APRIL 5, 1979

A CAHNERS PUBLICATION

EDN

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For complete specifications, performance curves and application information, refer to 78-79 MicroWaves' Product Data Directory (pgs 161-352) or EEM (pgs 2890-3058).

Model No.	Freq. (MHz)	Conv. loss (dB max.)	Signal 1 dB compr. level (dBm min.)	Con-nections	Size (w x l x ht.) (in.)	Price (Qty.)
TFM-1H	2 — 500	8.5	+14	4 pins	0.21 x 0.5 x 0.25	$23.95 (5-24)
TFM-2H	5 — 1000	10	+14	4 pins	0.21 x 0.5 x 0.25	$31.95 (5-24)
TFM-3H	0.1 — 250	8.5	+13	4 pins	0.21 x 0.5 x 0.25	$23.95 (5-24)
TAK-1H	2 — 500	8.5	+14	8 pins	0.4 x 0.8 x 0.25	$19.95 (5-24)
TAK-1WH	5 — 750	9.0	+14	8 pins	0.4 x 0.8 x 0.25	$23.95 (5-24)
TAK-3H	0.05 — 300	8.5	+13	8 pins	0.4 x 0.8 x 0.25	$21.95 (5-24)
ZAD-1SH	2 — 500	8.5	+14	BNC TNC	1.15 x 2.25 x 1.40	$40.95 (4-24)
ZAD-1WSH	5 — 750	9.0	+14	BNC,TNC	1.15 x 2.25 x 1.40	$44.95 (4-24)
ZAD-3SH	0.05—300	8.5	+13	BNC,TNC	1.15 x 2.25 x 1.40	$42.95 (4-24)
ZLW1SH	2 — 500	8.5	+14	SMA	0.88 x 1.50 x 1.15	$50.95 (4-24)
ZLW-1WSH	5 — 750	9.0	+14	SMA	0.88 x 1.50 x 1.15	$54.95 (4-24)
ZLW-3SH	0.05 — 300	8.5	+13	SMA	0.88 x 1.50 x 1.15	$52.95 (4-24)
ZFM-1H	2 — 500	8.5	+14	BNC, TNC SMA, N	1.25 x 1.25 x 0.75	$53.95 (1-24)
ZFM-2H	5 —1000	10	+14	BNC,TNC SMA,N	1.25 x 1.25 x 0.75	$61.95 (1-24)
ZFM-3H	0.05 — 300	8.5	+13	BNC,TNC SMA,N	1.25 x 1.25 x 0.75	$54.95 (1-24)

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EDN

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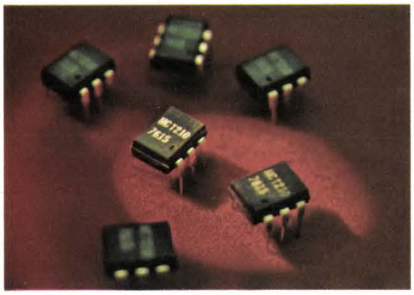
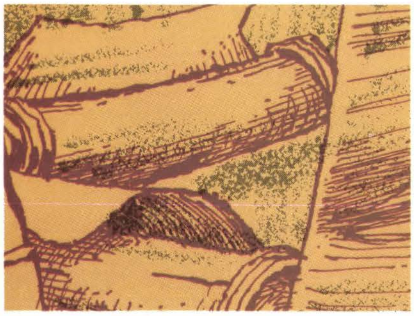


Optoisolators *find use in a variety of new applications (pg 48).*



The PASCAL language *offers designers a host of opportunities—and some dilemmas (pg 78).*

On the cover: *A μC development system is the cornerstone of effective system design (pg 62). (Photo courtesy Advanced Micro Computers)*

CP BPA ABP

DESIGN FEATURES

TECHNOLOGY NEWS

NEW PRODUCTS

DEPARTMENTS

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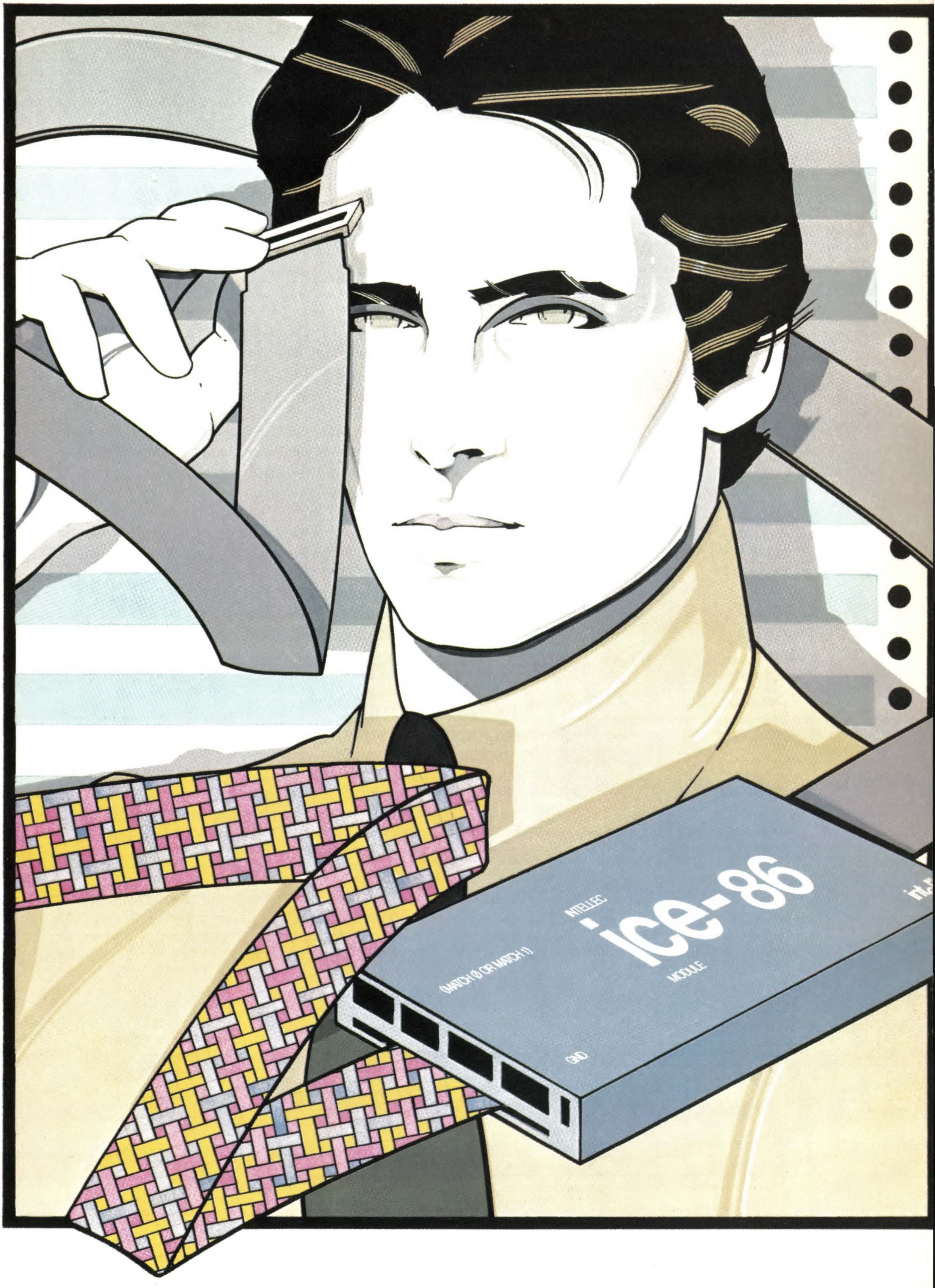
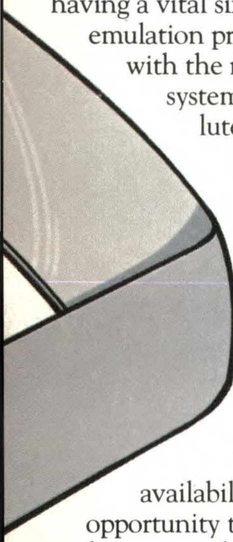

INTELLEC
ice-86
MODULE
(MATCH Ø OR MATCH 1)
GND

Sixth Sense for 8086 Users.

Intel delivers ICE-86™ emulator, the designer's direct diagnostic connection to 8086 system development.



Intel's new 8086 sets the standard for 16-bit microcomputers. It delivers the Architecture of the Future today, high-level languages for programming and the Intellec® development system for unsurpassed support.

Now that support moves even further out in front. Introducing the ICE-86 module. Experienced microcomputer designers have learned that having a development system with in-circuit emulation—ICE—is like having a vital sixth sense. Only ICE emulation provides designers with the real insight in actual system operation absolutely necessary for cost effective, efficient product development. Now Intel delivers that sixth sense for 8086 users.

ICE-86™ puts the future in your hands

The 8086's early availability provides the opportunity to get your new products to market a year or more ahead of your competitors who wait for follow-on 16-bit microprocessors. Only Intel delivers the future today.

The Intellec development system with in-circuit emulation enables you to seize that opportunity. You can actually begin software development and debugging in an 8086 environment before any prototype hardware exists. Or you can use the ICE-86 module to begin simultaneous hardware and software development and integration while your system is little more than an 8086 cpu and system clock.

The ICE-86 cable plugs into your system cpu socket to provide emulation of system operation, up to the full megabyte of memory the 8086 can address.

Communicate in English, or symbolic references.

The ICE-86 emulator is actually a complex breakpoint and logic trace system supporting the most advanced symbolic debugging techniques. English-like statements or symbolic references entered at the Intellec keyboard eliminate the need to search memory maps, keep track of address changes or get bogged down in the details of system operation.

And the ICE-86 emulator's powerful logic analysis capability helps find the cause and correct the problem when bugs do appear.

PL/M-86 for the Architecture of the Future.

The most powerful microcomputer ever deserves the most powerful microcomputer programming language. That's PL/M-86, an extension of the world's most widely used development language.

PL/M-86 is an ideal example of the block-structured languages the 8086's futuristic architecture can support. It gives you 32-bit floating point arithmetic and 16-bit signed integer arithmetic. And it takes full advantage of the program-compacting features of the 8086, such as hardware multiply and divide and byte-string operations.

PL/M-86 is best for fast composition of large and complex programs. For those who prefer the efficiency of assembly language, there's ASM-86. And CONV-86 converts 8080/8085 code to the 8086.

The future is even brighter. Planned expansion of the Intellec system promises programming in Pascal and FORTRAN and the added flexibility of a macro assembler. It's true today and will be true long into the future—the 8086 is the best supported 16-bit microcomputer you can buy.

Modular programming is here.

The Intellec system gives you the flexibility of modular programming. You can develop routines in small, manageable modules, choosing the best language for each. Then using the Intellec system's powerful relocation and linkage capabilities, you can merge modules using symbolic references.

We optimized Intellec hardware for 8086 development, providing a dual diskette, expandable to four drives and 2.5 megabytes of memory. And we'll be expanding the Intellec system with a 7-megabyte hard disk, enough memory to extend the 8086's capabilities into the realm of large mainframe computers.

A manual for your success.

We've compiled an in-depth Success Manual for 8086 Users, detailing the Intellec Microcomputer Development System, ICE-86 and the full software package for 8086 program development. For your copy, contact your local Intel sales office. Or write: Intel Corporation, Literature Dept., 3065 Bowers Avenue, Santa Clara, CA 95051.

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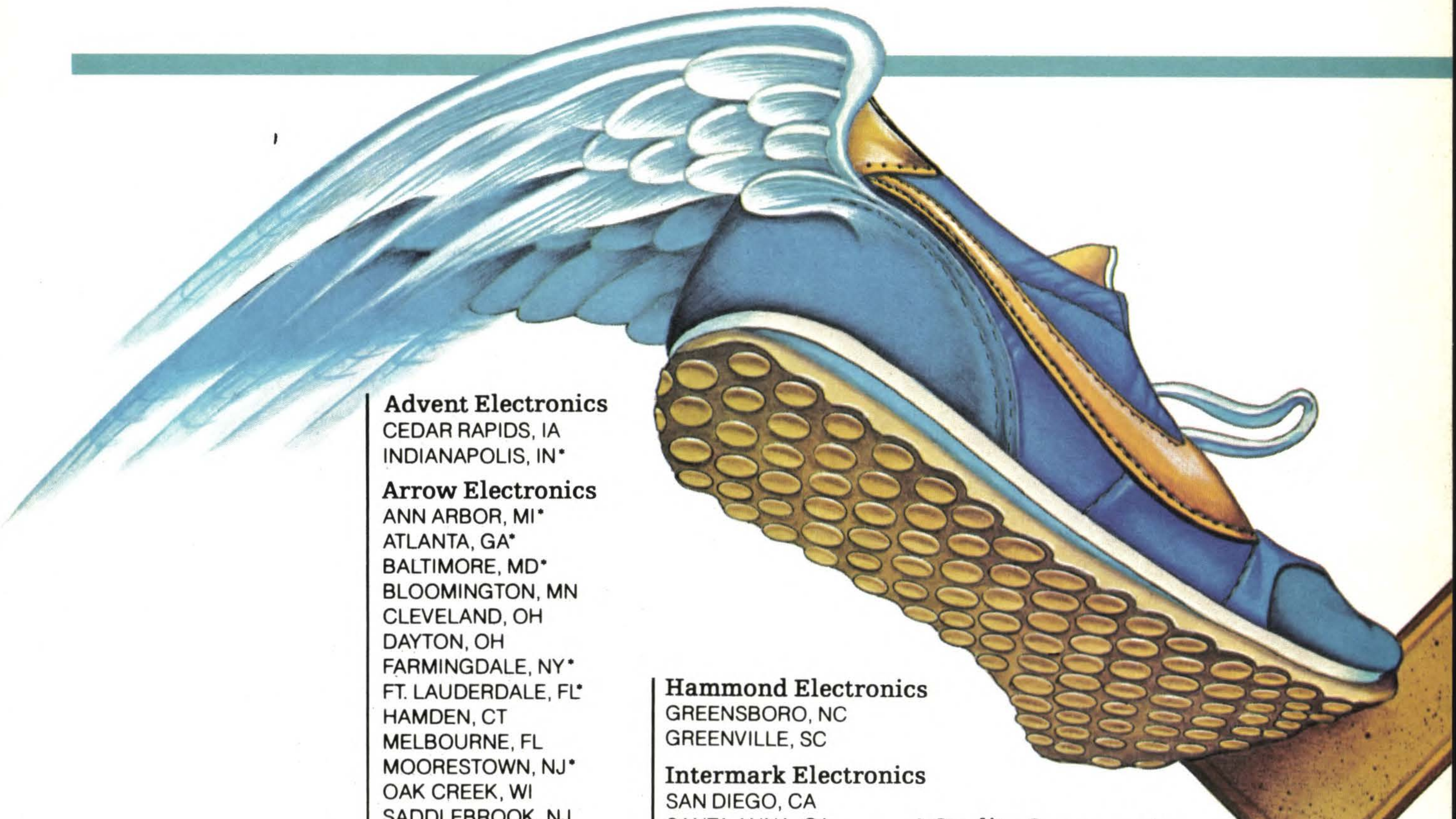

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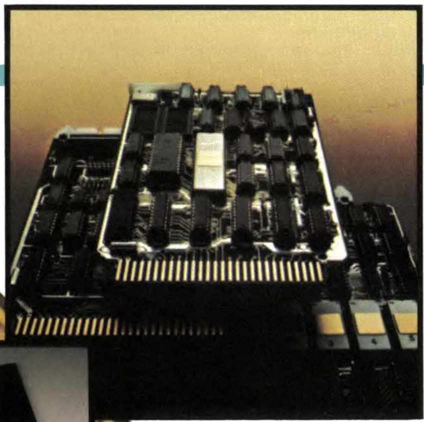

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Or begin with our MD Series™ of OEM microcomputer boards. It features our MDX-line of STD-Z80 BUS compatible modules for building your system one function at a time. You buy only what you need, and reduce hardware design time.

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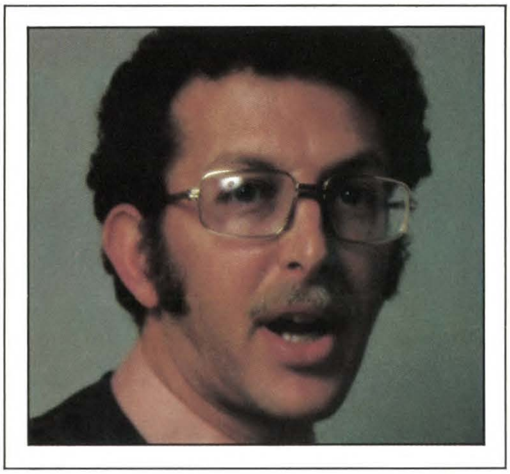

through thick manuals looking for escape clauses, the Starplex System guides you through your work path with a series of menus, prompts, lights, and audible signals.

And while some systems can communicate only in assembly, ours is fluent in BASIC and FORTRAN. Languages which can be loaded — as usual — with one keystroke.

Now others may have claimed their systems were "easy" before. But we've got the software to prove it. Which is why we

do not hesitate to publish here a comparison chart which will show at a glance where things really stand.

The Starplex System is designed to be used with current and future National microprocessors, as well as BLC/SBC Series/80 microcomputers.

It's fully expandable, with four chassis slots allowing the addition of standard Series/80 boards. Plus a programming station which accepts optional personality boards for 2708 and 2716 PROMs.

Integrated into the Starplex package are five microprocessors, 64K bytes of memory, dual 256K byte floppy discs, a 1920 character CRT, a 50 CPS printer, and standard ASCII keyboard in addition to the special function keypads.

All the software you'll need is included in the package. A powerful operating system, macro assemblers, editor, debugger, and other key software modules.

We also offer the In-System Emulator (ISE), an extremely valuable option for hardware development. It works through an easily understood command interface. ISE uses its own memory for memory mapping — a time-saving feature which also allows true real-time debugging.

Because Starplex ISE incorporates symbolic debugging, you can debug code in the same assembly mnemonics in which it was written. And it's the only system emulator capable of debugging two microprocessors simultaneously in a multiprocessor system.

By any standard of comparison, the Starplex Development System represents a colossal leapfrog over the field in every category, save one: Price. And so, while others ask in excess of $20,000 for the privilege of unnecessary toil, our price is just $13,800. On the theory that not only is less more, but more should cost less.

We would jump at the chance to tell you the whole story in detail. Write or call me for a complete brochure on the Starplex Development System. Address your request to Mark Levi, General Manager, Microcomputer Systems, National Semiconductor Corporation, Drawer 31, 2900 Semiconductor Drive, Santa Clara, California 95051. Or dial these toll-free numbers: 800-538-1866; 800-672-1811 in California.

In Europe, write National Semiconductor GmbH, Industriestrasse 10, 8080 Fuerstenfeldbruck, West Germany."

