, the people who eventually became Quadtech's marketers and engineers had been thinking about new products long before they knew that there would be a Quadtech. Although they realized that a cash-cow product line of a company with other fish to fry had little chance of getting significant R&D funds, one way the group sustained its morale and team spirit was by thinking about new products. Even though under GenRad the group hadn't received money for formal market research, the members had maintained close ties with customers. So when Quadtech became a separate company, it had a good handle on its customers' needs. This knowledge helped in the creation of a detailed written specification for the 1865.

Nevertheless, intuition played a greater role in defining the 1865 than it did in defining the multimeters discussed in Part I of this series (EDN, October 1, 1992, pg 60). Automatic-teller machines (ATMs) became the model for the user interface. Quadtech's engineers were confident of this approach because millions of people, even people who are afraid of computers, have learned to use ATMs and have done so without training.

The user interface is the first thing about an instrument, after the external appearance, that customers and potential customers react to. Warnock says that the customers to whom he's shown the 1865 are delighted with the unit's intuitive operation, especially when they compare it with competitive products. He is surprised that Quadtech's competitors, some of which have large human-factors staffs, apparently haven't devoted as much effort to ease of use as Quadtech has.

Because, as a relatively small company, Quadtech has limited resources, the 1865 had to be more than just a 1-shot product; it had to lay a foundation for further developments. The unit is a platform on which the firm can base a family of instruments. Everything that adapts it to a specific function—in this case, measuring high resistances—is on one pc board and a small segment of the front panel that contains the terminals you connect to the device under test. Quadtech can develop a family of instruments by designing a single board and connection panel for each one. Yet designing the product with this flexibility didn't lengthen the development effort, and it did not appear to raise the manufacturing cost.

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If the designers of an instrument make it look simple, they improve the chances that users will not encounter difficulties using the unit. Quadtech achieved that result in the 1865 TΩ meter, in part by modeling the user interface after that of automatic-teller machines. Like an ATM, the instrument has four soft keys at the right of its LCD screen and a familiar numeric keypad.

Tektronix Inc—HFS 9000 Data Time Generators

VXI is for more products than you think

John Hengeveld managed the digital design of the 9DG1 and 9DG2 630-MHz data time generator modules for Tektronix's HFS 9000 signal-source system. If you ask him about the VXI modular-instrumentation bus, he'll tell you, "VXI saved my bacon; I'm a believer!" He doesn't know of another way Tek could have taken the data time generators from initial concept to first customer shipments in only 12 months. Among VXI's benefits: the infrastructure of hardware- and software-support tools cut down on the ground work the design team had to do before it could tackle the real issues in the design. More important, VXI helped Hengeveld's team recover from a major miscalculation with a minimum of schedule slip.

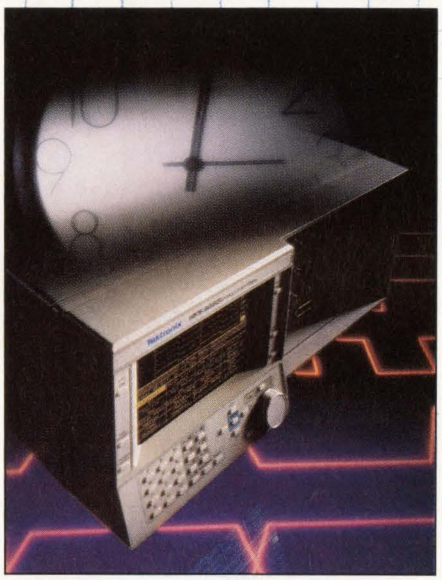
The 9DG1 and 9DG2 combine a data generator's deep pattern memory and multichannel capabilities with a pulse generator's precise control of such parameters as amplitude and pulse width. Tek's design replaces many of the analog function blocks usually found in pulse generators with digital blocks. The company claims that this novel approach results in significant benefits for users. For example, setting up for some applications takes minutes, rather than the days, that can be consumed using conventional instruments.

Cost was an important consideration in developing these signal sources. Tek cites an 8-channel configuration in which conventional instruments—data and pulse generators and a switch matrix—would cost approximately $85,000, yet a setup based on a data time generator costs only $28,000. Tek says that for this comparison, it didn't even select the most expensive competitive instruments.

Daring choice

The selection of VXI for a cost-sensitive commercial application was daring. Although the number of suppliers of VXI products is nearing 100, only a small number of companies use VXI technology in commercial benchtop and rack-and-stack instruments. Hengeveld suspects that more firms aren't using VXI in such products because of a widely held misconception that VXI is too expensive except in unusual cases. Hengeveld strongly disagrees. He figures that most of the design and marketing managers in other companies who could decide to use VXI in new instruments have not yet awakened to its advantages.

At this point, you may express skepticism. After all, Tektronix is a major supplier of VXI products, so you probably consider it a special case—a company that can profitably use VXI when others can't. Before you jump to that conclusion, remember that although the mainframes—the card cages and power supplies that house the data time generators—are standard Tek products that anybody can buy (you'll also find them in the pulse generators that are part of the HFS 9000 series), the modules are not; Tek sells them only as components of HFS 9000 systems. Therefore, although Tek obtains the mainframes at a favorable cost, it enjoys no similar savings on the modules.



If you didn't know that the HFS 9000 series data time generators were based on VXI technology, you might not guess. Use of VXI technology resulted in an economical, easily expandable design. Moreover, it helped the design team get evaluation units into the beta testers' hands early in the program, when incorporating their suggestions had caused the least schedule slip.

The modules are cost effective, despite a combination of handicaps that you might think would prove insurmountable:

- Because Tek sells the modules only as a part of systems, it can't achieve the economies of scale that might have resulted from selling the units separately.
- Tek builds the modules from scratch without the aid of the hardware components it sells to builders of small numbers of VXI modules.

Simple rules and customer rapport keep designs focused

Don't rush to define a product. Instead . . .

Allow yourself time to appreciate the needs of a representative group of customers. Get the customers to define their needs in their own terms.

Don't put words in the customers' mouths. The data time generator design team set out initially to solve a customer problem rather than to design an instrument. Although the expectation was that the solution would take the form of an instrument, that it would do so was not a foregone conclusion at the outset.

Make sure that each team member has close contact with customers. The rapport must be close enough that team members don't feel shy about calling the customers for inputs. The data time generator team found that its selected customer contacts were more than happy to discuss design decisions throughout the program. This rapport resulted in a shift in mind set from "Gee, this is a neat feature" to "This is what the customers want."

Concentrate on features that will make a difference to customers. To control creeping elegance, the team developed a set of questions for evaluating proposed features:

- Will adding it generate sales?
- Will *not* adding it cost us sales?
- Will adding it cost us sales (by increasing cost or delaying the introduction)?

Thoroughly characterize each component for its application; don't rely on guesses.

Specify hardware/software interfaces early in the project.

Develop the software that will drive custom ICs before you release the ICs. If you release the ICs before you have the software, you will either have to redo the IC designs or you will make a lot of extra work for the software developers who will have to work around the limitations imposed by the hardware. Either way, the cost and the impact on your schedule will be significant.

Don't build any more custom hardware than you absolutely need.

Don't go beyond what the customer needs.

Don't neglect weird intermittent problems in prototypes. If you do, they will return at the least opportune moment. Finding the cause and remedying it immediately may be inconvenient and unpleasant, but the debugging effort will be 100× more inconvenient and unpleasant later on.

Don't wait until your product is perfect to introduce it. Introduce it in phases; learn from the feedback; respond quickly.

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- The modules use hardware and bus interfaces they would not have needed with another approach.

An even more convincing argument for VXI is that Tek manufactures other modular-instrument families, and it could have used any of them—had there been one that could match VXI's performance at lower cost.

Nobody's perfect

So by choosing VXI for the HFS 9000 series, Tek achieved a flexible modular architecture, shortened development cycles, and attained favorable costs. Moreover, VXI helped the team recover from a serious error—a flaw in the user interface. Beta testers inside and outside of Tektronix, though impressed with the evaluation units' performance, were unanimous in condemning certain features. The designers had erred: they assumed that an earlier program, the HFS 9000-series pulse-generator development, had taught them everything they needed to know about what users wanted in the controls and displays of the more complex data time generators.

Because the use of VXI saved time early in the program, evaluation units were available relatively early. If the beta testers had had to wait longer for these units, the problems wouldn't have surfaced until later, so the schedule slippage would have occurred later and would have been more severe.

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EDITOR'S ANALYSIS

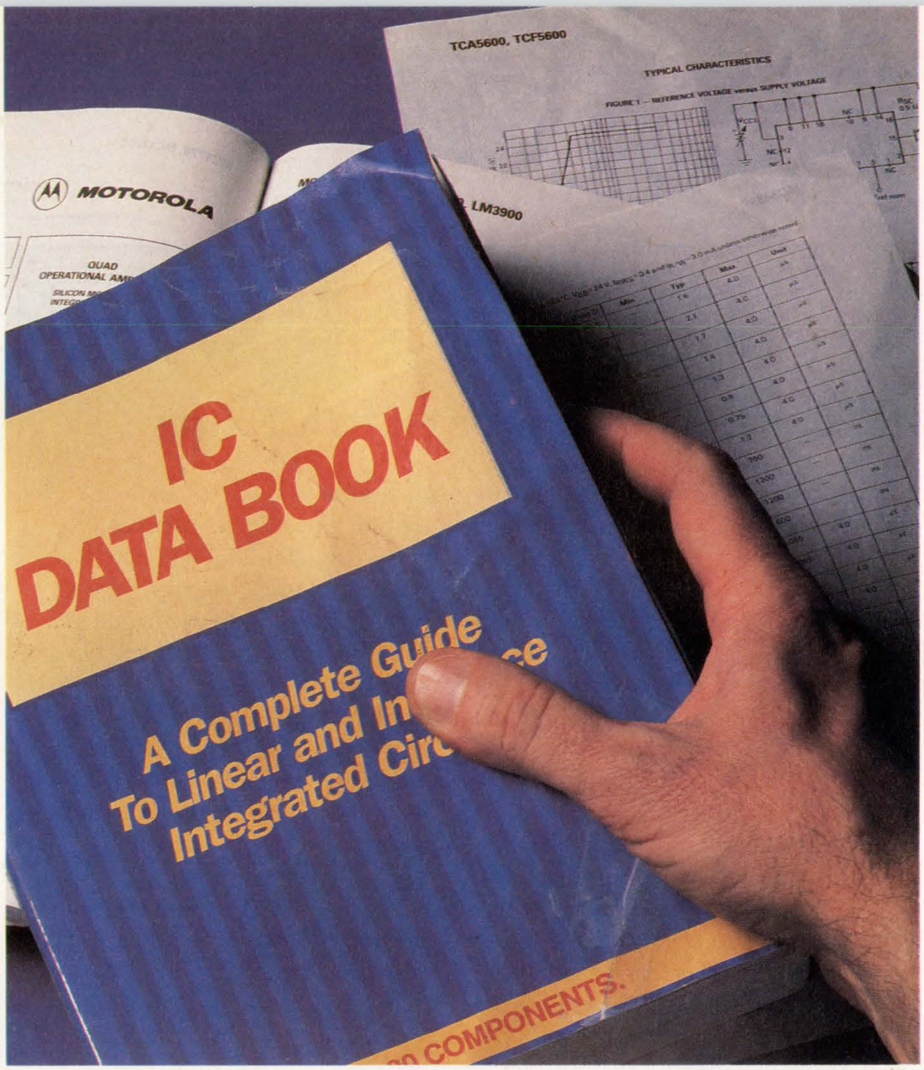
It's not over *even when* the fat lady sings

A funny thing happened during the research for this series. Although the editorial call letters we sent out referred to "Designing it Right," we never referred to "designing it right *the first time*." Nevertheless, a large percentage of the respondents apparently thought we had used the phrase "the first time," because their letters spoke of "EDN's upcoming series on 'Designing it right the first time.' " In fact, hardly any product discussed in the series is the first of a kind to be produced by its designers; nearly all incorporate improvements that result from experience with earlier products. It's highly probable that every company will produce successors to these products.

Designing it right, though it implies achieving excellence, doesn't necessarily mean attempting to create the ultimate product in a class. The idea that you can ever design the ultimate product is seductive, but probably wrong. It entices you to waste valuable time on creeping elegance—on refinements that too often are needless. If, instead of fine tuning endlessly, you bring out a solid, carefully engineered but possibly less than perfect product, customers will suggest improvements that you never thought of. However, if the product doesn't reach their hands, customers won't be inspired to make suggestions. More than likely, acting on customer suggestions will produce more sales and profits than all of the tweaks and modifications you could think of while sequestered in the sterile sanctum of your lab.

Next in Design It Right . . .

Part IV, the final part of Design It Right, will appear in the November 12, 1992, issue of EDN. It will tell the stories of two companies that based products on custom integrated circuits. One product, a large automatic-test system, uses 11 custom ICs from three vendors. The other, a plug-in for a modular logic-analysis system, uses two custom chips manufactured by another division of the same company. If you work for a multidivisional company, you know that buying a key part of your product from a sister division can sometimes require more skill than dealing with a separate company. Here's a story of successful relationships between divisions. Lastly, Part IV includes a story about a company that pioneered in forming strategic partnerships with other firms. The company engineers and manufactures a variety of high-tech products that hardly anybody knows it designs and builds.



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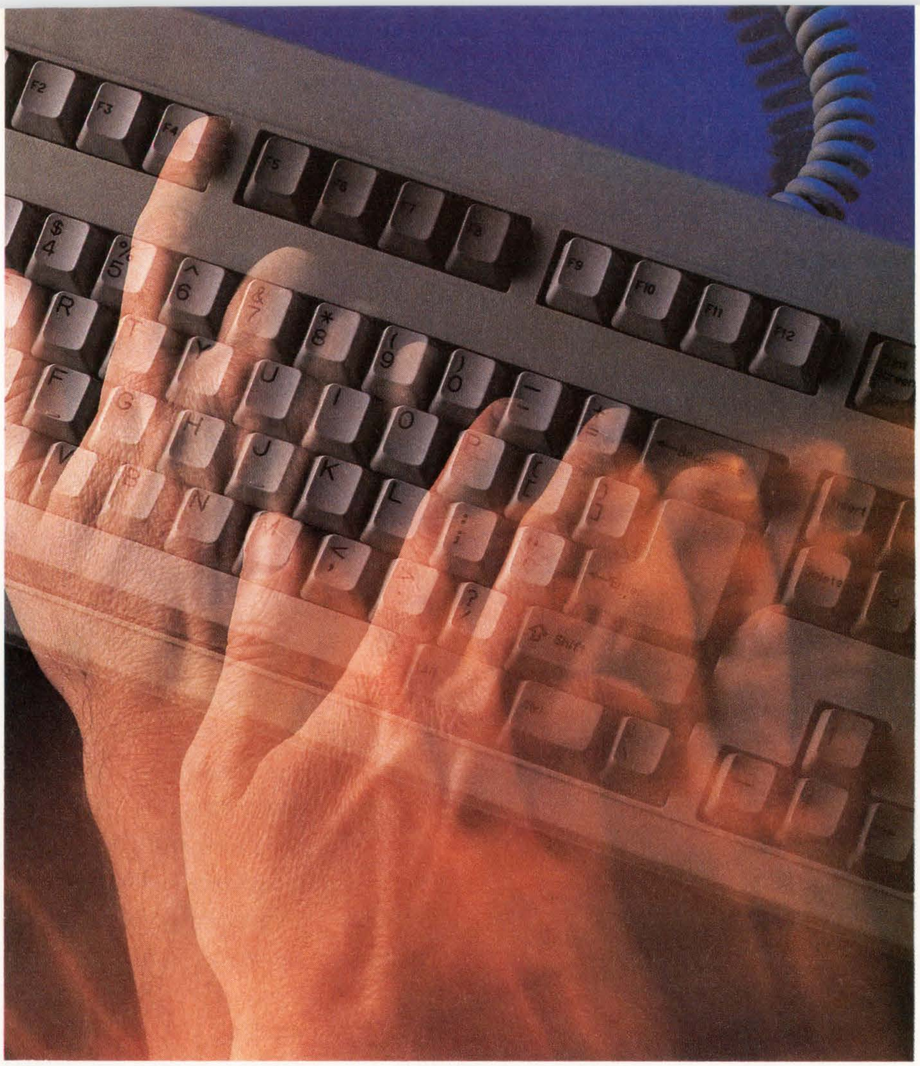

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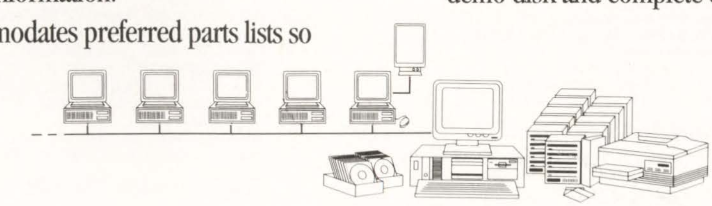

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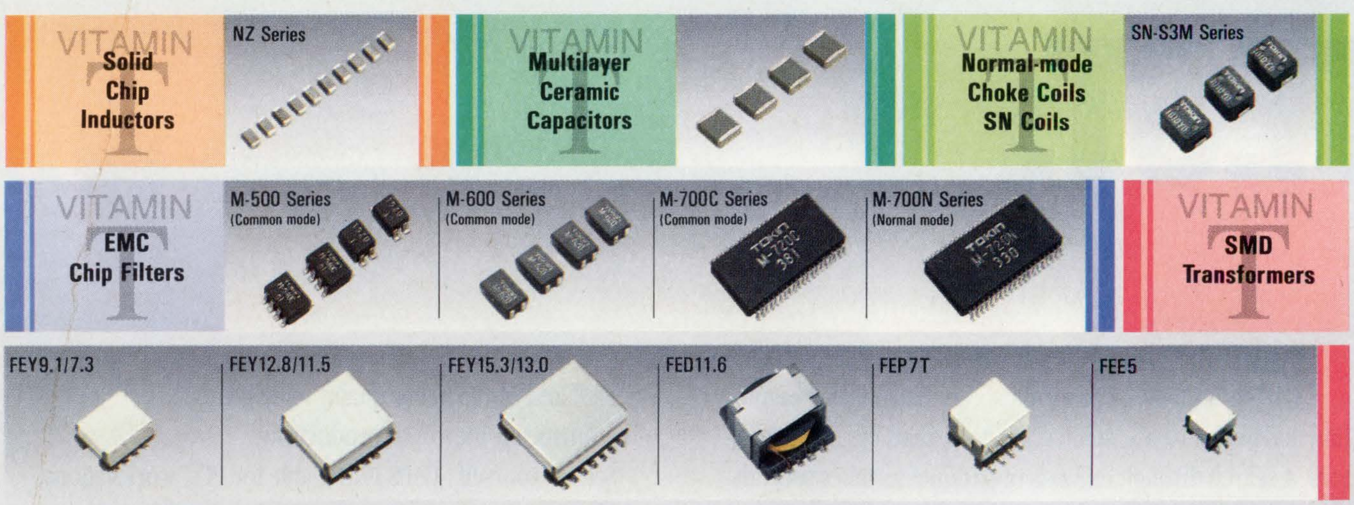

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 CIRCLE NO. 80

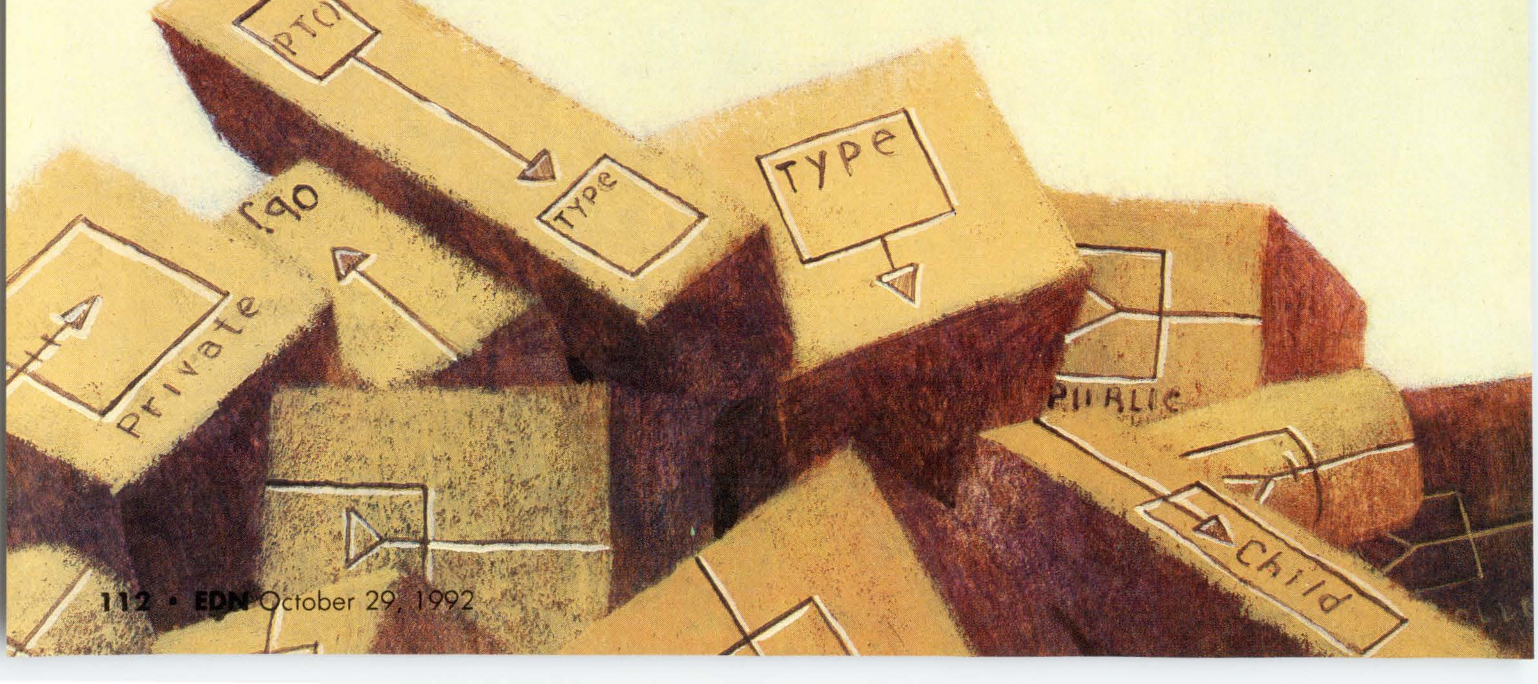
BUILD A STRONG FOUNDATION TO PROGRAM IN C++

Knowing how to distinguish the four kinds of "same name, different behavior" functions in C++ means you're on your way to mastery of programming with objects.

John C Napier, Technical Editor

As a C programmer moving to C++, you face a double challenge that can put you into an endless loop of misunderstanding. C++, as an extension of a procedural language, lets you use the principles of object-oriented programming (OOP) but does not teach them to you. Yet getting up to speed in any new language requires memorizing a lot of the language syntax. And, learning syntax by brute-force memorization is inordinately time consuming

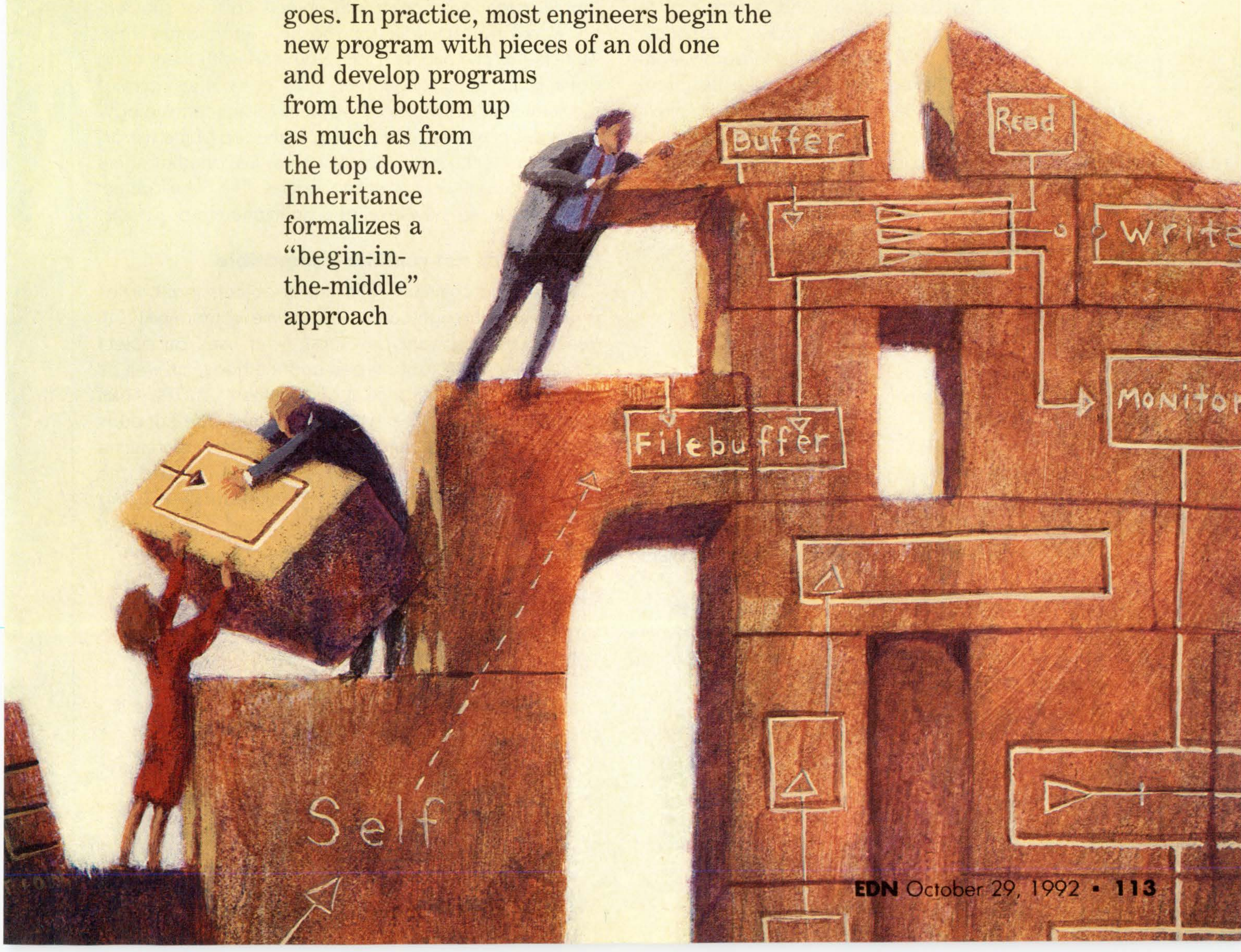
Illustration by Kevin Hawkes



if you lack a higher-level view of its purpose, such as, for C++, implementing OOP principles. One way to break out of this loop and teach yourself the missing chunk of C++ is to aim for a detailed understanding of how you use C++ to implement the core OOP concept, inheritance.

As an over-simplified description, you could call inheritance just an elegant way to avoid mistakes that usually come with the cut-and-paste method of making new programs from pieces of existing ones.

As an over-glorified description, you could call inheritance the basis of a new design methodology. Traditional programming projects march a straight line from problem analysis to system specification, design, coding, testing, and documentation—or so the story goes. In practice, most engineers begin the new program with pieces of an old one and develop programs from the bottom up as much as from the top down. Inheritance formalizes a "begin-in-the-middle" approach



to design (see **box**, "A warm, fuzzy touch of OOP").

A solid proposition lies between those extremes—inheritance lets you do "programming by difference." You can wrap up your work-to-date, give it a name (class), and use that name as a starting point for further work.

Where objects get sticky

Programming by difference is a new organizational tool that objects give you. Beyond simply bundling data and procedures, objects let you develop a program by making well-defined, incremental changes, even if the program is very large. They help you avoid duplicating code within one program. These benefits come at a price of additional complexity. As an example, consider the issue of the scope of a variable.

The scope of a variable in both C and C+ + boils down to whether a variable is either visible or nonvisible. Programming with objects tends to reduce scope of a variable to a less important issue because you encapsulate data—that is, that you operate on data only with procedures that belong to that data's own object, or its descendants. Encapsulation slightly simplifies programming. On the other hand, inheritance introduces scoped *procedures*: a member function of the same name can override, modify, or extend the *behavior* of a local function. That change of behavior is not just a simple visibility issue. The term distributed scope summarizes the complications that inheritance introduces to programming (**Fig 1**).

Object-oriented programming can baffle the programmer who retains the habit of distinguishing func-

A warm, fuzzy touch of OOP

You begin a procedural program holding in hand some specification of the design intent and purpose of the program. But design, by definition, lacks a formal syntax: you cannot compile a spec. The program is the most complex unit of executing code under the procedural approach. If you represent levels of complexity by indentation and separate compilable from noncompilable documents by a dotted line, a diagram of the procedural approach looks like:

```
design
-------------------------
   program
      procedures
         data
```

or perhaps:

```
design
-------------------------
   program
      data
         procedures
```

An object, like a program, includes persistent data, procedures (also called member functions or functions) that manipulate that data, and a way (called messages) to invoke the procedures. All users of the term "object" agree that, at the very least, an object bundles data and procedures together under one name. Given this much information, you can look at an object as a miniature procedural program complete in itself. You can diagram these OOP relationships as:

```
design
-------------------------
   program
      objects
         data
         procedures
```

Two features of this simple diagram give you a hint that learning to program with objects calls for substantial work and for understanding new information. First, objects are compilable code; you work with them using defined computer languages. They are not just part of the seeming anything-goes world of design terminology. Second, "program" is still sitting at the top of the hierarchy and object is not: "object" is not just another name for a program or for a procedure. The term object does introduce a new level of organization to programs.