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National Semiconductor Corporation

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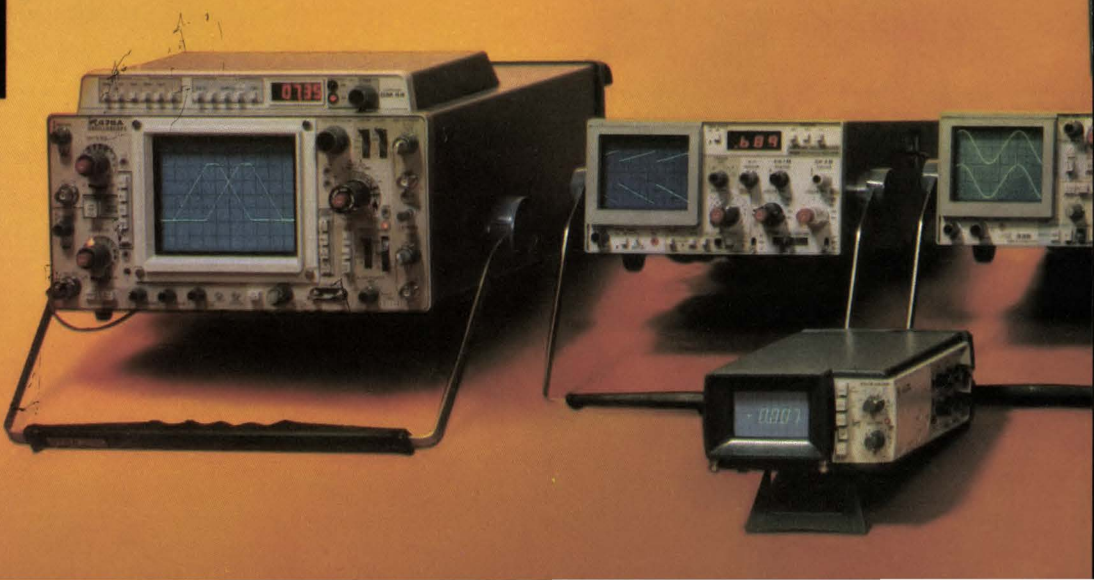
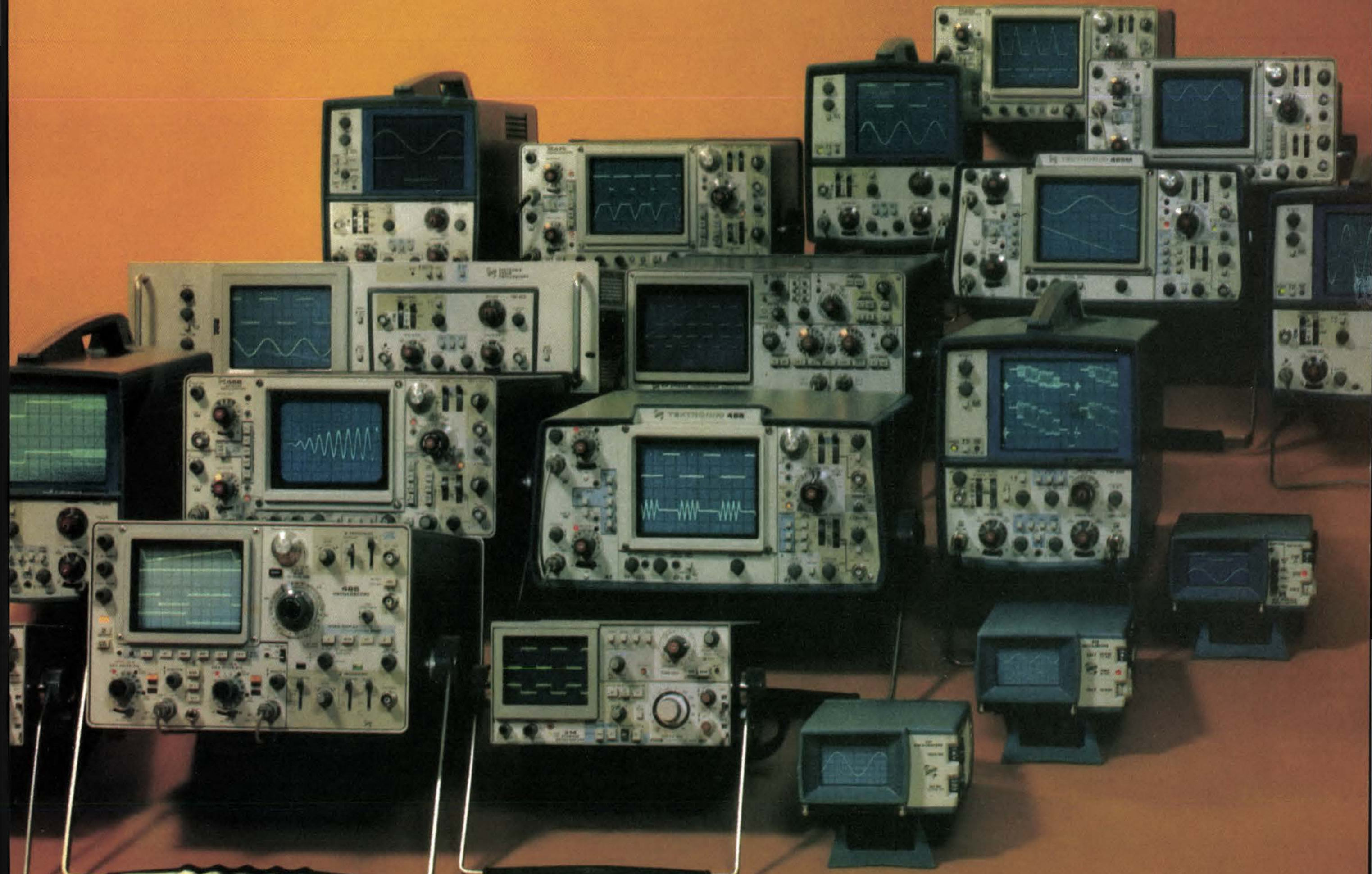


scope meets

	Product	Bw	Dual Trace	Delayed Sweep	Fastest Sweep Rate	Other Special Features	Price*
Storage Models	466	100 MHz @ 5 mV/div	yes	yes	5 ns/div	3000 div/μs stored writing speed	$5355
	464	100 MHz @ 5 mV/div	yes	yes	5 ns/div	110 div/μs stored writing speed	4375
	434	25 MHz @ 10 mV/div	yes		20 ns/div	Split-screen storage	3480
	314	10 MHz @ 1 mV/div	yes		100 ns/div	Only 10.5 lbs (4.8 kg)	2645
	214	500 kHz @ 10 mV/div	yes		1 μs/div	Only 3.5 lbs (1.6 kg)	1595
	T912	10 MHz @ 2 mV/div	yes		50 ns/div	Low-cost bistable storage	1545
Nonstorage Models	485	350 MHz @ 5 mV/div	yes	yes	1 ns/div	Widest bw in a portable	5725
	475A	250 MHz @ 5 mV/div	yes	yes	1 ns/div	High-performance 250-MHz portable	3800
	475	200 MHz @ 2 mV/div	yes	yes	1 ns/div	Highest gain-bw in a portable	3435
	465	100 MHz @ 5 mV/div	yes	yes	5 ns/div	Cost effective for 100-MHz bw	2495
	465M	100 MHz @ 5 mV/div	yes	yes	5 ns/div	Triservice standard 100-MHz scope	2620
	455	50 MHz @ 5 mV/div	yes	yes	5 ns/div	Cost effective for 50-MHz bw	2055
	335	35 MHz @ 10 mV/div	yes	yes	20 ns/div	Only 10.5 lbs (4.8 kg)	2175
	305	5 MHz @ 5 mV/div	yes		0.1 μs/div	Autoranging DMM	1725
	221	5 MHz @ 5 mV/div			100 ns/div	Only 3.5 lbs (1.6 kg)	1190
	213	1 MHz @ 20 mV/div			400 ns/div	DMM/Oscilloscope @ 3.7 lbs (1.7 kg)	1595
	212	500 kHz @ 10 mV/div	yes		1 μs/div	Low cost for dual trace & battery	1190
	T935A	35 MHz @ 2 mV/div	yes	yes	10 ns/div	Delayed sweep and differential	1535
	T932A	35 MHz @ 2 mV/div	yes		10 ns/div	Variable trigger-holdoff and differential	1245
	T922	15 MHz @ 2mV/div	yes		20 ns/div	Low-cost dual-trace scope	975
	T922R	15 MHz @ 2mV/div	yes		20 ns/div	Rackmount version of T922	1345
	T921	15 MHz @ 2mV/div			20 ns/div	Lowest-cost TEKTRONIX Portable	795
Time Interval Readout	DM44	Optional, factory-installed, direct numerical readout of time intervals and DMM functions for the 464, 465, 466, 475 and 475A					445

*U.S. sales prices are F.O.B. Beaverton, OR. For price and availablity outside the United States, please contact the nearest Tektronix Field Office, Distributor or Representative. Prices are subject to change without notice.



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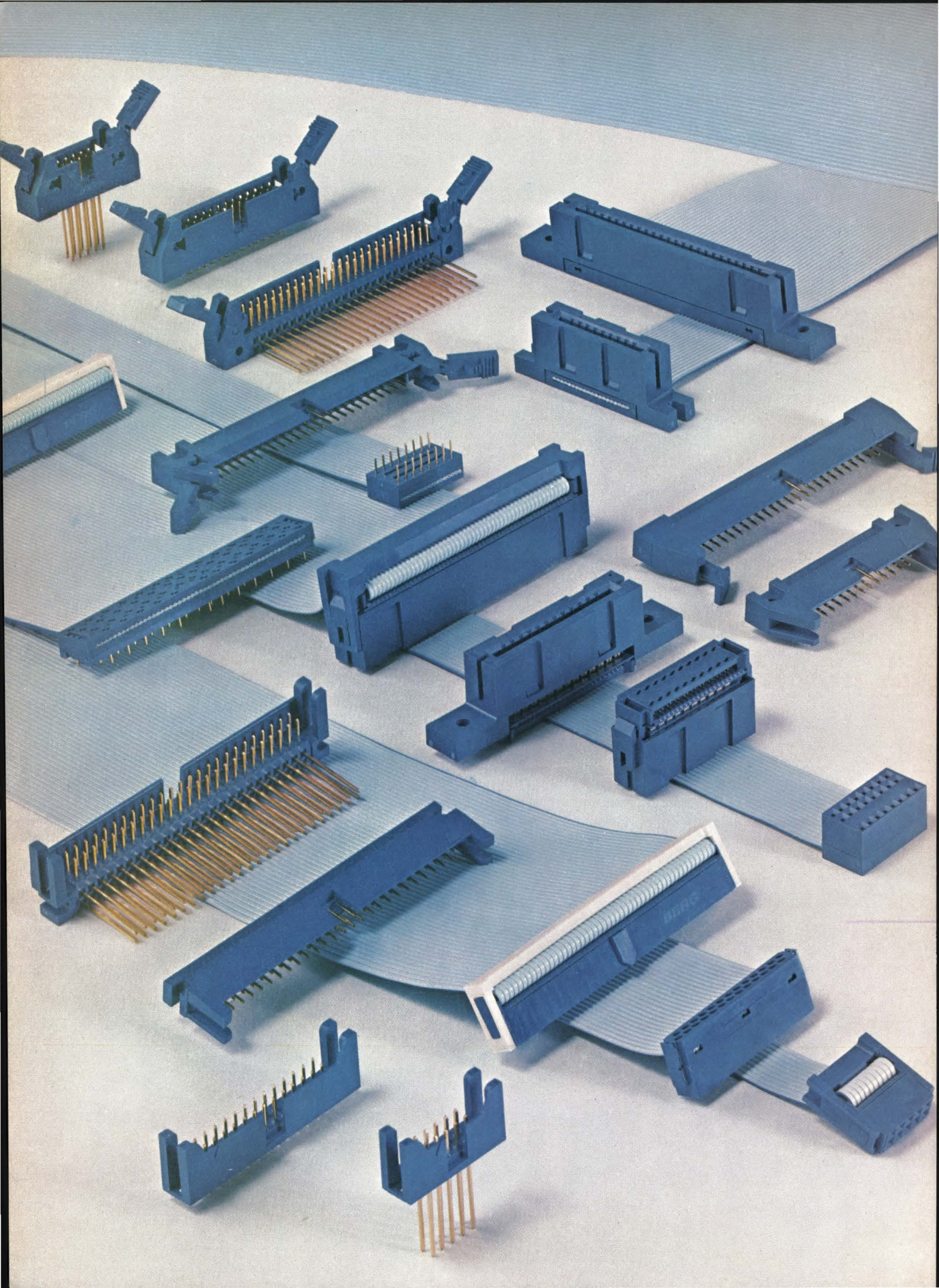
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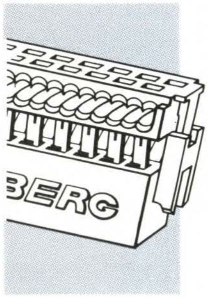
Efficient assembly saves time, material and money.

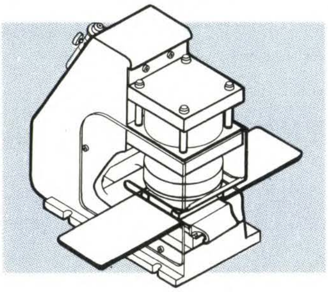
All connectors in the Quickie* system deliver reliable terminations in just a few seconds because:



• Cable slot designed to precisely position conductor for reliable termination, higher yields.

• Sight holes in cover permit visual inspection before and after assembly assuring proper cable alignment.

• The semi-automatic applicator completes terminations with a slide motion reducing assembly time. Or choose the manual applicator designed to minimize operator fatigue.



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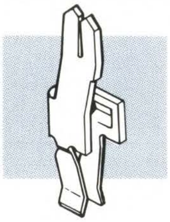
"Quickie" connectors are now specified by many of America's most quality conscious companies. Three high performance features demonstrate why:

1. Askewed tines firmly hold the wire for reliable termination.



2. Dual-beam contact assures redundant positive pin connection, even when subjected to vibration.

3. High-strength plastics withstand severe environments.

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*Du Pont's trademark for its mass termination connectors, cable, presses and accessories.

Signals & Noise

Add this to your list

Dear Editor:
Your article on chips and filters for Touch Tone receivers (EDN, January 5, pgs 115-120) was very timely and well prepared. Unfortunately, the article omitted a major manufacturer.

Teltone Corp has manufactured Touch Tone devices since 1968 and has led in the development of these devices for interfacing with tone-related equipment. Our high-performance tone receivers of central-office quality are used by all major telephone companies throughout North America, in various applications internationally and by many equipment manufacturers.

Sincerely,
Earl L Mason
Vice President, Marketing
Teltone Corp
Kirkland, WA

Fine-tuning a keyboard

Dear Editor:
The EDN January 20 Special Report on keyboards (pgs 64-72) seems to ignore a difference in format which has been a problem for us.

The box on pg 65 presenting keyboard specifications for your hypothetical word-processing terminal mentions that the "operator is experienced with high-speed typing on an IBM Selectric." But every keyboard pictured in the article has a Teletype Model 33 format, which differs from the Selectric format in its placement of punctuation and other symbols such as *, +, ", etc. (It's interesting, though, that Teletype Corp's Model 45 uses the Selectric format, as do Digital Equipment's Decwriter and video terminals.)

If an operator had to switch often between an IBM Selectric and any of the keyboards shown in the article, I would expect an error rate substantially higher than if the operator only had to use either one of the two formats. Our experience has shown this to be the case, and we are now standardizing on the Selectric format, mostly because we use those typewriters and a DEC computer.

Very truly yours,
Howard Hamer
Chief Engineer
Dranetz Engineering Labs
South Plainfield, NJ

Misplaced decimal

Mr Sidney Chertok, Director of Information Services at Sprague Electric, has informed us of an error appearing in Table 1 (pg 124) of the January 5 EDN article, "Optimize ripple/EMI performance in switching-regulator designs." The Sprague and Mallory stacked-foil capacitors described there show a typical ESL (nH) of 15—the figures should read 1.5 nH.

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Check EDN's Career Opportunities

EDN: Everything Designers Need

Has your power supply vendor left you high & dry?

If you're involved in a program to replace a power supply that is no longer available or your previous supplier is no longer around or can't deliver, Powercube standard modular power circuits may be the answer.

Used for over a decade by contractors for major military and space programs, these proven 1″ × 1″ × 2″ Cirkitblock® modules meet the toughest specs for size, weight, performance and environment.

We can optimize your design and save you money without getting bogged down in component selection, vendor delays or interface problems. Most Cirkitblock preregulators, power generators and output modules are available off the shelf.

Call the quick action company 617-667-9500 or circle the reader response number.

For more information, Circle No 10

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A SUBSIDIARY OF UNITRODE CORPORATION

POWERCUBE CORPORATION
EIGHT SUBURBAN PARK DRIVE
BILLERICA, MASSACHUSETTS 01821
(617) 667-9500

Books

Cut confusion with pocket-sized reference

Microprocessor Lexicon. *110 pgs; $2.95; Sybex Inc, Berkeley, CA, 1978.*

One definition of a lexicon is "the vocabulary of a language." Appropriately, this little book doesn't confine itself to the jargon of microprocessorists, but extends into the glut of acronyms that characterizes communications as well.

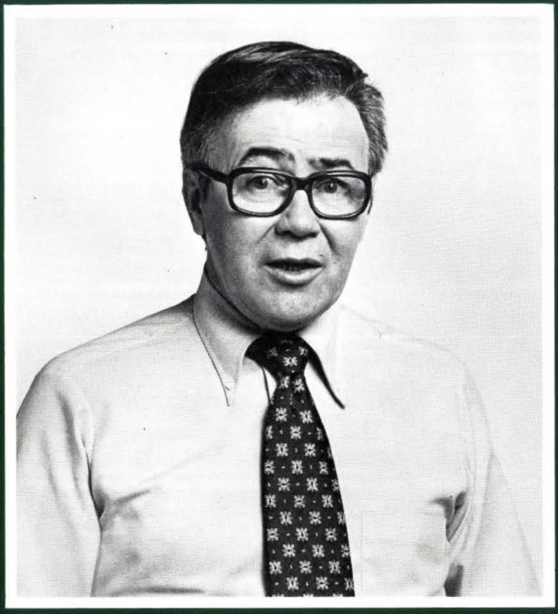
The bulk of this pocket-sized work attacks the vagaries of terminology. Although far from exhaustive, the definitions are accurate and sufficient for quick lookup.

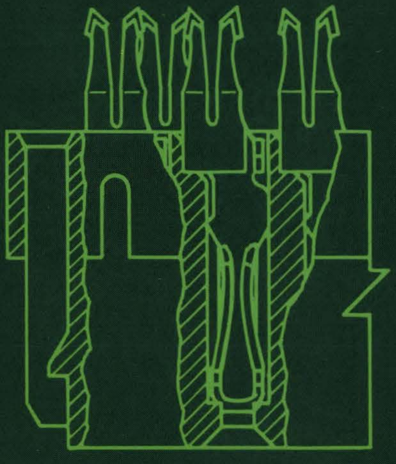
Numbers play an important part in the dialogues of the digital world. Thus, one section is devoted to "The Numbers Game," wherein the book translates common numeric designations.

The lexicon also mysteriously includes two manufacturers lists: one for μPs, another for μCs. Perhaps such lists serve a purpose, yet the industry's quicksilver nature renders the completeness and accuracy of any list in book format doubtful.

Realistically, if you're in the business, you probably don't need this book. Giving it to an engineering manager (or a nontechnical friend, for that matter), though, could save time and effort for both of you.—***Ed Teja***

"Look, I've got two challenges for my ribbon cable interconnects – to reduce manufacturing rejection rates and prevent contact damage during testing. Got any solutions?"





As fast as you can say "downtime" your production, test or repair people can activate an AMP Latch Easy Release Header with one hand. Just squeeze and the cable half is disengaged. No wrenching on the cable. No wiggling. And no damaged contacts. An important matter when

We sure do.

neither your production costs nor your on-board costs can take a back seat to one another. And one of many reasons why AMP Latch has drawn the attention of designers in the data processing, instrument and communications industries.

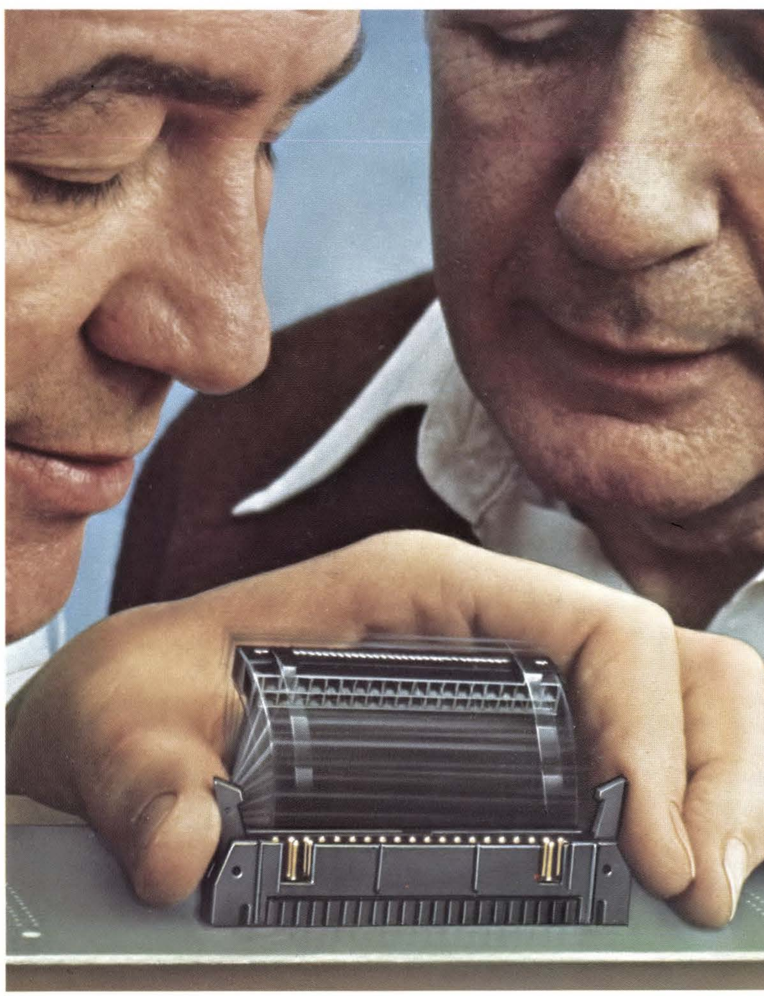
Yet AMP Latch offers a unique feature that extends far beyond what other ribbon cable connectors can offer. It offers precision registration built into the tooling which minimizes rejection rates.

Unquestioned reliability. That's what AMP Latch is about, too. You get a four-point electrical contact and mechanical grip for each conductor. Built-in inspection ports make test simpler than ever.

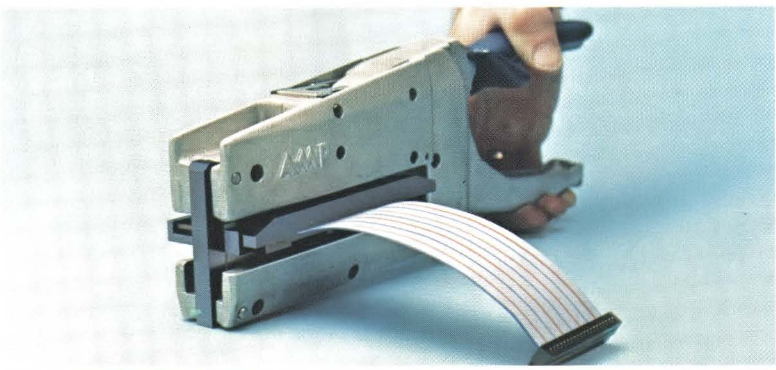
The fact is, nobody today has a wider range of easy-to-apply no-strip, no-solder, round conductor flat cable connectors than AMP.

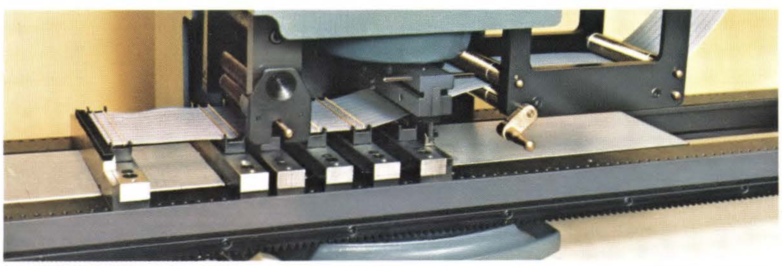
For more details, see the opposite page and the page overleaf.

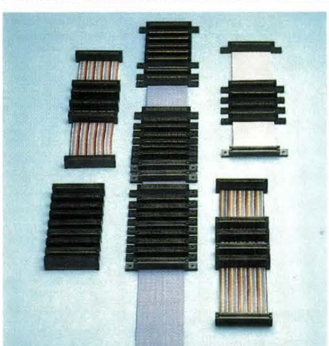
AMP has a better way.



And cost effective tooling.







With AMP Latch Tooling the terminations are made quickly, easily and simultaneously. No need for pre-stripping the insulation. One tool will terminate virtually all popular round conductor flexible cable, including those with flat side down or ribbed side down.

Two basic bench-mounted AMP Latch tools include: a heavy-duty pneumatically powered unit and a manually operated unit. Both are reliable. Both are easy to load. And precision cable registration is built in. Alignment is automatic and positive. Six different precision die sets are available for terminating receptacle, plug, card edge, paddle board and pin connectors as well as discrete wire.

Also available is equipment for daisy chain terminations, and a hand tool with interchangeable dies.

For the complete story on AMP Latch Connectors, AMP Latch Tooling, and the AMP Technical Support that goes with them, call AMP Latch Information Desk at (717) 564-0100. Ext. 8400. Or write AMP Incorporated, Harrisburg, PA 17105.

AMP

The last time you saw a really new bench/portable DMM was 1972.

That's the year our 8000A was introduced. Its custom LSI and solid owner benefits quickly established it as the world's leading DMM.

Now, look at the new 8010A and 8012A: single-chip CMOS designs for problem-solving in the eighties!

RAZOR-SHARP LCD for large, no-strain answers at first glance—in any light.

TOUCH AND HOLD probe option, so you can thread your way through a component jungle and capture the reading you need.

FUNCTION POWER: 22 ranges of AC and DC volts and current, six ranges of resistance, and three ranges of conductance — the missing function on other bench multimeters.

CONDUCTANCE RANGES for noise-free leakage measurements to 10,000 MΩ. A valuable function for bench-testing boards and components, conductance also measures transistor beta (using a bias resistor) and light intensity (by using a photocell).

OVERLOAD-PROTECTED—like no other DMM, including rejection of 6000V transients and up to 600V applied to the current terminals.

HONEST AC ANSWERS derived from a Fluke hybrid true rms converter. You'll even see the difference on your AC line between the correct value and what your average-responding meter reads. And 50 kHz bandwidth won't let any significant distortion products go unmeasured. Plus, 10 times the basic response you may be limited to now!

SPECS YOU EXPECT from Fluke—like ±0.1% on DC for one year. Both models available with rechargeable batteries, and backed by the same solid warranty and worldwide service that helped make the 8000A the industry standard.

LEADERSHIP HAS TO BE EARNED. And we're committed to keeping the price of your confidence as realistic as possible. Like $239 for the 8010A with a 10A current range, and $299 for the 8012A with two extra-low ohms ranges that allow measurements from 0.001Ω to 10,000 MΩ — making it the widest range ohmmeter available!

Contact one of the more than 100 Fluke offices and representatives, worldwide, or CALL (800) 426-0361* TOLL FREE. In the U.S., and all countries outside Europe, write: John Fluke Mfg. Co., Inc., P.O. Box 43210, Mountlake Terrace, WA 98043, U.S.A.

In Europe, contact Fluke (Nederland) B.V., P.O. Box 5053, Tilburg, The Netherlands. Telephone: (013) 673973. Telex: 52237.

Prices U.S. only.

*Alaska, Hawaii, Washington residents — please call (206) 774-2481.

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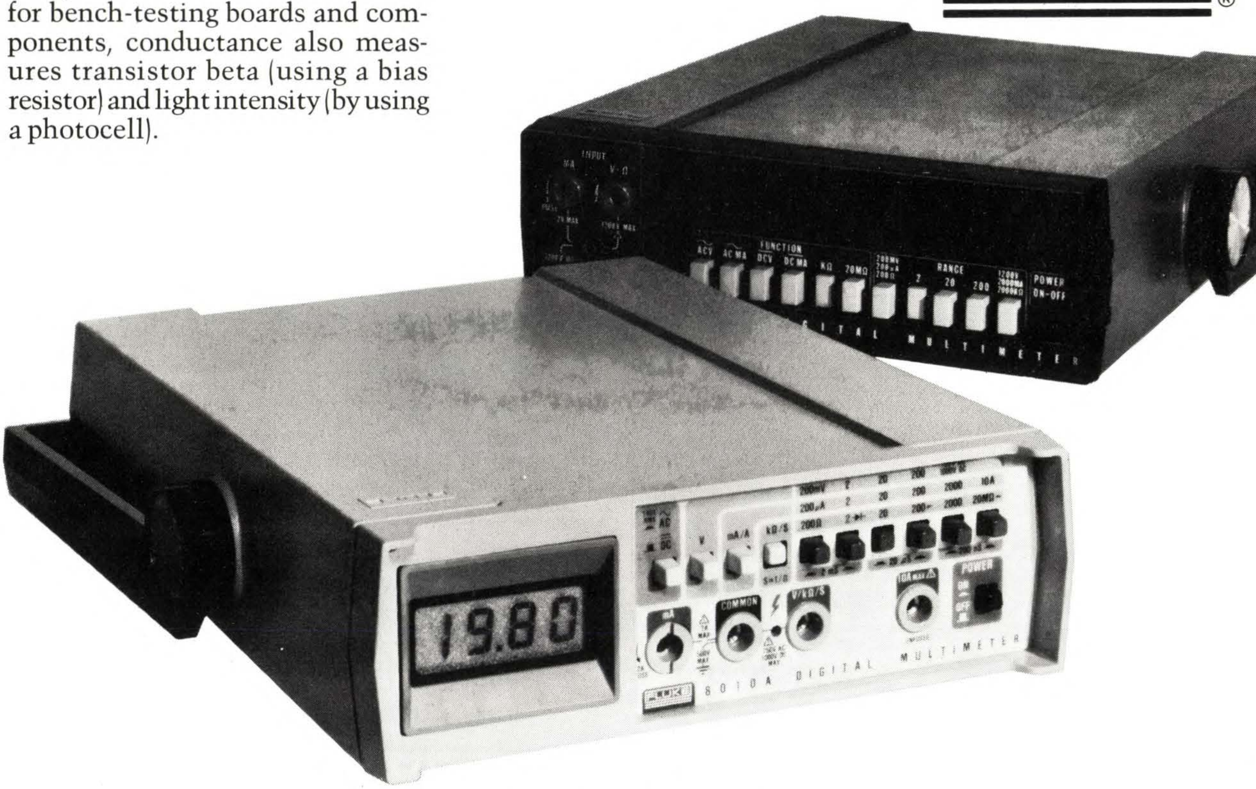
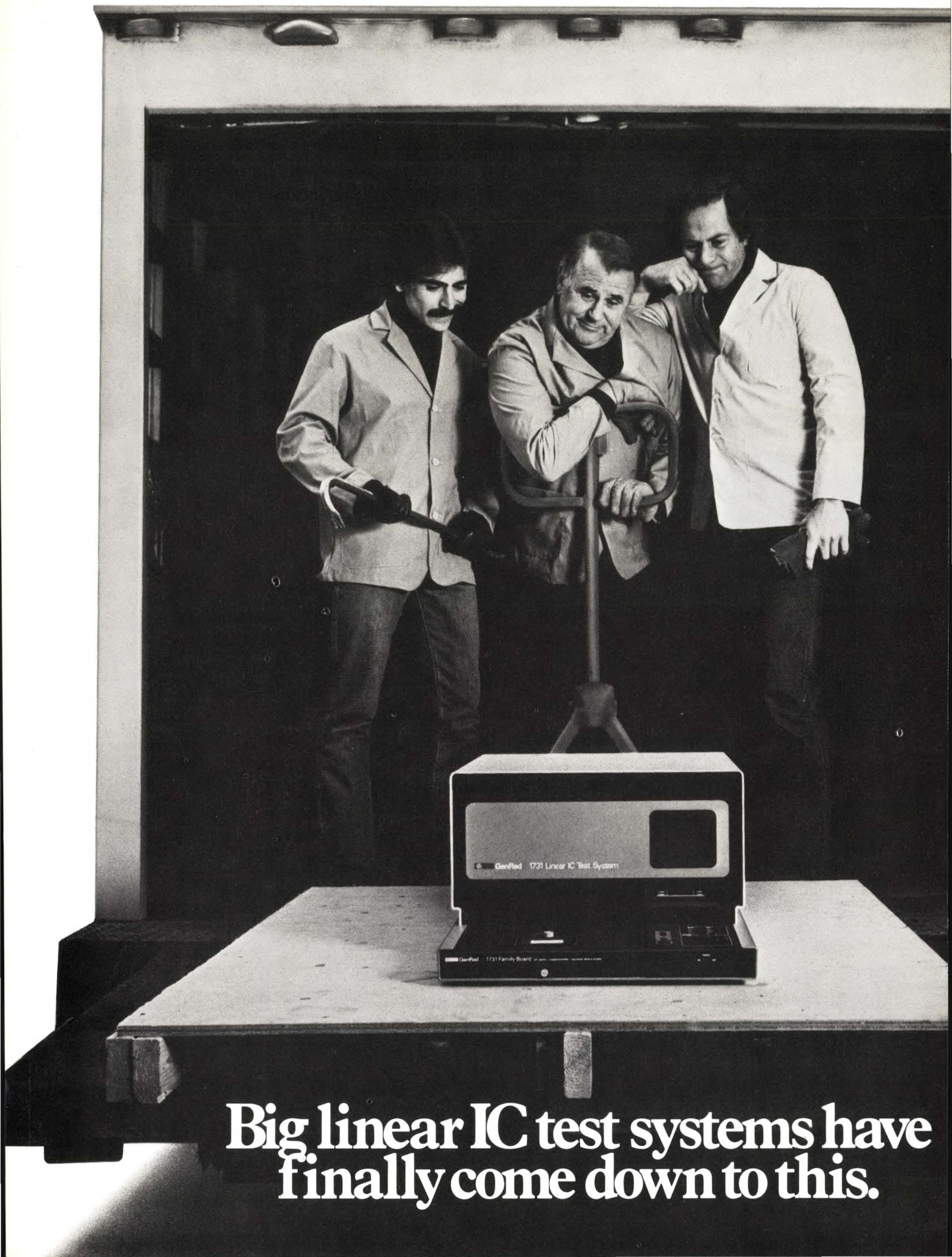
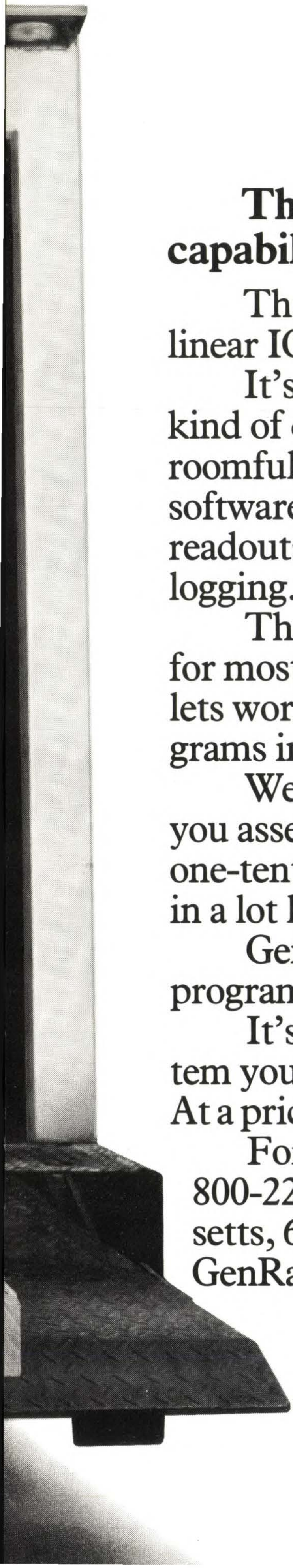


2502-8010

For literature Circle no 15
For demonstration Circle no 117


GenRad 1731 Linear IC Test System
GenRad 1731 Family Board
Big linear IC test systems have finally come down to this.



The new GenRad 1731. All the big system capability you need at one-fourth the price.

The GenRad 1731 is the first microprocessor-controlled linear IC test system.

It's no bigger than a benchtop tester, but offers the kind of capabilities that have only been available with a roomful of hardware. You not only get the flexibility of software-controlled measurements, but also qualitative readouts on each IC, summary sheets, binning, and data logging.

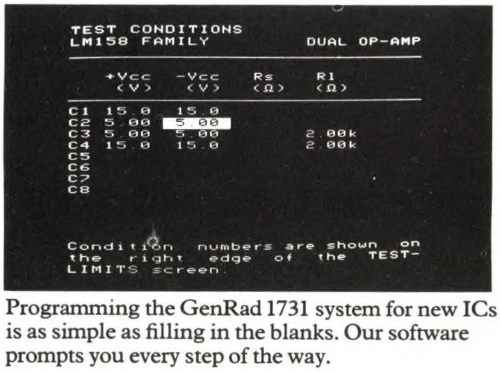
The GenRad 1731 system comes already programmed for most currently used ICs. And our high-level software lets workers with minimal experience develop new programs in minutes.

We also offer unique socket adaptor kits, which let you assemble new adaptors as you need them — for about one-tenth of what it would cost to buy them complete. And in a lot less time.

GenRad's 1731. Thorough diagnostics. Easy on-site programming. Fast turnaround.

It's the kind of test system you've dreamed about. At a price you never imagined.

For details, call toll-free 800-225-7335 (in Massachusetts, 617-779-2825) or write GenRad, Concord, MA 01742.



Programming the GenRad 1731 system for new ICs is as simple as filling in the blanks. Our software prompts you every step of the way.

GenRad

Put our leadership to the test.

For more information, Circle No 16

How Litronix' opens a new world

Rockwell
AIM 65
Microcomputer

Norand®
Sprint 100™
Order entry terminal

Now designers have a communications peripheral perfectly matched in size and cost to the world of microcomputers.
Litronix invented the Intelligent Display* to give microcomputers a new way of "talking" to users in words, numbers or even sentences. And not surprisingly, these displays are already

Part Number	Features	Character Height	Horizontal Row Spacing	Vertical Row Spacing	Viewing Angle	Character Positions	Character Segments
DL-1416	Standard General Purpose Display	.160"	.250"	1.200"	±25°	4	16
DL-1414	Compact Display For Hand Held Equipment	.112"	.175"	.800"	±50°	4	16
DL-2416	Premium Display New Rugged Package	.160"	.250"	.800"	±50°	4	17

*Intelligent Display is a trademark of Litronix, Inc.

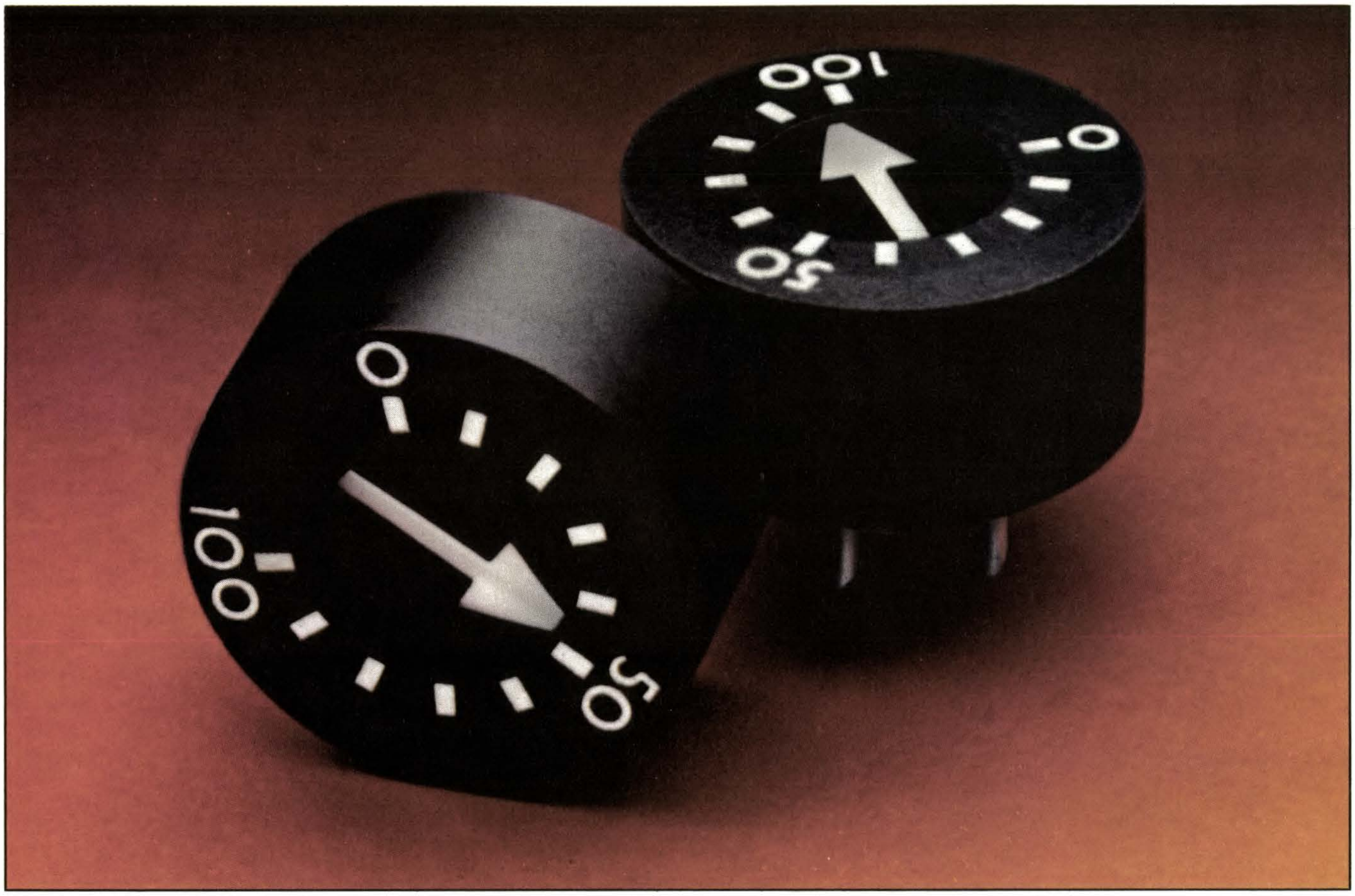
beginning to create a new class of microcomputer-based products.