Objects are not runtime-compatible

There is no common definition of objects that carries from design through coding to runtime compatibility. In general, the software developer who uses an object chooses its name, data types and methods, as well as their order of appearance in an argument list. The ANSI standard defines C+ + as a source language but does not standardize its compilation to the level of runtime compatibility. In other words, you cannot compile one object using a Borland compiler, another using Zortech's, another using Microsoft's, and another from Sun, then link them to form one executable program.

Class, Object—what's the difference?

Strictly speaking the C+ + language does not even include the term object. It only defines classes, which in OOP terminology are cooperating groups of types. You, the programmer, make an object by instantiating one from a class definition, that is, by declaring it.

tions mostly by giving them unique names. For example, OOP languages let you give the same name to differing functions within multiple objects as long as the objects themselves are not related by inheritance.

As you deal with distributed scope, relatively simple OOP features can become confusing. For example, you may be tempted to consign overloading to the dustbin of design jargon and forget that the term also refers to compiler behavior, which will get your program in trouble if you do not understand how to use it.

Finally, dynamically bound messages (or virtual-member functions, as C++ calls them) introduce the issue of runtime scope resolution. When you are learning to program with objects, dynamic binding may make objects seem not only somewhat unfamiliar but downright bizarre. However, you can learn how to use virtual functions and the other new tools C++ gives you for programming by difference.

Knowing where to look is half the battle

You pay for the new tools by learning how to deal with a syntax that distributes functions across an inheritance hierarchy. Even small working programs become too complex to clearly illustrate the scope resolution rules. The following example is trivial but makes the principles obvious.

When you are discussing principles without detailed examples, you can easily confuse the two OOP terms

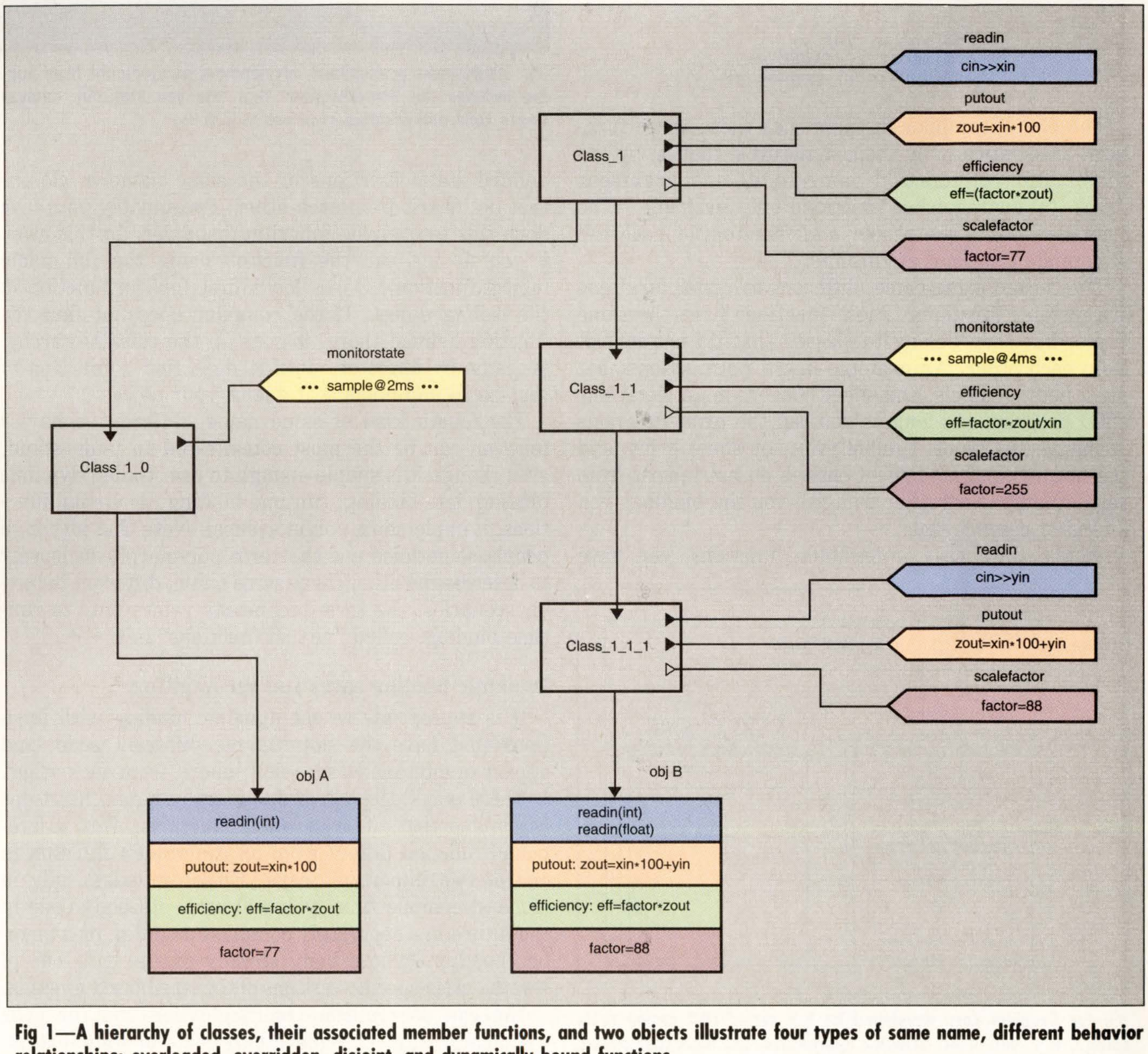


Fig 1—A hierarchy of classes, their associated member functions, and two objects illustrate four types of same name, different behavior relationships: overloaded, overridden, disjoint, and dynamically bound functions.

Build a foundation for C++

overloading and polymorphism. You may have heard both described nontechnically as "same name, different behavior"—this is an oversimplification. C++ gives you at least four kinds of same name, different behavior scenarios for

- overloaded functions
- functions in disjoint objects
- overridden functions
- dynamically bound functions.

Four ways to use the same name

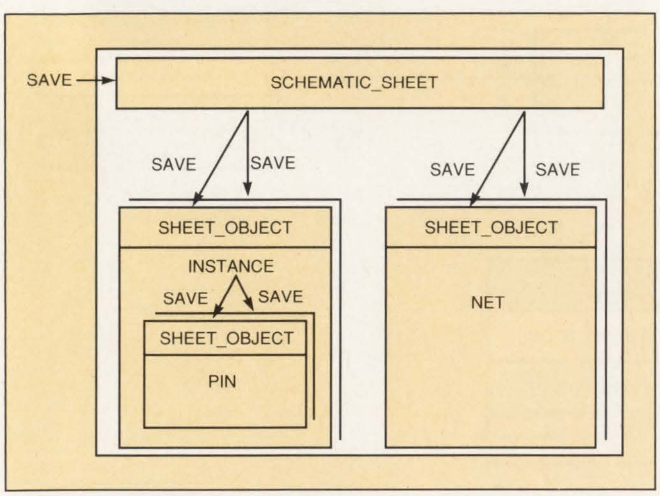
The first and simplest same name, different behavior function comes from overloaded functions. An example are the three functions

```
add(int x, int y)
add(float x, float y)
add(double x, double y)
```

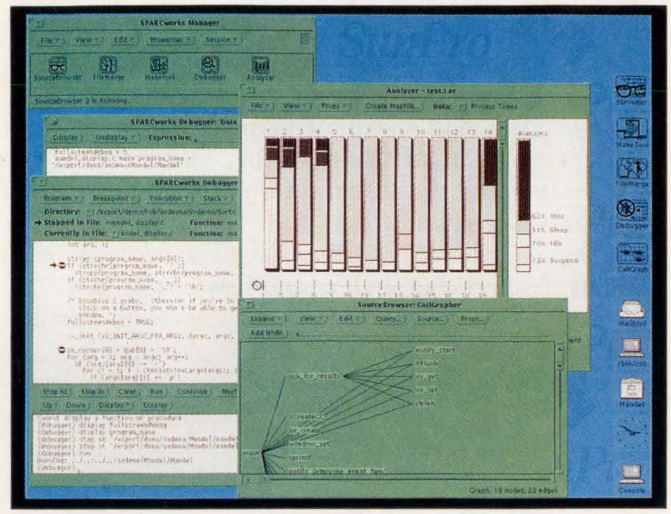
The C++ compiler distinguishes these three functions automatically by their signatures; that is, by the combination of function name (*add*) and argument types. (C distinguishes functions only by name.) The compiler selects the proper *add* function for each call at compile time, not at runtime.

The second same name, different behavior functions are disjoint functions. These functions have the same name, but they belong to classes that do not inherit from each other. An example might be functions that print nets, symbols, and sheet borders in an electronic CAD program. As long as you call the print functions by name (net.print, symbol.print, or sheet.print) and the net, symbol, and sheet classes do not inherit from each other, the compiler will give you the bindings you intend at compile time.

In the third case, overridden functions, you have



Mentor Graphics Corp developed its 8.x series EDA design tools using C++ and object-oriented approaches. The tools save sheets from hardware designs using the OOP principle of inheritance.



The SPARCworks professional development environment from SunPro includes the Sourcebrowser that lets you statically analyze source code and program structure in C++.

defined static functions of the same name in classes that do inherit from each other. Presumably you have done this to override inherited behavior. In this case, if you do not call the function using the full name (object.function), C++ looks first for the function in the calling object. If the compiler does not find the function defined there, it goes up the class hierarchy, ancestor by ancestor, until it does find a function of that name and binds that one to your object.

The fourth kind of same name, different behavior function can be the most complicated to understand, even though it is simple enough to use. Called dynamic binding, late binding, runtime binding, or virtual functions, it implements polymorphism. Note that although people sometimes use the term polymorphism loosely to describe the other three same name, different behavior scenarios, the term technically refers only to runtime binding, called "virtual functions" in C++.

Dynamic binding saves you recompiling

It is appropriate to use dynamic binding with functions that have the same name, different code, and appear in multiple classes that inherit from each other. In these ways, the use of dynamically bound functions resembles that of overridden functions. But a late-bound function differs from an overridden function in one of two important ways. Either it exists only in name at compile time (you will write its body code in the future in a separately compiled module), or a member function (whose body already exists) calls one of several, class-specific versions of the late-bound function.

You can use runtime binding when you (or your customers) want to achieve two goals in combination. The first goal is to avoid having to recompile in the future when you write extensions to class functions from an existing hierarchy. You may want to avoid this recompiling to save disk space, compiling time, or to keep your source code confidential. The second goal is to continue to use the existing compiled classes' functions to call those of your new extension classes. Because your extension classes are unknown when you compile your library, only a runtime lookup can make the binding between the two.

You must use runtime binding when one function calls another within the same class and you will specialize the second function in descendants of the class. You must use runtime binding here, as **Fig 2** and its explanation show. This example is actually a generalization of the previous case.

Compilers work to prevent duplications in your source code from becoming duplications in memory (the computer doesn't benefit from repetition as people do). C++ compilers, in particular, keep only one copy of a function, even if many objects use it (through inheritance). So far so good. But when one function calls another and specializes that second function in subclasses, the compiler has a problem.

The problem is not with binding the object, or its

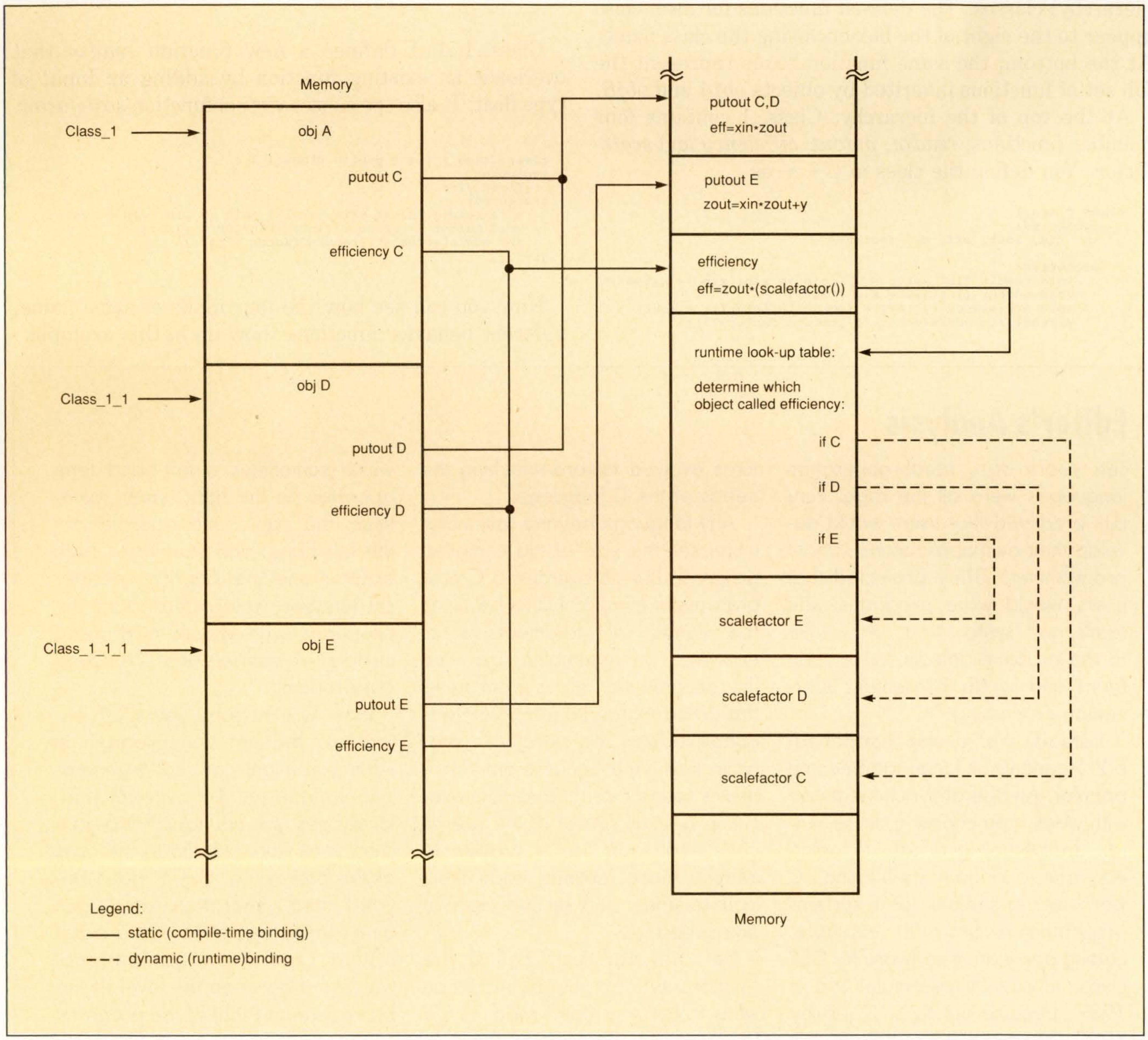


Fig 2—A member function that calls another member function within the same class will require dynamic binding if the second function is specialized within subclasses. Because a C++ compiler keeps only one copy of both the caller and called functions, the caller function must consult a lookup table to choose one of several called functions based on which object called it.

Build a foundation for C++

descendants, to the one copy of the caller function. The compiler can do that. The problem comes up when the compiler goes to bind the one copy of the caller function to each of the several called functions. That binding is one-to-many; which one of the many is right depends on which object does the calling, and that cannot be determined until runtime. Therefore, the compiler sets up a runtime table to make the call dynamically.

Fig 1 illustrates inheritance using four function types: overloaded, overridden, disjoint, and dynamically bound. It shows four classes and two objects that represent instantiations of the two "leaf" (bottom of hierarchy) classes. The defined functions for each class appear to the right of the box enclosing the class name. At the bottom, the same function boxes represent the full set of functions inherited by objects *objA* and *objB*.

At the top of the hierarchy, Class_1 contains four member functions, *readin, putout, efficiency* and *scalefactor.* You define the class in C++ as

```
class Class_1  {
   protected:
   int xin, zout, eff, sc, factor;

   protected:
      void readin (int xstep = 2) {cin >> xin; xin += xstep;}
      void putout () {zout = xin * 100;}
      void efficiency () {eff = (sc=scalefactor()) * zout);}
      virtual int scalefactor () {return(factor=77);}
};
```

Next, the two child classes (Class_1_0 and Class_1_1) of the top object inherit all member functions defined for the top object and add their versions of other functions. Both new classes also add the new function *monitorstate.* In addition, Class_1_1 overrides function *efficiency* and specializes virtual function *scalefactor.*

```
class Class_1_0 : public Class_1 {
   protected:
      void monitorstate () {......sample at 2 msec rate......}
};

class Class_1_1 : public Class_1 {
   protected:
      void monitorstate () {.....sample at 4 msec rate.....}
      void efficiency () {eff = ( (sc=scalefactor()) * zout/xin);}
      int scalefactor () {return(factor = 255);}
   };
```

Class_1_1_1 defines a new function *readin* that overloads an existing function by adding an input of type float. It also specializes virtual function *scalefactor.*

```
class Class_1_1_1 : public Class_1_1 {
protected:
   float yin;
protected:
   void readin (float ystep = 3.5) {cin >> yin; yin += ystep;}
   void putout () {zout = (int) (xin*100 + yin);}
   int scalefactor () {return(factor = 88);}
};
```

Now you can see how the four kinds of same name, different behavior functions show up in this example.

Editor's Analysis

Ten years ago, fourth-generation languages were all the rage. Pundits predicted that users would develop their own applications without programmers. They projected that users would write programs with terms and syntax that are unique to the problem domain rather than terms and syntax of generic information processing.

Instead, the reverse happened; a 2½-generation language became popular. An operator-rich language with weak type checking, terse syntax, freewheeling access to pointers, and abundant bit-fiddling, C won over assembler and systems programmers first. For example, coding application software for DSP chips, mostly an assembler job in 1987, became mostly a C job by 1990. Of course, it also helped that 16- and 32-bit DSP-μP architectures evolved toward matching the needs of the C language.

Any language beyond assembler increases the size of the compiled program, but on average a C program might compile 1.3 to 1.8 times the number of statements of its equivalent in assembler. The time the programmer saves from using the (moderately) high-level language offsets the penalty in program size. And because most programs spend most of their time executing a small subset of the overall code, you can use a profiler to identify those routines, code them in assembler, and recoup most of any speed loss.

Yet, the sarcastic call C the "write-only" language—you can write it but you can't read it. C's Unix-inspired pipeline, or toolbox, approach leads to lines of code in which sometimes a left-hand term operates on the right hand, sometimes the right hand operates on the left hand, and sometimes both occur in one line. C's rich operator set lets you write abbreviated expressions with dense and deep nesting of symbols that confound easy reading.

Now C++ gives you OOP extensions that let you program in what you might call a 3½-generation language. Third-generation languages give you tools for organizing your work only up to the level of the procedure. C++ goes beyond third-generation languages by inserting the notion of the class/object into the organizational wasteland between the level of the procedure and that of the program.

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Build a foundation for C++

Overloaded function:

readin—This function name occurs twice with different types of arguments (one an int, the other a float). C++ distinguishes one from the other on that basis, called a difference in signature.

Overridden function:

efficiency—This function occurs first in the top class of this hierarchy (Class_1) and then again in its child (Class_1_1). The compiler binds the local version of the function to the local object in each case, hiding the higher-level function by binding the lower-level one. Note that you can still instruct the child class to use the top class's version by explicitly naming it using the scope-resolution operator (::), as in *Class_1::efficiency()*. Similarly, a child object can call the top object's version as in the message *Class_1.efficiency()*.

Disjoint functions:

monitorstate—This function name occurs in two classes that are not related by inheritance. The compiler binds each function to its own object.

Dynamically bound functions:

scalefactor—In the top class, Class_1, member function *efficiency* calls virtual member function *scalefactor*. Because the compiler keeps only one copy of all member functions, it can form only one-to-one bindings. You declare *scalefactor* as virtual so that the one copy of function *efficiency* can call any one of the many versions of *scalefactor* that may appear in descendent classes. The resulting runtime lookup table for this example contains three entries, one each for the three classes that specialize in the function (**Fig 2**). EDN

Acknowledgment

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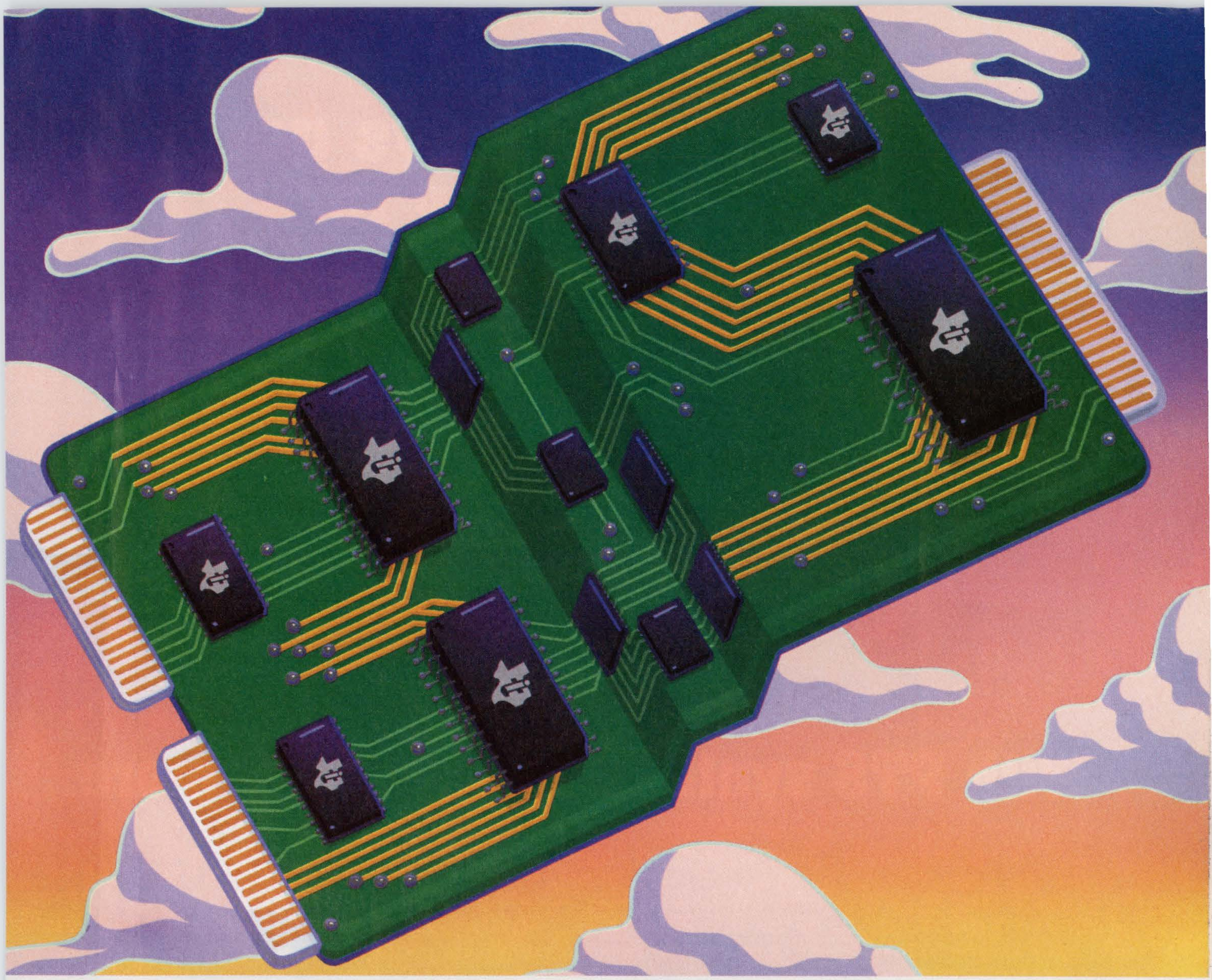

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Designing supplies for powering LCD backlighting

Jim Williams, Linear Technology Corp

Supplies for powering LCD backlights have some unique requirements. The units must be very efficient, have a variable sine-wave output, and include provisions for intensity and contrast control.

Current-generation portable computers and instruments use backlighted LCDs. Cold-cathode fluorescent lamps (CCFLs) provide the most efficient way for backlighting the display. These lamps require high-voltage ac to operate, so you'll need an efficient high-voltage dc/ac converter. In addition to high efficiency, the converter should deliver the lamp drive in the form of a sine wave to minimize RF emissions. Such emissions can cause interference with other devices, as well as degrade overall operating efficiency. The circuit should also provide for lamp-intensity control from zero to full brightness with no hysteresis or pop-on. The LCD also requires a bias supply for contrast control. The supply's negative output should be regulated and variable over a considerable range.

The small size and battery-powered operation associated with LCD-equipped apparatus mandate low component count and high efficiency for these circuits. Size constraints place severe limitations on circuit architecture, and long battery life is usually a priority. Laptop and handheld portable computers offer an excellent example. The CCFL and its power supply are responsible for almost 50% of the battery drain. Additionally, these components, including pc board and all hardware, usually must fit within the LCD enclosure, which has a height restriction of 0.25 in.

Any discussion of CCFL power supplies must consider lamp characteristics. These lamps are difficult to drive (particularly for a switching regulator) because they have a negative resistance characteristic—the starting voltage is significantly higher than the operating voltage. Typically, the starting voltage is about 1000V and the operating voltage is about 300 to 400V. These are typical figures and they can vary for different bulbs. CCFL bulbs will operate from dc, but migration effects within the bulb will quickly damage them. Therefore, the waveform must be ac—no dc content should be present.

The negative-resistance characteristic, combined with the frequency-compensation problems associated with switching regulators, can cause severe loop instabilities, particularly on startup. Once the lamp is in its operating region, it assumes a linear load characteristic, easing stability criteria. Bulb operating frequencies are typically 20 to 100 kHz, and a sine-wave drive is preferred. The sine wave's low harmonic content minimizes RF emissions, which could cause interference and efficiency degradation.

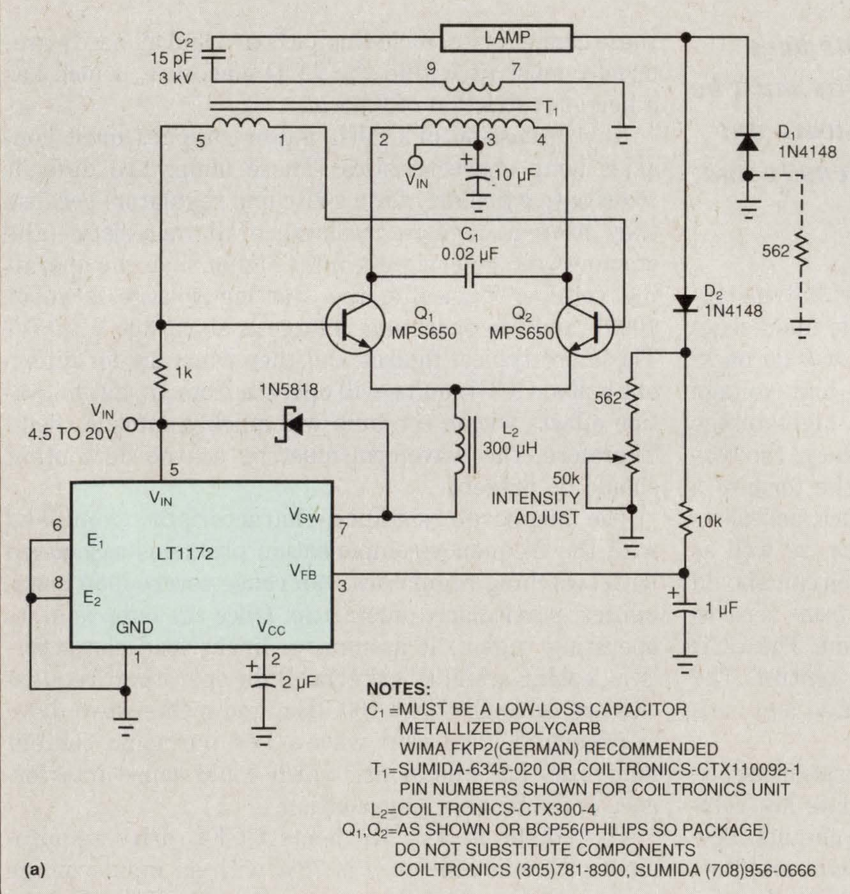
The circuit in **Fig 1a** meets CCFL drive requirements. Circuit efficiency is 78% with an input-voltage range of 4.5 to 20V. If you can drive the LT1172 from a 3 to 5V input, 82% efficiency is possible. Additionally, lamp intensity is continuously and smoothly variable from zero to full intensity. When power is applied, the voltage level at the feedback pin of the LT1172 switching regulator is below the device's internal 1.23V reference and generates full duty-cycle modulation at the VSW pin (Trace A in **Fig 1b**). L_2 conducts current (Trace B) that flows from T_1's center tap through the transistors and into L_2. The regulator switches L_2's current to ground.

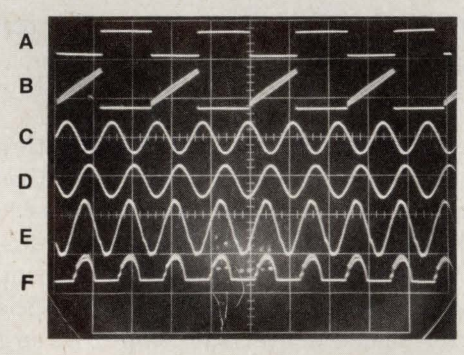
T_1 and the transistors form a current-driven Royer-class converter that oscillates at a frequency primarily set by T_1's characteristics (including its load) and the 0.02-μF capacitor. The LT1172 drives L_2, which sets the magnitude of the Q_1-Q_2 tail current, and hence T_1's drive level. The 1N5818 diode maintains L_2's current flow when the LT1172 is off. The LT1172's 100-kHz clock rate is asynchronous with respect to the push-pull converter's 60-kHz rate.