The Intelligent Display is an alphanumeric LED readout that incorporates ASCII decoder, multiplexer, memory and LED driver in a built-in CMOS IC. It interfaces simply and directly to any microprocessor bus, much like a RAM. Power is from a single +5V supply, and operating current is low enough for any battery powered device.

Litronix puts intelligent communications in the palm of your hand or anywhere panel space is limited. Three versions of the Intelligent Display are already available to fit a wide variety of applications. The smallest lets you fit 20 characters side by side in a space of only 3.5 inches.

Litronix' Intelligent Displays are already being used in the portable terminal, the low cost microcomputer and electronic translator above. They're also ideally suited for applications like control panel readouts. Handheld computer

DESIGN BECKMAN TRIMMERS IN. DESIGN PROBLEMS OUT.



Presenting the 93P. Our new half-inch trimmer with its built-in dial is a turn for the better.

For the first time, you can have a cermet half-inch single-turn, with dial setting capabilities. A variable resistor that's somewhere between trimmer and precision pot, designed to save labor costs with screwdriver position adjustability, and high-resistance capabilities.

Now you can write your manuals, and specify fast setting instructions. Using the 93P means reduced labor. It'll take less time to make that initial setting, less time to check the board. Calibration time is minimized. And the 93P has custom dial setting capabilities, too.

Cermet technology has many advantages over wire wound. With 10% tolerance, and 100 ohms to 2 meg ohms resistance range, it wins hands-down at high resistances. Inductive problems are eliminated. And the 93P is sealed for environmental stability.

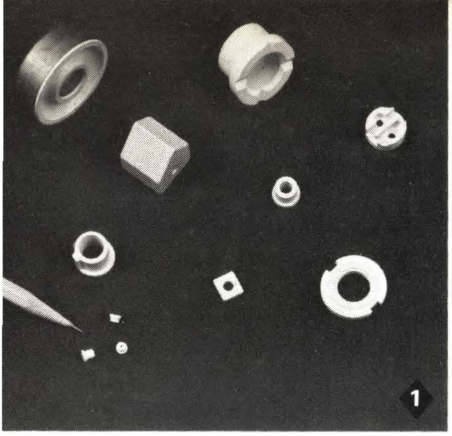
Why a larger cermet part? The longer the element, the more the power dissipation. And it stands to reason, you can get more marking and more adjustability.

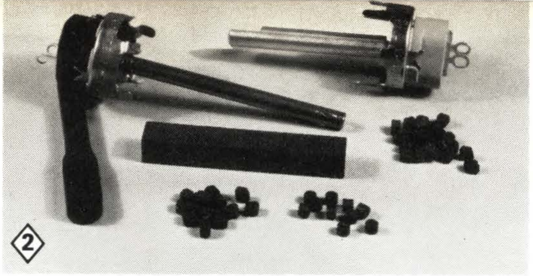
Design in a trimmer that's not a trimmer as you've known it until now. The 93P.

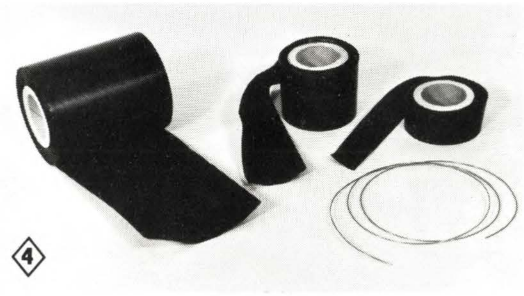
Call your local Beckman Helipot distributor for free evaluation samples. To get his number, or immediate technical literature, call (714) 871-4848, ext. 1776. Start designing problems out today.

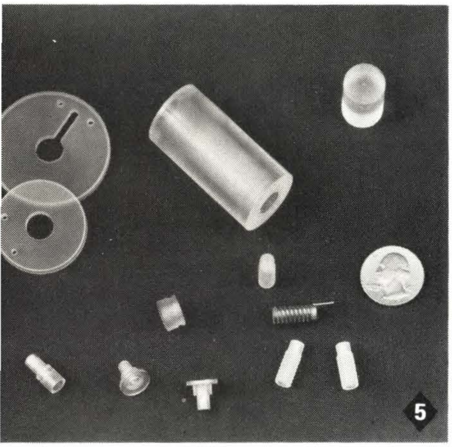
BECKMAN®

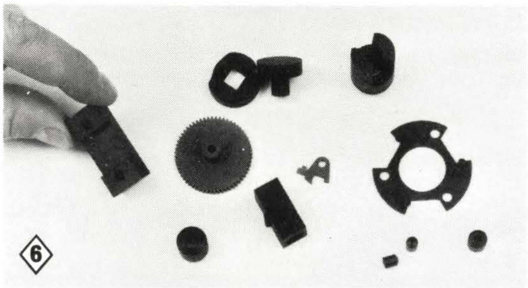
For more information, Circle No 20

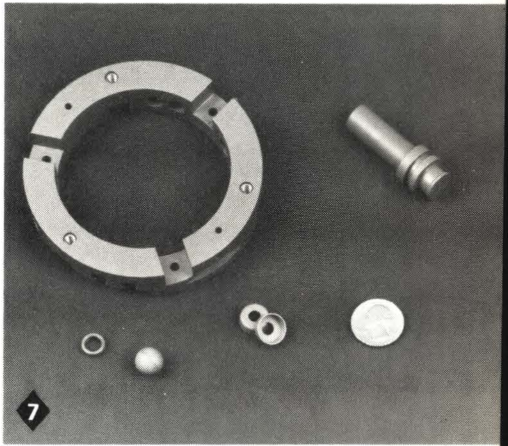












① **Fluorosint® 500** — A proprietary synthetic mica-filled TFE with a low coefficient of thermal expansion, Fluorosint 500 offers a wide continuous service temperature range. Form stability remains constant to 650°F and the dielectric constant is only slightly affected by frequency changes. Ideal for coil forms, standoff insulators and electrically insulating wear parts. ***Circle no 53***

② **Conductive Fluorosint® 220 and 221** — TFE type materials are well known for their wear characteristics. Now Polymer has gone them all one better, because Fluorosint 220 and 221 provide excellent conductive properties as well. Natural choices for contact, non-static or conductive bearings and potentiometer applications. ***Circle no 54***

③ **Polymet® AG and CZ** — A proprietary metal-polymeric alloy designed to operate at temperatures to 500°F with greater strength and stability than conventional metal-filled plastics. Good wear resistance, high thermal and electrical conductivity and dimensional stability are its trademarks. Should be evaluated for sliding and rolling contacts, instrument bearings, and self-lubricating high thermal transfer bearings. ***Circle no 55***

④ **Conductive TFE** — Processed into tape, this TFE, with a volume resistivity in the range of 2 - 3.5 ohm/cm, makes meeting design requirements of static bleed-offs and conductive chute linings an easy assignment. Wound as a .030″ diameter monofilament sheathed in .005″ nylon for strength, it provides 20-30,000 ohms/ft. resistance. Also transparent to microwave radiation. ***Circle no 56***

⑤ **Polypenco® Q200.5** — A cross-linked polystyrene whose dielectric constant stays virtually unchanged from 10^1 to 10^{10} Hertz. Rigid enough to produce only 1.15% deformation under load, Q200.5 is superior to TFE in radiation resistance. ***Circle no 57***

⑥ **Nylasint® M4** — A proprietary combination of specially processed nylon for toughness and wear plus MoS_2 solid lubricant. Used for high wear bearings or bushings in electrical or electronic components. ***Circle no 58***

⑦ **Torlon* 4203** — Exhibits very good electrical properties at temperatures to 500°F. and displays excellent resistance to radiation with only minimal changes after exposure to 10^9 rads of gamma radiation for seven months in a nuclear reactor. A natural for many electrical components such as insulators. ***Circle no 59***

WHICH ONE'S FOR YOU? Whenever your designing in plastics for electronic or electrical applications Polymer can help. Have a question or need some help? Call Bob Alberts, Marketing Manager for electronic applications at (215) 929-5858 or write to him at The Polymer Corporation, Reading, PA 19603. In Canada, we're Polypenco Canada Limited.

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IMAGINATION IS ALL THAT LIMITS OUR PLASTICS FOR ELECTRONIC/ELECTRICAL APPLICATIONS

Polymer manufactures a wide range of plastics that have been proven successful for use in electronic and electrical components. Applications as diverse as trolley car collector shoes and thermistor leads. Each material has its own unique set of electrical and mechanical properties, and one of them may just be the answer to your next tough design problem.

Plus...a new Professional Advancement Seminar Program.

Designed to provide in-depth coverage of those topics most essential to the power conversion specialist, POWERCON 6 Professional Advancement Seminars offer designers, managers and users a comprehensive selection of invaluable learning opportunities under the direction of some of the world's leading authorities.

- Power converter circuit modeling, analysis, and measurement.
- Shaping and controlling feedback loop response.
- Assessing and controlling power converter EMI.
- High frequency magnetics... materials and design.
- Ultra-high-frequency power converter design.
- An introduction to switched-mode design.
- Automated testing and functional specification of power supplies.
- ...and for those in the "business end" of the field, a special market awareness seminar.

In the interest of providing a quality learning experience, seminar registrations will be limited, and may not be available to last-minute registrants.

Hotel Headquarters for POWERCON 6...

The Fontainebleau-Hilton.

Located only 20 minutes from Miami International Airport, on Miami Beach, this world-famous resort hotel has been only recently refurbished by Hilton from the ground up. Combining the ultimate in pleasant surroundings with tennis, bowling, jacuzzis, an olympic-size swimming pool, incredible room rates, and an incomparable location on the Atlantic Ocean, Hilton has welcomed POWERCON 6 with open arms.

Special half-price room rates for POWERCON 6 attendees extend from 3 days prior to the conference until 3 days after:
Singles: $30-$35
Doubles: $35-$41

For further information concerning POWERCON 6, please call: (805) 985-6978 or (805) 486-5463.

POWERCON 6, PO Box 5226, Ventura, CA 93003

Please register me for:
☐ Conference and Exhibit, May 2 thru 4 (all 3 days), $195.00*
☐ Conference and Exhibit, May____ (1 day only), $120.00*
☐ Seminars: ____________________

(Please call for schedule and fees.)

Name____________ Title____________

Company____________

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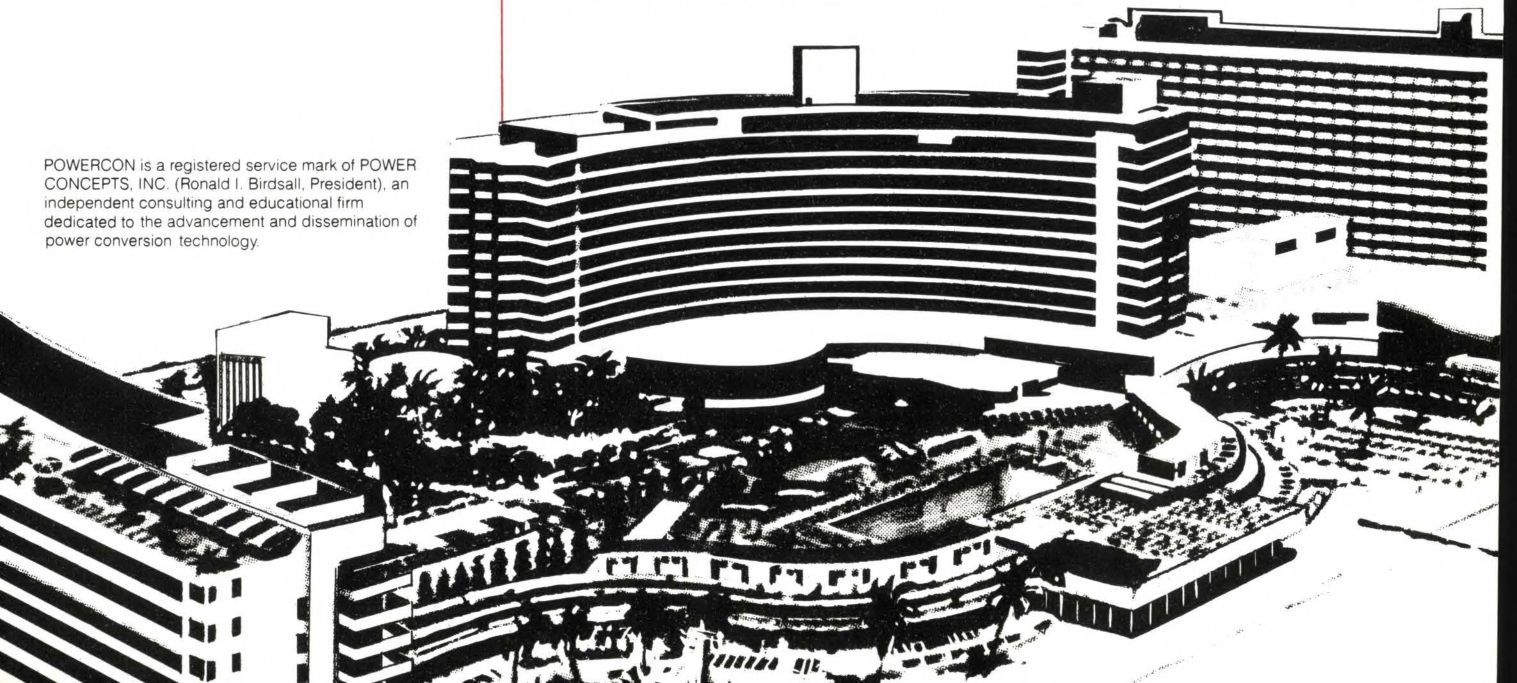
☐ Check or P.O. enclosed.
☐ Please bill my company. Address invoice attention of: ____________

I understand that this reservation cannot be confirmed until my company's check is received in full payment.

*Includes proceedings and POWERCON 6 luncheon on Thursday. Press by invitation only.



Sixth National Solid-State Power Conversion Conference and Exhibit

May 1-4, 1979
Fontainebleau-Hilton Hotel
Miami Beach, Florida

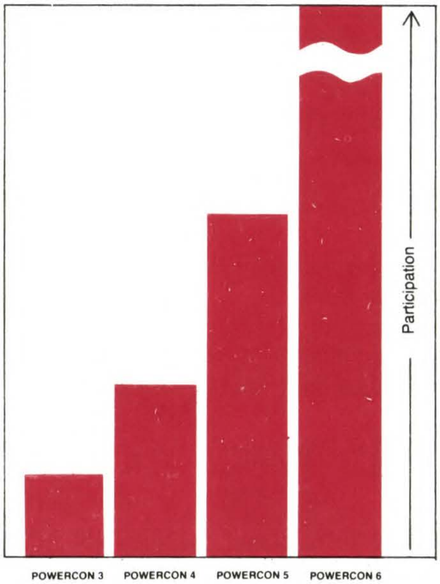
Some facts about POWERCON...

Over 85% of the attendees at a POWERCON conference are practicing engineers and engineering managers.

POWERCON conferences, seminars and tutorial exhibits are designed by practicing power conversion technologists, like you. That means we know what you need most.

A POWERCON must be *experienced*, for the value of even the most exemplary technical presentation cannot begin to compare to the catalytic effect of being among, and comparing notes and experiences with, the hundreds of your contemporaries who attend.

The participation in POWERCON's has more than doubled each year since 1976. And POWERCON 5 sold out.



POWERCON. Once a technical luxury. Now a professional and practical necessity.

The Conference.

Sixth in a series of annual national technical conferences devoted exclusively to the practical design and application of solid-state power conversion equipment and components. Emphasizing the modern trend to switched-mode and other "non-dissipative" technologies, the POWERCON 6 conference offers a comprehensive and intensive three-day examination of the latest and most important developments in the power conversion field.

- Three full days of technical presentations.
- Over 30 papers, presented by outstanding authorities.
- Nine sessions, chaired by distinguished experts.
- VMOS...Proportional drive... Sinewave synthesis...Microprocessors as feedback elements...Controlled resonant conversion...Reliability... Computer-aided design... High voltage...EMI... Non-dissipative load-line shaping...Motor control...plus much, much more.

The Tutorial Exhibit

Informal tutorial and "hands-on" (fully instrumented and working) demonstration exhibits presented by technologists from over 50 major suppliers in and to the power conversion field. Each exhibit is specifically configured to enhance your technical expertise through improvement of your detailed knowledge of the supplier's technology and processes.

- Investigate working circuits and waveforms.
- See new devices in action.
- See working demonstrations of new power conversion topologies.
- See new instrumentation and test equipment for power conversion.
- Magnetics. Capacitors. EMI/RFI. Heat transfer. IC's and hybrids. Complete power supplies and inverters. Motor controls.
- and much, much more.

Leadtime Index

PASSIVE COMPONENTS

PRODUCT	LEADTIME IN WEEKS Min	Max	Trend
CAPACITORS			
Ceramic, disc	6	12	=
Ceramic, monolithic	8	14	=
Electrolytic, aluminum	9	15	=
Electrolytic, tantalum	8	11	=
Film	7	12	=
Mica	11	18	up
Paper	9	14	up
Trimming	7	10	=
CRYSTALS, FILTERS AND NETWORKS			
Filter, active	7	10	=
Filter, EMI	14	16	=
Filter, lumped-constant	10	13	=
Filter, quartz (monolithic)	12	16	up
Frequency determining crystal	10	12	up
ENCLOSURES			
Custom	9	12	=
Modified standard	8	12	up
Standard	6	8	up
FANS AND BLOWERS	20	24	▼
FRACTIONAL HP MOTORS	14	18	=
INTERCONNECTION COMPONENTS			
Back panel	4	12	up
Flat cable	4	12	up
Multipin circular high-density	14	19	up
Multipin circular standard	12	18	up
Packaging panel	4	12	up
PC, one-piece	4	12	up
PC, two-piece	4	12	up
Rack and panel	4	12	up
RF coaxial	11	16	up
Socket	4	12	up
MAGNETIC COMPONENTS			
Coil	8	12	up
Solenoid	7	12	up
Transformer, power	8	12	up
Transformer, other	7	12	=
PRINTED CIRCUITS			
Double-sided	9	11	up
Flexible	8	10	up
Multilayer	12	14	=
Single-sided	7	10	=
RELAYS AND TIMERS			
Crystal can	11	15	up
General purpose	6	9	=
Reed, dry	7	11	=
Reed, mercury-wetted	7	10	=
Solid state	5	7	=
Telephone	7	13	=
Time delay and timer	8	11	=
RESISTORS, FIXED			
Carbon film	4	6	=
Composition	4	8	=
Metal film	11	16	up
Network	14	22	▼
Nonlinear	10	14	=
Wirewound	10	14	=
RESISTORS, VARIABLE			
Pot, nonprecision WW	10	12	=
Pot, precision WW	14	16	=
Pot, nonprecision comp	6	8	=
Pot, precision comp	10	14	=
Trimmer, WW	9	12	=
Trimmer, comp	7	11	=
SWITCHES AND KEYBOARDS			
Circuit breaker	9	14	=
Dual in-line	6	8	=
Keyboard and keyswitch	7	10	=
Lighted pushbutton	9	12	=
Pushbutton	8	12	=
Rotary	6	9	=
Snap action	3	5	=
Thumbwheel	8	10	=
Toggle	6	9	up
TRANSDUCERS			
Pressure	6	8	=
Temperature	5	8	=
WIRE AND CABLE			
Coaxial	3	8	=
Flat and ribbon	4	6	up
Single conductor hookup	4	8	=
Multiconductor	3	8	=

Leadtimes are based on recent figures supplied to *Electronic Business* magazine by a composite group of major manufacturers and OEMs. They represent the typical times necessary to allocate manufacturing capacity to build and ship a medium-sized order for a moderately popular item. Trends represent changes expected for next month.