The 0.02-μF capacitor combines with T_1 to produce a sine-wave voltage drive at the Q_1 and Q_2 collectors (Traces C and D, respectively). T_1 steps up the voltage and about 1400V p-p appears at its secondary (Trace E). Current flows through the 15-pF capacitor into the lamp. On negative waveform cycles, the lamp's current goes to ground via D_1. The positive waveform cycles that appear across the 562Ω-50 kΩ potentiometer chain (Trace F) represent ½ the lamp current. The 10 kΩ-1 μF combination filters this signal and steers it to the LT1172's feedback pin.

This last connection closes a control loop that regulates lamp current. The 2-μF capacitor at the V_{CC} pin of the LT1172 provides stable loop compensation. The loop forces the LT1172 to switch-mode modulate L_2's average current to whatever value is required to maintain a constant current in the lamp. You can vary this current value, and hence lamp intensity, with the potentiometer. The constant current drive allows 0 to 100% intensity control with no lamp dead zones or pop-on at low intensities.

You should keep several points in mind when observing this circuit's operation. To monitor T_1's high-voltage secondary, you can only use a wideband, high-voltage probe that is fully specified for this type of measurement. The majority of oscilloscope probes will break down and fail if used for this measurement (see **box**, "Obtaining meaningful efficiency measurements").





Trace	Vertical	Horizontal
A	20 V/DIV	10 μsec/DIV
B	0.4 V/DIV	10 μsec/DIV
C	20 V/DIV	20 μsec/DIV
D	20 V/DIV	20 μsec/DIV
E	1000 V/DIV	20 μsec/DIV
F	5 V/DIV	20 μsec/DIV

(b)

Fig 1—Efficiency for this CCFL drive circuit (a) equals 78% for a 4.5 to 20V input-voltage range. The circuit's operating waveforms are shown in (b). When power is applied, voltage at the LT1172 switching regulator's feedback pin is less than the 1.23V internal reference, which generates full duty-cycle modulation at the V_{SW} pin (Trace A).

Waveform monitoring is another consideration. The LT1172's switching frequency is completely asynchronous from the Q_1-Q_2 Royer converter's switching rate. As such, most oscilloscopes cannot simultaneously trigger and display all the circuit's waveforms. To obtain waveforms like those in **Fig 1b** requires a dual-beam oscilloscope. LT1172-related waveforms (Traces A and B) are triggered on one beam, while the remaining traces are triggered on the other beam. You can also use single-beam instruments with alternate sweep and trigger switching, but they are less versatile and will only display four traces.

Be sure of efficiency measurements

Obtaining and verifying high electrical efficiency requires some amount of diligence. The optimum efficiency values given for C_1 and C_2 are typical and will vary for specific types of lamps. C_1 sets the circuit's resonance point which varies, to some extent, with the lamp's characteristic. C_2 ballasts the lamp, effectively buffering its negative resistance characteristic. Small values of C_2 provide the most load isolation but require relatively large transformer output voltage for loop closure. Large C_2 values minimize transformer output voltage but degrade load buffering. Also, C_1's best value is somewhat dependent on the type of lamp used. Typical values for C_1 are 0.01 to 0.047μF. C_2 usually ends up in the 10 to 47 pF range. C_1 must be a low-loss capacitor, and it would be wise to use the type listed in **Fig 1a**.

A poor-quality dielectric for C_1 can easily degrade efficiency by 10%. You select C_1 and C_2 by trying different values for each and iterating toward a minimum-

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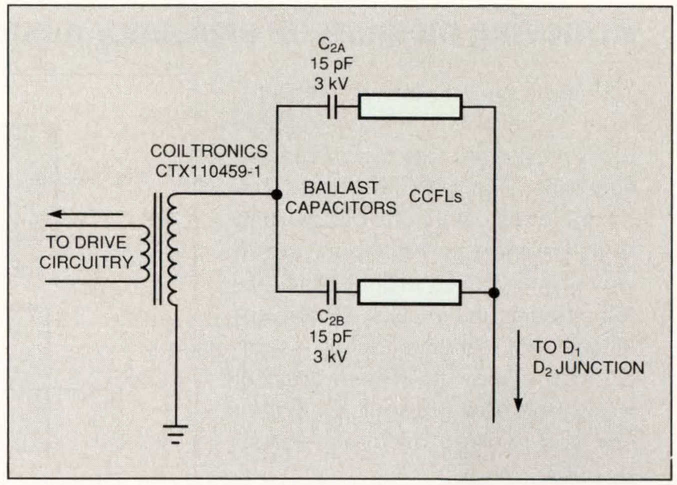

Fig 2—The drive circuit must deliver more power when the backlighting scheme involves two CCFLs. The transformer in this circuit can develop an 11-mA output—the transformer in Fig 1a delivers only 7.5 mA.

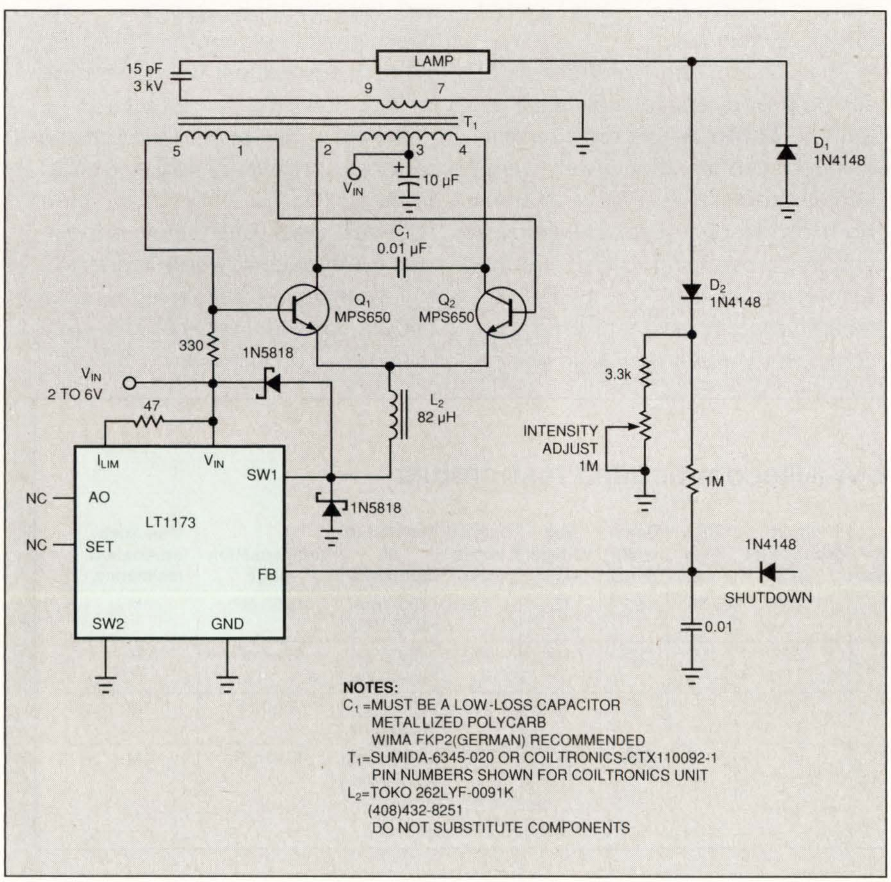

Fig 3—Optimized for low-current operation, this drive maintains control down to tube currents of 1 mA—a very dim light. This design suits applications that need to maximize battery life. Primary supply drain ranges from hundreds of microamperes to 100 mA with tube currents of microamperes to 1 mA.

Achieving meaningful efficiency measurements

You must pay attention to measurement techniques to obtain reliable efficiency data for cold-cathode fluorescent-lamp (CCFL) circuits. The combination of high voltage and high-frequency harmonic-laden waveforms makes it difficult to obtain meaningful results. When selecting test instrumentation, it's important to know how the instrument works and how to use it. Only then can you hope to avoid unpleasant surprises.

Consider the case of test probes, for example. The selected probes must respond accurately under a variety of conditions. Measuring across the resistor in series with the CCFL is the most favorable circumstance because you can use a standard 1× probe to make this low-voltage, low-impedance measurement. The probe's relatively high input capacitance does not introduce significant error. You can also use a 10× probe for this measurement, but you must be sure to address frequency compensation issues.

On the other hand, the high-voltage measurement across the lamp is considerably more demanding on the probe. The waveform fundamental in this case is in the 20- to 100-kHz range, and harmonics can range into the megahertz region. This activity occurs at peak voltages in the kilovolt range.

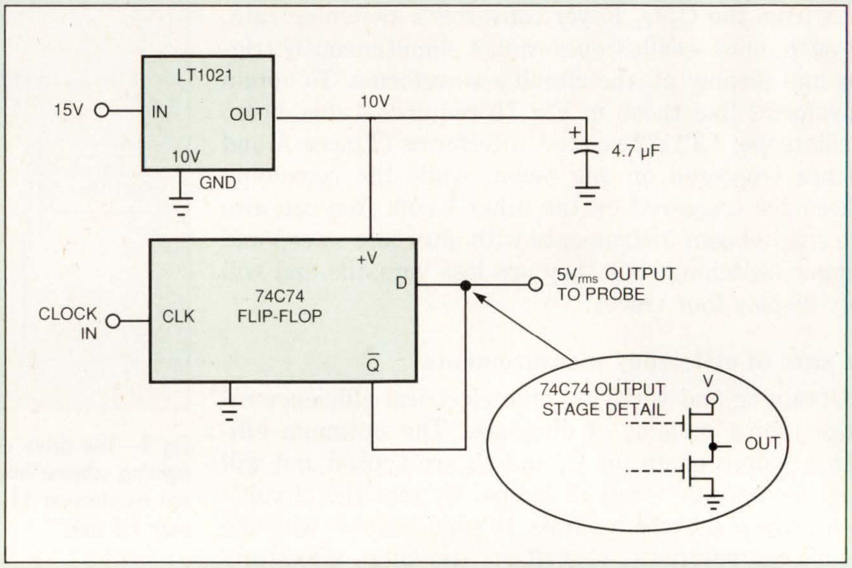

Fig A—To generate a known rms voltage, this circuit takes advantage of a voltmeter's insensitivity to waveform shape.

The probe must have a high-fidelity response under these conditions. Additionally, the probe should have low-input capacitance to avoid loading effects that would corrupt the measurement.

The design and construction of such a probe requires significant attention. **Table A** lists some recommended probes along with pertinent characteristics. Almost all standard oscilloscope probes will fail if you try to use them to measure the waveform across the CCFL. Attempting to circumvent probe shortcomings by resistively dividing the lamp voltage also creates problems because large-value resistors often have significant voltage coefficients and shunt capacitance that is high and unpredictable. Similarly, common high-voltage probes designed for dc measurement will have large errors because of ac effects.

The P6013A and P6015 are the preferred probes for making measurements across the CCFL; their 100-MΩ input and small capacitance introduce low-loading error. You sacrifice output level to gain 1000× attenuation, but the right voltmeters can make this tradeoff.

Table A—Recommended test probes

Tektronix probe type	Attenuation factor	Accuracy	Input resistance	Input capacitance (pF)	Rise time (nsec)	Band-width (MHz)	Max voltage (kV)	Derated above (kHz)	Derated to at frequency	Compensation range	Assumed termination resistance
P6007	100x	3%	10M	2.2	14	25	1.5	200	700 Vrms at 10 MHz	15-55 pF	1M
P6009	100x	3%	10M	2.5	2.9	120	1.5	200	450 Vrms at 40 MHz	15-47 pF	1M
P6013A	1000x	Adjustable	100M	3	7	50	12	100	800 Vrms at 20 MHz	12-60 pF	1M
P6015	1000x	Adjustable	100M	3	1.4	250	20	100	2000 Vrms at 20 MHz	12-47 pF	1M

All of the recommended probes are designed to work into an oscilloscope input. Such inputs typically have an impedance of 1 MΩ in parallel with a capacitance of 10 to 22 pF. Appropriate voltmeters have significantly different input characteristics **(Table B)**. As a result, you must compensate oscilloscope probes to accommodate the voltmeter's input characteristics. Normally, you can readily determine and adjust the optimum compensation point by observing probe output on an oscilloscope. Using a square input of known amplitude (usually from the oscilloscope calibrator), you can adjust the probe for the correct response.

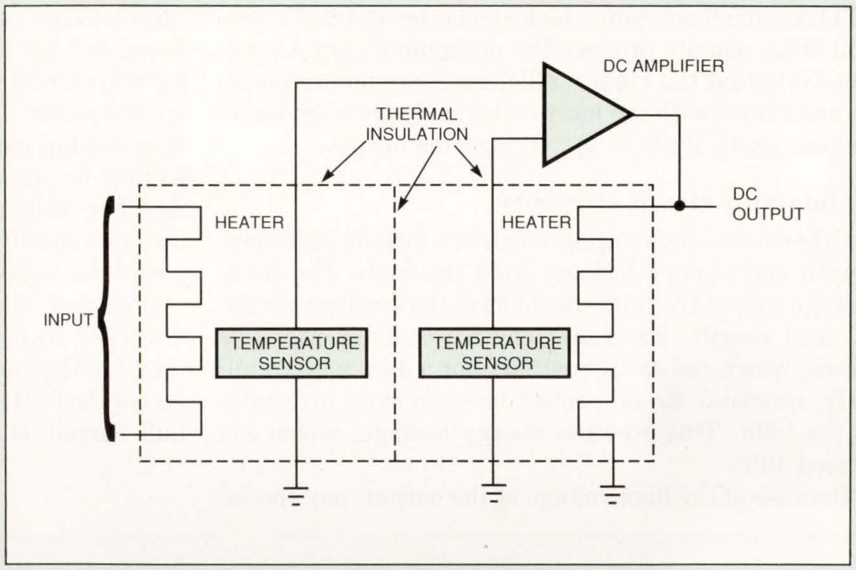

Fig B—The conceptual thermal rms/dc converter will reject ambient temperature shifts only if the heater sensor pairs are isothermal.

Using the probe with the voltmeter presents an unknown impedance mismatch and makes it difficult to determine when compensation is correct. The impedance mismatch occurs at low and high frequency. You can correct the low-frequency term by placing an appropriate value resistor in shunt with the probe's output. For a 10 MΩ voltmeter input, a 1.1 MΩ resistor is suitable. This resistor should be built into the smallest possible BNC-equipped enclosure to maintain a coaxial environment. Do not use any cable connections; you should locate the enclosure directly between the probe output and the voltmeter input to minimize stray capacitance. This arrangement compensates for the low-frequency impedance mismatch.

Correcting the high-frequency mismatch term is more involved. The range of voltmeter input capacitances combined with the added shunt resistor's effects presents problems. One solution is to feed a predetermined rms signal to the probe-voltmeter combination and adjust compensation for a proper reading. **Fig A** shows a simple way to generate a known rms voltage. This scheme takes advantage of the recommended voltmeter's insensitivity to waveform shape. A stable 10.00V source drives the CMOS flip-flop. The CMOS output stage, which is purely ohmic, switches error between the supply and ground rails. Clocking the flip-flop generates a square wave output with a 10.00V amplitude. The result is a known 5.00V rms output. Now, you adjust the probe's compensation for a 5.00V voltmeter reading. This procedure, combined with the added resistor, completes the probe-to-voltmeter impedance match.

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Table B—Thermally based rms voltmeter characteristics

Manufacturer and model	Full-scale ranges	Accuracy at 1 MHz	Accuracy at 100 kHz	Input resistance and capacitance	Max bandwidth	Crest factor
Hewlett-Packard 3400 Meter Display	1 mV to 300V, 12 ranges	1%	1%	0.001 to 0.3V range=10M and <50 pF, 1 to 300V range=10M and <20 pF	10 MHz	10:1 at full scale, 100:1 at 0.1 scale
Hewlett-Packard 3403C Digital Display	10 mV to 1000V, 6 ranges	0.5%	0.2%	10- and 100-mV range=20M and 20 pF±10%, 1 to 1000V range=10M and 24 pF±10%	100 MHz	10:1 at full scale, 100:1 at 0.1 scale
Fluke 8920A Digital Display	2 mV to 700V, 7 ranges	0.7%	0.5%	10M and <30 pF	20 MHz	7:1 at full scale, 70:1 at 0.1 scale

input supply current. You can ensure that loop closure is maintained during this procedure by monitoring the LT1172's feedback pin, which should be at 1.23V. Several trials usually produce the optimum C_1 and C_2 values. Note that the highest efficiencies are not necessarily associated with the most esthetically pleasing waveshapes, particularly at Q_1, Q_2, and the output.

Maintaining circuit efficiency

Other issues influencing efficiency include bulb-wire length and energy leakage from the bulb. The high-voltage side of the bulb should have the smallest practical lead length. Excessive length results in radiative losses, which can easily reach 3% for a 3-in. wire. Similarly, no metal should contact or be in close proximity to the bulb. This prevents energy leakage, which can exceed 10%.

Because of the high voltage at the output, pay special attention to the layout of the circuit board. You must place the output coupling capacitor carefully to minimize leakage paths on the circuit board. A slot in the board will further minimize leakage. Such leakage can permit current flow outside the feedback loop, which wastes power. In the worst case, long-term contamination buildup can increase leakage inside the loop, resulting in starved lamp drive or destructive arcing. Another technique for minimizing leakage is to evaluate and specify the silk-screen ink for its ability to withstand high voltages.

Once you follow these procedures, you can measure efficiency by calculating bulb current and voltage. To measure the current, you can measure the rms voltage across the 562Ω resistor (short the potentiometer). The bulb current is

$$I_{bulb} = 2(E/R)$$

Achieving meaningful efficiency measurements *(continued)*

Efficiency measurements require a voltmeter with an rms response. This instrument must respond accurately at high frequency to irregular and harmonically loaded waveforms. These considerations eliminate almost all ac voltmeters, including digital voltmeters with ac ranges. There are a number of ways to measure rms ac voltage. Three of the most common include average, logarithmic, and thermal. Averaging instruments are calibrated to respond to the average value of the input waveform, which is almost always assumed to be a sine wave. Deviation from an ideal sine-wave input produces errors. Logarithmically based voltmeters attempt to overcome this limitation by continuously computing the input's true-rms value. Although these instruments are real-time analog computers, their 1% error bandwidth is well below 300 kHz and the crest-factor capability is limited. Almost all general-purpose DVMs use a logarithmically based approach and, thus, are not suited for CCFL efficiency measurements.

Thermally based rms voltmeters are direct acting thermo-electronic analog computers. They respond to the input's rms heating value. This technique is explicit, relying on the very definition of rms (the heating power of the waveform). By turning the input into heat, thermally based instruments achieve vastly higher bandwidth than other techniques. Additionally, thermal voltmeters are insensitive to waveform shape and easily accommodate large crest factors. These characteristics are necessary for the CCFL efficiency measurements.

Fig B shows a conceptual thermal rms-to-dc converter. The input waveform warms a heater, increasing the output from its associated temperature sensor. A dc amplifier forces a second identical heater-sensor pair to match thermal conditions of the input-driven pair. This differentially sensed feedback-enforced loop makes ambient-temperature shifts a common-mode term, eliminating their effect. Although the voltage and thermal interaction is nonlinear, the input-output rms voltage relationship is linear with unity gain. In order for this arrangement to reject ambient-temperature shifts, the heater-sensor pairs must be isothermal.

You can make the pairs isothermal by thermally insulating them with a time constant well below that of ambient shifts. If the time constants to the heater-sensor pairs are matched, ambient temperature terms will affect the pairs equally in phase and amplitude. The dc amplifier will reject this common-mode term. Note that, although the pairs are isothermal, they are insulated from each other. Any thermal interaction between the pairs reduces the system's thermally based gain terms, causing unfavorable signal-to-noise performance and limited dynamic operating range.

The output in **Fig B** is linear because the matched thermal pair's nonlinear voltage-temperature relationships cancel each other. The instruments listed in **Table B** are typical of what is required for meaningful results. The HP 3400A and the Fluke 8920A are currently available from their manufacturers. The HP 3403C is no longer produced but is readily available on the secondary market.

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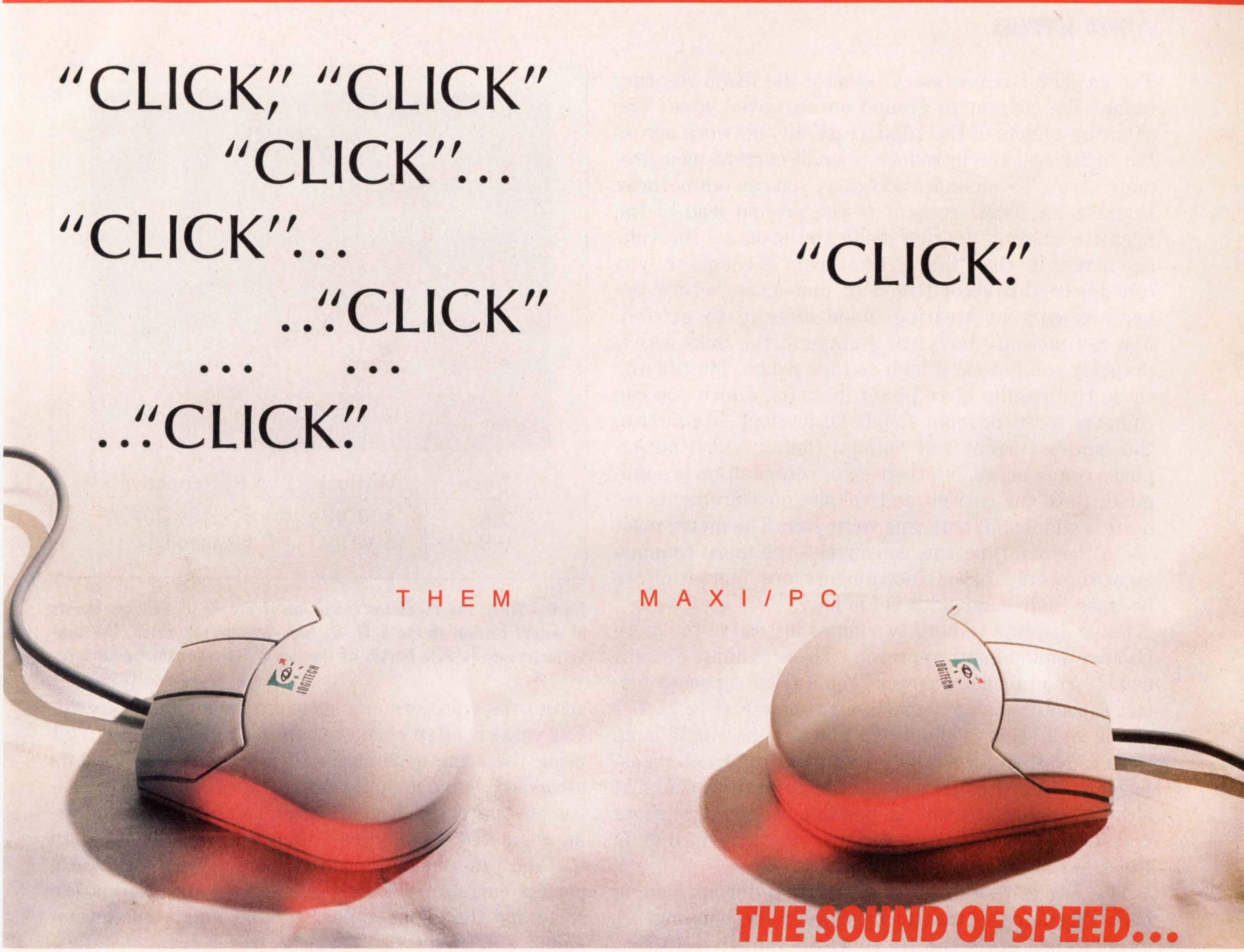

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The 2x factor is necessary because the diode steering dumps the current to ground on negative cycles. The shunting effects of the 10 kΩ-1 μF RC network across the 562Ω resistor introduce a small current-measurement error. To maximize accuracy, you can temporarily insert a 1%, 562Ω resistor in the ground lead of the negative-current steering diode and measure the voltage across it. Once this measurement is complete, you can delete this second resistor and again return the negative-current steering diode directly to ground. You can measure bulb rms voltage at the bulb with a properly compensated high-voltage probe. Multiplying these two results gives power in watts, which you can compare to the dc input supply EI product. In practice, the lamp's current and voltage contain small out-of-phase components, but their error contribution is negligible. Both the current and voltage measurements require a wideband, true-rms voltmeter. The meter must use a thermal-type rms converter—the more common logarithmically based instruments are inappropriate because their bandwidth is too low.

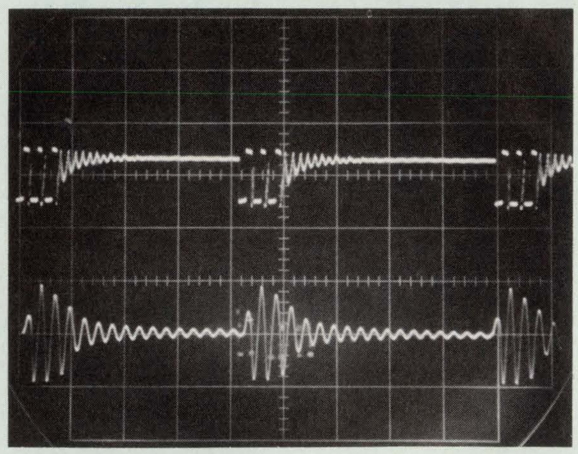
Some displays require two lamps instead of the more popular single-lamp approach. These 2-lamp designs usually require more power. You'll need separate ballast capacitors to accommodate two lamps (**Fig 2**), but circuit operation is similar to that for the single-lamp circuit. Higher power may require a different transformer rating. **Fig 1**'s transformer can supply 7.5 mA, although more current is possible with appropriate transformer types. For reference, the transformer in **Fig 2** has an 11-mA capability.

The **Fig 2** design reflects slightly different loading back through the transformer's primary winding. C_2 usually ends up in the 10- to 47-pF range. Note that C_{2A} and C_{2B} appear with their lamp loads in parallel across the transformer's secondary winding. As such, C_2's value is often smaller than in a single-lamp circuit using the same type lamp. Ideally, the transformer's secondary current splits evenly between the two capacitor lamp branches, with the total load current being regulated. In practice, differences between C_{2A} and C_{2B} and differences in lamp-wiring layout preclude a perfect current split. However, these differences are small and the lamps appear to emit equal amounts of light.

The design in **Fig 3** (the so-called dim backlight) is

A

B



Trace	Vertical	Horizontal
A	5 V/DIV	50 μsec/DIV
B	5 V/DIV	50 μsec/DIV

Fig 4—When the regulator comes on (Trace A), it delivers bursts of output current to the L_1,Q_1-Q_2 high-voltage converter. The converter responds with bursts of ringing at its resonant frequency.

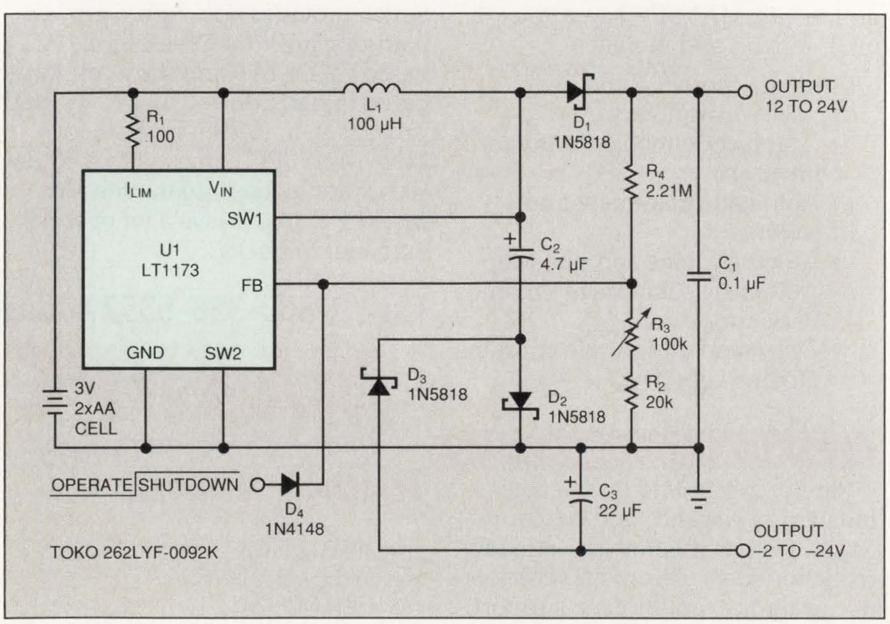


Fig 5—To develop bias for an LCD, this generator circuit converts the 3V input to a 24V output. The circuit will deliver 7 mA from a 2V input at 75% efficiency.

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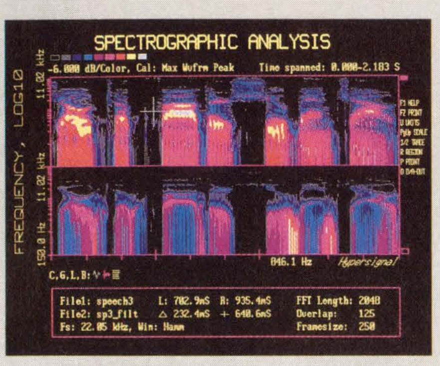

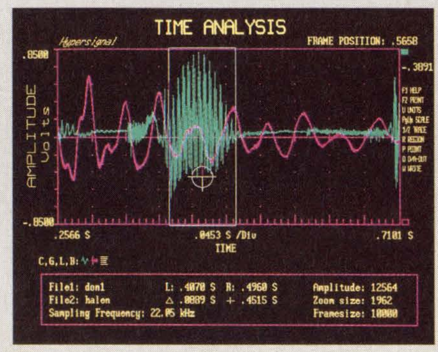

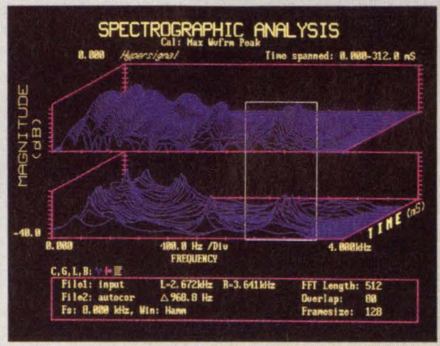

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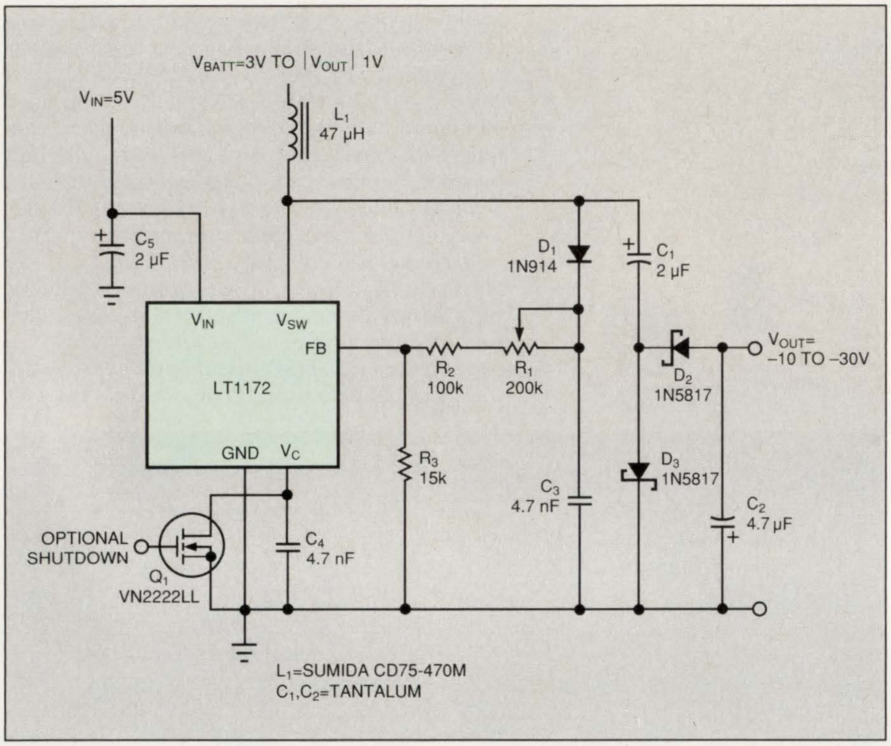

Fig 6—To generate negative bias for LCD drivers, this circuit combines switching regulator and charge pump techniques. The variable −10 to −30V output can provide contrast control for the display.

optimized for single-tube operation at very low currents. The circuit is designed for use at low-input voltages—typically 2 to 6V. **Fig 1a**'s circuit drives 5 mA max, but the low-power design tops out at 1 mA. The circuit in **Fig 3** maintains control down to tube currents of 1 mA—a very dim light. This design is aimed at applications looking to maximize battery life. Primary supply drain ranges from hundreds of microamperes to 100 mA with tube currents of microamperes to 1 mA. In shutdown, the circuit draws only 110 mA.

The basic design requires some modifications to maintain high efficiency at low tube currents. The operating current level in **Fig 1a**'s circuit must be lowered to achieve high efficiency. To do this, the circuit uses an LT1173 in place of the LT1172. The LT1173 is a burst-mode type regulator. When the 1173's feedback pin voltage is too low, the unit delivers a burst of output-current pulses, putting energy into the transformer and restoring the feedback point. The regulator maintains control by appropriately modulating the burst duty cycle. The ground-referred diode at the VSW pin prevents substrate turn-on due to excessive L_2 ring-off.

During the off periods, the regulator is essentially shut down. This type of operation limits available output power but cuts quiescent current losses. In contrast, **Fig 1a**'s LT1172 pulse-width modulator-type regulator maintains housekeeping current between cycles. This design results in more available output power, but higher quiescent currents. **Fig 4** shows operating waveforms. When the regulator comes on (Trace A), it delivers bursts of output current to the L_1,Q_1-Q_2 high-voltage converter. The converter responds with bursts of ringing at its resonant frequency. The circuit's loop operation is similar to that of **Fig 1a**.

Providing bias for LCDs

LCDs also require a bias supply for contrast control. The supply's variable negative output permits adjustment of display contrast. Relatively little power is involved, which eases RF radiation and efficiency requirements. The logic sections of display drivers operate from single 5V supplies, but the actual driver outputs swing between +5V and a negative bias potential. Varying this bias causes the contrast of the display to vary.

The design in **Fig 5** is an LCD bias generator. In this circuit, IC_1 is an LT1173 micropower dc/dc converter. IC_1's switch, L_2, D_1, and C_1 convert the 3V input. The switch pin (SW1) also drives a charge pump composed of C_2, C_3, D_2, and D_3 to generate 24V. Line regulation is 0.2% min with 2- to 3.3V inputs. Load regulation measures 2% with a 1- to 7-mA load. The circuit will deliver 7 mA from a 2V input at 75% efficiency.

If you need more output power, you can drive the **Fig 5** circuit from a 5V source. You have to change R_1 to 47Ω and C_3 to 47 µF. With a 5V input, the circuit

will output 40 mA at 75% efficiency. To obtain shutdown, simply bring the anode of D_4 to a logic high, which forces the feedback pin of IC_1 to go above the internal 1.25V reference voltage. Shutdown current is 110 mA from the input source and 36 mA from the shutdown signal.

Fig 6 shows a boost converter that can provide negative bias from a 5V supply. The converter is half switcher and half charge pump. The flying node at V_{SW} drives the charge pump (C_1, C_2, D_2, and D_3). The output is variable from 10 to 30V and provides contrast control for the display. On low voltage supplies (6V or less), you can tie V_{IN} and V_{BATT} together. To obtain higher efficiency with higher battery voltages, run the LT1172 V_{IN} pin from 5V. Shutting off the 5V supply automatically turns off the LT1172. The maximum value for V_{BATT} is equal to the negative output +1V. Also, the difference between V_{BATT} and V_{IN} must not exceed 16V. R_1, R_2, and R_3 have large values that minimize battery drain in shutdown because they are permanently connected to the battery via L_1 and D_1. Efficiency is about 80% at $I_{OUT}=25$ mA. EDN

Author's biography

Jim Williams, staff scientist at Linear Technology Corp (Milpitas, CA), specializes in analog-circuit and instrumentation design. He has served in similar capacities at National Semiconductor, Arthur D Little, and the Instrumentation Lab at the Massachusetts Institute of Technology. A former student at Wayne State University (Detroit, MI), Jim enjoys art, collecting antique scientific instruments, and restoring old Tektronix oscilloscopes.

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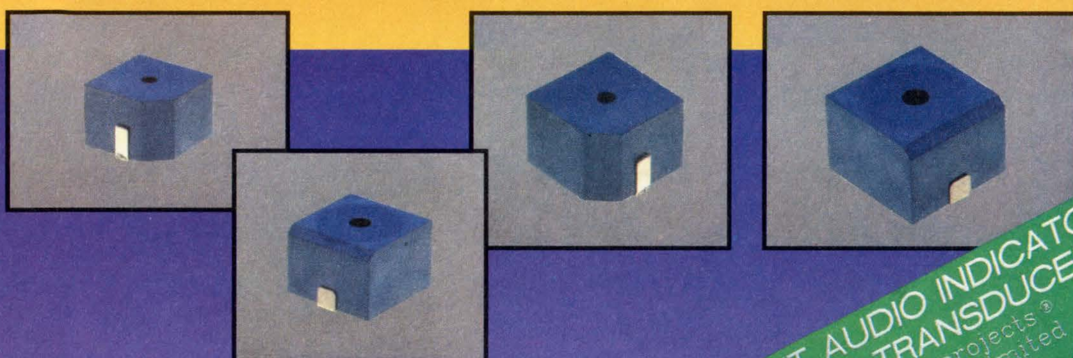

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LINEAR TECHNOLOGY
DESIGN NOTES

2 AA Cells Replace 9V Battery, Extend Operating Life

Design Note 63

Steve Pietkiewicz

Operating life is an important feature in many portable battery-operated systems. In many cases the power source is the ubiquitous 9V "transistor" battery. 5V generation is accomplished with a linear regulator. Significant gains in battery life can be obtained by replacing the 9V/linear regulator combination with 2 AA cells and a step-up switching regulator. Two (alkaline) AA cells occupy 1.3 cubic inches, the same as a 9V battery, but contains 6WH of energy, compared to just 4WH in an alkaline 9V battery. Two AA cells also cost less than a 9V battery.[1] The additional energy in the AA cells provides longer operating life when compared to a 9V battery based solution.

An evaluation of the three approaches with a 30mA load illustrates the differences in battery life. An HP7100B strip chart recorder provides a nonvolatile record of circuit performance. The linear regulator circuit shown in Figure 1 uses an LT1120 micropower low-dropout regulator IC. A minimum of external components are required. No inductors or diodes are needed; however, the linear step-down process is inherently inefficient. The step-down switcher shown in Figure 2 uses an LT1173 configured in step-down mode driven from an alkaline 9V battery. In Figure 3 the step-up circuit uses an LT1173 configured in step-up mode driven from a pair of alkaline AA cells. The two switching circuits require an external inductor, diode and output capacitor in addition to the IC.

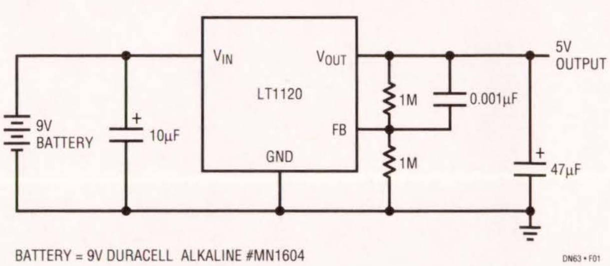

Figure 1. 9V to 5V Linear Regulator

1. A quick check at the local drugstore yielded $2.99 for a 4-pack of alkaline AA cells and $2.49 for a single 9V battery (after $1.00 mail-in rebate).

Circuit operation of the switching step-down regulator is straightforward. A comparator inside the LT1173 senses output voltage on its "sense" pin. When V_{OUT} drops below 5V, the on-chip switch cycles. As current ramps up and ramps down in L1, it flows into C1 and the load, raising output voltage. When V_{OUT} rises above 5V, the cycling action stops and the regulator goes into a standby mode, pulling 110μA from the supply. C1 is left to supply energy to the load. These "bursts" of cycles occur as needed to keep the output voltage at 5V. 50mV of hysteresis at the sense pin eliminates the need for frequency compensation. The step-up regulator operates in a similar fashion, although in this case the inductor current flows into the load only on the discharge half of the switch cycle. Output voltage is regulated in a similar manner.

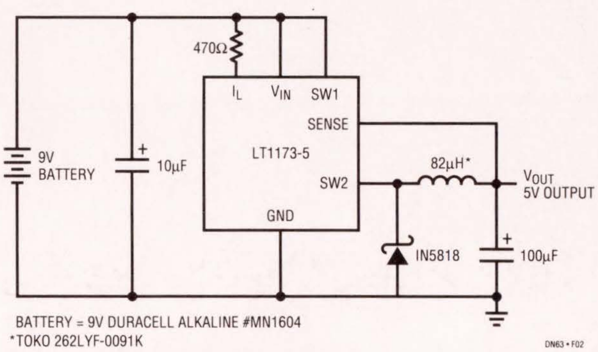

Figure 2. 9V to 5V Step-Down Converter

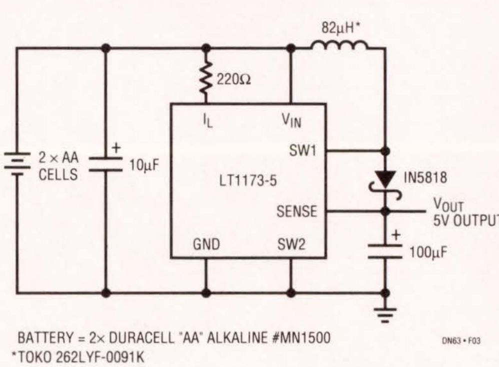

Figure 3. 3V to 5V Step-Up Converter

Efficiency curves for the three circuits are shown in Figures 4 and 5. The linear regulator circuit has efficiency of 52% with a fresh battery. As the input-output differential decreases, the efficiency increases and at end of battery life exceeds 90%. Regulator ground current limits efficiency at drop-out. The switch-mode step-down circuit has almost constant efficiency, ranging from 84% at 6.3V input to 82% at 9.5V input. Minimum V_{IN} is set by the drop of the emitter follower switch inside the LT1173. Performance for the step-up converter is shown in Figure 5. At higher inputs, the switch drop is a lower percentage of supply, resulting in higher efficiency.

The three regulators show substantial differences in operating life. The linear regulator operates for 16.5 hours, as shown in Figure 6. Figure 7 shows a 19 hour operating life for the step-down switching circuit. The step-up regulator circuit's performance, detailed in Figure 8, yields an operating life of 26 hours. This is an increase of 58% over the linear step-down approach at less cost and 37% over the switching step-down approach.

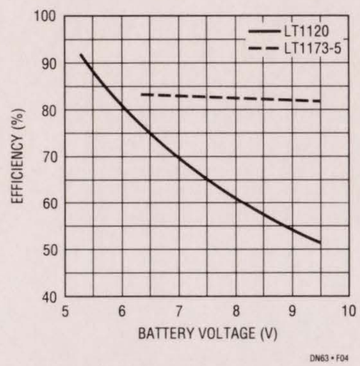

Figure 4. Step-Down Conversion Efficiency – 5V Output, 30mA Load

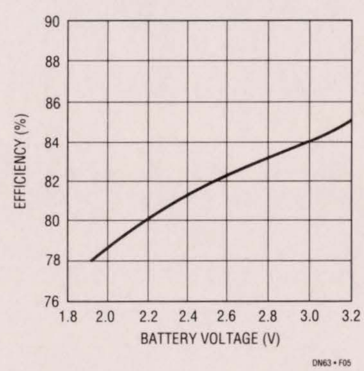

Figure 5. Step-Up Conversion Efficiency – 5V Output, 30mA Load

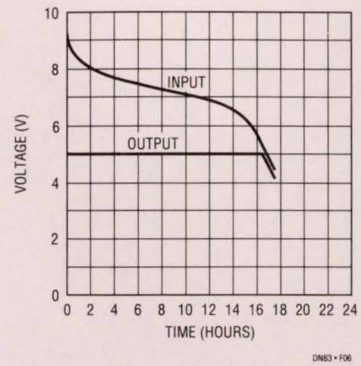

Figure 6. 9V to 5V Step-Down Linear – LT1120, 30mA Load

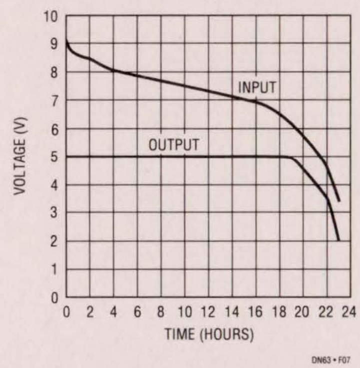

Figure 7. 9V to 5V Step-Down Switcher – LT1173-5, 30mA Load

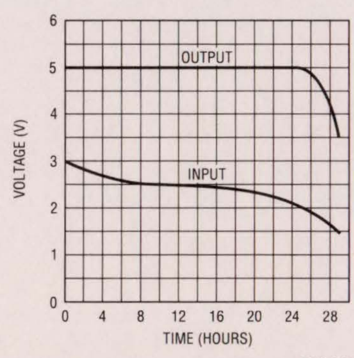

Figure 8. 3V to 5V Step-Up Switcher – LT1173-5, 30mA Load

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EDITED BY CHARLES H SMALL & ANNE WATSON SWAGER

Latching relay disconnects low battery

Yongping Xia, EBT Inc, Torrance, CA

The circuit in **Fig 1** uses a latching relay to disconnect the load when a battery voltage drops to a certain level. Because the latching relay can hold its status, the circuit consumes very little current, about 3 μA, under normal working conditions. Another attractive point for the low-voltage power supply is that the relay has no drop voltage.

The circuit configures a MAX404 low-power op amp as a voltage comparator with a 30-MΩ positive-feedback resistor. Using the component values in **Fig 1**, the comparator has a positive threshold, V_{H+}, of $5.88 \times V_R$ and a negative threshold, V_{H-}, of $4.41 \times V_R$, where V_R is a reference voltage provided by LED D_1. When a small current flows through D_1, the LED shows lower dynamic resistance, that is, a flatter slope of the VI curve, than a normal or zener diode. For example, experiments show that the voltage drops across the LED are 1.47V at 10 μA and 1.36V at 1 μA. For a 1N4148 diode, the drops are 0.39 and 0.25V, respectively. The LED's smaller change in voltage with changes in current make it a better regulated voltage reference than a standard diode.

When S_1 turns on, if the battery voltage is higher than V_{H+}, which in this case is 7.9V because V_R equals 1.34V, the op amp's output changes from low to high. This high signal produces a narrow positive pulse through C_1, R_1, and R_2 that drives Q_2. Thus, one of the latching-relay coils will have power for a moment to turn the relay on. Once the battery voltage is below V_{H-} (5.9V in this case), the op amp's output goes low. This low signal sends power to another coil though C_2, R_3, R_4, and Q_1 to turn the relay off. Q_1 and Q_2's H_{fe} should be greater than 200. **EDN BBS /DI_SIG #1191**

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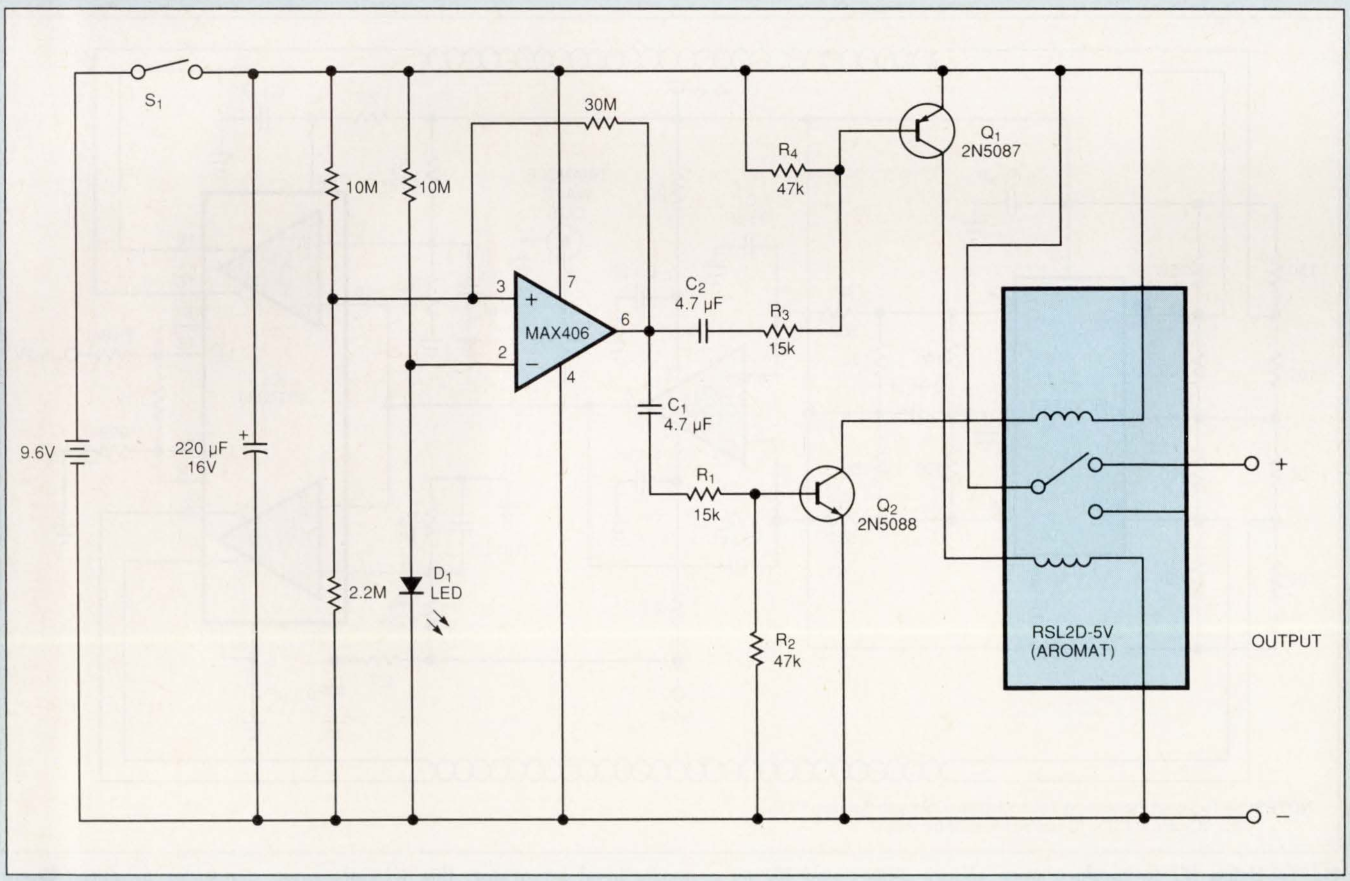

Fig 1—This circuit cuts off a low battery while and consumes only 3 μA.

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Thomas P Hack, Comlinear Corp, Fort Collins, CO

Using several new high-performance ICs that simplify high-frequency triangle-wave generation, **Fig 1**'s circuit provides 10-MHz, 1V p-p bipolar-output triangle waves into 50Ω loads.

The circuit generates triangle waves by way of the following scenario. Assume flip-flop IC_1 is set and the output of integrator IC_2 pin 6 is between −1 and +1V. Comparator A's and B's Q outputs (IC_3, pins 1 and 16) are low. IC_2's output ramps up until the voltage into comparator A's input (pin 8) exceeds its trip point (+1V, set by voltage divider R_5 and R_6). Comparator A's Q output pulses high, resetting IC_1. With IC_1 reset, IC_2's output ramps down until the voltage into comparator B's input (pin 10) is less than its trip point (−1V set by R_3 and R_4), pulsing comparator B's output high, thereby setting IC_1. The cycle repeats at this point. The circuit produces triangle waves at the output of IC_2. Trigger outputs are available at pin 2 or pin 15 of IC_3.

A differential-input integrator topology provides high half-wave symmetry and eliminates offset circuitry that would be required in a single-ended input integrator. An MC10E131 works better than gate-based R-S flip-flops for IC_1 because the MC10E131's lower Q-to-$\overline{Q}$ skew (30-psec typical, 50-psec maximum) reduces flat spots at the triangle waveform's endpoints.

Linear 10-MHz triangle waves require low amplitude and phase errors of Fourier components well past 100 MHz. IC_1 must generate excellent square waves, and IC_2 must have a nearly ideal integrator transfer function up to 100 MHz. To meet these requirements, the circuit uses ECLinPS logic for IC_1 and a CLC420 current-feedback op amp for IC_2. Careful passive-component selection ensures that self resonances and other effects due to device parasitics are well above 100 MHz. The circuit uses 33-pF NPO ceramic capacitors for C_1 and C_2 so that self resonance occurs at approximately 300 MHz. Keeping R_1 and R_2 below 850Ω ensures that the 0.6-pF parasitic capacitance typical of RNC55 metal-film resistors produces an inte-

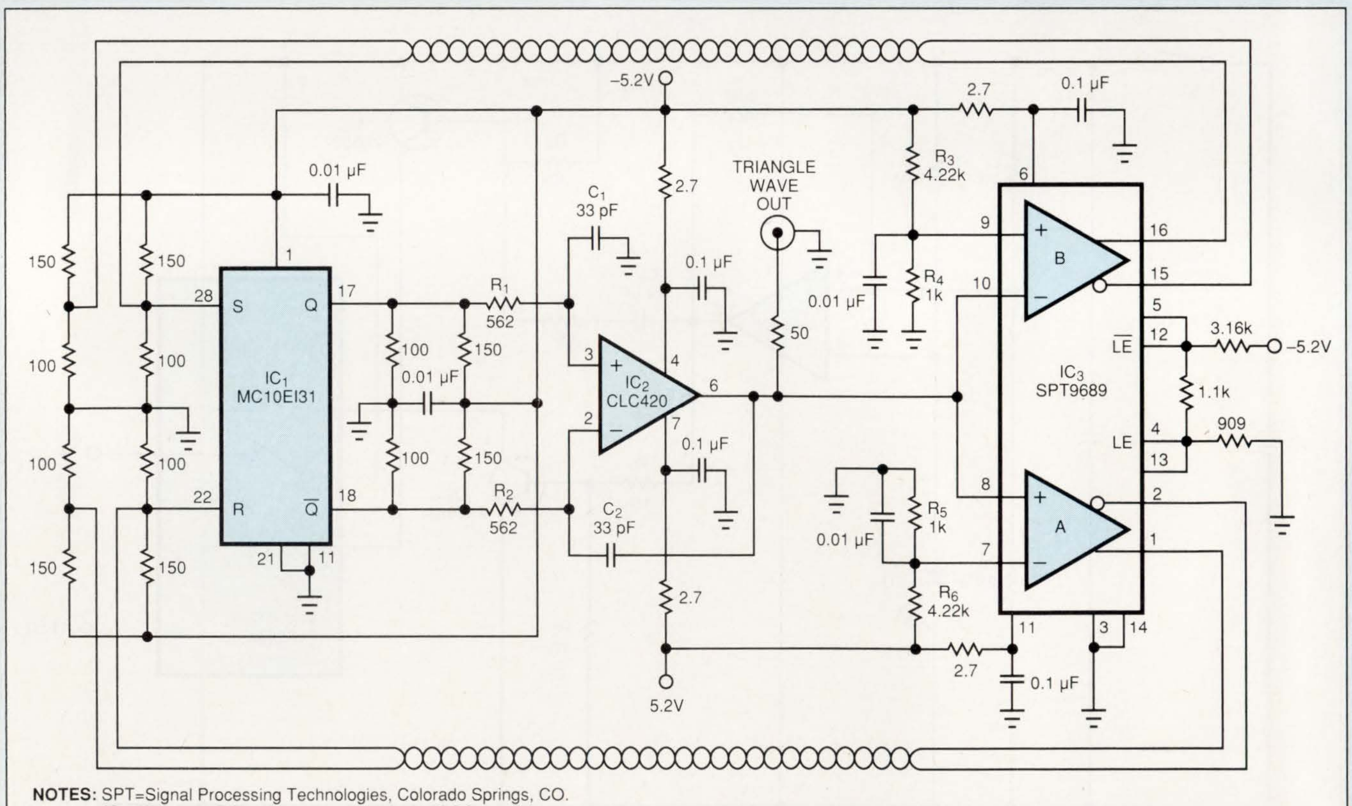

Fig 1—Using IC_1 to produce pure square waves and IC_2 as a nearly ideal integrator, this triangle-wave generator produces linear 10-MHz, 1V p-p triangle waves that exhibit low second harmonics of −51 dBc.

grator zero above 300 MHz. If you use precision buffed resistors, which have a distributed capacitance of 0.06 pF, higher values of R_1 and R_2 are tolerable.

This circuit requires careful consideration of grounding, layout, and decoupling. Use a ground plane. The circuit should be laid out as it is drawn in **Fig 1**. Use the shortest lead lengths for R_1 and R_2. ECL terminators at Q and $\overline{Q}$ of IC_1 should have minimum lead lengths. The terminations should also share a common bypass and tie point to -5.2V. The 2.7Ω resistors and 0.1-μF ceramic capacitors decouple the comparator and the integrator from the rest of the circuit and from one another, preventing potential instability. Adding a Schottky-diode clipping in the signal path between IC_1 and IC_2 could boost performance.
EDN BBS /DI_SIG #1192

To Vote For This Design, Circle No. 394

Meter indicates 455-kHz carrier level

Alexandru Ciubotaru, Polytechnic Institute of IASI, Romania

Using a high-speed OPA404 op amp, **Fig 1**'s circuit accurately indicates the carrier level of a 455-kHz amplitude-modulated signal (modulation index less than 1). The circuit also produces a demodulated signal output at little extra cost. The circuit is a half-wave precision rectifier and connects a low-power buffer, which draws approximately 0.5 μA when no input signal is present, to the output of amplifier IC_{1A}. The circuit connects the amplifier and buffer in a basic follower configuration so that the duo's output is virtually ground for ac signals. The excitation of the circuit is a current that flows either through Q_1 or Q_2, depending on the current's polarity.