"Choosing Intel gave us a twelve month jump on the competition."

Dr. Wang: "We were first with a unique, new approach to word processing—using microcomputers to implement distributed intelligence in multiple station systems. That approach has enabled us to increase our market share 50% a year in a market that's growing 40% a year. This year our word processing sales will pass $100 million. In 1974 they were just $9 million.

"We decided on Intel's 8080 microprocessor for our distributed logic system. Only Intel offered PL/M, the microcomputer programming language we needed to get our software written quickly. So quickly that we introduced our system a year ahead of any competition. And Intel's tools for programming have continued to help us offer our customers the high quality software they expect from Wang."

Intel's extensive microcomputer design tools have helped hundreds of companies just like Wang Labs capture the marketing advantage with Intel microcomputers and semiconductor memory.

Our Intellec® Microcomputer Development System makes it possible and profitable for companies like yours to take full advantage of the promise and potential of the microcomputer. For example, the world's most advanced microcomputer, our new 16-bit 8086, is the first and only 16-bit microcomputer supported by a high-level programming language—PL/M, part of the total 8086 software development package available for the Intellec system.

To begin writing your own success story, contact Intel Corporation, 3065 Bowers Avenue, Santa Clara, CA 95051 408/987-8080.

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intel® delivers.

Intelligent Display™ of microcomputer applications.

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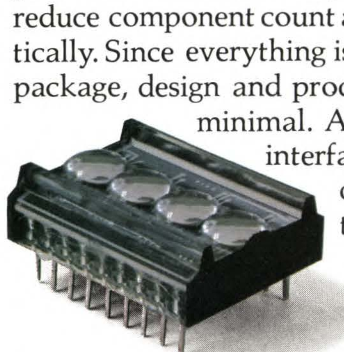

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Editorial

The VTR's day in court

An important trial is currently underway in the Federal District Court in Los Angeles: the copyright-infringement suit brought by Universal Studios and Walt Disney Productions against Sony Corp. At issue is the use of the Betamax videotape recorder (VTR) to record and replay copyrighted material—in this case, movies produced by the two studios and broadcast on TV. Meanwhile, VTR buyers remain totally unaware that the outcome of this suit might determine the manner in which they can legally operate their versatile home-entertainment equipment.

Lawyers for the plaintiffs claim that studios, advertisers and creative employees will suffer economic hardships because VTR recordings will significantly reduce the audiences for live TV programming. Replying to this argument, Sony's lawyers challenge the validity of all copyrights related to TV-broadcast material, then cite surveys indicating that most VTR users record programs intact (with commercials) for viewing at a more convenient time, not to build permanent libraries of material.

Against the background of this court trial, MCA (Universal's parent company) and Magnavox have launched a program to market the video-disc player, the VTR's prime competition. A read-only device, the video-disc machine uses special "records"— rugged media containing appropriately copyrighted material. Initial sales of the player are encouraging, thanks to three factors: the availability of considerable "software" (discs containing a wide spectrum of entertainment); the unit's novel operating features, including stop frame; and the rugged nature of the medium. The last factor, incidentally, could encourage the development of a significant swap/sell used-disc market and thus greatly reduce owner costs.

Final disposition of the court case, however, remains some time in the future, because after the judge hands down his ruling (promised within 90 days of final arguments) an appeal to the US Supreme Court is possible. And beyond that, Congress might have to address this public-policy issue.

Yet all this legal maneuvering could be academic. If the VTR/video-disc consumer market develops to a significant size, as it quickly might, and if buyers overwhelmingly choose one video-recording concept over the other, lawyers and lawmakers will be forced to reconfigure the law to accommodate the established reality.

Walt Patstone
Editor

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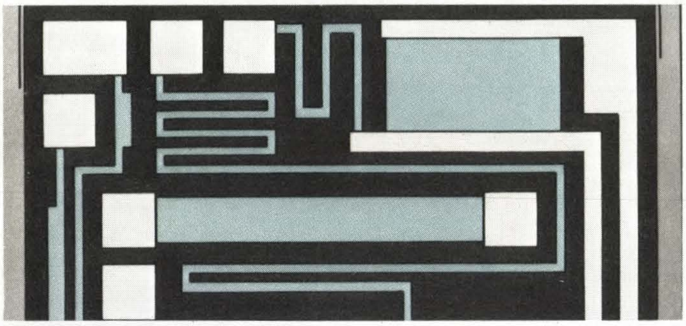

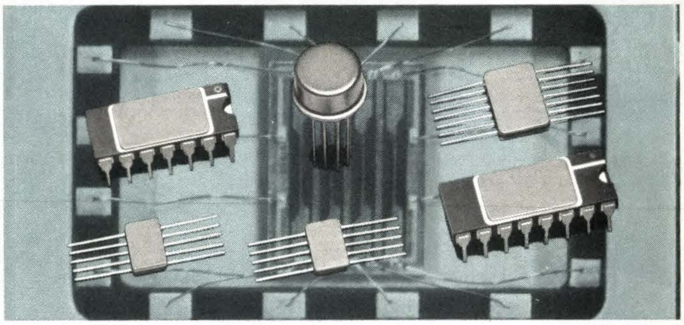

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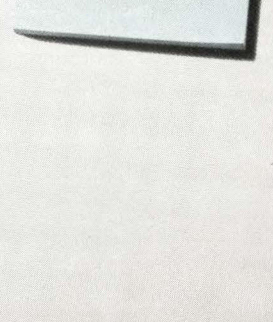

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Alternative production technologies promise increased solar-cell use

Dale Zeskind,
Contributing Editor

Solar-cell researchers are investigating a variety of alternative cell technologies, which could lend themselves to less expensive production requirements than current designs. If these researchers succeed in their efforts, photovoltaic energy conversion — once limited primarily to outer-space applications—will quickly be brought to earth in a variety of terrestrial uses.

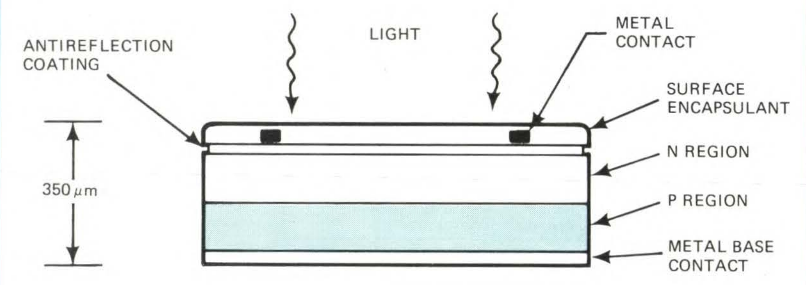


Fig 1—Conventional pn-junction silicon solar cells, *made from a wafer of high-quality single-crystal silicon, are commercially available, though expensive. Efficiencies for these cells range between 10 and 15%; the US Dept of Energy hopes that improvements in manufacturing processes and/or the use of alternative cell technologies will eventually make photovoltaic energy conversion cost-competitive with other forms of electric-power generation.*

The US Department of Energy (DOE) is aiding these research efforts. Through its National Photovoltaic Program, the DOE aims to ensure that photovoltaic conversion systems significantly contribute to the nation's energy supply by the year 2000.

Today, ten US manufacturers produce single-crystal silicon cells and cell arrays (modules). Unfortunately, these cells require energy- and time-consuming, labor-intensive manufacturing techniques, so their costs are high—on

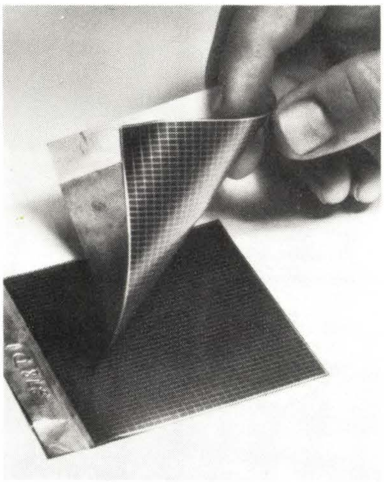
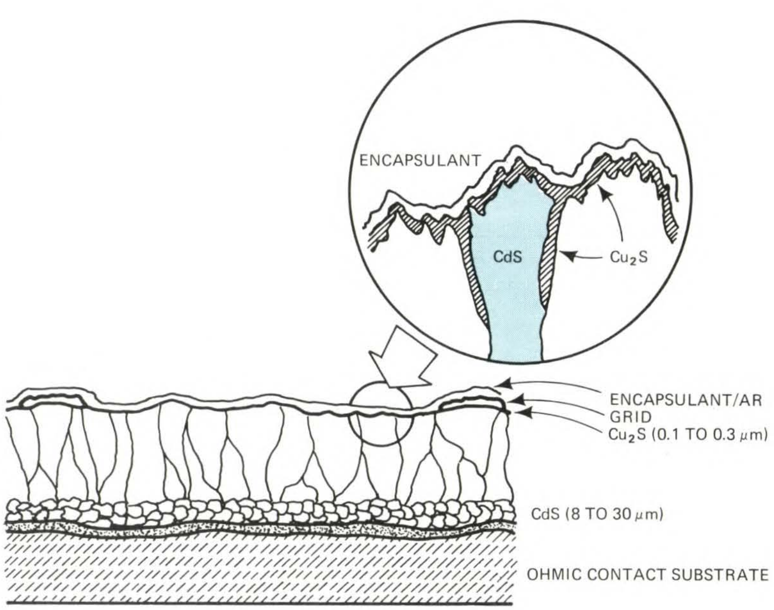


Fig 2 — Thin-film solar cells *could sell for $0.25/W (1975 dollars) by 1982. Produced by vapor deposition of CdS onto plastic- or metal-film substrates, these cells readily adapt to continuous-processing techniques. (Courtesy Institute of Energy Conversion)*



the order of \$12/W. This high cost limits the terrestrial use of conventional cells to geographically remote applications, such as radio repeaters and navigational aids.

As part of its program, however, the DOE has set a cost goal of \$2/W by 1982 and \$0.50/W by 1986 (in 1975 dollars). At the latter price level, photovoltaic systems should compete for some distributed and larger-load-center utility applications. The resulting increased demand would encourage large-scale cell production and spur a further improvement in availability and cost.

Thin films offer promise

A conventional pn-junction silicon cell (**Fig 1**) is made from a thick wafer of high-quality single-crystal silicon cut from a slowly grown ingot. (The cutting process turns much of the material to dust—an additional drawback to conventional cell technology.)

After this cutting step, the wafers must be polished, their pn junctions grown by means of high-temperature diffusion, and the necessary contacts plated. These conventional cells have typical solar-to-electric-power conversion efficiencies of 10 to 15%.

To reduce manufacturing costs, one experimental cell-fabrication technique uses single-crystal silicon grown from continuous sheets rather than ingots. Such sheets require less polishing than the conventional ingots, and less material is wasted during cutting.

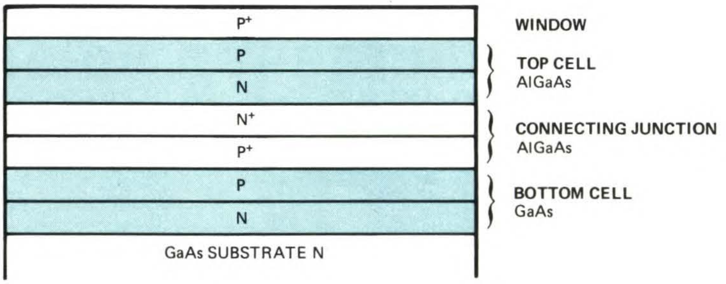


Fig 3—Stacking cells monolithically *improves solar-to-electric-power conversion efficiency. But the approach requires optimizing the cells to respond to different portions of the solar spectrum. Each layer is approximately 1 to 2 μm thick. (Courtesy Research Triangle Institute)*

The CdS/Cu_2S thin-film cell pictured in **Fig 2**, for example, is constructed by vapor-depositing a thin-film CdS layer onto a thin metal substrate or metallized plastic film. Reaction in a solution of CuCl forms the Cu_2S layer.

These cells consume miniscule amounts of materials in their fabrication, and their construction lends itself to continuous (as opposed to batch-type) processing. J D Meakin, director of solar-cell research at the University of Delaware's Institute of Energy Conversion in Wilmington, reports that the CdS/Cu_2S cells are theoretically capable of achieving 16% conversion efficiencies; the practical goal is an 11% figure.

Meakin has to date observed efficiencies as high as 9.15% and hopes to exceed 10% some time this year. His group is currently designing a pilot production plant that he expects will demonstrate the feasibility of producing these or similar cells at a selling price of \$0.25/W by 1982.

Composite methods

Most solar cells respond efficiently only to a limited portion of the solar spectrum, so much of the light that strikes them converts to heat rather than electricity. To solve this problem, researchers have built cells that respond to different portions of the spectrum. Then, by spectrally splitting the incident light and directing the appropriate portions of it to the proper cells, they have improved overall system conversion efficiency.

A group at the Research Triangle Institute, Research Triangle Park, NC, recently achieved a significant advance with this approach. The group fabricated two spectrally tailored cells monolithically; the cells are deposited one on top of the other and internally connected so they operate in series, both optically and electrically (**Fig 3**).

This structure's layers are grown by liquid-phase epitaxy (LPE). The heavily doped connecting region acts as a tunnel diode, providing a low-impedance electrical path between the two cells.

Researcher S M Bedair reports observing 15% conversion efficiencies in these experimental stacked cells, and he expects to achieve efficiencies of up to 30% within the next 2 yrs—a figure that makes this approach attractive despite its complexity.

As an added benefit, the stacked cells have an open-circuit voltage of 2V, compared with 0.7V for conventional silicon cells. As a result, they can deliver more power than the conventional units at a given current level.

Increasing concentration

Rather than reducing cell-manufacturing costs, several laboratories hope to meet the DOE's goals by taking a system-optimization approach. They aim at demonstrating cost effectiveness by utilizing extensive optical systems to concentrate sunlight onto cells.

In such systems, because the cost of the cell is a relatively small part of total system cost, system designers can freely use highly efficient (though costly) cells; the stacked-cell concept could prove particularly well suited to these concentrator applications.

Researchers are also developing unusual new materials for solar-cell applications. For example, Energy Conversion Devices recently unveiled an amorphous (noncrystalline) material which it claims could serve as the basis for a low-cost class of cells. However, other solar-cell researchers find it difficult to evaluate the Troy, MI company's claims because it has failed to release sufficient data.

In another development, investigator M J Cohen of Rockwell International, Thousand Oaks, CA, has reported on the development of the first polymer/GaAs Schottky-barrier cell—one with output voltages about 40% higher than those of metal/GaAs cells. The latter devices have also been investigated as low-cost replacements for silicon cells.

Is silicon doomed?

In light of all of these recent solar-cell developments, do single-crystal silicon cells have any future? Most researchers agree that these conventional cells will play a major interim role in energy conversion for at least the next 10 yrs; silicon technology has been refined considerably over the past 20 yrs, and a sizable industry already exists.

Which of these new technologies will dominate? Most observers agree that no one technology will "win"; instead, most expect several complementary approaches to develop. **EDN**

Switching-power-supply improvements will dominate Powercon 6

Sam Davis, Manager,
Western Editorial Office (S)

Power-conversion design techniques—many of them relating to switching supplies—will provide the main attraction at Powercon 6. Highlighting the more than 30 papers, 60 exhibits and several short courses will be "how-to" presentations on

- A 1-kW on-line switcher
- A simple method to correct switcher power factors from 0.6 to almost unity
- An 8048-μP-controlled switcher
- Computer modeling of semiconductor power-supply components.

Innovative switcher design

The most important Powercon presentations could well be those describing a 1-kW (60V at 15A) on-line switching power supply that inherently eliminates pulsating currents in both its input and output. The unit thus requires no input filtering and no output-filter capacitor. This switcher is the first application of a concept—termed optimum topology — described in 1978 at Powercon 5 by Assistant Professor Slobodan Ćuk of the California Institute of Technology, Pasadena.

Prof Ćuk, assisted by graduate students Loman Rensink, Art Brown and Shi-Ping Hsu, will report on such design considerations as component sizing, methods of driving the power switch and the choice of the switcher's transformer turns ratio. This last factor is the result of a tradeoff between the switcher's ON current and OFF voltage.

In a tutorial seminar scheduled for the day before the conference, Prof Ćuk and Prof R D Middlebrook, also of Cal Tech, will explain how to model a switching converter and measure the magnitude and phase of the device's small-signal response in the presence of high switching noise. And because many engineers have trouble measuring these response parameters, according to Middlebrook, he and Ćuk will demonstrate on an actual power supply.

Middlebrook will also explain how to analyze the response-measurement results, and he will present a small-signal model of the converter and regulator. Generally, he intends to show how designers can apply simple, physically interpretable analytic techniques to real circuits to obtain correspondingly simple, useful and practical design criteria.

Reduce line current

Another switching-supply-related paper will detail a dynamic power-factor (PF) correction technique that reduces line current below values possi-

Powercon 6: Who, what, when, where

Powercon 6 will be held May 1-4 at the Fountainebleau-Hilton Hotel in Miami Beach, FL. The conference is sponsored by Power Concepts Inc, a consulting and educational firm specializing in applied power-conversion technology, and will be chaired by the firm's president, Ronald I Birdsall.

You can obtain additional Powercon information by contacting Powercon 6, Box 5226, Ventura, CA 93003. Phone (805) 985-6978.

Tutorial short courses

In addition to its exhibits and papers, Powercon 6 will also offer a number of short courses oriented toward power-supply designers, including:

- A high-frequency-magnetics design course presented by members of the Magnetic Material Producers Association; it will focus on available magnetic materials and their limitations
- A course on high-frequency (over 400 kHz) converters that reduce the size and weight of subsystems usually required in a switcher (EDN, January 20, pg 44), delivered by Rudy Severns, VMOS applications manager at Intersil, Cupertino, CA
- A presentation on the causes of—and methods for controlling—EMI/RFI, by Edith Kamm, an EE at the Naval Ocean Systems Center, San Diego, CA
- A practical circuit-design technique for controlling a power supply's frequency response—including a simple method for transient-response design—shown by Bill Wise, president of WIC Inc and a member of the EE staff at Lawrence Livermore Labs, Livermore, CA
- A short course on power-supply testing presented by Robert Cox, VP of Autotest, San Antonio, TX, and Jim Burens, president of California DC, Westlake Village, CA.

The more than 60 exhibits at Powercon 6 will include such offerings as a demonstration of supply transient response using an electronic load by ACDC Electronics; automated power-supply testing by Autotest; new VMOS power FETs by International Rectifier, El Segundo, CA; isolated-case power transistors by General Semiconductor Industries, Tempe, AZ; μP power supplies by Texas Instruments, Dallas; Silicon General's power hybrids; a safe-operating-area transistor tester from Hewlett-Packard; and Cal Tech's 1-kW switcher.

ble with conventional off-line switchers. As described by Derek Chambers, engineering manager of Sorensen Co, Manchester, NH, the technique can raise a typical supply's power factor from 0.6 to 0.95. As a result of this PF correction, a supply originally drawing 18A would draw only 14A—an additional benefit for electronic equipment obtaining its power from lines equipped with standard 15A circuit breakers.

Chambers explains that off-line single-phase switchers typically impose a nonlinear power-line load produced by their rectifier/filter - capacitor inputs. To correct for this nonlinearity, his firm utiliz-

POWERCON® 6 CONFERENCE PROGRAM

	WED MAY 2	THURS MAY 3	FRI MAY 4
8:30	SESSION A: THE POWER SUPPLY AS A SYSTEM ELEMENT	SESSION D: HIGH-VOLTAGE AND HIGH-POWER TECHNIQUES	SESSION G: SWITCHED-MODE CONVERSION: REDUCING ANALYTICAL METHODS TO PRACTICE
	Optimizing minicomputer power-subsystem design Design techniques for controlling the point-of-load high-frequency performance of power supplies Design techniques to limit EMI in switching-mode converters	Optimizing boost-chopper charger design Design techniques for miniaturized spacecraft HV supplies Eliminating power-supply interaction with high-power pulsed loads	Optimizing passive-input filter design Computer-predicted steady-state stability of pulse-width-controlled dc/dc converters Modeling and design of the Cuk converter
10:30	BREAK	BREAK	BREAK
11:00	SESSION B: CIRCUIT DESIGN TECHNIQUES	SESSION E: CIRCUIT AND FUNCTIONAL INTEGRATION	SESSION H: NEW DESIGN METHODS AND CONVERTER CONFIGURATIONS
	Designing nondissipative current snubbers for switched-mode converters A new, improved and simplified proportional base-drive circuit Dynamic power-factor correction in capacitor-input off-line converters	Toward a high-frequency, universal power switch Simplifying switching-regulator applications with a new class of self-contained hybrid regulators Functional power-conditioning modules: new building blocks for converter design	A μP-controlled VMOS power supply Designing the off-line, high-efficiency venable converter Design of a kilowatt off-line switcher using a Cuk converter
1:00	LUNCH BREAK	POWERCON 6 LUNCHEON	LUNCH BREAK
3:00 TO 5:00	SESSION C: SEMICONDUCTORS FOR POWER CONVERSION	SESSION F: NEW DESIGN METHODS AND CONVERTER CONFIGURATIONS	SESSION I: SPECIAL POWER-CONVERSION TOPICS: ENERGY SYSTEMS AND RELIABILITY
	Simplifying predictable converter design with CAD power-semiconductor models Using high-voltage power MOSFETs in off-line converter applications Applying ultrafast power thyristors in high-frequency-converter design	Reducing magnetic component size with reverse-biased ferrite cores A new PWM control technique that eliminates transformer-unbalance problems in power converters Designing improved high-frequency dc/dc converters with a new resonant thyristor technique A new technique for simplifying sine-wave-synthesis inverter design	Optimizing solar photovoltaic power-system design Design techniques for achieving high reliability in switched-mode converters The effects of operating parameters on aluminum electrolytic capacitor reliability in switched-mode converters Factors affecting the application reliability of Schottky rectifiers
6:00 TO 7:30	INDUSTRY-SPONSORED COCKTAIL PARTY		

PROFESSIONAL ADVANCEMENT SEMINAR PROGRAM

TUES MAY 1		WED MAY 2		THURS MAY 3		FRI MAY 4	
9:00 AM TO 5:00 PM	Modeling and measurement of dc/dc switching converters and regulators *Dr R D Middlebrook and Dr Slobodan Cuk, California Institute of Technology*	2:00 PM TO 5:30 PM	A simplified technique for achieving predictable closed-loop performance *W L Wise, Lawrence Livermore Laboratory, and president, WIC Inc*	8:30 AM TO 12:00N	Designing very high-frequency VMOS FET converters *Rudolf Severns, VMOS applications manager, Intersil*	2:00 PM TO 5:30 PM	Predicting and controlling EMI in state-of-the-art power converters *Edith Kamm, electronic engineer, Naval Ocean Systems Center*
9:00 AM TO 1:00 PM	The "business end" of the business: market awareness *Chairman: Robert Boschert, President, Boschert Inc*					2:00 PM TO 5:30 PM	Production verification of power-converter performance *Robert Cox, Autotest; James Burens, California DC; and Scott Noltensmeier, Intel*

es switching transistors and magnetic components that supply power from the line to the filter capacitor when the line voltage reaches about 30% of its peak value.

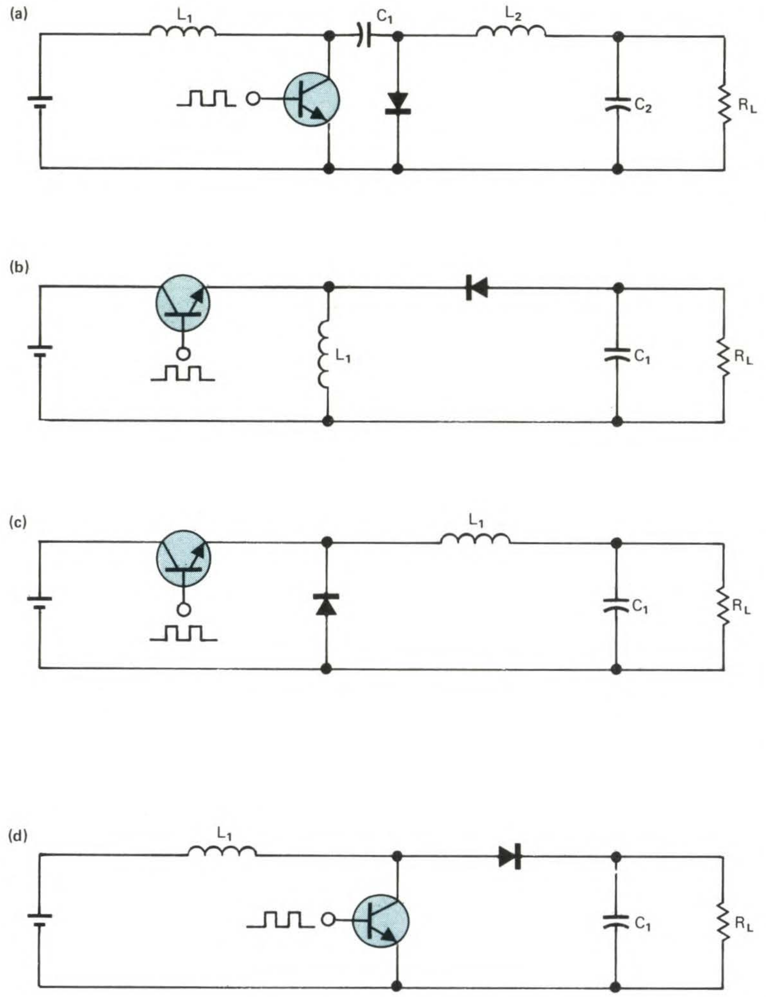
As a result, the capacitor current stays nearly in phase with the applied voltage for most of the power cycle; hence the supply's power factor improves almost to unity.

Sophisticated control

Another method of improving switching-supply performance utilizes an 8048 μP, a PROM and a DAC to control a supply's regulation loop. Applications engineer Dave Hoffman, of Siliconix, Santa Clara, CA, will explain this control method, which also includes a firmware filtering algorithm to reduce line ripple.

The Siliconix unit's μP generates a reference voltage (via the DAC) that's compared with the supply's output voltage. The comparator output then feeds back to the μP, which responds with pulse-width-modulated control for the supply's VMOS power-FET switches. Thus, the system even allows keyboard control of the supply's output-voltage and waveform characteristics.

Pulse-width modulation also eliminates transformer-imbalance problems in a switching supply scheduled for presentation by Walt Hirschberg, VP for product development at ACDC Electronics, Oceanside, CA. He notes that these transformer imbalances can result from load-current modulation near the switching frequency and can cause internal-component failure.



An optimum-topology power converter (a), *developed at the California Institute of Technology, can increase or decrease supply voltage, as can a buck-boost circuit **(b)**; the buck **(c)** and boost **(d)** designs can only decrease the voltage.*

Building blocks

Circuit designers who would rather avoid some of the tedious component-level considerations associated with assembling a switcher might find an alternative in a family of switching-supply building blocks to be introduced at the show by Silicon General, Garden Grove, CA. Housed in 10-pin, 2.5×1.5×0.3-in. modules, these units can save assembly time and money, as well as making RFI control easier because of their small size, according to applications manager Pete Wood. The hybrid modules dissipate up to about 3W—a figure made possible by a proprietary substrate with low thermal impedance.

One of the four modules contains a controlled phase-angle rectifier that charges an external input-filter capacitor to prevent large inrush currents. Another

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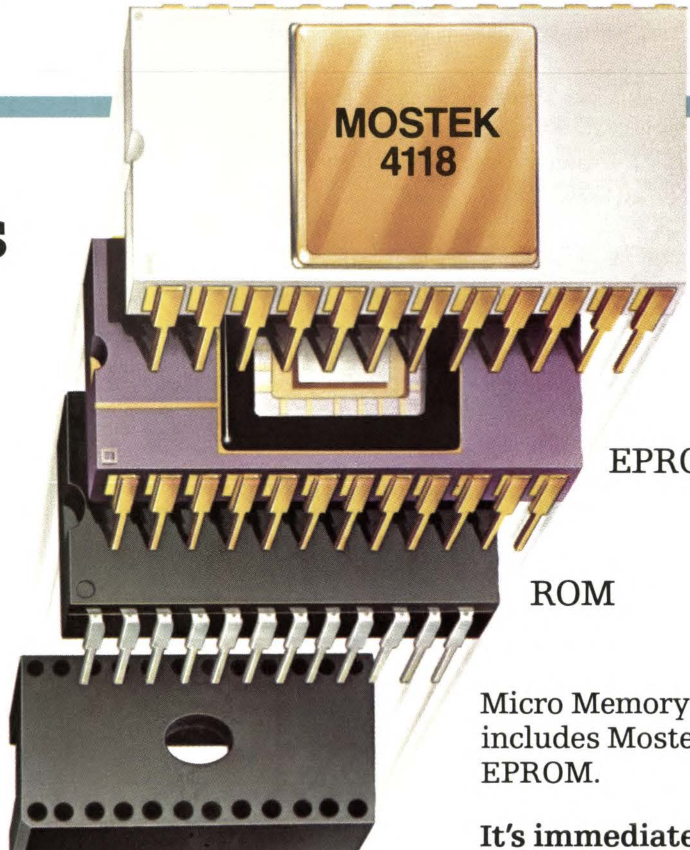

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module—a power-stage unit—accepts unregulated dc inputs from 100 to 400V at 10A; it operates between 50 and 100 kHz. The switching system's transformer and the output rectifier and filter are all external.

A bias-converter module supplies low-voltage power for the switching system's regulator circuit (which consists primarily of an SG1525 regulator IC). This low-power module operates from unregulated dc and produces a regulated output between 15 and 20V. The fourth module, a drive circuit still in development, amplifies the regulator IC's output to drive the power module.

Computer models help

A design-oriented Powercon paper that isn't restricted to switching power supplies will focus on the computer modeling of semiconductor power-supply components. Dr James Bowers, a professor at the University of South Florida in Tampa, will present a brief description of available computer-analysis programs, then describe his technique for measuring a power semiconductor's parameters, establishing its equivalent circuit and developing a corresponding computer model.

Dr Bowers and his colleagues have developed models for hundreds of diodes, SCRs, bipolar and MOSFET transistors, and integrated power op amps.

Engineers can use these models to save time and money when designing power supplies, says Bowers. He notes that although a special device can often take 6 to 8 wks to obtain, an engineer using its computer model can accurately design a power-supply circuit on paper before receiving the part itself.

The models can also help determine a supply's worst-case design. "The computer model allows a variation of parameters—such as beta or collector current—and helps determine their impact on the circuit," Bowers notes. "There is no practical way to duplicate all the possible variations using the actual components." And, he adds, "We have never found a mistake in our computer-analysis technique." **EDN**

64-pin-chip packaging developers offer an alternative to JEDEC standard

Bob Peterson,
Associate Editor

Two manufacturers have joined forces to introduce a 64-pin quad-in-line packaging (QUIP) system that—compared with an equivalent DIP—saves pc-board space while still allowing easy access to the IC's pins for testing purposes. And although this packaging arrangement does not conform to the standardization guidelines proposed by JEDEC for space-saving IC packages (EDN, Sept 20, 1978, pg 119), it does offer certain advantages.

Developed jointly by Intel Corp, Aloha, OR, and 3M Co, St Paul, MN, the QUIP system consists of three parts: a zero-insertion-force socket with four rows of standard pins on 100-mil centers, a leadless ceramic chip carrier with two rows of leads on 50-mil centers and a metal clip that holds the chip carrier's contacts against the socket's contacts. The clip also helps dissipate heat generated by the chip.

While the 64-pin QUIP requires less pc-board area than a DIP (2.1 vs 3.5 in.^{2}, respectively), the closest equivalent package suggested by JEDEC requires even less board area (1.4 in.^{2} for a 68-pin device). On double-sided pc boards, however, the QUIP can save space by allowing designers to run traces between its leads. And because it also permits use of standard wave-soldering techniques in board fabrication, the QUIP can serve, in many cases, as an economical packaging scheme. **EDN**

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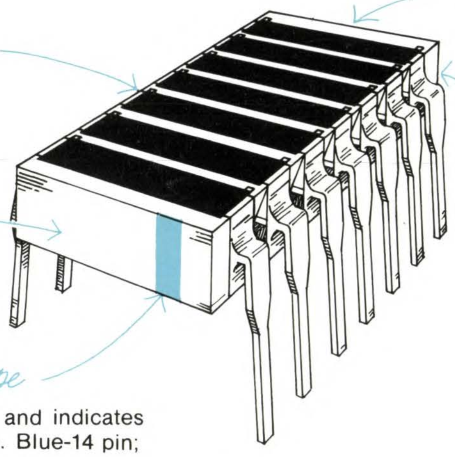

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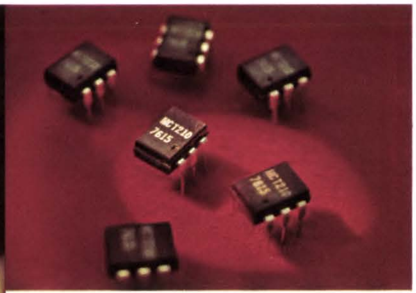
EC149B

Versatile optoisolators, couplers move into new applications

Robert Grossman, Manager, Western Editorial Office (N)

Designed for high-performance applications, *H-P's HCPL2601 provides 3000V isolation, with a 70% typical current-transfer ratio* (I_C/I_F).



Offering up to 2500V-dc surge isolation, *Monsanto's MCT210 optoisolator drives up to 200 mW with an output-phototransistor collector-to-emitter voltage of 30V max.*

Optoelectronic isolators and couplers are replacing the slow and bulky electromechanical devices that previously isolated delicate circuitry—especially in telecommunications, which constitutes the devices' biggest market, according to an assessment by the top three suppliers. And as optoisolators mature in complexity and capability, they could become commonplace in all kinds of digital equipment.

With the increase in distributed processing, for example, optoisolators have taken on a new importance to the computer industry. Optical devices can prevent unwanted interaction among any physically separable parts of a computer system—such as CRT terminals or printers—as well as isolating a system from the outside world.

Industrial-noise solution

Industrial environments can present a very harsh "outside world" to a process-control computer; noise and damaging tran-

Illuminating the market

The steady growth of the optoisolator market indicates the importance and versatility of these products. Specifically, Monsanto's marketing manager for optoelectronic products, Bill Bottini, pegs the 1978 market for optoisolators at $41 million—a figure supported by Hewlett-Packard's optocoupler product manager, Gary Labelle. Both men see a steady 20 to 25% annual market growth in the next few years.

Semiconductor houses such as Motorola, Fairchild and Texas Instruments are challenging the three optoisolator market leaders—General Electric, Hewlett-Packard and Monsanto—for a larger share of the market. The leaders are also feeling the increasing presence of smaller companies—Spectronics, Optron and Litronix, for example.

With regard to the leaders' overall marketing philosophy, GE, for one, does not intend to produce single-function parts for specialized industries. Joe McSweeney, the firm's optoelectronic product planner, states that GE's product line will have a "broad-based market." With this strategy, the company hopes to continue its growth in industries where the trend is toward solid-state components and away from mechanical ones.

Monsanto sees optoisolators as common, reliable devices that designers can now utilize even when they are not absolutely required. This manufacturer feels that its growth in the optoelectronics field will be tied to the continuing computerization of American factories.

In contrast to the other market leaders, H-P has concentrated its efforts on the high end of the market. While all optocouplers employ some form of hybrid bipolar processing, H-P has designed its products to allow even more integration than usual on one chip. "Most devices have had to compromise performance between speed and efficient light capture," according to Labelle. "We combined the amplifier and optocoupler on the same chip for high-speed performance up to 10M bps."

sients abound. Inserted between digital circuitry and this ac environment, optoisolators provide inexpensive circuit protection and permit control of high-current devices such as SCRs and triacs.

One potentially important industrial market that optoisolators have *not* yet entered is the automotive business. As electronic engine control becomes more prevalent (EDN, March 5, pg 37), Detroit might turn to inexpensive optical isolators as a solution to electrical-noise problems. For now, though, most optoisolators operate from 5V supplies rather than 12V, and Detroit's designers have other problems—such as emission control—on their minds, so penetration of the auto market remains but a possibility for optoelectronics.

Coupler or isolator?

Most of the current and prospective application areas utilize two separate capabilities of optoelectronic devices: coupling and isolating. Whereas opto*couplers* simply form an interface between two electrically independent circuits (configured from two incompatible logic families such as TTL and CMOS, for example), opto*isolators* must protect a circuit from potentially damaging voltage transients.

In reality, though, the only difference between optoisolators and optocouplers is one provided by marketing gamesmanship. Basically the same device, these optoelectronic components change names to suit the particular market segment in question.

Letting the light in

In its simplest form, an optoisolator/optocoupler contains two active devices on one die: an LED and a photodetector. The LED is fabricated in a standard manner. But it doesn't have an exposed emitting element; all of its light is directed onto the enlarged base region of the photodetector. Thus, when the isolator's input signal modulates the LED's light level, the photodetector senses the changes, and the input signal—now electrically isolated from the input—appears at the output.