The circuit's input impedance is approximately 2 kΩ. The 500Ω potentiometer lets calibration adjustment compensate for the internal resistance of the signal source. The demodulator's sensitivity has a value of 3, and the cutoff frequency of the output lowpass filter is 4 kHz. If necessary, you can use the other two op amps from the OPA404 package to perform additional filtering and amplification. **EDN BBS /DI_SIG #1193**

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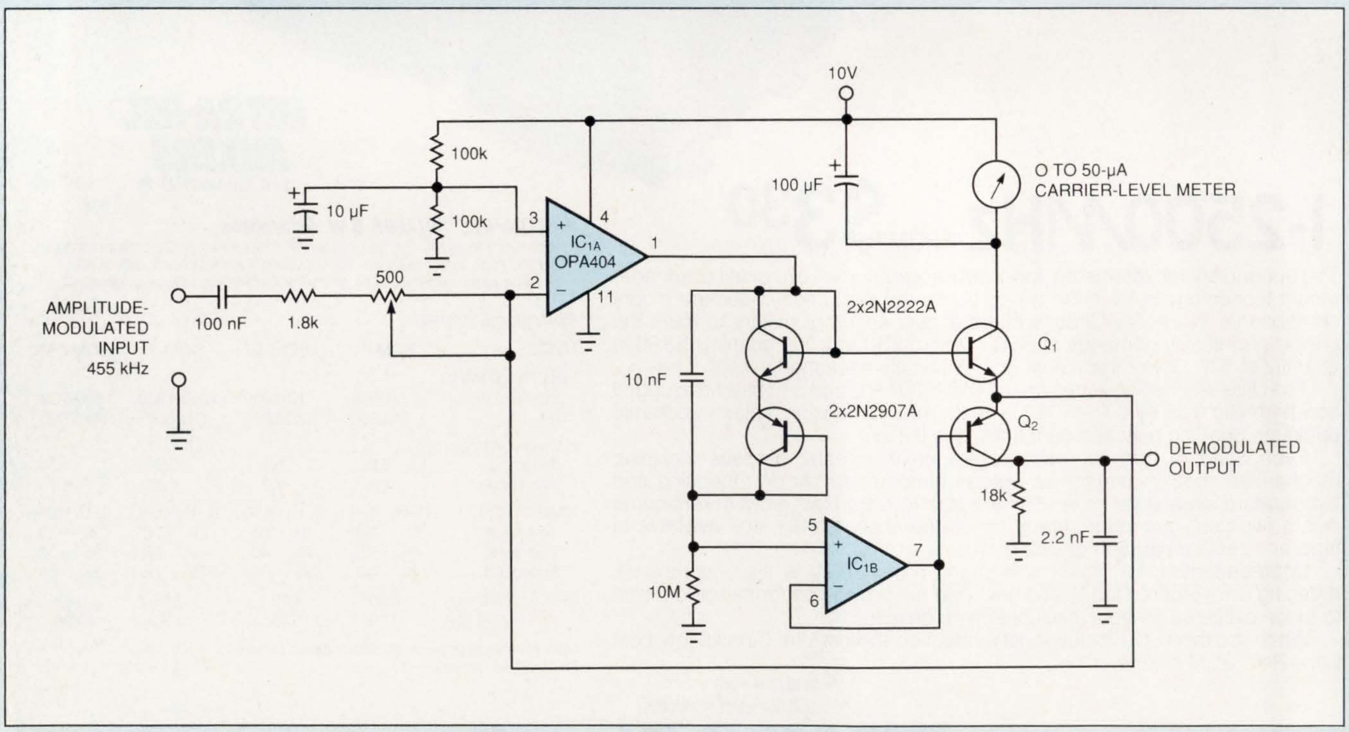

Fig 1—This circuit indicates the carrier level of a 455-kHz AM signal and produces a demodulated output.

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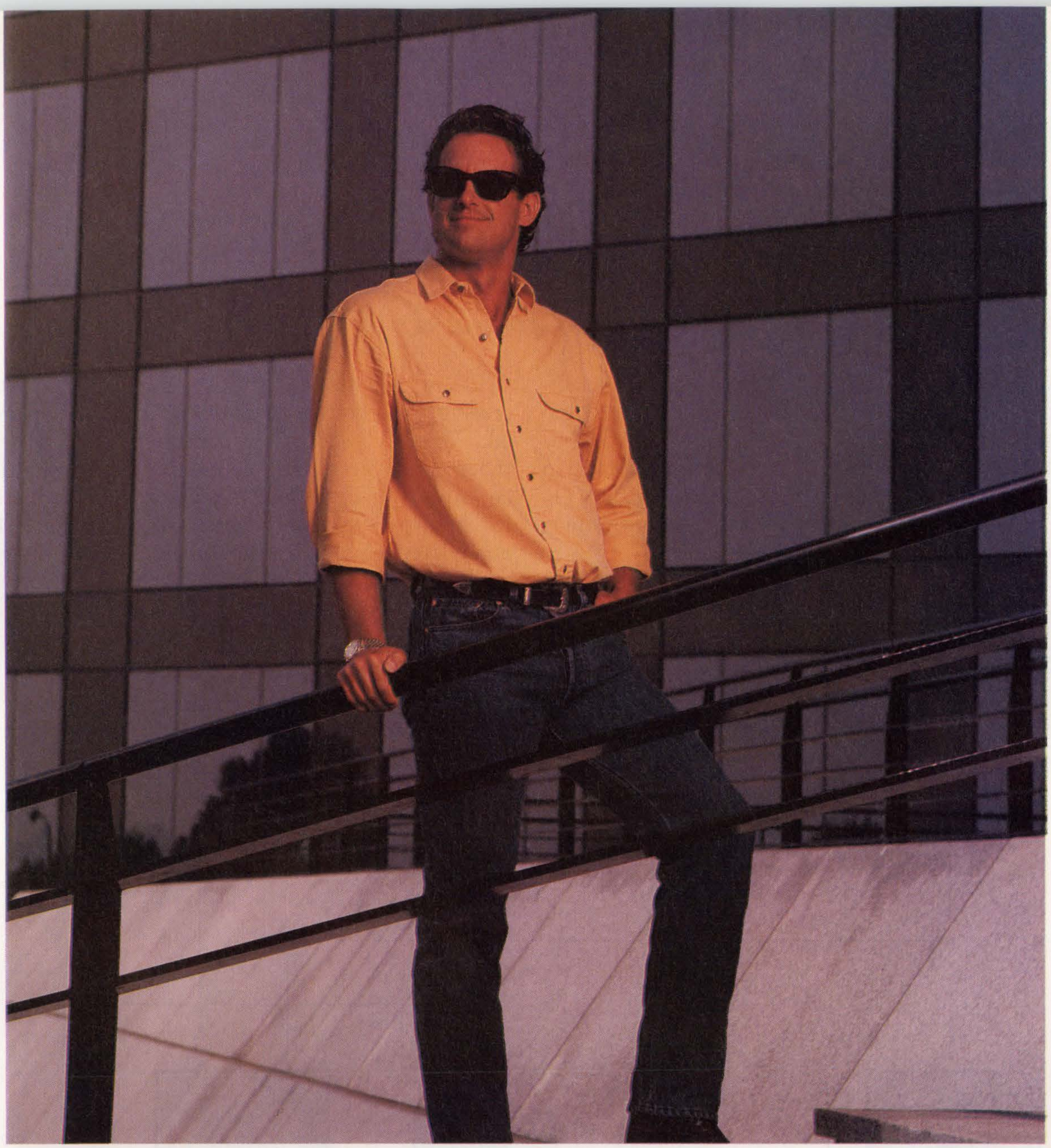

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CIRCLE NO. 95

Backup supply sustains pseudostatic RAMs

Chuck Thurber, Illy King, and Roger Chen, Maxim Integrated Products, Sunnyvale, CA

The battery-backed supply in **Fig 1** will keep self-refreshing, pseudostatic RAMs alive using only a single 3V lithium cell. Pseudostatic RAMs have high density and require no external refresh circuitry, making them attractive for battery-powered systems. However, their minimum supply voltage is 4V, necessitating a step-up converter for 3V backup cells.

In **Fig 1**, power supervisor IC_3's internal switchover circuit connects V_{CC} to V_{OUT} for normal operation. If the 5V supply fails, its declining output triggers two events: at 4.75V, IC_3's pin 6, LLB, goes low and inverter IC_2's outputs go high, delivering power to switching regulator IC_1. IC_1 pumps charge into C_1, causing V_{BATT} to rise toward 4.5V as V_{CC} continues to fall. When $V_{CC}<V_{BATT}$ (which occurs well above 4V) the switchover circuit completes the transition to backup power by connecting V_{BATT} to V_{OUT}. Note that IC_1 receives power only when V_{CC} is less than 4.75V, minimizing current drain during normal operation. **EDN BBS /DI_SIG #1180**

To Vote For This Design, Circle No. 392

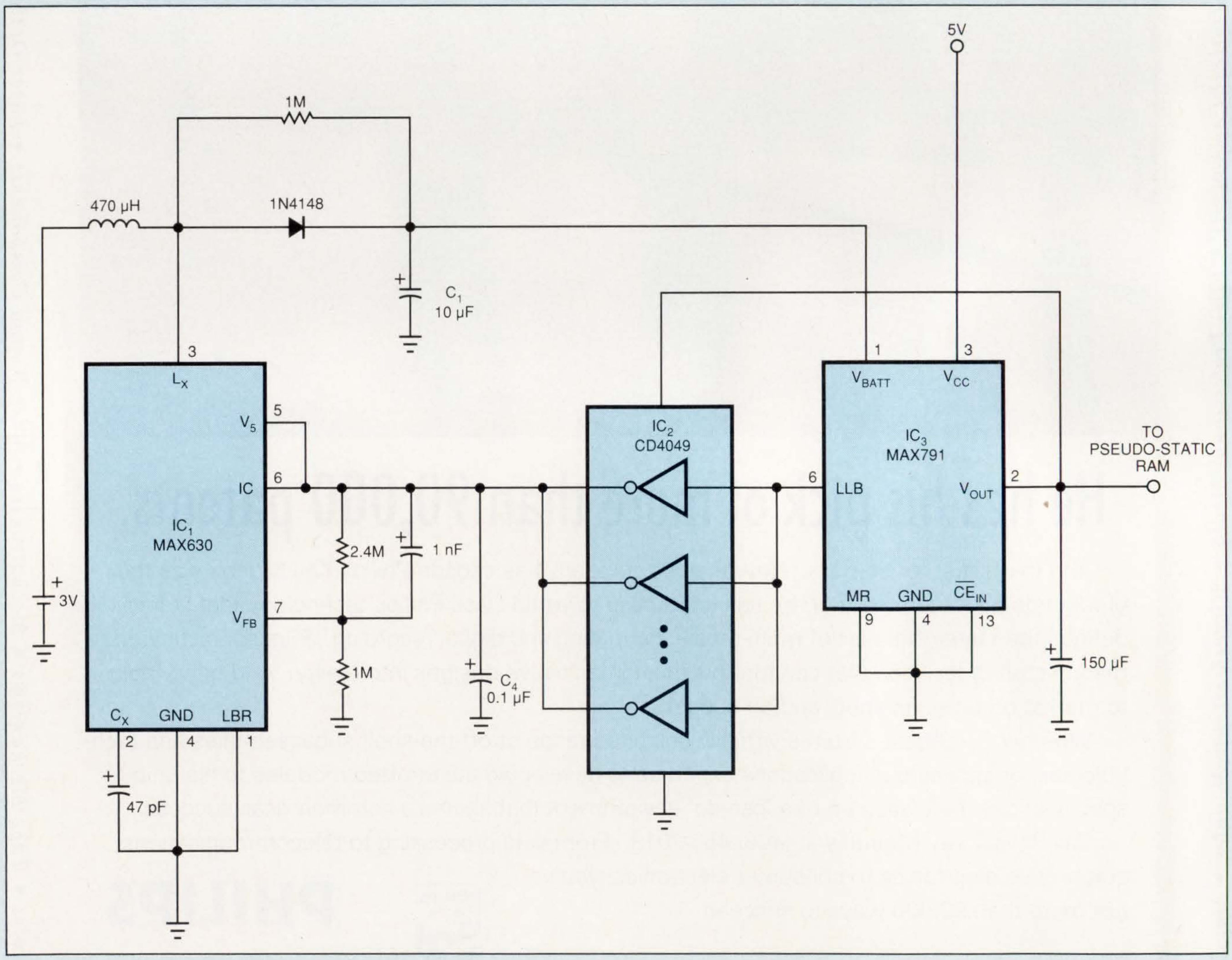
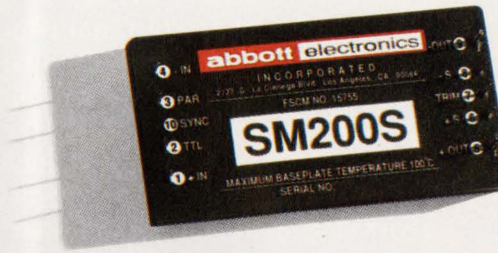


Fig 1—A power supervisor, IC_3, uses a ganged inverter, IC_2, as a miniature solid-state relay to power a step-up regulator, IC_1, only when the main 5V supply fails. The backup supply can supply 4V from a single 3V lithium cell to keep pseudostatic RAMs alive.



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- Mil-Std qualifications: none
- Board-mountable: *not*
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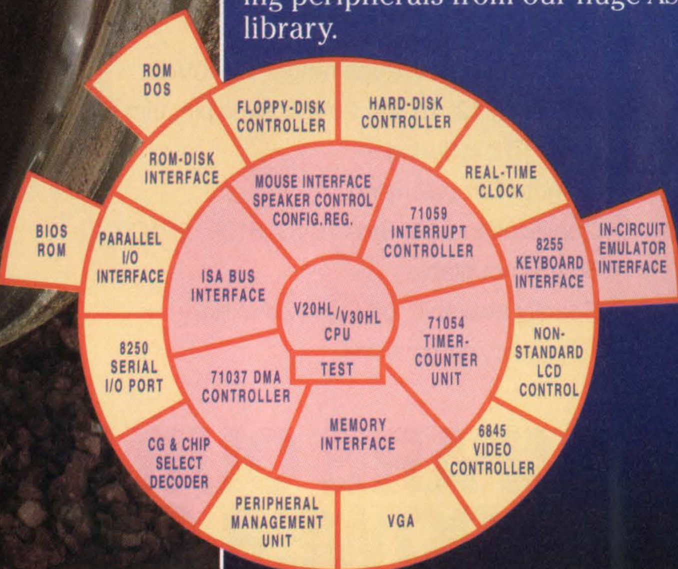

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UNIVERSAL INPUT

HOT SWAPPABLE POWER

flected back onto the mains below the limits of FCC docket 20780, level A and VDE 0871, level A. HSP are capable of sustaining full load operation through the loss of one full mains cycle at any source voltage and without indication of failure. If the mains power is lost for more than one cycle, HSP provides a flag a minimum of 5 milliseconds before the output loses regulation. They meet the ANSI C62.41 guidelines for withstanding surges on the mains.

HSP are plug-in designs. Their 5″ x 5″ crossection allow three HSP to be mounted in a standard 5.25″ x 19″ rack adaptor. Output voltage and current limit can be preset outside of the housing so that an HSP can be installed without powering down the system.

Their outputs are fully protected for any overload including a short circuit. The normal overload protection mode is continuous current limiting. A switch selectable option will latch the power off after 30 seconds to avoid damage to load wires. An overvoltage protector latches the power off whenever the output exceeds a user-set limit.

Remote control of the HSP is provided via one of two isolated TTL-level signals, one normally high, the other normally low. An internal 5V supply powers this circuit and provides an auxilliary 5V, 100mA output on all models. This voltage is available whenever source power is applied whether or not the main output is inhibited. The main output is normally ON if no remote logic is applied. The main output voltage is remotely trimmable by resistance.

Both output voltage and current limit are adjustable via remote analog programming, or can be computer controlled with Kepco digital programmers.

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HSP OUTPUT CHARACTERISTICS

SPECIFICATIONS		RATING/DESCRIPTION	CONDITION
Output setting range		−30% to +10%	Of nominal output
		−30% to +25%	48V Model only
Source effect	typ	0.05%	Nominal ±15%
	max	0.1%	
Load effect	typ	0.05%	5%-100% load operation 0-5% has increased ripple and degraded transient response
	max	0.1%	
Temperature effect	typ	0.01%	Per degree C (0 to 50°C)
	max	0.02%	
Combined effect (source, load temperature & time)	typ	0.15%	
	max	0.3%	
Time effect (drift)	typ	0.05%	0.5-8.5 hours
	max	0.1%	
Start up time	max	1 second	Any source/load
Recovery characteristics	Excursion	<3% of Nominal Output	50-100% load
	Recovery	100 Microseconds	Return to 1% of setting
Ride through	min	22 Milliseconds	From loss of source to flag signal
Hold up time	min	5 Milliseconds	After signal flag
Overshoot		None	Turn on/off
Error sense	3.3 & 5V	0.25V	Voltage allowance per wire
	All others	0.4V	
Series connection (output floats)		500V	Maximum voltage off ground
Parallel connection (for redundancy)		Current shares within 5% of rated load	Hot swappable
Over voltage protection		130% of nominal	Latched, reset by cycling source power off
Current limiting		Constant current mode	Optional; output off after 30 seconds
Remote on/off	RC-1	Normally high	Isolated form C or TTL
Remote on/off	RC-2	Normally low	Isolated form C or TTL
Over temperature		Thermostat	Auto re-start with hysteresis

HSP GENERAL SPECIFICATIONS

SPECIFICATIONS		RATING/DESCRIPTION	CONDITION
Temperature		−20° to +71°C (see model table)	Operating
		−40° to +85°C	Storage
Humidity		0 to 95% RH	Non condensing operating & storage
Shock		20g 11msec ±50% half sine	3-axes 3 shocks each axis
Vibration		5-10Hz 10mm double amplitude	Non operating 1 hour each axis
		10-55Hz 2g	
Altitude		Sea level to 10,000 ft	
Isolation	Output-case	500V d-c	25°C, 65%RH
Withstand voltage	Input-output	2500V a-c	25°C, 65%RH Y CAPS removed
	Input-case	1500V a-c rms	
Safety		UL 478, 1950; EN 950; CSA 1402C (level 3)	Recognition and certification applied for
Type of construction		Enclosed, plug-in style includes status LEDs circuit breaker, handle voltage/current trimmers monitor test points	Stand alone or rack mountable into RA-57 to accommodate up to 3 plug-in units
Cooling		Internal d-c fan	Exhaust to rear

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HSP MODEL TABLE

SPECIFICATION	OUTPUT VOLTAGE		OVP SETTING	OUTPUT CURRENT			RIPPLE		NOISE	EFFICIENCY
Unit	Volts		Volts	Amps			mV p-p		mV p-p	Percent
Condition	Factory Set	Adjustment Range	Nominal Input 25°C	50°C	60°C	71°C	Source max	SW max	(Spike) 20MHz	100% Load Any Input
1000 WATT PLUG-IN MODELS										
HSP 3.3-230	3.3	2.3-3.6	3.9-4.7	230	173	105	20	20	50	78
HSP 5-200	5	3.5-5.5	5.9-7.2	200	150	95	20	20	50	78
HSP 12-84	12	8.4-13.2	14-17.2	84	63	40	20	25	75	81
HSP 15-66	15	10.5-16.5	17.6-21.4	66	49.5	31.4	20	25	75	82
HSP 24-42	24	16.8-26.4	28.1-34.3	42	31.5	20	20	30	100	84
HSP 28-36	28	19.6-30.8	32.8-40	36	27	17	20	30	100	87
HSP 48-21	48	33.6-60.0	63-77	21	16	10	20	30	100	88

1KW 5″ x 5″ x 15.5″ POWER SUPPLIES

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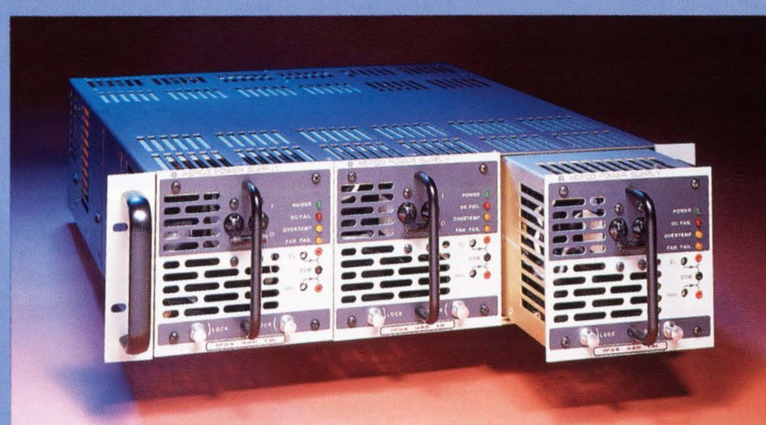
The Kepco HSP Series is a group of seven, kilowatt-size power supplies with outputs from 3.3 Volts to 48 Volts. They feature current-sharing for parallel operation and hot swappability for redundancy applications. Kepco's HSP have a universal input (85-277V a-c), and incorporate power factor correction (0.998) to meet IEC 555-2. These modern power supplies operate at 100KHz (200KHz for the boost converter) in current mode. This provides rapid response to source and load changes and tight stabilization.

They are designed in accordance with EN 950 and UL 1950 and will be submitted for approval by UL/CSA/TÜV. A built-in conducted EMI filter attenuates the noise re-

HSP INPUT CHARACTERISTICS

SPECIFICATIONS		RATING/DESCRIPTION	CONDITION
a-c Voltage	nominal	100/120/220/240/250V a-c	Single phase
	range	85-277V a-c	Wide range
d-c Voltage	range	125-420V d-c	Polarity insensitive
Brownout voltage	min	75 Va-c	
Frequency	nominal	50-60Hz	>63Hz, Input leakage current exceeds spec
	range	47-63Hz (400Hz)	
Current	120V a-c	11A rms	Maximum
	240V a-c	5.5A rms	
Initial turn-on surge		22.5A	For all source conditions
Power factor	min	0.998	For all source conditions, 10%-100% load
Efficiency	min	See model table	100% load any source voltage
Current harmonics		Within EN 555-2 limits	For all source conditions, 10%-100% load
Total harmonic distortion		<7%	
Source transients		Meets ANSI C62.41 (1980) surge withstanding guidelines	Near lightning strike replaces IEEE 587
EMI		Meets FCC docket 20780 level A and VDE 0871, level A	
Leakage current	120V a-c	<0.25mA	Source frequency in 47-63Hz range
	240V a-c	<.5mA	
Circuit type		Forward converter, current mode	
Switching frequency	typ	100KHz Load/200KHz boost	Synchronized



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HSP SIGNALS AND FLAGS

SPECIFICATIONS	RATING/DESCRIPTION	CONDITION
Status flags	ACFAIL (source fail) signal asserted 5 Msec prior to loss of output voltage	Both NO and NC available
(Form C relay contacts)	DCOK Indicates normal operation	
	OVERTEMP Over temperature shutdown	
	FANFAIL Failure of internal fan	
Status indicators front panel LEDs	Power Green	Lit when a-c is sufficient (>83V a-c)
Status indicators and status flags are isolated and operate independently although driven by the same detector circuit	DCFAIL Red	Lit when d-c is ±5% beyond limits
	OVERTEMP Yellow	Lit when thermostat activates
	FANFAIL Red	Lit when fan failure is detected
Test points	Monitor setpoint voltage	0.1 x E out
	Monitor setpoint current	0-10 Volts full scale
Auxiliary voltage	4.5-5.5V d-c (parallelable) 0-100 milliamperes	Present whenever housekeeping supply is operating

HSP CONTROL

SPECIFICATIONS		RATING/DESCRIPTION	CONDITION
Voltage set programming (mode selected by internal switches)	Internal	Multiturn potentiometer	The DCOK/DCFAIL fault detect window tracks the programmed output voltage, OVP trip unaffected
	External 1	Resistance, 1000 ohms/volt	
	External 2	Voltage, 0-10V = 0-100% of rated output voltage	
Current limit programming (mode selected by internal switches)	Internal	Multiturn potentiometer	
	External	Voltage, 0-5V = 0-110% of rated output current	
Remote ON/OFF	Normal H	TTL level	Isolated 5V, 100mA internal pull up supply
	Normal L	TTL level	
Forced load share		Single wire connection between modules	0-5.5V signal indicates each module's current

HSP PHYSICAL CHARACTERISTICS

SPECIFICATIONS		RATING/DESCRIPTION	CONDITION
Dimensions	English	5″ x 5″ x 15.5″	Excluding front latch, circuit breaker, handle and rear connections
	Metric	127 x 127 x 394 mm	
Weight	English	15 lbs	
	Metric	6.8 Kg	
Source connection		3 pin IEC Connector	Compatible with molded line cord
Load connection		Two bus bars 1.25″ x 0.125″ x 2.5″	Bright nickel finish
Signal connection		37 Pin D-subminiature connector	

Instrumentation and Bench

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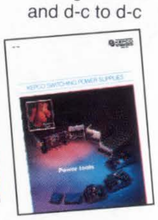
Switching a-c to d-c and d-c to d-c



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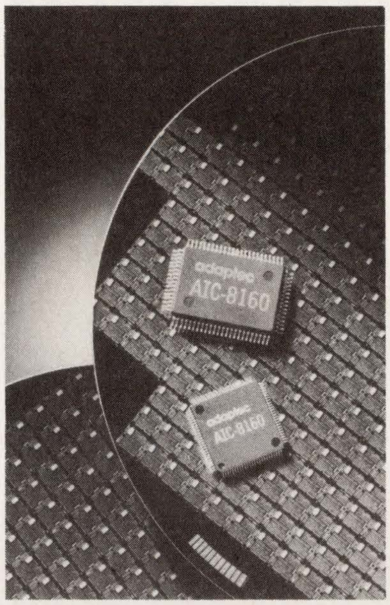
Resolver-to-digital converter. The HSD/HRD1066 converts signals from a resolver to 10-, 12-, 14-, or 16-bit resolution. A type II tracking loop provides an accuracy of ±1.3 arc-minutes and a zero velocity lag error for a 1800°/sec tracking rate. An antifalse lock circuit prevents locking to a 180° phase step. A differential signal conditioner provides 70 dB of common-mode rejection for the resolver inputs. From $630. **Natel Engineering Co,** 4550 Runway St, Simi Valley, CA 93063. Phone (805) 581-3950. **Circle No. 402**



IDE hard-disk controller. The AIC-8160 hard-disk controller automates ISA bus I/O tasks that usually require a local μC. The chip provides 11 bits of error detection and correction and can continuously read while correcting. A data-flow manager controls data flow in and out of a buffer RAM while both the host and disk ports are operating. The chip also has power-down modes. $15.95. **Adaptec Inc,** S Milpitas Blvd, Milpitas, CA 95053. Phone (408) 945-8600. FAX (408) 262-2533. **Circle No. 403**

Communication chip set. The HDMP-1000 Gigabit-Link chip set provides point-to-point communication as fast as 1.5 Gbps. A transmitter and receiver transfers data over a fiber-optic link as far as 10 km. A parallel ECL bus option enables transmission of 16-, 17-, 20-, or 21-bit parallel data. You can select data rates from 100 to 1500 Mbps. $710. **Hewlett-Packard,** 19310 Pruneridge Ave, Cupertino, CA 95014. Phone (800) 752-0900. **Circle No. 404**

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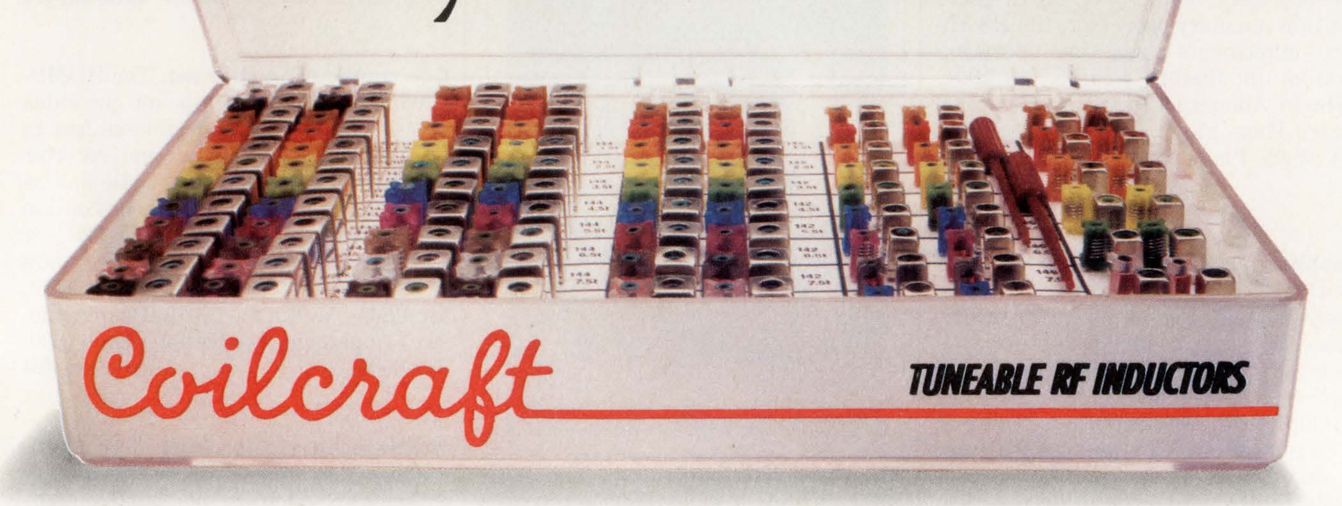

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19 values (10 of each) **Kit C103 $60**

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Inductance: 2.5 nH - 43 nH
10 values (12 of each) **Kit C102 $60**

RF Inductor Kits

"Unicoil" 7/10 mm Tuneable Inductors
Inductance: .0435 µH - 1.5 µH
49 shielded, 49 unshielded (2 of each)
Kit M102 $60

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Inductance: 9 nH - 281 nH
19 Shielded, 19 unshielded (2 of each)
Kit M105 $60

"Slot Ten" 10 mm Tuneable Inductors
Inductance: 0.7 µH - 1143 µH
18 shielded, 18 unshielded (3 of each)
Kit M100 $60

"Slot Seven" 7 mm Tuneable Inductors
Inductance: 0.094 µH - 275 µH
39 values (3 of each) **Kit M106 $60**

Axial Lead Chokes
Inductance: 0.1 µH - 1000 µH
25 values (5 of each) **Kit F102 $50**

Horizontal Mount Inductors
Tuneable and fixed
Inductance: 31.5 nH - 720 nH
33 values (3 of each) **Kit M104 $60**

EMI/RFI Filter Kits

Common Mode Data Line EMI Filters
Attenuation: 15 dBm, 1.5 - 300 MHz
DC current capacity: 100 mA
2, 3, 4, 8 line, surface mount and leaded (4 each)
Kit D103 $75

Common Mode Line Chokes
Current: .25 - 9 Amps rms
Inductance: 508 µH - 10.5 mH
8 styles (2 of each) **Kit P202 $100**

Power Magnetics Kits

Current Sensors
Sensing range: 0.5 - 35 Amps
Freq. resp.: 1 - 100 kHz, 50 - 400 Hz
Transformer and sensor-only versions
8 styles (15 total pieces) **Kit P203 $50**

Base/Gate Driver Transformers
Inductance: 1.5 mH Min. Freq: 10 - 250 kHz
2 single, 2 double section (2 of each)
Kit P204 $50

Mag Amp Toroids
Current: 1.5 Amps
Volt-time product: 42 - 372 V - µsec
6 styles (2 of each) **Kit P206 $100**

Power Filter Chokes
Current: 3, 5, 10 Amps Inductance: 5 - 300 µH
18 styles (48 total pieces) **Kit P205 $75**

Axial Lead Power Chokes
Current: .04 - 4.3 AC Amps
Inductance: 3.9 µH - 82 µH
30 values (2 of each) **Kit P209 $150**

Other Magnetics Kits

Low Pass LC Filters
Poles: 3, 5 and 7 Cutoff frequency: 17 MHz
Impedance: 50 Ohms
3 filters (4 each) **Kit D102 $60**

Coilcraft

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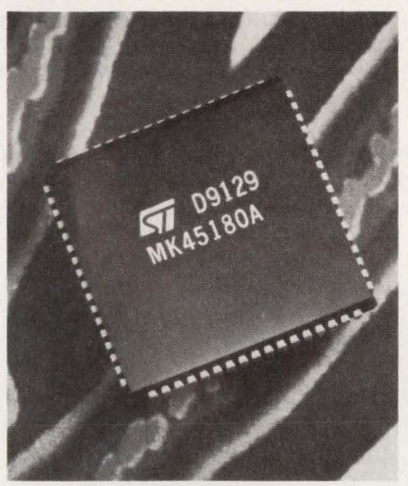
1102 Silver Lake Rd., Cary IL 60013 800/322-2645 Fax 708/639-1469

CIRCLE NO. 97

mixes and simultaneously displays graphics data. CL-PX2070, $85; CL-PX2080, $65. **Cirrus Logic Inc,** 3100 W Warren Ave, Fremont, CA 94538. Phone (510) 623-8300. FAX (510) 226-2240. **Circle No. 405**

Octal DACs. The MP7641 and MP7651 contain eight independent 8-bit DACs. Each DAC has a 10-MHz input bandwidth. The maximum clock rate is 12.5 MHz. The MP7651 includes an addressable chip-select feature via a serial data bus. The chips operate from −40 to +85°C and come in 28-pin DIPs. $8.90 (1000). **Micro Power Systems Inc,** 3100 Alfred St, Santa Clara, CA 95054. Phone (408) 562-3615. FAX (408) 562-3605. **Circle No. 406**



Specialty memories. The MK45180 SnoopTAG is a cache TAGRAM with integrated-bus-snooping logic. The chip also has a 4k × 10-bit asynchronous dual-port SRAM (static RAM), a comparator, a match output, and a flash-clear input. The MK62486 BRAM is a 32k × 9 bit SRAM that features a parity bit and an integrated 2-bit burst counter for 486-compatible µPs. MK45180, $29.33; MK62486, $13.29 for 8-nsec version (5000). **SGS-Thompson,** 1000 E Bell Rd, Phoenix, AZ 85022. Phone (602) 867-6100. FAX (602) 867-6102. **Circle No. 407**

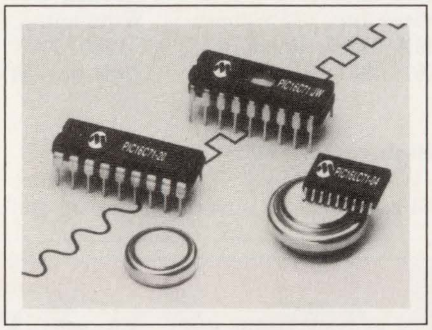
Codecs. The AD1848 and AD1849 codecs feature a pair of 16-bit sigma-delta ADCs and a pair of 16-bit sigma-delta DACs. The devices provide a dynamic range and a S/N ratio that exceeds 80 dB over the 20-kHz audio bandwidth. The devices operate with sample rates from 5.5 to 48 ksamples/sec. The AD1848 has a parallel ISA bus-compatible interface and costs $33 (1000). The AD1849 has a serial interface and costs $30 (1000). **Analog Devices Inc,** 804 Woburn St, Wilmington, MA 01887. Phone (617) 937-1480. FAX (617) 937-1011. **Circle No. 408**

High-current PLDs. The GAL16VP8B-15/25L and GAL20VP8B-15/25L feature 64 mA of output sink (IOL) current and 32 mA of output drive (IOH) current. The devices have Schmitt-trigger inputs that have a typical hysteresis of 200 mV. They operate as fast as 80 MHz and have maximum propagation delays of 15 nsec. The devices typically draw 90 mA. GAL16VP8B-15L in a DIP, $3.75; GAL20VP8B-15L in a DIP, $5.60 (1000). **Lattice Semiconductor Corp,** 5555 NE Moore Ct, Hillsboro, OR 97124. Phone (503) 681-0118. FAX (503) 681-3037. TLX 277338. **Circle No. 409**

Fast static RAMs. These three 256-kbit fast static RAMs have access times as fast as 8 nsec. Versions are also available having 10- or 12-nsec access times. The MCM6706A has a 32k×8-bit organization. The MCM6708A and MCM6709A have 64k×4-bit organizations. The MCM6709A doesn't have an output enable pin. The 8-nsec version, $52.90 (1000). **Motorola Inc,** Box 52073, MD 56-102, Phoenix, AZ 85072. Phone (512) 928-7726. **Circle No. 410**

13-bit serial A/D converter. The ML2223 is an A/D converter that provides serial RS-232C-compatible output data. The chip contains a 13-bit A/D converter, sample-and-hold circuit, voltage reference, RS-232C UART, and baud-rate generator. It performs a conversion in 35.5 μsec and transmits data at 19.2 kbps. $14.50. **Micro Linear Corp,** 2092 Concourse Dr, San Jose, CA 95131. Phone (408) 433-5200. **Circle No. 411**

8-bit RISC μC. The PIC16C71 is an 8-bit RISC μC containing a 4-channel, 8-bit A/D converter. A sleep instruction places the core in a low-power sleep mode while the analog section converts the sampled signal using a dedicated

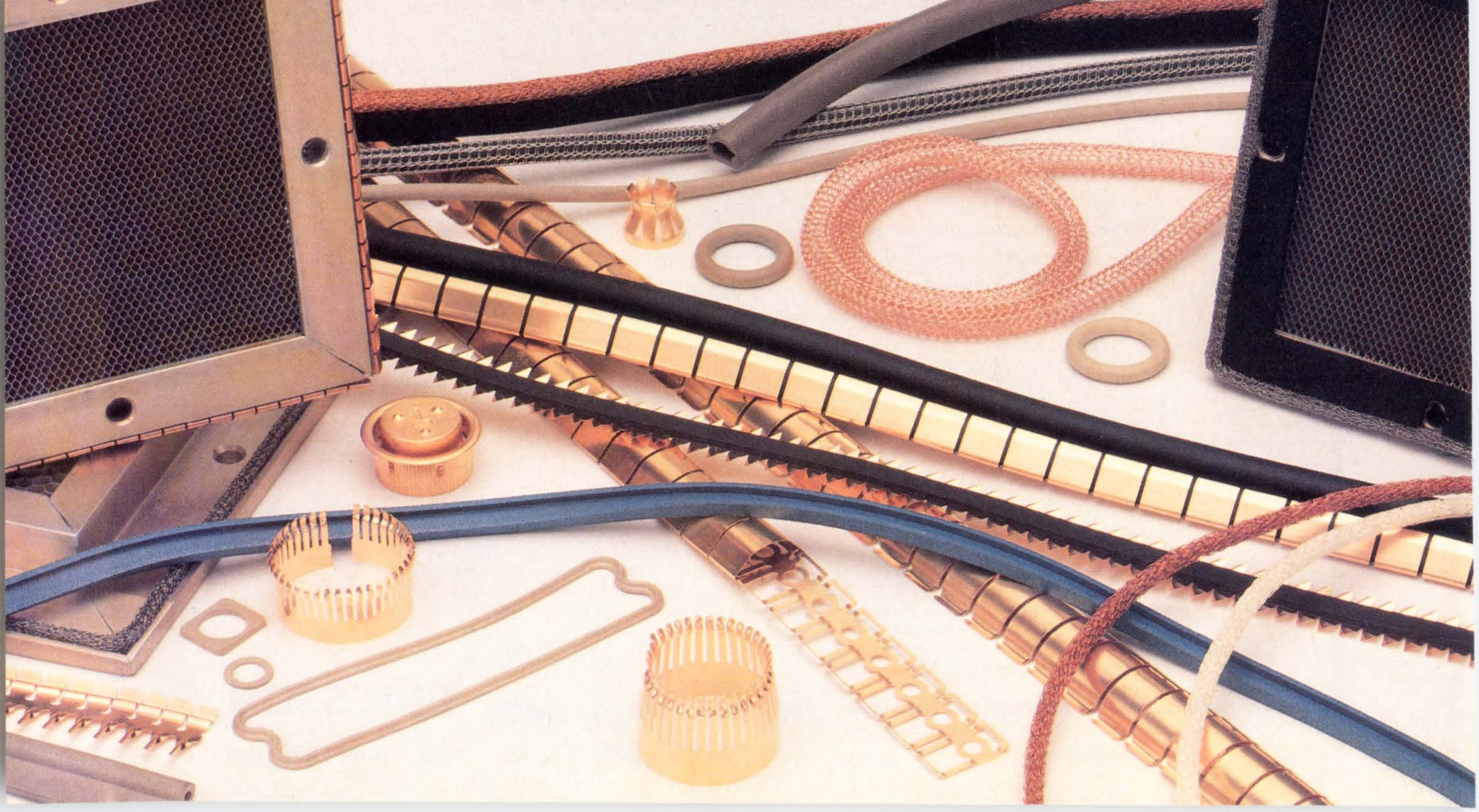


RC oscillator. After conversion, an interrupt awakens the core to store the converted data. The core operates at 20 MHz and incorporates a 1024×14-bit program EPROM. $3.25 (10,000). **Microchip Technology Inc,** 2355 W Chandler Blvd, Chandler, AZ 85224. Phone (602) 963-7373. **Circle No. 412**

Power-line modem. The ST7536 modem chip permits data communications on 110/220V ac power lines. The chip employs frequency shift keying to transfer data at 600 or 1200 bps in half-duplex mode. The carrier frequency is in the 70- to 90-kHz band. You must add a transformer, line driver, and a 60-Hz input filter to complete the modem design. $10. (5000). **SGS-Thomson Microelectronics,** 1000 E Bell Rd, Phoenix, AZ 85022. Phone (602) 867-6100. FAX (602) 867-6102. **Circle No. 413**

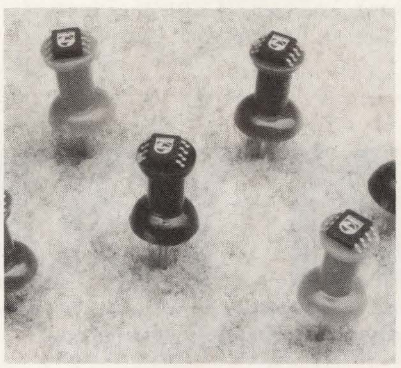
3V ADC chips. Three A/D converter chips operate from 3.3V. The 10-bit LTC1283 and 12-bit LTC1289 contain 8-channel multiplexers. The 12-bit LTC1287 comes in an 8-pin miniature DIP. The chips employ a successive-approximation converter, a S/H acquisition system, and a 3- or 4-wire serial port. LTC1283, $11.40; LTC1287, $16.70. LTC1289, in surface-mount package, $22.05 (100). Delivery, stock to 60 days ARO. **Linear Technology Corp,** 1630 McCarthy Blvd, CA 95035. Phone (408) 432-1900. **Circle No. 414**

Low-noise op amp. The LT1128 op amp has a typical input noise density of 0.85 $nV/\sqrt{Hz}$ and is stable at unity



gain. Other features include maximum offset voltage of 40 μV; minimum open-loop gain of 7×10^6; gain-bandwidth product of 13 MHz; and minimum slew rate of 5V/μsec. The chip comes in an 8-pin small-outline surface-mount package or a DIP. $4.95. **Linear Technology Corp,** 1630 McCarthy Blvd, Milpitas, CA 95035. Phone (408) 432-1900. FAX (408) 434-0507. **Circle No. 415**

14-bit A/D converters. The AD1465 family of 14-bit A/D converters offers conversion speeds as fast as 5 MHz. The devices provide a spurious-free dynamic range of −88 dB and a signal-to-noise ratio of 82 dB. They come in 3×4-in. metal packages and consume 1.7W each. The devices have latched TTL outputs and integrated timing- and error-correcting circuitry. From $265 (100). **Edge Technology,** 15 Pine St, Lynnfield, MA 01940. Phone (617) 334-3330. **Circle No. 416**



Low-power prescaler. The NE/SA701 is a dual-modulus divide by 128/129 or 64/65 prescaler. The NE/SA702 is a triple-modulus divide by 64/65/72 prescaler and the NE/SA703 is a triple-modulus divide by 128/129/144 prescaler. The chips operate with input-signal frequencies as high as 1.2 GHz. The chips come in 8-pin surface-mount plastic packages. NE/SA701, $2.95 (1000). **Signetics Co,** 811 E Arques Ave, Sunnyvale, CA 94088. Phone (408) 991-2000. **Circle No. 417**

Testable octal transceivers. Each of five octal transceivers incorporates an IEEE 1149.1 test access port. The chips have less than a 5-nsec propagation delay. The devices are the SN74ABT8245 octal transceiver; SN74ABT8543 octal-latched transceiver; SN74ABT8646 octal-registered transceiver; SN74-ABT8652 octal-enhanced registered transceiver; and the SNABT8952 octal-registered transceiver with clock enable. $4.50 (5000). **Texas Instruments Inc,** Semiconductor Group, Box 809066, Dallas, TX 75380. Phone (214) 995-6611, ext 3990. **Circle No. 418**

3V SRAMs. Four CMOS static RAMs (SRAMs) operate from 2.7 to 5.5V. The CXK58257AP/AM-12LB, and the CXK58257ATM/AYM-12LB are 256-kbit SRAMs with 32k×8-bit organization. The chips have a 150-nsec access time at 3.3V and 120 nsec at 5V. Typical 3V power consumption is .75 μW in standby mode. The CXK 581000P/M-12LB and CXK581100TM/YM-12LB are 1-Mbit SRAMs having 132k×8-bit organization. 256-kbit chips, $4.50; 1-Mbit chips, $12. **Sony Corp of America,** 10833 Valley View St, Cypress, CA 90630. Phone (800) 288-7669. FAX (714) 229-4333. **Circle No. 419**

Computers & Peripherals

Accelerator card. The Micro Express has resolutions to 1280 × 1024 pixels with 16 colors and 1024 × 768 pixels with 256 colors. The card is based on the S3 video processor and includes 1 Mbit of video RAM. The card comes with a variety of software drivers and has refresh rates to 72 Hz. The card offers noninterlaced operation to 1024 × 768-pixel resolution and interlaced operation to 1280 × 1024 pixels. Video memory is organized as 256 × 4 bits. $245. **Micro Express,** 1801 Carnegie Ave, Santa Ana, CA 92705. Phone (714) 852-1400. FAX (714) 852-1225. **Circle No. 434**

Video system. This board set consists of the Commotion Video and the Commotion Video Developers Toolkit. Commotion Video offers real-time compression and decompression of full-color moving video images with a resolution of 640 × 480 pixels at 30 frames/sec. The Toolkit provides the information and tools needed to produce video applications; it includes 80286 assembler source code for the TSR (terminate and stay resident) video capture and display drivers. A software package provides a function-key interface to standard functions for audio and video transceiving. $7900 per set. **AW & Associates,** 5000 E Spring St, Suite 100, Long Beach, CA 90815. Phone (310) 420-9696. FAX (310) 420-2875. **Circle No. 435**

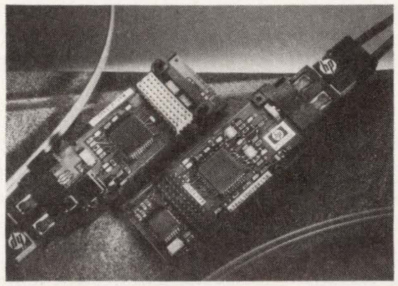
Tape-backup systems. The QICVault Series of 720-Mbit ¼-in. tape-backup systems are compatible with the DC600 standard and have speeds as high as 15 Mbits per minute. The line includes five models. To achieve the 720-Mbit capacity, the systems use high-density encoding, which expands storage capacity through the use of extended-length tape, software enhancements, and data compression. From $1139. **Tecmar,** 6225 Cochran Rd, Solon, OH 44139. Phone (216) 349-0600. FAX (216) 349-0851. **Circle No. 436**

Optical disk drive. The SS-1000 drive suits harsh-environment applications. It has an ANSI-standard SCSI interface, uses ISO/ANSI-standard media, and has an average seek time of 35 msec and data-transfer rate of 10 Mbps. The unit can store as much as 1 Gbyte of data using the zoned-constant angular-velocity recording method. $10,500. Delivery, six to eight weeks ARO. **Mountain Optech Inc,** 4775 Walnut St, Suite A, Boulder, CO 80301. Phone (303) 444-2851. FAX (303) 444-4431. **Circle No. 437**

Bridge/routers. The ConnectLAN family of Token-Ring and Ethernet bridge/routers consists of the 2000, 3000, and 5000. The ConnectLAN 2000 comprises five local or remote 802.5 4/16-Mbyte bridge/routers that work with four WAN ports at 2.048 Mbps. The ConnectLAN 3000 is an 802.3 Ethernet bridge and concurrent router providing connectivity within a locally dispersed LAN environment. The 5000 is a family of stand-alone and hub/concentrator multiprotocol bridge/routers that provide connectivity within multiprotocol local and remote distributed 802.3 Ethernet and/or 802.5 Token-Ring LAN environments. From $3250. **Teleglobe Communications Inc,** 40 High St, North Andover, MA 01845. Phone (508) 681-0600. FAX (508) 681-0660. **Circle No. 438**

Port card. The TR114 fits into a single ISA-compatible bus slot. It has a dedicated CPU with a DSP on each channel. The card can simultaneously transmit and receive voice or fax data on four analog or four/eight digital channels. The CPUs in each channel are NS32FX16 processors operating at 25 MHz. They include a 32-bit CISC with a built-in, fixed-point DSP core. All are linked by a parallel data bus as well as a PCM highway. Each channel has 1 Mbit of parity checking dynamic RAM. \$2995. **Brooktrout Technology Inc,** 144 Gould St, Needham, MA 02192. Phone (617) 449-4100. FAX (617) 449-9009. **Circle No. 439**

Single-board computers. The CPU-EC30 and CPU-EC40 offer integer-processing power in a configuration suited to embedded-control applications. The boards are available with 4- and 16-Mbyte shared-DRAM options. Both units feature full I/O capabilities. An Ethernet controller with a dedicated 64-kbyte data buffer is available via the front panel. The SCSI controller and floppy-disk-drive controller provide mass-memory control. \$2690 and \$2990 for the CPU-EC30 and CPU-EC40, respectively. **Force Computers Inc,** 3165 Winchester Blvd, Campbell, CA 95008. Phone (408) 370-6300. **Circle No. 440**



Optical-link card. The HOLC-0266 optical-link card transmits at 266 Mbps and complies with the ANSI Fiber Channel standard. The card connects the mother board or I/O-channel card of a desktop computer or workstation to a fiber-optic cable. The unit fully implements the FC-0 physical layer, incorporating the transmit and receive functions for both the electrical and optical interfaces. The card interfaces with multimode fiber. \$495. **Hewlett-Packard Co,** Box 58059, Santa Clara, CA 95052. Phone (800) 752-0900 or local sales office. **Circle No. 441**

Protocol converter. The PPC programmable protocol converter supports various datacomm devices. It comes with a number of ready-made routines, including drivers for CAD/CAM devices and a 50-user, 3-modem dial-back program. Users can program from a PC, and can download and store in EPROM as many as 20 programs at once. The basic device comes with two RS-232C ports. Options include two additional ports, a real-time clock, 16-bit analog I/O, and memory cards. \$699. **The Saelig Co,** 1193 Moseley Rd, Victor, NY 14564. Phone (716) 425-3753. FAX (716) 425-3835. **Circle No. 442**

Computer module. The Coremodule/386SX contains the equivalent of a 25-MHz, 80386SX-based PC/AT motherboard and several expansion cards. Its built-in functions include the CPU, 4 Mbytes of DRAM, a serial/parallel interface, a keyboard, and speakers. An onboard, bootable solid-state disk, a watchdog timer, and power-monitor functions are also included. The unit requires a 5V supply and operates over 0 to 70°C. $571 (100). **Ampro Computers Inc,** 990 Almanor Ave, Sunnyvale, CA 94086. Phone (408) 522-2100. FAX (408) 720-1305. **Circle No. 443**

Multiport board. The One Slot combination multiport board allows a single ISA or EISA expansion slot to work with seven peripheral devices. Compatible with hundreds of Windows, multimedia, OS/2, Novell, SCO Unix, SCO Xenix, and DOS applications, the unit connects in minutes and requires no device-driver installation. $349. **Star Gate Technologies Inc,** 29300 Aurora Rd, Solon, OH 44139. Phone (800) 782-7428; (216) 349-1860. **Circle No. 444**

Industrial computer. A typical SafeCase 4000 includes a 386 or 486 CPU with as much as 32 Mbytes of memory mounted on a full-function plug-in card; a 4-slot backplane; a 100-Mbyte hard-disk drive; a floppy-disk drive; a keyboard; and a 640×480-pixel, VGA-compatible LCD. A dual-fan system wards off airborne particles. The aluminum case provides maximum protection during transport, and the fixed disk drives are shock mounted. $5975. **Industrial Data Systems Inc,** 14900 Woodham, Building 170, Houston, TX 77073. Phone (713) 821-3200. **Circle No. 445**

Modem. Model 92 is a miniature sync/async short-haul modem that provides full-duplex, synchronous, serial data communications at 1.2 to 19.2 kbaud with a Manchester-encoded self-clocking signal. The transmission of a self-clocking signal on a balanced differential voltage loop permits the transfer of clocking information as well as data. An externally accessible DIP switch lets users employ the unit in asynchronous applications. For operating power, the unit appropriates basic power from the interface signals on the RS-232C connectors. $175. **Telebyte Technology Inc,** 270 E Pulaski Rd, Greenlawn, NY 11740. Phone (800) 835-3298; (516) 423-3232. FAX (516) 385-8184. **Circle No. 446**

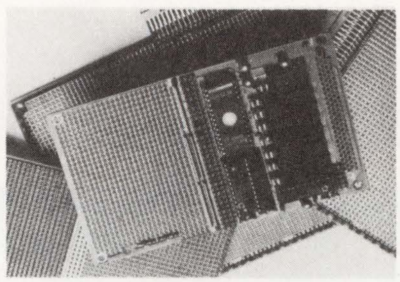
Mouse. The Z Mouse is a 3-D device that integrates the features of a conventional mouse with a 3-axis trackball and Z thumbwheel. The combination provides six degrees of freedom, which allows users to pick up an object, rotate it, look at it from any angle, and manipulate it. $250. **Multipoint Technology Corp,** 319 Littleton Rd, Suite 201, Westford, MA 01886. Phone (508) 692-0689. FAX (508) 692-2653. **Circle No. 447**

Color monitor. The 1024×768-pixel, noninterlaced Viewsonic 5E has a 72-Hz refresh rate at all resolutions. Circuitry in the 14-in. monitor adjusts to vertical frequencies of 50 to 60 Hz and horizontal frequencies of 31 to 60 kHz. The unit features a silica-coated nonglare screen. All controls are located up front. $599. **Viewsonic,** 20480 E Business Pkwy, Walnut, CA 91789. Phone (800) 888-8583; (714) 869-7976. FAX (714) 869-7958. **Circle No. 448**

Modems. The FasTalk V.32bx is a fully compatible CCITT V.32 bis, 14.4-kbps modem. It supports full-duplex, asynchronous, or synchronous data, and it can transmit over dial-up or leased lines. The FasTalk FAX32bx modem has all the same features but adds a 9600-bps, Group III, Class 1 fax. This unit lets you fax materials with a PC. FasTalk V.32bx, $795; FasTalk FAX32bx, $845. **UDS Motorola,** 5000 Bradford Dr, Huntsville, AL 35805. Phone (205) 430-8000. FAX (205) 430-8208. **Circle No. 449**

Graphics adapter. The XTC/2000 is a hardware-accelerated, true-color graphics-display adapter for PCs and compatibles. Providing 2 Mbytes of video display memory, the unit can display as many as 256 colors at a 1280×1024-pixel resolution and as many as 65,536 colors at an 800×600-pixel resolution. The board comes with software drivers for a variety of applications, including AutoCAD, Windows 3.0 and 3.1, Digital Research GEM, X-Windows X11R5, and Lotus 1-2-3. $499. **Video Dynamics Inc,** 1550 Bryant St, San Francisco, CA 94103. Phone (415) 863-3023. FAX (415) 863-2979. **Circle No. 450**

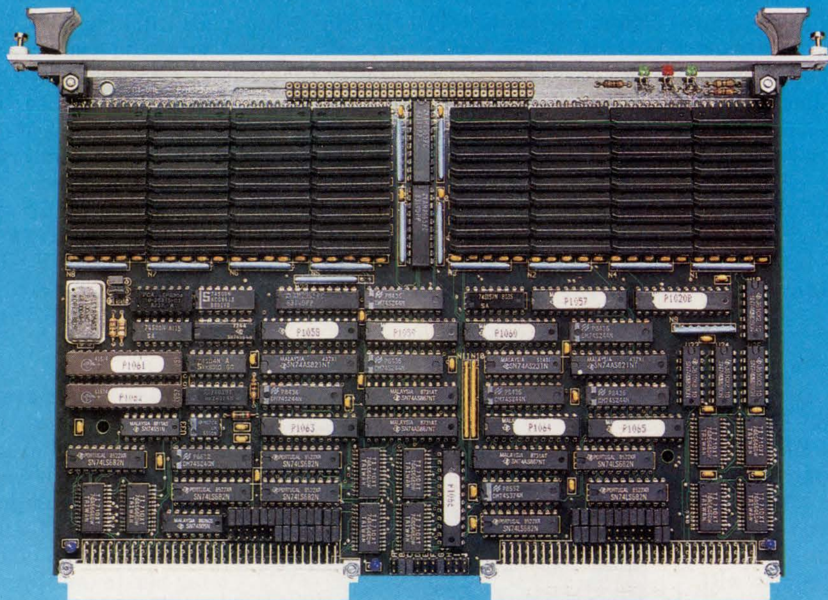
Bitbus controller. The DIP335/44 Bitbus-compatible digital controller provides 24 bits of bidirectional I/O and is compatible with the Intel 44/10 Bitbus controller. The 100×220-mm Eurocard module is shipped with extended C-language support, including low-level device drivers, a real-time clock, power up/down monitoring, table-driven I/O, and software counter/timers. From $249. **DIP Inc,** Box 9550, Moreno Valley, CA 92552. Phone (714) 924-1730. FAX (714) 924-3359. **Circle No. 451**



Development board. The DPSS-1 complies with the Sun Microsystems and SBus specification for slave devices. Featuring a 3×4.75-in. prototyping area, the board includes FCT logic drivers and receiver/buffers to assist in prototyping and testing SBus circuitry. The board consists of a Forth code boot PROM, SBus interface circuitry, a 6-pin header interface, and three PAL devices. An additional resistor-network socket is available for pullup terminations. $495. **Dawn VME Products,** 47073 Warm Springs Blvd, Fremont, CA 94539. Phone (510) 657-4444. **Circle No. 452**

Network modem. The Lanfast DM25 modem attaches directly to LAN cabling and acts as a network node. The unit contains a built-in network-interface card and an integral, fully compliant V.32 bis, 14.4-kbps modem. The device includes V.42bis data compression for maximum throughput rates as high as 57.6 kbps. It also features an additional RS-232C port that lets users connect a second modem or digital device for simultaneous dial-in or dial-out. $2595. **UDS Motorola,** 5000 Bradford Dr, Huntsville, AL 35805. Phone (205) 430-8000. FAX (205) 430-8208. **Circle No. 453**

40 MB/SEC DUAL-PORT VME/VSB MEMORY



CI-VME40

The CI-VME40 is the ultimate high-speed, high-capacity DRAM memory board with a dual-port interface to the VME and VSB Busses. The CI-VME40 is optimized for Block Transfer Cycles yielding a bus transfer rate up to forty megabytes per second. Chrislin is the only memory supplier to offer such an advanced and versatile dual-ported VME/VSB memory!

THE CI-VME40 FEATURES:

- 20ns write/20ns read ACCESS TIMES in BLOCK CYCLE
- 90ns write/140ns read ACCESS TIMES in SINGLE CYCLE
- 63ns write/83ns read CYCLE TIMES in BLOCK CYCLE
- 195ns write/195ns read CYCLE TIMES in SINGLE CYCLE
- 4MB, 8MB, 16MB, 32MB, 64MB in one VMEbus/VSB slot
- Byte Parity Error Detection
- Memory start and end addresses selectable on 256KB boundaries
- VMEbus and VSB memory start and end addresses configured independently

ALSO AVAILABLE FOR THE VMEBUS ARE...