Most of the actual differences between devices on the market stem from different output-stage designs. Most outputs utilize a 3-terminal semiconductor with one of its terminals (depending on semiconductor type) replaced by a photodetector: If a phototransistor is used, the photodetector replaces the transistor's base, while phototriacs and SCRs substitute the detector for their triggers. Some output stages also employ Darlington amplifiers to boost signal levels. **EDN**

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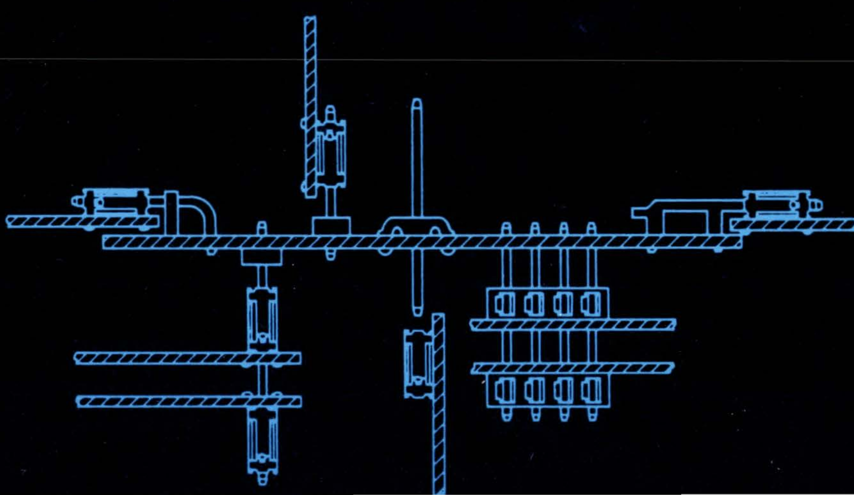

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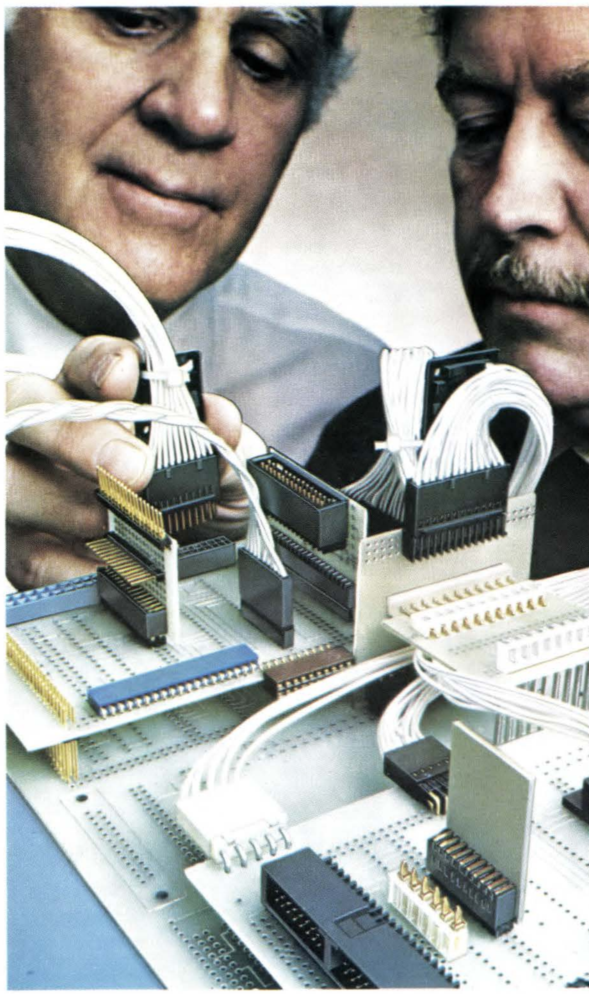

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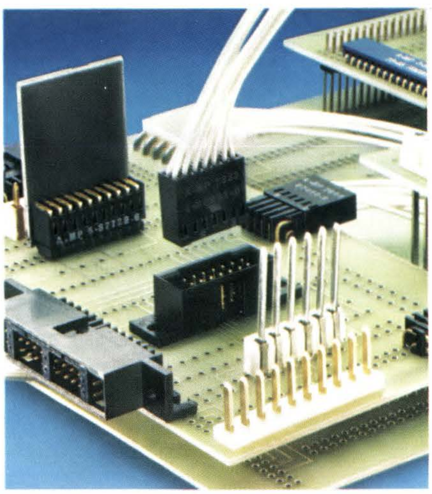

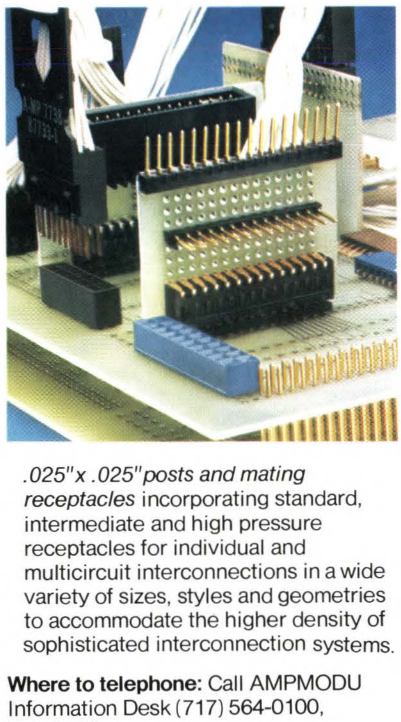

Some facts worth knowing about AMPMODU connectors

Function: The AMPMODU Interconnection System is a reliable, inexpensive way to provide three dimensional interconnections through a unique modular technique employing two mating members (posts) and female members (receptacles). The posts and receptacles fall into two general classifications:

.031"x .062" posts and mating receptacles and multicircuit housings. These are generally used in memory boards, power supplies and rugged interconnection systems.

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Where to write: AMP Incorporated, Harrisburg, PA 17105

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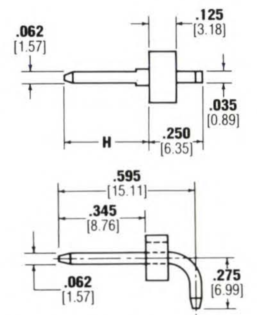
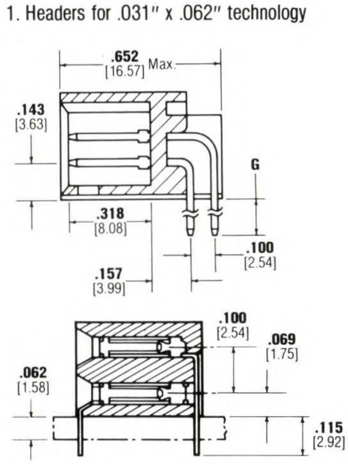
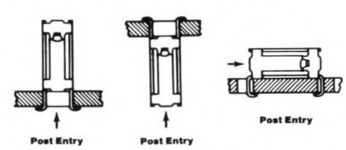


1. Headers for .031" x .062" technology

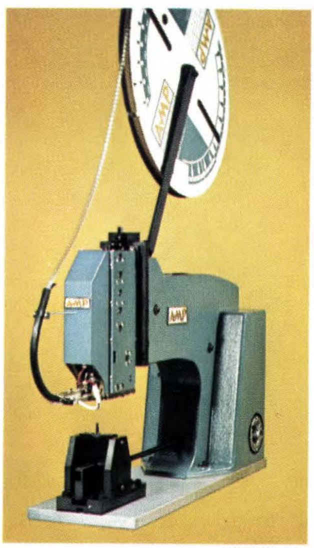


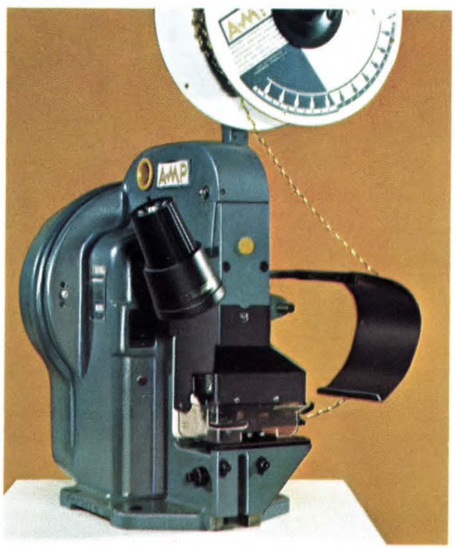
2. Headers for .025" x .025" technology

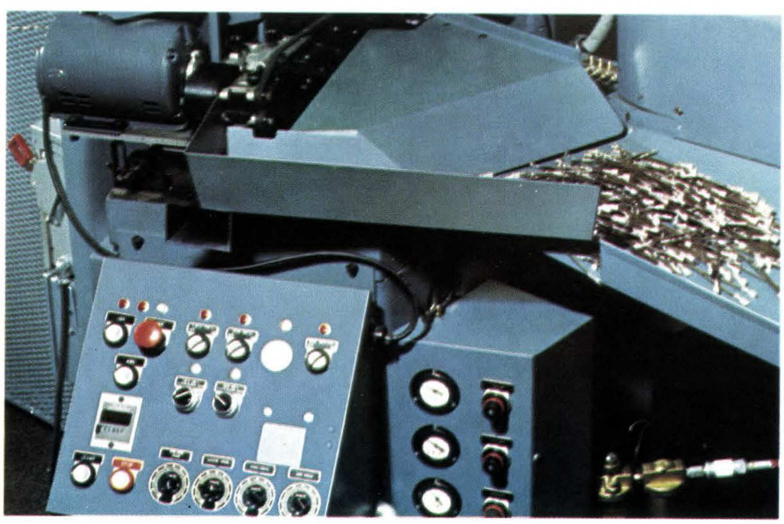


3. Board mount receptacle configurations

...and with cost effective tooling.







Quick staking, rapid terminations and low on-board costs are the hallmarks of AMPMODU Application Tooling.

The AMP Pantograph Machine, for instance, is a strip feed machine which stakes up to 12,000 posts and/or receptacles an hour. And it can do it with remarkable accuracy.

The production rate on the AMP Printed Circuit Board Insertion Machine can be as high as 2000 insertions per hour, depending on the operator. Styles are available for both the .031" x .062" and .025" x .025" components.

AMP also offers a complete range of wire terminating equipment, including bench machines, and high volume automatic lead making machines capable of terminating several thousand leads per hour.

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AMP

μComputerist Corner

Simple circuit multiplies in 800 nsec

Prakash Dandekar
Andhra Valley Power Supply, Bombay, India

Currently available NMOS μPs require relatively long times (200 μsec and more) to perform a multiplication; for high-speed control and signal-processing applications, designers usually opt for an expensive multiplier chip or a bipolar μP to achieve times faster than this. You can reduce the multiplication bottleneck, however, by using a separate hardware subsystem interfaced to the μP. The design presented here requires about 20 MSI/SSI ICs and costs less than $30. With ordinary 7400 Series TTL, its highest usable clock frequency of 10 MHz permits 800-nsec 8-bit multiplication.

The subsystem (**Fig 1**) uses the simple shift-and-add algorithm flowcharted in **Fig 2**. The hardware consists of two 8-bit operand registers accessible to the μP (X and Y), a 16-bit result register (Z) and a counter that controls the multiplication sequence. Interfacing to a μP system is simple: DEVSEL X and DEVSEL Y are two strobes generated by decoding the system address lines. These two signals load the X and Y registers; DEVSEL Y also clears the subsystem and starts the multiplication. Upon completion of the operation, the DONE flag goes HIGH; this flag is used by an interrupt-driven system.

The system clock period should be sufficiently long to provide a delay between the shifting-X and strobing-Z operations. The period must include the maximum clock-to-output delay of the 7495, the ripple-carry delay of the 7483 and the setup time and propagation delay of the 74175. Use of standard TTL permits a clock period of 100 nsec and thus a multiplica-

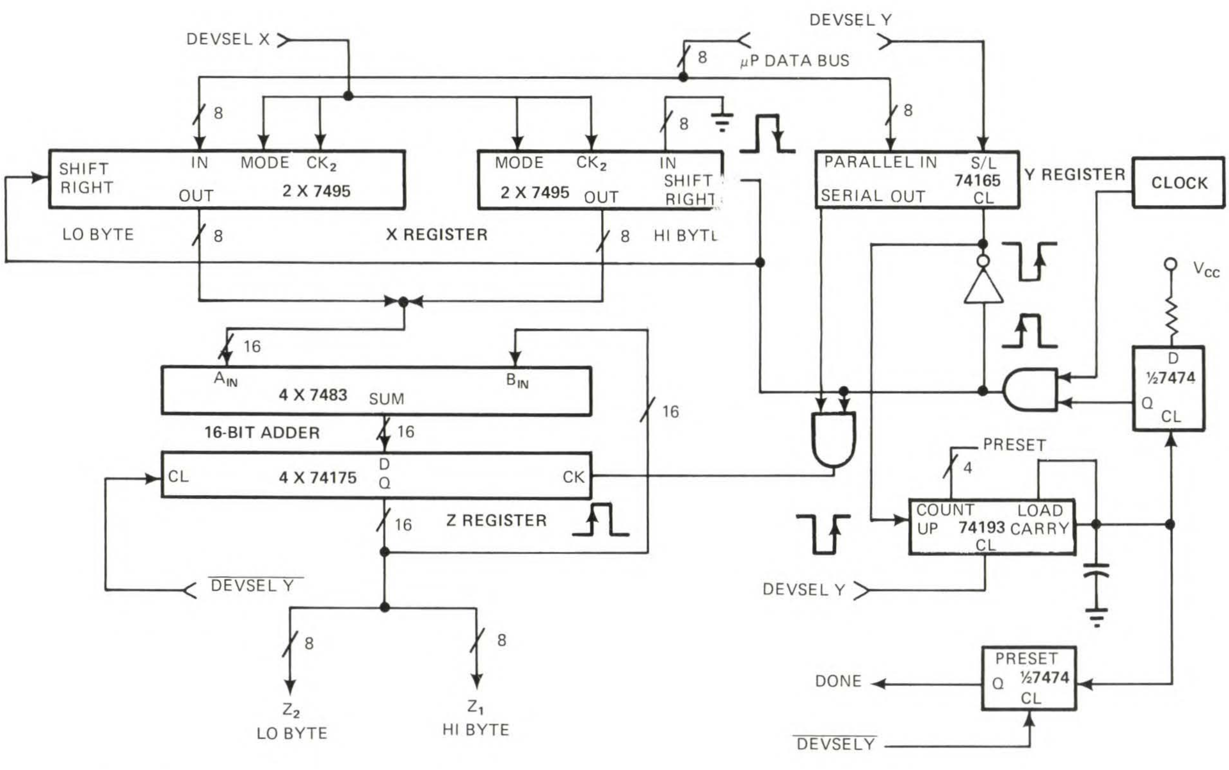

Fig 1—With careful selection of edge-triggered devices, *this circuit performs an 8× 8-bit multiplication in 800 nsec.*

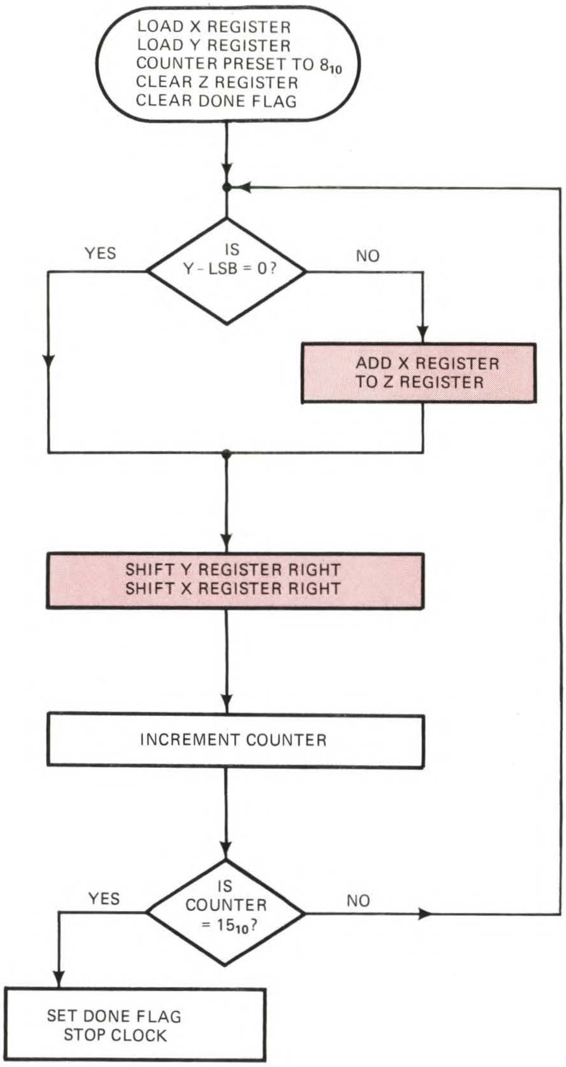

Fig 2—A shift-and-add algorithm *makes the subsystem go.*

tion time of 800 nsec.

Because most instructions of an NMOS µP require 2 to 10 µsec, an 800-nsec multiplication time represents engineering overkill. In such cases, you can use a lower clock frequency—using the CPU clock for this purpose saves circuitry.

In a typical 8080A-interfaced application, the X, Y, Z_1 and Z_2 registers are assigned consecutive memory locations; the X and Y operands are in the B and C registers, respectively. Use the code in **Fig 3** to perform the multiplication; the 2-byte result is stored in DE.

The multiplication routine requires about 22 µsec, compared with an all-software multipli-

```
MULT:  LXI  H, X    ; X-register address loaded
                    ; in (H, L) pair
       MOV  M, B    ; X loaded
       INX  H       ; (H, L) incremented
       MOV  M, C    ; Y loaded, multiplication
       INX  H       ; proceeds
       MOV  D, M    ; Z1 (high-byte of result)
                    ; is brought into D register
       INX  H       ; address of Z2 register
       MOV  E, M    ; low-byte of result in E
       RET          ; register
```

Fig 3—Use this code when interfacing *the multiplier with an 8080A system.*

cation time of about 230 µsec. Close examination of the routine reveals that the time between the loading of the Y register and the retrieval of the high byte from Z_1 is about 4 µsec (eight microcycles at a 2-MHz clock frequency). Thus, using the 8080A's ϕ_2 clock, the subsystem clock frequency can be lowered so that the operation takes at most 4 µsec.

This basic multiplier can be expanded to handle two 16-bit words. But in a hardwired system, the X, Y and Z registers double in width and thereby increase component count. If board space or parts cost is important, use the 8-bit subsystem as a byte multiplier together with an expanded software routine. **EDN**

Software notice

Access to more than 85 types of business, medical, accounting, research and hobby programs is free to members of the 8080 Etc users' group. Programs include routines in word processing, general accounting, billing, materials management, text editing, financial analysis, physics, and electrical, civil and chemical engineering. If you are interested in 8080 Etc membership, set your terminal for 300-baud transmission, dial (209) 638-6392 and type the passwords: Hello-w101, 8080-Etc. For a free list of program titles, send a self-addressed stamped envelope, together with a description of your system and any questions, to: Membership, The 8080 Etc, Box 894, Fresno, CA 93714. **EDN**

Photo: an 8 pin, 7 resistor SIP network substrate employing TanTin (colbalt blue) and copper terminations.


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EDN Software Note #27

Execute MK3870 magnitude comparisons

Don Ward
Mostek Corp, Carrollton, TX

By testing the appropriate status bit(s) of an MK3870, you can make magnitude comparisons without altering the contents of the device's accumulator or memory.

The µC's instruction set provides two comparison instructions which do not store a result: CI (compare immediate) and CM (compare memory). These instructions add the two's-complement value of the accumulator to the immediate byte (CI) or to the memory byte (CM) referenced by the data counter. Although a comparison's result is discarded, the operation alters the status register according to the rules of two's-complement addition.