THE CI-VMEmory FEATURES:

- Low-cost high-power VME memory with 4, 8, or 16MB
- VME Revision C.1 compatibility
- Lower and upper memory addressses independently selectable in 64K byte increments
- Byte Parity Error Detection with selectable trap on Parity Error
- On-board Control Status Register

THE CI-VSB-EDC FEATURES:

- Low-cost high-power dual-ported VMEbus/VSB EDC (Error Detection and Correction) memory
- 4, 8, 16, 32 or 64MB in one VMEbus/VSB slot
- VME Revision C.1 compatibility, VSB Revision C
- Lower and upper memory addressses independently selectable on 256K byte boundaries
- Single-Bit Error Detect and Correct, Double-Bit Detect

Chrislin Industries, Inc.

31312 Via Colinas, Suite #108, Westlake Village, CA 91362

TEL: (818) 991-2254 FAX: (818) 991-3490

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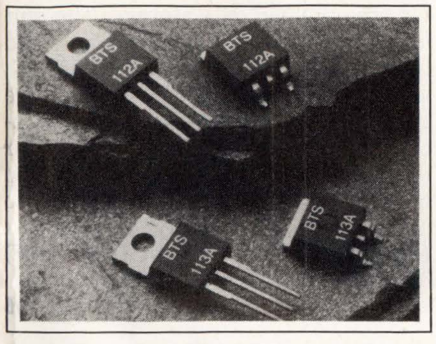
CIRCLE NO. 106



MOSFETs. The BTS 112A and 113A both have on-chip overtemperature protection that shuts off the transistors at junction temperatures in excess of 150°C. The 112A has a 0.15Ω on-resistance and is designed for applications with a 10V gate drive requirement. The 113A has a 0.17Ω on-resistance and is designed for 5V gate drive service. The units are available in through-hole and surface-mount packages. BTS 112A, $1.38; BTS 113A, $1.43 (10,000). **Siemens Components,** IC Div, 2191 Laurelwood Rd, Santa Clara, CA 95054. Phone (408) 980-4589. **Circle No. 454**

Schottky diodes. SPTS455 high-current dual diodes are housed in fully isolated packages. The units come in current ratings of 120, 160, and 240A with repetitive peak reverse voltage ratings of 35 and 45V. Voltage drop at a 240V forward current equals 0.91V. $14.71, $14.96, and $25.50 for 120, 160, and 240A devices, respectively (500). **SGS-Thomson Microelectronics,** 1000 E Bell Rd, Phoenix, AZ 85022. Phone (602) 867-6100. FAX (602) 867-6102. **Circle No. 456**

Ultrasonic transducer. The ISU4000 has a 12-bit D/A output. Sensing range spans 6 in. to 60 ft. Resolution and accuracy equal 0.007 in. and ±1%, respectively. The transducers come in plastic or stainless-steel enclosures designed with NPT fittings for mounting in standard fixtures and flanges. From $399. **Contaq Technologies Corp,** 15 Main St, Bristol, VT 05443. Phone (802) 453-3332. FAX (802) 453-4250. **Circle No. 457**

Transistors. Part of the U1 Series, these IGBTs (insulated-gate bipolar transistors) come with internal diodes. The units have 600V blocking voltage ratings and handle current to 50A. The fast-switching version IXGH30N60AU1 is rated for 600V at 50A and has a $V_{CE(SAT)}$ of 3V and a fall time of 800 nsec. The IXGH30N60U1 has a 2.5V $V_{CE(SAT)}$ and a 1500-nsec fall time. The -AU1 unit, $12.50; the -U1, $13.13 (1000). **IXYS Corp,** 2355 Zanker Rd, San Jose, CA 95131. Phone (408) 435-1900. FAX (408) 435-0670. TLX 384928. **Circle No. 458**

Power MOSFETs. The OM11N60 and OM11N55 are rated at 600 and 550V at 11A, respectively. $R_{DS(ON)}$ is as low as 0.42Ω. The devices are supplied in TO-254 hermetic isolated metal packages in side-tab and top-tab configurations. $47.50 (100) for the OM11N55. **Omnirel Corp,** 205 Crawford St, Leominster, MA 01453. Phone (508) 534-5776. FAX (508) 537-4246. **Circle No. 459**

LCD module. The DMX-973 requires a panel cutout of 1.53×2.81 in. and is furnished with a bezel to simplify mounting. All display memory and driver circuits are on board to ease interfacing via IDC ribbon connectors. Each of the 70×32 pixels is individually addressable. Twelve available commands include display, read-write, scroll, and display on-off. $123. **Martel Electronics,** Box 897, Windham, NH 03087. Phone (800) 821-0023; (603) 893-0886. FAX (603) 898-6820. **Circle No. 460**

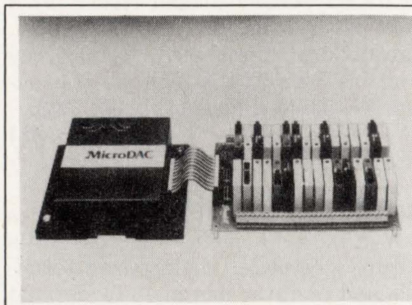
Pushbutton switches. Series 584 lighted switches have a 75° cone of vision. A rod-mount feature allows for gang-mounting a number of units into a small panel opening. Available with an 8A rating, the 0.625-in. square switches can be matrix or individually mounted. The matrix accepts MIL-C-39029/57-354 terminals. Options include RFI/EMI protection and splash-proof front-panel seals. $95 to $285 (1000). **Eaton Corp,** Aerospace & Commercial Controls Div, 4201 N 27th St, Milwaukee, WI 53216. Phone (414) 449-7326. **Circle No. 461**

DIP switches. The DHS Series switches have a 0.050-in. pitch. The spst units feature gold plated contacts and terminals and are available in 4-, 6-, 8-, and 10-position versions. Contacts are rated to carry 100 mA at 50V dc and switch 100 mA at 5V dc. Operating life equals 1000 cycles, and operating range spans −20 to +80°C. $3.95 (1000) for an 8-position model. **MORS/ASC,** Box 544, Wakefield, MA 01880. Phone (617) 246-1007. FAX (617) 245-4531. **Circle No. 462**

Schottky diodes. The surface-mountable CMPD6263 and CMPSH-3 Series diodes are designed for applications requiring forward voltage drops in the 0.29V range and with switching times of 5 nsec max. All eight devices are housed in SOT-23 cases. The CMPD6263 units operate at 15 mA at 70V; the CMPSH-3 devices are rated for 100 mA at 30V. Each line features four configurations—single, dual common anode, dual common cathode, and dual in series. $0.176 to $0.208 (3000). **Central Semiconductor Corp,** 145 Adams Ave, Hauppauge, NY 11788. Phone (516) 435-1110. FAX (516) 435-3388. **Circle No. 463**

DC/DC converters. XW Series 30W single-output converters have an output noise of 10 mV p-p. The six units in the line operate at 84% efficiencies and have a 500V input-to-output isolation. Internal suppressors protect input and output against spikes, and a 6-sided shielded case provides RFI protection. Line and load regulation equals 0.05%, and operating range spans −25 to +80°C. $117.60 (100). **Calex Mfg Co Inc,** 2401 Stanwell Dr, Concord, CA 94520. Phone (800) 542-3355; (510) 687-4411. FAX (510) 687-3333. **Circle No. 464**

Connectors. FI Series connectors feature 16 or 20 crimp or solderable terminations. The units feature a single-action locking system that permits quick connect/disconnect. Contact pitch equals 1.27 mm. $5 per mated pair (1000). **Hirose Electric USA Inc,** 2688 Westhills Ct, Simi Valley, CA 93065. Phone (805) 522-7958. FAX (805) 522-3217. **Circle No. 465**



Industrial controllers. The MicroDAC handles up to 32 single-point I/O modules in any analog-digital combination. The unit can exchange ASCII messages at speeds ranging to 115.2 baud. The unit features 64 kbytes of flash EPROM and 64 kbytes of battery-backed RAM for program and data storage. The unit is compatible with IBM-compatible and other industrial computers. Basic, C, and Pascal drivers are available. The unit comes in a metal enclosure and includes local RS-232C and SBX ports for interface with third-party plug-in boards. $600 to $850. Delivery, four to eight weeks ARO. **Grayhill Inc,** Box 10373, LaGrange, IL 60525. Phone (708) 354-1040. FAX (708) 354-2820. **Circle No. 466**

DC/DC converter. HPR7XXX467 5W converters come in a SIP, have a 16W/in.^{3} density, and operate at 85% efficiency. The line includes nine single-and dual-output models. The units accept inputs of 5, 12, and 15V and output 5, ±5, ±12, and ±15V. Operating range spans −25 to +70°C. $16.25 (1000). Delivery, stock to six weeks ARO. **Burr-Brown Corp,** Box 11400, Tucson, AZ 85734. Phone (602) 746-1111. FAX (602) 889-1510. **Circle No. 468**

Mounting rack. The MPB-16PC provides a simple interface to motors, relays, and other high-voltage, high-current devices. Using 16 lines of the printer port, the rack handles loads as high as 260V ac or dc and current levels of 3A. Isolation equals 4000V. The unit accepts Opto 22 (G4) and Grayhill (G5) modules. Operating range spans −40 to +85°C. Software libraries are included on disk. $75. **Octagon Systems Corp,** 6510 W 91st Ave, Westminster, CO 80030. Phone (303) 430-1500. FAX (303) 426-8126. **Circle No. 469**

Solid-state relay. The HSSR-7110 spst relay is housed in an 8-pin hermetic DIP. Contacts are rated for 0.8A ac/dc at 24V ac or 28V dc. The relay operates from a logic-level control signal (5 mA nom). Input/output isolation equals 1500V dc. The unit operates over the −55 to +125°C military temperature range. $75. **Hewlett-Packard Co,** Box 58059, Santa Clara, CA 95052. Phone (800) 752-0900, or local sales office. **Circle No. 470**

Pressure switch. The 744 Type C pressure switches feature set pressure adjustment ranges of 25 to 6000 psig. A tamper-resistant locking device on the adjusting sleeve maintains the integrity of the set point. The snap-action switch at the output is rated for 7A at 115 to 230V ac and 7A resistive, 4A inductive,

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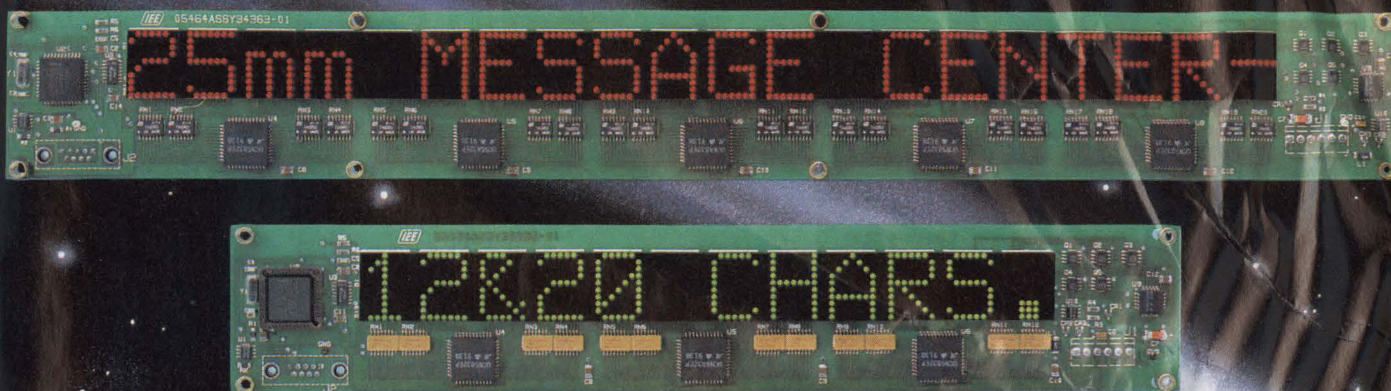

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The unique 7 × 10 dot matrix LED display modules that command attention!

★ VISTA's 1″ (25.4mm) high characters are visible to up to 40 feet away—perfect for use in production floor displays, warning systems, parking lots, security, communications, fire alarms, refineries, etc.

★ Character generators for U.S. ASCII, General European, Katakana, Hebrew, and Cyrillic are all included.

★ VISTA is intelligent—A built-in microprocessor controller handles all display refresh and overhead functions.

★ VISTA enables the user to:
- Create and download 16 custom characters.
- Select one of four brightness levels to suit various ambient light conditions.
- Blink, clear, or reset the display.
- Horizontally scroll messages.

★ Available in both 1 × 20 and 1 × 12 formats.

★ 9600 baud serial ASCII interface—RS-422 with RS-449/DB-9 I/O.

★ Low power—5VDC, 2.5 Amps typical on brightest setting!

★ VISTA modules are available in red, green, yellow and super-bright (sunlight readable) red. All modules are available with contrast enhancing optical filters.

COMPACT—VISTA mounts anywhere!

Overall dimensions of the VISTA 6800 series:

★ 1 × 20: 20.55 × 2.5 × 0.90″ (WHD) 522.0 × 63.5 × 22.9mm

★ 1 × 12: 13.85 × 2.5 × 0.90″ (WHD) 351.8 × 63.5 × 22.9mm

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and 2.5A lamp at 28V dc. Operating range spans −40 to +250°F. $69.10 to $90.10. **Sigma-Netics Inc,** 1 Washington Ave, Fairfield, NJ 07004. Phone (201) 227-6372. FAX (201) 882-0662.

Circle No. 471

DC/DC converters. LAN-1 converters accept inputs of 5 or 12V and provide a single 9V output or 10/5V dual output at 250 mA. Regulated units have line and load regulation of ±0.3% and ±0.5%, respectively. The units are housed in a 24-pin DIP, feature pi input filters, and operate over a −25 to +71°C range without any derating. $19.50 for single-output regulated models. Delivery, stock to eight weeks ARO. **D1 International Inc,** 95 E Main St, Huntington, NY 11743. Phone (516) 673-6866.

Circle No. 472

Input module. The 7B35 4- to 20-mA-current input module includes an isolated loop power supply, which eliminates the need for an external supply when using a 2-wire transmitter. It operates from a single unregulated 24V supply and features a ±0.1% max span error, ±0.02% span nonlinearity, and ±1-μV/°C temperature stability. A galvanic transformer provides 1500V-rms isolation. The module meets IEEE-STD-472 and IEC-255-4 standards for transient protection. From $75 (1000). **Analog Devices Inc,** 181 Ballardvale St, Wilmington, MA 01887. Phone (617) 937-1428.

Circle No. 473

Switches. HB Series snap-action switches are available in single- and double-pole models. Contact ratings range from 1 to 22A. Electrical terminations include solder terminal, screw terminal, and quick connect. The devices are available in a variety of actuators. A pin-plunger model rated for 20A, from $1.99. **Unimax,** Box 152, Wallingford, CT 06492. Phone (203) 269-8701. FAX (203) 265-5398.

Circle No. 474


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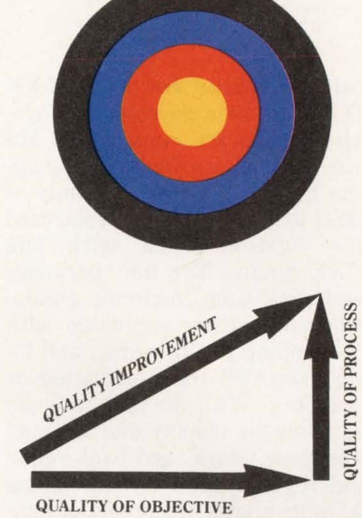
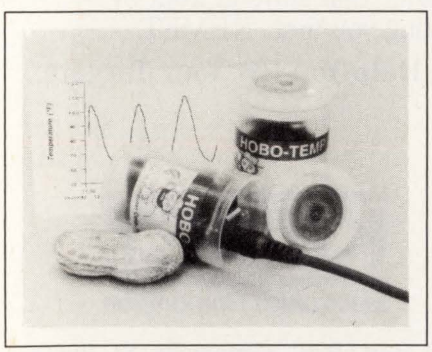
KEMET CAPACITORS


QUALITY IMPROVEMENT
QUALITY OF PROCESS
QUALITY OF OBJECTIVE

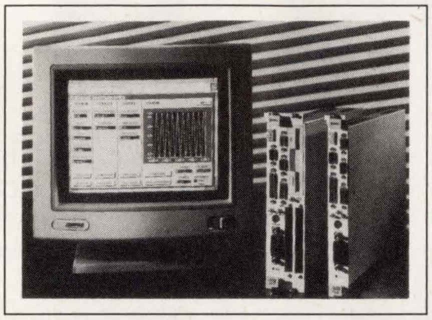
Test & Measurement Instruments

In-circuit emulator for PIC16CXX μCs. The Picmaster development system, whose software runs under MS Windows V3.x, allows you to debug applications for the PIC16CXX family of 8-bit RISC μCs. Changing a probe card lets the system work with the PIC17CXX family. The unit performs full-speed, real-time in-circuit emulation, program-memory emulation with memory mapping to 64k words, and instruction execution from emulation or target memory. With the unit, you can obtain a symbolic display and alter all special-purpose, stack, and bank registers, and register files. Synchronizing multiple units allows debugging of multiprocessor systems. $2995, including the Picpro programmer. **Microchip Technology Inc,** 2355 W Chandler Blvd, Chandler, AZ 85224. Phone (602) 963-7373. FAX (602) 899-9210.
Circle No. 475

Clamp-on digital multimeter. The 600 measures dc and ac rms current in two ranges, 200 and 600A, with 1% maximum error. On the lower range, the resolution is 0.1A. The meter also has two ac and dc voltage ranges, 200V ac or dc and 1 kV dc/750V ac. A resistance range extends to 2 kΩ and offers protection against 500V ac or dc overloads; a continuity buzzer sounds below 500Ω. The current clamp jaws open to 1.2 in. and accommodate conductors as large as 1⅛-in. in diameter. $249. **LEM USA,** 6643 W Mill Rd, Milwaukee, WI 53218. Phone (800) 236-5366; (414) 353-0711. FAX (414) 353-0733. **Circle No. 476**



Miniature data logger for MS-DOS PCs and Macintoshes. The Hobo-Temp is a tiny pc board housed in a 2.1-in.-long × 1.3-in.-diameter plastic cylinder. The unit connects to an MS-DOS PC's or Apple Macintosh's serial port. You can obtain the loggers with integral or external sensors and with ranges of −39 to +123, −5 to +37, or −37 to +46°C. The loggers receive power from the serial port. They store 1800 readings in a flash EEPROM. Optional software lets you acquire readings at 31 rates from 2 readings/sec to 5 readings/day. $99; $149 with software. If a unit fails during an experiment, the vendor will repair the unit and retrieve your data or it will replace the logger. **Onset Computer Corp,** Box 1030, North Falmouth, MA 02556. Phone (508) 563-9000. FAX (508) 563-9477.
Circle No. 477

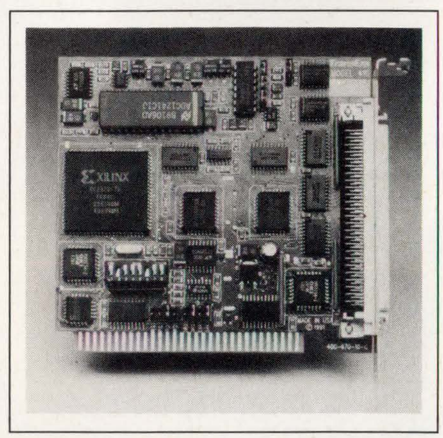


50-MHz i486DX2-based VXIbus computers. The three versions of the VXIpc-486 Model 500 occupy one, two, and three C-size slots. They include from 1 to 16 Mbytes of dual-ported RAM; RS-232C, parallel, and IEEE-488 ports; and either a 640×480-pixel (VGA) display adapter with 256 kbytes of video RAM or a 1024×768-pixel (supervideo-graphics-array) adapter with 1 Mbyte of video RAM. The 1-slot unit includes a hard disk that stores as much as 80 Mbytes; the 2-slot unit offers a choice of hard disks that store as much as 240 Mbytes and adds a 3.5-in. floppy-disk drive; the 3-slot unit can have a 426-Mbyte hard disk. From $5595. **National Instruments Corp,** 6504 Bridge Point Pkwy, Austin, TX 78730. Phone (800) 433-3488; (512) 794-0100. FAX (512) 794-8411. TLX 756737.
Circle No. 478

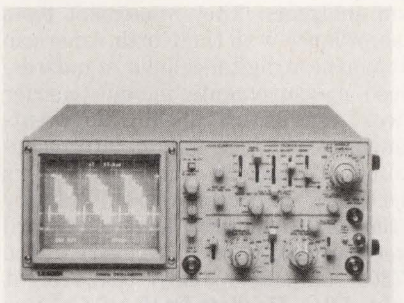
Optical attenuation/return loss test set. The FOT-900-BR is a handheld unit that, at the press of a single key, allows testing of fiber-optic cables at wavelengths of 1310 and 1550 nm. From US$6700; delivery four to six weeks, ARO. **Exfo EO Engineering Inc,** 465 Godin, Vanier, QC, PQ G1M 3G7, Canada. Phone (418) 683-0211. FAX (418) 683-2170. **Circle No. 479**

In-circuit emulator for i960 CF RISC μP. The Express III supports the i960 CF RISC μP as well as the i960 CA. Versions are available that operate at 25, 33, and 40 MHz. The development system includes a source-level debugger, SDBug960, that works with multiple compilers and runs under MS Windows 3.x. Versions are also available for Sun-3, Sun-4, and IBM RS 6000 hosts. Adding an Ethernet interface to the host permits remote debugging. Among the system features are a 32k-frame trace buffer with passive trace and time stamping; hardware and software breakpoints with multilevel, logic-analyzer-style hardware triggering and store-control facilities; and 71 hardware-range match words and breakpoints. From $10,500. **Step Engineering Inc,** Box 3166, Sunnyvale, CA 94088. Phone (800) 538-1750; (408) 733-7837. FAX (408) 773-1073. TWX 9103399506. **Circle No. 480**

2- and 4-channel, 150-MHz, 400M-sample/sec DSOs. The 4066 ($5800) and 4068 ($7700) have two and four channels, respectively. They perform calculations on acquired data at high speeds and update displays of calculated waveforms in 650 msec or less. Calculations include FFTs, filtering, differentiation, and integration. Both models perform cursor measurements. They store measurement sequences as well as front-panel setups. **Gould Inc,** 8333 Rockside Rd, Valley View, OH 44125. Phone (216) 328-7000. FAX (216) 328-7400. **Circle No. 481**



Low-power, 50k-sample/sec, 13-bit ISA bus data-acquisition board. The 410 is a half-size card that uses only two supply voltages, 5 and 12V, at 500 mW (operating) and 50 mW (standby)—attributes that suit it to data acquisition in several laptop PCs. The card provides 16 single-ended or eight differential analog inputs, a 3-channel counter/timer, and 16 digital I/O lines. The ADC, which has a ±5V range is preceded by an amplifier having software-programmable gains of 1, 2, 4, and 8 and a sample/hold circuit. Maximum sensitivity is 153 μV/count. The hardware supports a 512-point channel/gain list and DMA transfers. $495. **TransEra Corp,** 3707 N Canyon Rd, Provo, UT 84604. Phone (801) 224-6550. FAX (801) 224-0355. TLX 296438. **Circle No. 482**



2-channel, 100-MHz dual-timebase scope. The 8101, which can display four traces, has 12 sensitivity ranges to 5V/div. Bandwidth is 20 MHz on the 1-mV/div and 2-mV/div ranges. The maximum sweep speed is 5 nsec/div. Delayed-sweep and variable hold-off increase the resolution of short segments of long sweeps. Alternate-sweeps and chopped displays are possible as are X-Y displays. $1895. **Leader Instruments Corp,** 380 Oser Ave, Hauppauge, NY 11788. Phone (800) 645-5104; (516) 231-6900. **Circle No. 483**

Combinational in-circuit/functional pc-board-test systems. The vendor aims the GR2283 and GR2284 at companies that need the capabilities of expensive testers but that, until now, could not afford them. In many cases, a budget for only a manufacturing-defects analyzer will now allow acquiring a full-fledged tester with as many as 1920 pins. The new testers also address the need for rapid construction of test fixtures. Software allows creation of fixtures in parallel with test-program generation. From $100,000; delivery, eight weeks, ARO. **GenRad Inc,** 300 Baker Ave, Concord, MA 01742. Phone (508) 369-4400. **Circle No. 484**

ICE for 50-MHz SPARClite RISC μP. The vendor calls the Excell-930 the first in-circuit emulator for any chip using a SPARC architecture. The emulator is available in 40- and 50-MHz versions. It has an 8k-frame trace buffer and 32 external inputs. It has 16 software and five hardware breakpoints and permits tracing the execution of instructions stored in the μP's on-chip cache. The unit works with Microtec Research's x-ray source-level debugger and allows remote debugging from a Sun-4 workstation. From $15,875. **Step Engineering Inc,** Box 3166, Sunnyvale, CA 94088. Phone (800) 538-1750; (408) 733-7837. FAX (408) 773-1073. TWX 910-339-9506. **Circle No. 485**

DMM for automotive testing. Besides performing the usual DMM functions, the 4000-count model 78 measures duty cycle, dwell, temperature, and frequency. A $49 accessory permits rpm measurements. Maximum ac and dc voltage is 500V; maximum current is 10A ac or dc; maximum frequency is 20 kHz; maximum resistance is 40 MΩ. The most sensitive range is 400 mV. Dwell readout is direct for 3-, 4-, 5-, 6-, and 8-cylinder engines. With the included thermocouple probe and adapter, the unit reads to 980°F or C. $269. **John Fluke Mfg Co Inc,** Box 9090, Everett, WA 98206. Phone (800) 873-5853; (206) 347-6100. FAX (206) 356-5116.
Circle No. 486

Philips Test and Measurement, Building TQIII-4, 5600 MD Eindhoven, The Netherlands. Phone local office.
Circle No. 487

Wafer-level reliability-test software. WLR software permits verification of semiconductor-device quality and prediction of potential reliability problems before the costs of packaging individual dice have been incurred. The software, which runs on the vendor's S900 system with as many as five source-measure units, controls standard electromigration accelerated tests, charge-breakdown tests, hot-carrier-injection tests, measurement of maximum substrate current, and CMOS latch-up tests. $2500. **Keithley Instruments Inc,** 28775 Aurora Rd, Cleveland, OH 44139. Phone (800) 552-1115; (216) 248-0400. FAX (216) 248-6168. **Circle No. 488**

Measurement personality cards for digital cellular radio testing. The 85718A and 85720A plug into any of the vendor's 8590 E series portable spectrum analyzers. They implement tests in accordance with the North American and Japanese digital-cellular standards. These measurements include carrier power, carrier-off power, adjacent-channel power, base-station intermodulation, and mobile-station power vs time. Each card costs $2500. Delivery of the 85718A (North American) card takes four weeks ARO. Delivery of the 85720A (Japanese) card takes eight weeks ARO. **Hewlett-Packard Co,** Box 58059, MS 51L-SJ, Santa Clara, CA 95051. Phone (800) 452-4844.
Circle No. 489

Real-time, multitasking, data-acquisition software for MS Windows. Notebook and Notebook/XE let you collect data, display the data in real time, simultaneously log the data to disk, and perform triggering and control functions based on the data. The software allows gap-free real-time sampling at rates to 1 kHz. Notebook costs $1495. Notebook/XE, which supports IEEE-488 instruments and handles 250 channels vs 50 for Notebook, costs $2495. Owners of earlier Windows versions of either package can upgrade for $250. For owners of MS-DOS versions, the upgrade cost is $600. **Laboratory Technologies Corp,** 400 Research Dr, Wilmington, MA 01887. Phone (800) 879-5228; (508) 657-5400. FAX (508) 658-9972. **Circle No. 490**

1-Hz-to-10-MHz pulse generator. The B-1010 supplies pulses of seven widths from 50 nsec to 50 msec (in decade steps). With a 50Ω load, the pulse amplitude is adjustable from 0 to 5V; rise and fall times are <10 nsec. There are six ranges of variable delay, from 0 to 50 nsec to 0 to 500 msec. The internal oscillator has a maximum frequency that you can switch through seven decades and vary within each decade. The highest frequencies in each decade range from 10 Hz to 10 MHz. $499. **Protek Inc,** Box 59, Norwood, NJ 07648. Phone (201) 767-7242. FAX (201) 767-7343. **Circle No. 491**

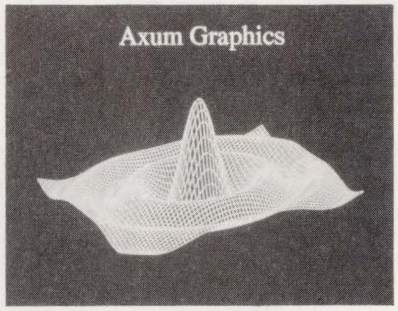
CAE & Software Development Tools

Task-set design tool. Viewtask software for the PC lets you define a set of tasks by name, timing, and triggering methods as well as other parameters. You can then choose a processor from a list of common μPs and microcontrollers (μCs) and simulate those tasks. A graphics display illustrates timing relationships as the tasks run. When you are satisfied with the performance of your task set, the software documents the task specifications, timing analysis, and diagrams, and it translates the specifications into source-code frameworks in Borland and Microsoft-compatible C. US price, $495. **US Software Corp,** 14215 NW Science Park Dr, Portland, OR 97229. Phone (503) 641-8446. FAX (503) 644-2413. **Circle No. 420**

Software development tools. C++ Softbench 3.0 is a software-development tool set that saves time in building, debugging and editing. The tool set facilitates the use of C++ 3.0 by offering templates, nested classes, and exception handling. The software also includes three graphical browsers: The Static Graph Browser shows relationships among program variables, functions, and C++ classes; the Dependency Graph Browser gives graphical views of program makefile structures; and the Data Graph Browser displays a program's data structures. Additional features include a File Compare and Combine Tool, an Encapsulator, an incremental linker, and a Motif interface to the vi and emacs editors. For HP 9000 and Sun SPARCstation, $4500. **Hewlett-Packard Co,** Direct Marketing Organization, Box 58059, MS511l-SJ, Santa Clara CA 95051. Phone (800) 752-0900. **Circle No. 421**

Active-filter design software. Active 2.08 lets you design both active-and switched-capacitor filters. Other improvements include software that handles up to 45 circuit topologies, five types of cascaded filters, filters of order 1 to 50, and eight types of filters, including Linear Phase and Inverse Chebyshev. $745. **Tatum Labs Inc,** 1287 N Silo Ridge Dr, Ann Arbor, MI. Phone (313) 663-8810. FAX (313) 663-3640. **Circle No. 422**

PC-board design software. Criterion software integrates schematic and layout tools for pc-board design. It gives you tools for both analog and digital design, including radio-frequency and surface-mount work. The software also handles round boards and curved traces. Runs on the PC. $650. **Dynacomp Inc,** 178 Phillips Rd, Webster, NY 14580. Phone (716) 265-4040. **Circle No. 423**



Technical graphics software. Axum 2.0 adds batch processing; plots unlimited-size 3-D mesh surfaces with color; provides additional curve-fitting plot types, automatic axes scaling and tick placement, adjustable tick labeling; and comes with a 600-pg manual. It runs in as little as 420 kbytes of memory and automatically uses extended and expanded memory. For the PC, $495. **Trimetrix Inc,** 444 NE Ravenna Blvd, Suite 210, Seattle, WA 98115. Phone (206) 527-1801. FAX (206) 522-9159. **Circle No. 424**

Electronic circuit optimizer. PC-Opt+ performs Spice-like simulation and can also change selected component parameters to make a circuit meet performance specifications. Specifications can combine objectives, constraints, and weighting factors. The software also lets you link component values so that they track one another and optimize in more than one domain at once. Examples of domains are dc behavior, frequency response, gain, bandwidth, and rise time. $950. **Electrical Engineering Software Inc,** 4675 Stevens Creek Blvd, Suite 200, Santa Clara, CA 95051. Phone (408) 296-8151. FAX (408) 296-7563. **Circle No. 425**

Board/system-level design tools. The System Workbench combines tools for design entry, PLD/FPGA design, simulation, physical design, and board/system-level analysis. The tool set includes front-end tools such as Composer design-entry software and the Verilog-XL simulator, as well as Allegro Correct-by-Design physical design and analysis tools. The user can follow a default design flow or customize the design flow to manage tool encapsulation, tool sequencing, and methodology automation. A minimum tool set for design entry, packaging, and physical design starts at $58,000. The complete tool set starts at $145,000. **Cadence Design Systems Inc,** 555 River Oaks Pkwy, San Jose, CA 95134. Phone (408) 943-1234. FAX (408) 943-0513. **Circle No. 426**

PC-board layout software. The Eagle Autorouter 2.6 gives 100% routing by ripup/retry and a minimum routing grid of 4 mils. Additional features include handling surface-mount devices and multilayer boards. A layout editor and a schematic-entry package are also available and work with the autorouter. Autorouter, layout editor, schematic module: $399 each. **Cadsoft Computer GmbH,** 801 S Federal Hwy, Delray Beach, FL 33483. Phone (407) 274-8355. FAX (407) 274-8218. **Circle No. 427**

Memory-management libraries for C and C++. VMData gives you a single data memory-management tool that works across multiple operating systems for the PC. Instead of making calls to the OS, you call tool set functions to instruct a virtual-memory manager to dynamically allocate space for data. The program distinguishes between addressable, fast-access, and disk storage, and it allocates these resources according to frequency of data use and to user-specified priority. The tool uses all available memory for DOS, MS-Windows, and OS/2. $495 for first OS; $295 for each subsequent OS. **Pocket Soft Inc,** Box 821049, Houston, TX 77282. Phone (713) 460-5600. FAX (713) 460-2651. **Circle No. 428**

Numerical-analysis tool for X-Window system. Xmath 1.1 includes improvements to previous versions, such as a programmable user interface that lets you develop and run interactive design tools. Such tools can create and manipulate objects built from the Motif widget set without software development in a low-level language such as C. Additional improvements include extended graphics, linking with C and Fortran routines, and the ability for C/C++ routines to call Xmath functions. For Sun SPARCstation and DEC workstations, $2500. **Integrated Systems Inc,** 3260 Jay St, Santa Clara, CA 95054. Phone (408) 980-1500. FAX (408) 980-0400. **Circle No. 429**

See EEM Volume B, Page 1606.

EDIF translator for Design Architect. DXL800 lets you convert schematic designs and symbol libraries from the Mentor Graphics' Design Architect design environment into the EDIF data format. The software also converts schematics and symbols from EDIF format back to Design Architect format. The software also lets you define libraries and specify property names, units of numerical quantities and output data types. For HP/Apollo 68K and HP 9000/400 workstations and Domain operating system. $4800 single-direction seat license; $8000 for bidirectional seat license. **Engineering DataXpress Inc,** 5 Town & Country Village, Suite 736, San Jose, CA 95128. Phone (408) 243-8786. FAX (408) 243-8994. **Circle No. 430**

Multimedia operator-interface development. Rave 1.4 is a video/sound development and runtime package for OS-9000 80386/80486 systems. The software comes with all the OS-9000 system modules and development tools needed to create interactive graphics and display panels. It provides sound for real-time process control, automation, and

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Analog and mixed-signal tools. The DSP Station is a suite of tools for designing the digital signal-processing portions of analog/digital systems. It provides design entry, simulation, optimization, and implementation of DSP designs. You can choose board, ASIC, or IC implementations. The software does "what-if" analysis from early stages of design, including hardware/software tradeoffs, analog vs digital partitioning, and architectural optimizations. HP/Apollo version, $33,000. Also available for Sun. **Mentor Graphics Corp,** 1001 Ridder Park Dr, San Jose, CA 95131. Phone (408) 436-1500. FAX (408) 451-5538. **Circle No. 432**

Image processing and analysis for Macintosh. IPLab Spectrum 2.2 contains features for scientific visualization, image enhancement, and region analysis. Its new view, called Perspective, lets you view 2-D image data from a 3-D perspective. The software's image registration allows you to place registration marks on images, then find the best rotation, scale, and shift parameters to align the marks in the images. **Signal Analytics Corp,** 374 Maple Ave E, Suite 204, Vienna, VA 22180. Phone (703) 281-3277. FAX (703) 281-2509. **Circle No. 433**

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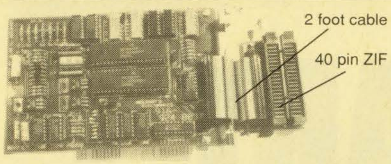

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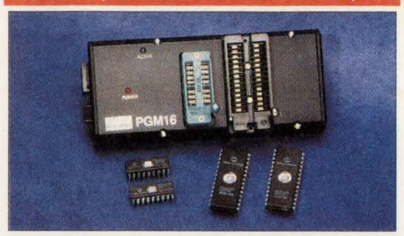

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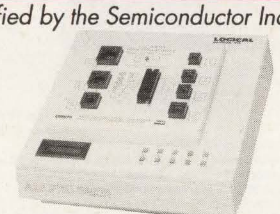

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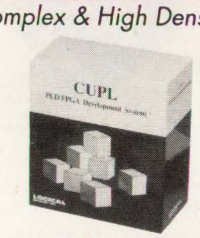

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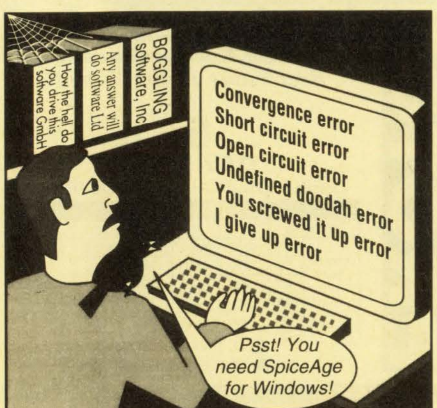

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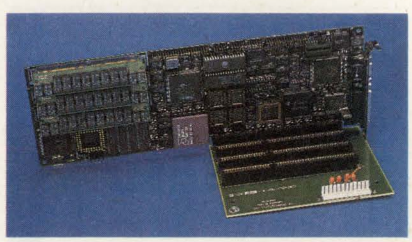

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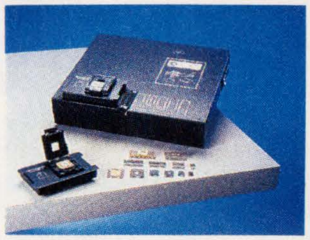

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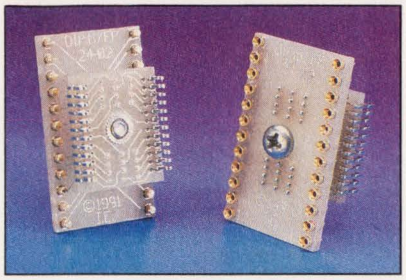

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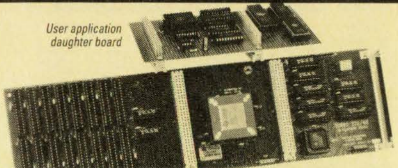

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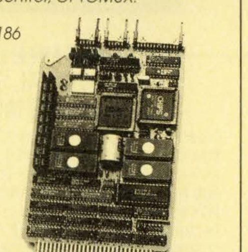

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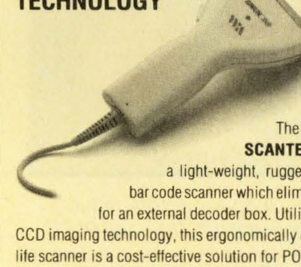

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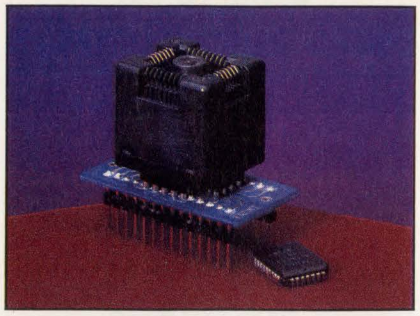

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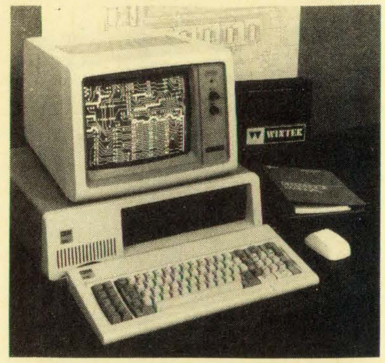

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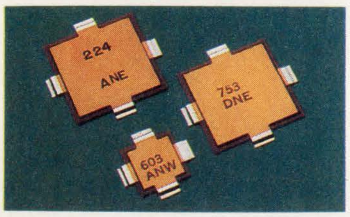

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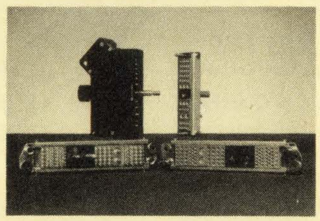

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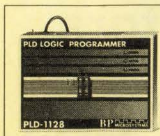

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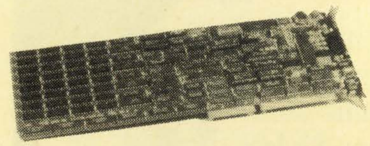

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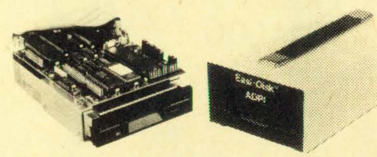

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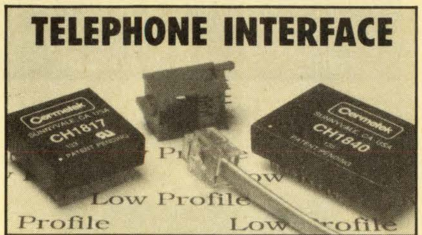

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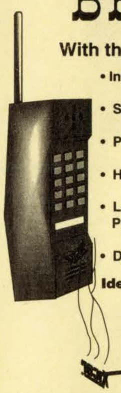

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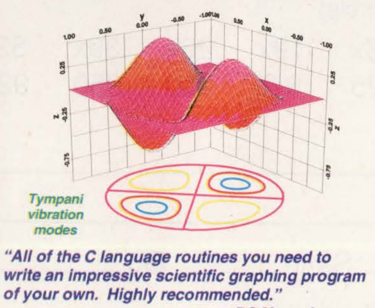

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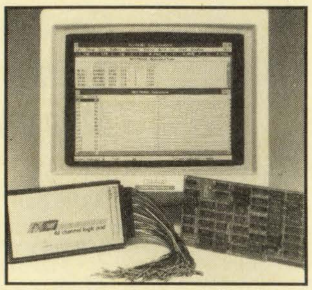

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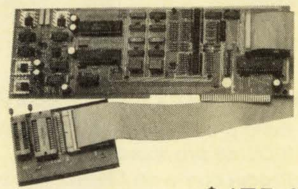

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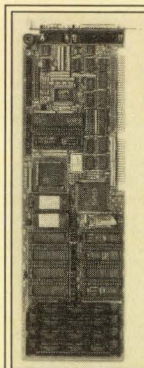

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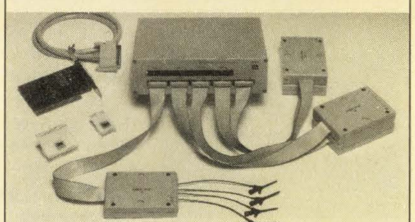

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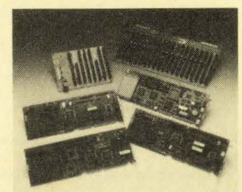

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EDN Magazine	Nov. 26	Nov. 5	19th Annual Microprocessor Directory • ASICs • Sensors • EDN's "Innovation Crusade"–Winners Coverage
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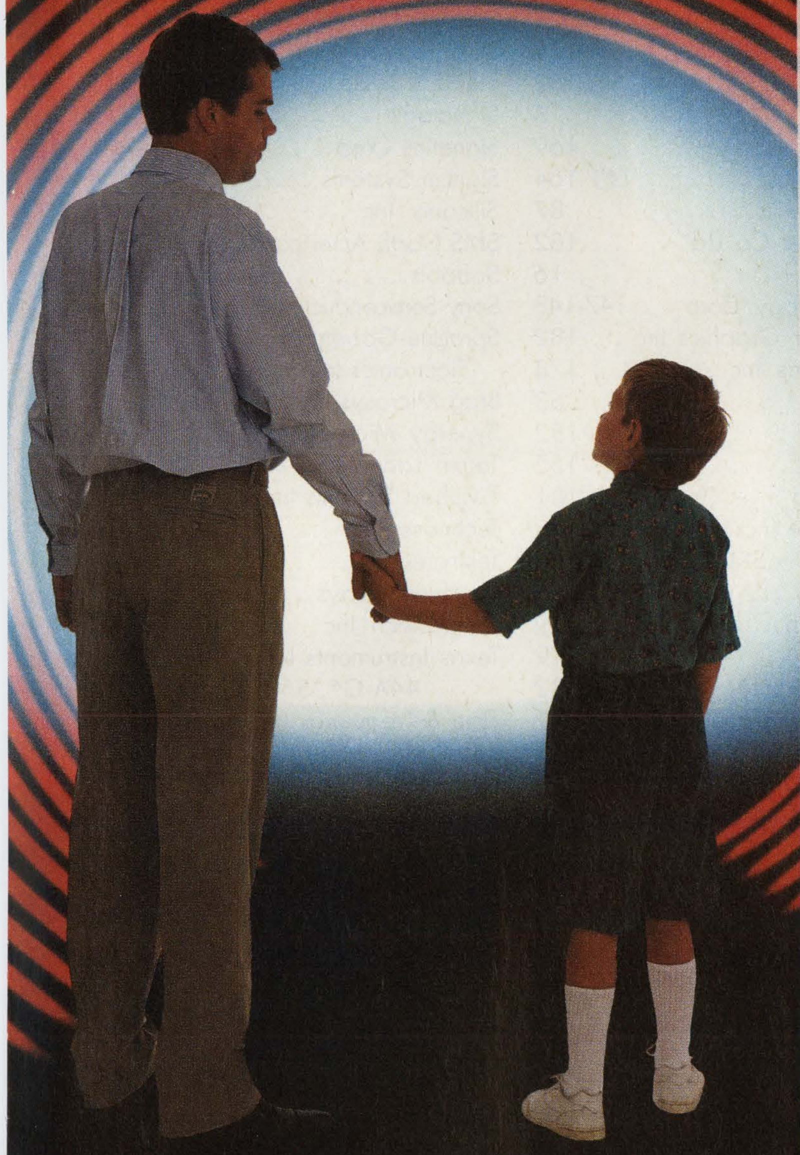

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ZiLOG

Doing It Right.

CIRCLE NO. 124

EDN·ACRONYMS & ABBREVIATIONS

A/D—analog-to-digital
ATM—automatic-teller machine
BIOS—basic input-output system
CAD—computer-aided design
CCFL—cold-cathode fluorescent lamp
CIS—Card Information Structure
CPU—central processing unit
DRAM—dynamic random-access memory
DSO—digital storage oscilloscope
IC—integrated circuit
I/O—input-output
ISA—Industry Standard Architecture
LAN—local-area network
LCD—liquid-crystal display
LSI—large-scale integration
μP—microprocessor
MS-DOS—Microsoft disk operating system; the dominant operating system on PCs that use microprocessors in the 80x86 family
OOP—object-oriented programming
PC—personal computer
PCMCIA—Personal Computer Memory Card International Association
pSOS—an operating system for embedded systems, published by Software Components Group, Santa Clara, CA
RAM—random-access memory
ROM—read-only memory
VGA—video-graphics array, originally an IBM standard for PC displays
VXI—VME extensions for instrumentation

This list includes acronyms and abbreviations found in EDN's Special Report, Technology Updates, and feature articles.

My last Heathkit?

The era of people starting their careers in electronics by building Heathkits may be drawing to a close. Increasing product complexity and competition in the consumer electronics arena have caused the Heath Co to eliminate most kits from its catalog. Kit-built color TVs and stereo receivers no longer make any sort of financial sense. I ordered one of the few remaining Heathkits so that I could share the experience of building an electronic kit with my 10-year-old daughter, Shaina. We built the $24.95 Model SK-118 Dragonfly during a pleasant two hours on a rainy Fourth of July. During those two hours, Shaina learned how to solder, and she can now identify several common electronic parts.

The Heathkit Dragonfly has wings made of piezoelectric film. The wings flutter when excited by 260V pulses. A simple 1-transistor, 10-kHz oscillator driving a step-up transformer generates the excitation voltage for the wings and 5V for the rest of the circuitry. A low-frequency oscillator built from a CMOS quad NAND-gate IC alternately applies the 260V to each side of the film wings through switching transistors, causing the wings to first flex one way and then the other. A small potentiometer adjusts the oscillator frequency so that you can run back and forth through the system's mechanical resonance point.

Unlike the Heathkits I built years ago, this kit arrived in a blister pack designed to hang from a peg. Instead of the familiar 8½×11-in. yellow Heathkit manual, this kit contains a smaller manual consisting of several printed sheets saddle-stitched into a 43-page booklet. The kit is actually made in Hong Kong instead of Benton Harbor, MI, but I was pleased to see that information in the manual was presented in the same clear, thorough style I remember.

Before starting the assembly, we inventoried all of the parts to make sure nothing was missing. This was also a good time for Shaina to learn what resistors, capacitors, transistors, transformers, and ICs looked like. The parts list includes illustrations that make kit building easy for a novice. With the usual childish eagerness, we skipped the 6-page explanation of how the Dragonfly worked and started with the assembly. Shaina was forming leads and soldering components on the pc board less than 10 minutes after opening the package.

I was fascinated to watch my daughter develop her assembly skills. I showed her how to hold the needle-nose pliers, but she needed little help after that. Without my coaching, she started doing many of the same things I had learned to do: blowing the resin smoke away after soldering a joint, bending component leads to hold the parts in the board until they could be soldered, and checking to make sure that the parts stayed down on the board before soldering them in place. She also found out how easy it is to put transistors in backwards.

As is usual with electronic projects, the mechanical aspects proved the toughest. The dragonfly portion of the kit sits a few inches above the circuit board, supported by a heavy wire. You're supposed to attach this wire to the dragonfly with double-sided foam tape, but the foam tape was too stiff. We improvised with some thinner tape.

At the moment of truth, Shaina slipped the AA battery into its holder and pressed the power switch. The wings fluttered. I watched my daughter experience the usual smoke-test jitters and the thrill of first-time success. Those are the experiences that made Heathkits famous. I will be very sad if they ever disappear entirely.

—Steven H Leibson

Heath Co, Box 8589, Benton Harbor, MI 49023. Phone (800) 253-0570; (616) 925-4914. FAX (616) 925-4876.

The Czar of Bandgaps provides solid trouble-shooting advice

Whoever said "Engineers can't write" has obviously never encountered the works of Bob Pease. *Troubleshooting Analog Circuits*, derived (and considerably expanded) from a series of EDN articles, is a joy to read. What's more, its practical, how-to advice makes it indispensable for any analog-circuit designer.

Bob's highly personalized writing style is scintillating and witty. In fact, it becomes downright hilarious when he unleashes his diatribes against computers in general and Spice simulation in particular. His basic premise is that you generally can't trust computer simulations of analog circuits; you must get your hands dirty and breadboard the circuits. Furthermore, he maintains that blind reliance on computer-based design is inimical to a designer's developing a feel for the inner workings of linear circuits.

The book contains thirteen chapters and eight appendices. The chapter topics are: troubleshooting philosophy, choosing equipment, resistors and inductors, capacitors, pc boards and connectors, relays and switches, diodes, transistors, op amps, spurious oscillations, A/D issues, references and regulators, miscellaneous loose ends, letters that Bob has received and responded to, and a collection of real circuits and their potential problems.

Chapter one, covering Pease's philosophy of troubleshooting, is a general discussion of fault-finding methodology. The sound advice he gives in this section includes making a list of things that could (and things that couldn't) cause the problem, appointing a "Czar" for a particular problem area, and making Murphy's Law work for you (by designing for testability, for example). At National Semiconductor, Bob has appointed himself "Czar of Bandgaps"—he keeps a log of all successful and less-than-successful circuits, failure causes, and failure fixes for this product category.

A sprinkling of levity lightens the reading task in this chapter and, indeed, throughout the book. For example, if a circuit component gives you a lot of grief in failure analysis, you simply "Widlarize" it (in honor of the late, great Bob Widlar)—place it on an anvil and beat it into tiny pieces with a hammer. To quote: "You know that component will never vex you again." Good therapy, Bob.

The chapter on choosing equipment presents a list of 28 items a well-stocked failure-analysis facility should have. In addition to the obvious DVMs, oscilloscopes, et al, Pease advocates some not-so-obvious aids, like a short-circuit detector, freeze mist and a hair dryer, and a thermocouple-based thermometer, to name a few. He gives schematic diagrams for the short-circuit detector and the thermometer, in case you would like to roll your own.

Passive- and active-component problems take up seven chapters. Pease goes into considerable detail in delineating the idiosyncrasies and pitfalls associated with almost every conceivable type of passive component and linear IC. He covers issues such as TCs (and TC nonlinearity) and parasitic effects of various types of resistors; ESR (equivalent series resistance), soakage (dielectric absorption), breakdown characteristics, and inductances of different capacitor types.

Detail abounds also in the chapters covering transistor, diode, and IC problems. Spec interpretation (notably, CMRR), noise characteristics, and oscillation proneness are only some of the topics Pease covers in the chapter on op amps. And at the end of this chapter, he gives good advice: Rely only on min/max specs in op-amp data sheets—the typical figures are nonbinding nonguarantees of nothing.

In addition to prescribing troubleshooting methods, Pease gives proven techniques for preventing trouble in the design stage. Bypassing practices, overload-protection circuits, op-amp compensation techniques, and antireversal diodes on power-supply lines are only a few of the tricks he recommends to avoid future failures in your designs. Here, Bob pokes a little fun at MIL-HDBK-217, which, if followed blindly, would predict *lower* reliability for a circuit with added protection devices.

One delightful photo shows Bob hurling a computer to its doom from the roof of a parking garage.

Especially valuable is the chapter on quashing spurious oscillations. Pease shows you how to detect masked high-frequency oscillation, as well as how to prevent it. One useful technique he proposes is to jolt the output of your circuit with square waves of various amplitudes and frequencies. By observing the ringing and settling characteristics at the circuit's output, you gain a good idea of the circuit's inherent stability.

In addition to the text describing various gremlins, the book contains many cookbook tables for troubleshooting a variety of circuit types—what to look for and how to look for it, and what to eliminate as a possible cause, given almost every conceivable symptom. Pease makes it clear, however, that no table can possibly cover all maladies. You have to have a good grasp of how your circuit functions, and you have to develop sound failure-analysis techniques.

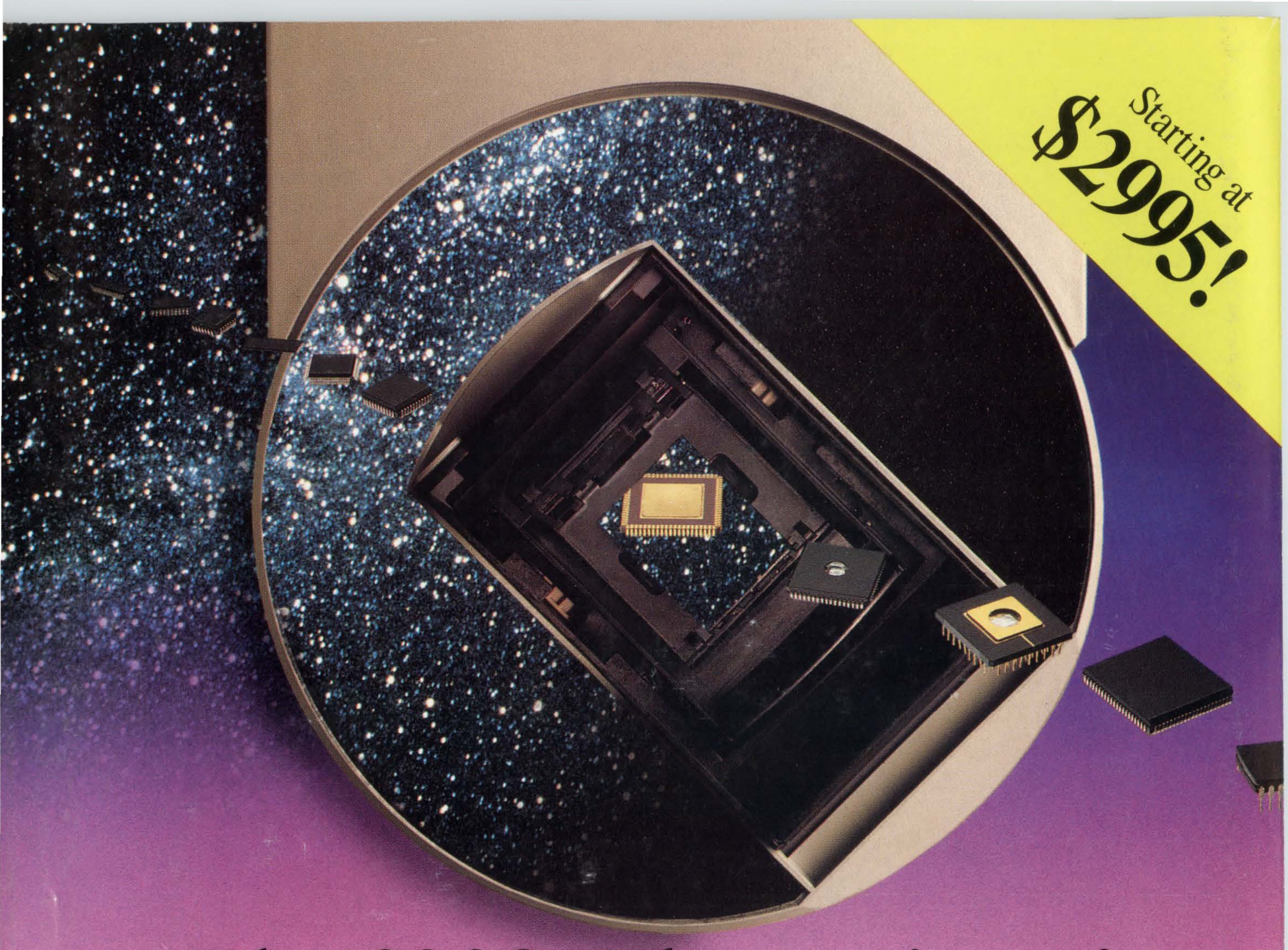
The artwork in this book is both informative and enjoyable. Schematics galore illustrate the points Pease makes in the text. Amusing captions accompany several photos of the bearded guru at work. One delightful photo, for example, shows Bob hurling a computer to its doom from the roof of a parking garage.

So, if you've ever been perplexed by an analog circuit that malfunctions only between 9:30 and 10:00, or that drifts out of sight when you open the blinds, or that screams with oscillation when you put your hand near it, this book's for you. And Pease's writing is so delicious, I'd be willing to bet that a person who never heard of a transistor would enjoy reading this tome.

—Bill Travis

Troubleshooting Analog Circuits, Robert A Pease, Butterworth-Heinemann, 80 Montvale Ave, Stoneham, MA 02180, 208 pgs, $32.95, Phone (800) 366-2665, FAX (617) 279-4851; in Europe: Reed Book Services Ltd, Special Sales Dept, Box 5, Rushden, Northants NN10 9YZ, UK, Phone 0933-58251, FAX 0933-50284.

Bill Travis is a freelance writer living in Worcester, MA. He has been an EDN editor and an international marketing manager at Micro Network.



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