For two numbers, A and B (signed or unsigned magnitudes), the **table** indicates the status conditions necessary for each comparison. The routines in the **figure** test for each condition and perform a branch if the relation is true. Although these routines use CI, CM can be substituted for memory comparison. **EDN**

RELATION	UNSIGNED O Z C S	SIGNED O Z C S
A = B	– 1 – –	– 1 – –
A <> B	– 0 – –	– 0 – –
A > B	– – 0 –	0 – – 0 or 1 – – 1
A <= B	– – 1 –	0 – – 1 or 1 – – 0
A < B	– 0 1 –	1 – – 0 or 0 0 – 1
A >= B	– – 0 – or – 1 – –	0 – – 0 or 1 – – 1 or – 1 – –

A magnitude comparison in an MK3870 *sets testable status conditions. A "-" in this reference table indicates a "don't-care" bit.*

```
>0000                B         EQU    H'00'    ASSIGN B TO SOME VALUE.
                     *
                     * (A)  A = B
                     *        Same as Example 1.0 (A).
                     *
                     *
                     *
                     * (B)  A <> B
                     *        Same as Example 1.0 (B).
                     *
                     *
                     *
                     * (C)  A > B
'0000  2500                    CI     B        COMPARE VALUES.
'0002  990E                    BF     9,AGTB   BRANCH IF OVF=S=0.
'0004  9803                    BNO    ALEB     S=1 IF OVF=0.
'0006  810A                    BP     AGTB     BRANCH IF OVF=S=1.
'0008  2B            ALEB      NOP             FLOW HERE IF OVF=1, S=0.
                     *
                     *
                     *
                     * (D)  A <= B
'0009  2500                    CI     B
'000B  9305                    BF     9,AGTB   BRANCH IF OVF=S=0.
'000D  98FA                    BNO    ALEB     S=1 IF OVF=0.
'000F  91F8                    BM     ALEB     BRANCH IF S <> 0.
'0011  2B            AGTB      NOP             CONTINUE HERE IF OVF=S.
                     *
                     *
                     *
                     * (E)  A < B
'0012  2500                    CI     B
```

In this code for signed and unsigned magnitude comparisons, *"A" represents the accumulator and "B" the comparison value.* (*Continued on next page*)

```
'0014  9905      0039            BF       9,AGEB    BRANCH IF OVF=S=0.
'0016  9C0C      0040            BF       12,ALTB   BRANCH IF OVF=Z=0.
'0018  910A      0041            BM       ALTB      BRANCH IF S=Z=0.
'001A  2B        0042 AGEB       NOP                CONTINUE HERE IF OVF=S
                 0043 *                             OR Z=1.
                 0044 *
                 0045 *
                 0046 *
                 0047 * (F)  A >= B
'001B  2500      0048            CI       B
'001D  99FC      0049            BF       9,AGEB    BRANCH IF OVF=S=0.
'001F  9C03      0050            BF       12,ALTB   BRANCH IF OVF=Z=0.
'0021  81F8      0051            BP       AGEB      BRANCH IF S=1.
'0023  2B        0052 ALTB       NOP                CONTINUE HERE IF O <> S
                 0053 *                             AND Z=0.
                 0054 *
                 0055 *
                 0006 * EXAMPLE 1.0      UNSIGNED MAGNITUDE COMPARISONS.
                 0007 *
 >000F           0008 B          EQU      H'0F'     ASSIGN B TO SOME VALUE.
                 0009 *
                 0010 * (A)  A = B
'0000  250F      0011            CI       B         COMPARE VALUES.
'0002  8406      0012            BZ       EQUA      Z FLAG SET IF A = B.
'0004  2B        0013 NEQU       NOP                ELSE NOT EQUAL.
                 0014 *
                 0015 *
                 0016 *
                 0017 * (B)  A <> B
'0005  250F      0018            CI       B
'0007  94FC      0019            BNZ      NEQU      Z FLAG CLEAR IF A <> B.
'0009  2B        0020 EQUA       NOP                ELSE EQUAL.
                 0021 *
                 0022 *
                 0023 *
                 0024 * (C)  A > B
'000A  250F      0025            CI       B
'000C  9206      0026            BNC      AGTB      CARRY CLEAR IF A > B.
'000E  2B        0027 ALEB       NOP                ELSE A <= B.
                 0028 *
                 0029 *
                 0030 *
                 0031 * (D)  A <= B
'000F  250F      0032            CI       B
'0011  82FC      0033            BC       ALEB      CARRY SET IF A <= B.
'0013  2B        0034 AGTB       NOP                ELSE A > B.
                 0035 *
                 0036 *
                 0037 *
                 0038 * (E)  A < B
'0014  250F      0039            CI       B
'0016  9203      0040            BNC      AGEB      CARRY CLEAR IF A >= B.
'0018  9408      0041            BNZ      ALTB      Z CLEAR AND C SET IF A < B.
'001A  2B        0042 AGEB       NOP                ELSE A >= B.
                 0043 *
                 0044 *
                 0045 *
                 0046 * (F)  A >= B
'001B  250F      0047            CI       B
'001D  92FC      0048            BNC      AGEB      CARRY CLEAR IF A > B.
'001F  84FA      0049            BZ       AGEB      Z SET AND C SET IF A = B.
'0021  2B        0050 ALTB       NOP                ELSE A < B.
                 0051 *
                 0052 *
```

FLUKE'S MICROPROCESSOR-BASED SCANNER IS COMPATIBLE WITH EITHER IEEE 488 OR RS232.

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μC development

Regardless of its physical condition, *a prototype can often benefit from some form of development-system diagnostics. (Photo of System 65 Courtesy Rockwell International)*

systems

No two development systems are alike, but no two development tasks are, either. The ideal system remains flexible, satisfying your specific needs.

Edward Teja, Associate Editor

Although nearly every μC system currently on the market features some development tools, many of these systems are not designed for complex development work. And even if you consider only those systems touted specifically for development tasks, their sheer variety will confuse any attempt at specific point-by-point comparisons.

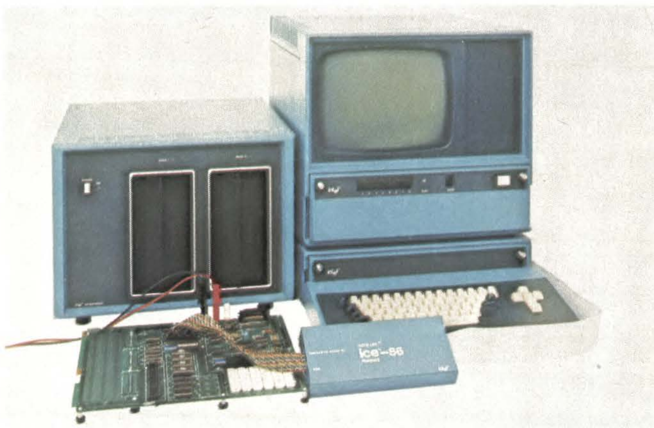
Clearly, though, a $500 system does not offer the same capabilities as a $20,000 one; they don't compete directly. The question, then, is not which development system is the best, but which development tools best suit your task. After ascertaining that requirement, you can then determine which system provides these tools in the most cost-effective package.

Start by defining the development task; realistically assess the minimum and maximum requirements your system must meet. The questions in the nearby **box** can serve as a guide to a first-level evaluation. For example, if your end product's available memory is limited, writing programs in PASCAL would be unrealistic—even though many development systems either now offer it or will add it during the next year. The requisite interpreter alone resides in approximately 10k of ROM in most PASCAL versions—and that does not include the program size. FORTRAN, to name a second example, compiles nicely, yet its run-time package, whose size varies from compiler to compiler, requires additional memory. In fact, for products with less than 8k of memory, programming in anything higher than assembly language can prove to be a blue-sky proposition.

Evaluating the suppliers

In the beginning, development systems were created for one purpose: to sell silicon. Semiconductor manufacturers realized that the ease of producing software for a processor correlated with the volume of that device's sales. Although these manufacturers still produce development systems to sell their chips, the entry of independent equipment manufacturers into the market has led some semiconductor makers to market their systems as independent-profit-center products. The successful entry of independent firms has made it clear that selling development systems and development tools is profitable in

All the tools *for software and hardware development and debug for Z80 and 3870 μPs come in Mostek's AID-80F. The enclosure, a CPU with 32k of RAM, two single-sided drives, a card case and cabling cost $5995 total.*



Costing $14,500, *Intel's Intellec Series II Model 230 comprises 64k of RAM; two dual-density floppy-disc drives; a 2000-character CRT and the ISIS-II operating system. (The ICE module for 8086 emulation and the SDK-86 board shown in the photo are not included in this price.)*

Independent vendors add features to dedicated systems

and of itself.

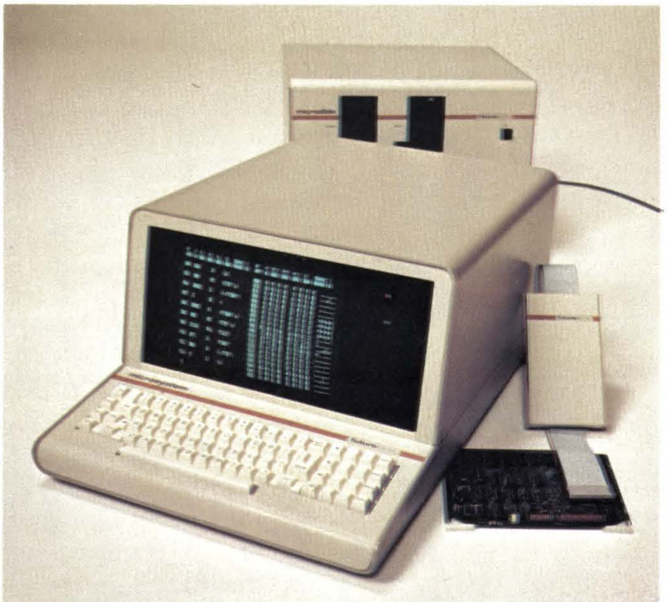
The independent equipment manufacturers (companies not engaged in making μPs) typically offer universal systems. ("Universal," in this context, means only that a system, rather than being committed to a particular processor, functions as a development station for several processors.) Tektronix, one of the best-known independents, views the market as one for test equipment. Thus, its Model 8002's emulator circuitry and debug capability were developed by logic-analyzer designers.

The 8002's Real-Time Prototype Analyzer option, for example, provides a trace of up to eight locations on a prototype circuit. This sophistication is costly, though: An 8002 with F8, 3870 and 3872 support packages costs $13,700. The system also supports 6800, 8080A, 8085, Z80 and TMS 9900 μPs.

The time lag between the appearance of a new μP and the availability of development systems that serve it is significant to OEMs. Naturally, the chip's manufacturer will offer first delivery on development support; the availability of support for the chip on universal systems, though, typically awaits mass-market acceptance of the device. Thus, if you can't wait for an indefinite period of time for a software or hardware module that supports the new device on your universal system, you'll either have to write your own cross assembler or buy the appropriate dedicated system from the chip manufacturer.

Independents perform another service beyond broadening the variety of available alternatives—they provide products that make dedicated systems slightly more universal. Proc-

Development tools *don't always come in system packages. Applied Microsystems' EZ-80 permits full emulation of Z80 μPs while providing built-in diagnostics.*



Several users can share *a single CPU and mass-storage devices when working on Futuredata's Microsystems. These systems range from $11,500 to $69,450, depending on configuration.*

An all-in-one configuration, *Zilog's ZDS-1 provides emulator, logic analyzer and ROM/RAM-simulator functions.*

A general-purpose system *designed more for business than development work, Pertec's 8085-based PCC 2000 can nonetheless serve for some development tasks.*

essor Innovations, for example, can (for $1500) utilize the magic of cross assembly to provide Intel development-system users with TMS 9900, SBP 9900 and S9900 development capabilities.

As another alternative, Solid State Scientific Inc proffers a $500 macro assembler that permits use of Intel's Intellec system as an SCP1802 development system. In the same manner, cross assemblers can convert any μC into a development system—EDN did it for the 8086 (EDN, February 5, 1979, pg 115). Incidentally, Intel used cross assemblers and cross compilers (PL/M) to make the 8080-based Intellec system do development work for the 8086.

Just as adding software increases the versatility of an existing system, a similar approach can compensate for a shortage of specialized development hardware. Intersil, for example, provides its Model 6920 EPROM programmer for use with any system having either an RS-232 or current-loop interface. Thus, for approximately $1000, virtually any system can program PROMs.

In short, just because a development system is purchased as a dedicated configuration doesn't mean it must stay that way.

Making more than a development system

There's another alternative, though. Many higher priced systems, such as National Semiconductor's Starplex, offer blandishments (such as FORTRAN) unrelated to their systems' use in the development task. National assumes that many OEMs can't afford to pay $10,000 or more for "only" a development system and that a system offering full-service computational power covers a broader range of applications. The extra capability isn't free, of course, but bundled into the price of a development system, it becomes less noticeable.

Assume, for example, that your company can afford (or will authorize) only part of the necessary cash for a development system; assume also that some EEs in the firm are using time sharing to solve problems in FORTRAN. If you are willing to share access to the system, all of you can combine budgets to buy one system that does both jobs.

Contrast this approach with the method used by companies such as Futuredata: It believes multiuser development systems are an effective means of reducing development costs. Its Six Station Network, for example, provides facilities for six users simultaneously, including four software-development stations; two hardware-development stations; four double-sided, double-density floppy discs; and a 300-lpm printer. The system accommodates five different user-specified 8-bit processors. Cost per programmer is about $11,575—not cheap by any standard—but Futuredata feels that each programmer must have a separate console in a realistic development effort. Tools such as symbolic debug

Defining the development task

In order to select a system that will maximize your development effort, you must first define your job in terms of the available development tools. The necessary questions divide into hardware and software categories.

Hardware

1. How many different types of μPs must the system be able to accommodate?

2. Will the code to be developed reside in PROM?

3. Is the application hardware sufficiently complex that it would benefit from in-circuit emulation?

4. Will the system be available for uses other than development?

5. How many programmers must have access to the system at any one time?

Software

1. Is the code to be developed sufficiently long (and complex) to require modularized writing? If so, make sure that the assemblers and compilers provided with the development system produce relocatable, linkable code. The former permits modification of its addresses at load time; the latter uses pseudo-ops to maintain communication between separately compiled modules and the main program. For detailed discussions of these features, see "The software wall and what you need to scale it" (EDN, March 5, 1978, pg 75).

2. Can your code be written in a high-level language? A secondary question here should be: What languages do members of your development team already know? You shouldn't have to spend time learning new languages unnecessarily.

3. Will programmers be using the system to write code for processors other than the resident CPU? If so, can cross assemblers be produced in-house? Are cross assemblers that produce code for the target processor available on the development system?

4. Will some routines be used repeatedly? What hardware/software does the system offer to facilitate building libraries of subroutines?

5. Will the system be shared for other engineering tasks? If yes, you will want FORTRAN or some high-level language for the individuals involved in those tasks. Don't expect BASIC to be adequate.

Extra capability makes dedicated systems generally useful

and interactive editing, hallmarks of this kind of system, make system development this network's primary purpose.

Setting system guidelines

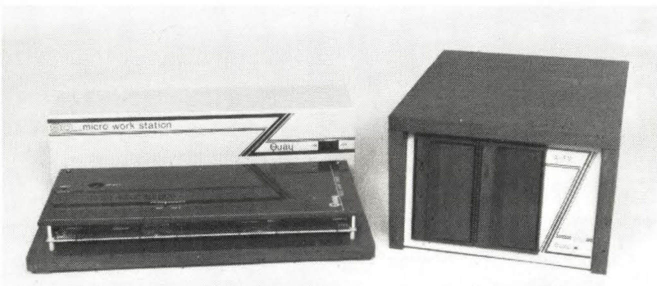
Are there such things, then, as standard system tools? No; they depend on the application. You wouldn't consider hardware emulation necessary if the target product were relatively trivial, yet for complex products, Intel's ICE, National's In-System Emulation or one of the numerous other emulator products can save time and effort—permitting a real-time analysis of code as it executes on your hardware.

And if the software in your job is trivial, the best solution might not be a development system at all. A stand-alone emulator, such as the EM-6800 or EZ-80 from Applied Microsystems, provides an alternative for testing hardware prototypes. To emulate a chip, the EM-68 plugs into a 6800 CPU socket. You can take one home for $1860.

Millennium Systems also uses plug-in modules in its Microsystem Analyzer, supporting 6800, 8080, 8085A-2 and Z80 μPs. You can equip this stand-alone emulator, which costs $2750, with a $1000 signature-analysis option for time-domain capability.

Although the necessary set of tools is entirely task dependent, though, it *is* possible to outline requirements that apply to any μC system used in a commercial environment. These general system requirements don't relate specifically to the required set of development tools, but rather to the concept of realistic system hardware and software. Your system's capabilities will be more flexible if the system is chosen according to these guidelines:

- Include at least two floppy-disc drives.



Flexible enough to expand *into any application, Quay Corp's Model 90MWS, equipped with 4k of RAM but without floppy discs, starts at $1050.*

Putting everything in an integrated package, *Tano's Outpost features a macro assembler and STRUBAL+ compiler.*

From tutor to tool

Rockwell's Aim 65 began as a teaching tool but is currently finding use as a development system. As such, it's one example of the diverse nature of "development systems."

The company wanted to design a portable system that furnished enough tools to illustrate the power of its 6502 processor and peripheral chips. To that end, the Aim 65 board houses a thermal printer, keyboard and alphanumeric display; two 4k ROMs store an advanced monitor. An interface permits adding a cassette, thereby extending the unit's system-software base. The fully equipped board retails for about $500—a reasonable price for a teaching machine.

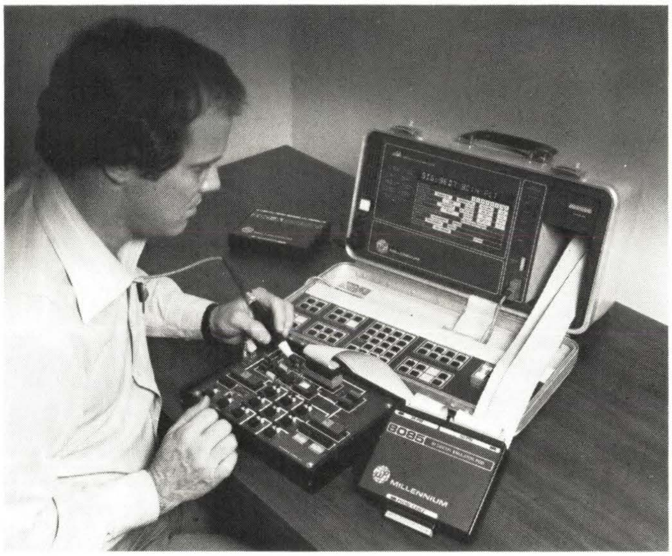
Not initially intended for use as a development system, *Rockwell's Aim 65 has become a fierce competitor in that field.*

The marketplace had different applications in mind for the unit, though; engineers began buying it as a development system. Rockwell's management suspects that one reason for this unexpected trend is that the system's price tag suits an engineering department's petty-cash budget, thus keeping accounting and purchasing departments out of the buy decision. After a project can be justified to upper management—with the Aim 65 running the software—the department gets budget approval for a development system.

An unrealistic scenario? Perhaps, but the systems are selling to people and companies who already know how a 6502 works.

Regardless of the storage capacity of these drives, it makes sense to use one write-protected disc for a system disc and one for development. Also, disc copying for backup purposes is much easier when you can perform a straight disc-to-disc copy. Why opt for discs at all? Using paper tape can add hours to each stage of the development process; a single edit-and-assemble session can take hours. Furthermore, magnetic tape is limited in speed and capacity, and more importantly, its files are strictly sequential, whereas discs support directories of named files—another factor that reduces development time. In addition, most high-level-language implementations are disc based—for large development tasks, you will want this design and development aid.

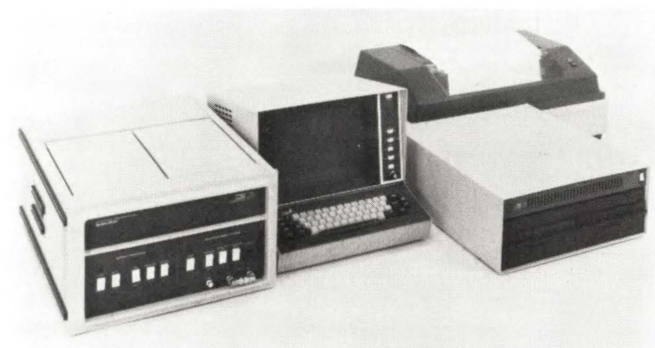
- Look for a good text editor. Regardless of the type of development your task entails, a large percentage of your time will be spent interfacing with the editor, so ensure that it is powerful and easy to use. Compare many of these editors before committing to one.
- Large jobs require a high-speed printer. Making a top-notch programmer wait for a teletypewriter printout is akin to hiring top-notch hardware designers and making them do their own drafting.
- Make sure that the operating system provides flexible utilities. An impressive array of hardware can be misleading; you must ensure that the operating system will actually transfer data and information to desired locations and devices from designated locations and devices assigned by dynamically alterable utilities. See EDN's Software Design Course (November 20, 1978) for a description of the work you can reasonably expect an operating system to do. Some powerful operating systems are available; the bogus ones will be obvious after you spend a little time comparing systems.



Plug-in modules *emulate the 6800, 8080, 8085A-2 and Z80 μPs, making Millennium's Microsystem Analyzer a reasonable alternative to a full development system.*

Incorporating complete hardware and software *for any 6800-based development task, Motorola's Exorterm 220 costs either $8600 or $9200, depending on whether you choose dynamic or static memory.*

Hoping to capitalize *on the Starplex's nondevelopment-system capabilities, National Semiconductor expects the system to find a home with customers who can't afford to buy just a development system.*



Designs using bit-slice μPs *can take advantage of Advanced Micro Computers' System 29, aimed at microprogramming applications ($18,850).*

Consider the human factor

As a final consideration before deciding on a system, spend some time with a demonstrator. Type in some code; do an assembly; print out some listings. Once you purchase the system, it and its quirks become part of your work environment. *Before* you buy is the time to discover that you can't stand the clunk the discs make when the heads load, or that the printer slides across the table as it prints.

Sound a bit like kicking the tires on a used car? Perhaps it is. Perhaps it is also time to recognize that you are more efficient (substitute "cost effective" in reports to management) in a comfortable environment. And efficient production of error-free code, after all, is the sole object of buying a development system. **EDN**

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Manufacturers of development systems and related equipment

For more information on development systems, development-system software, stand-alone emulators or general-purpose µC systems used in development-system applications, contact these manufacturers directly or circle the appropriate numbers on the Information Retrieval Service card.

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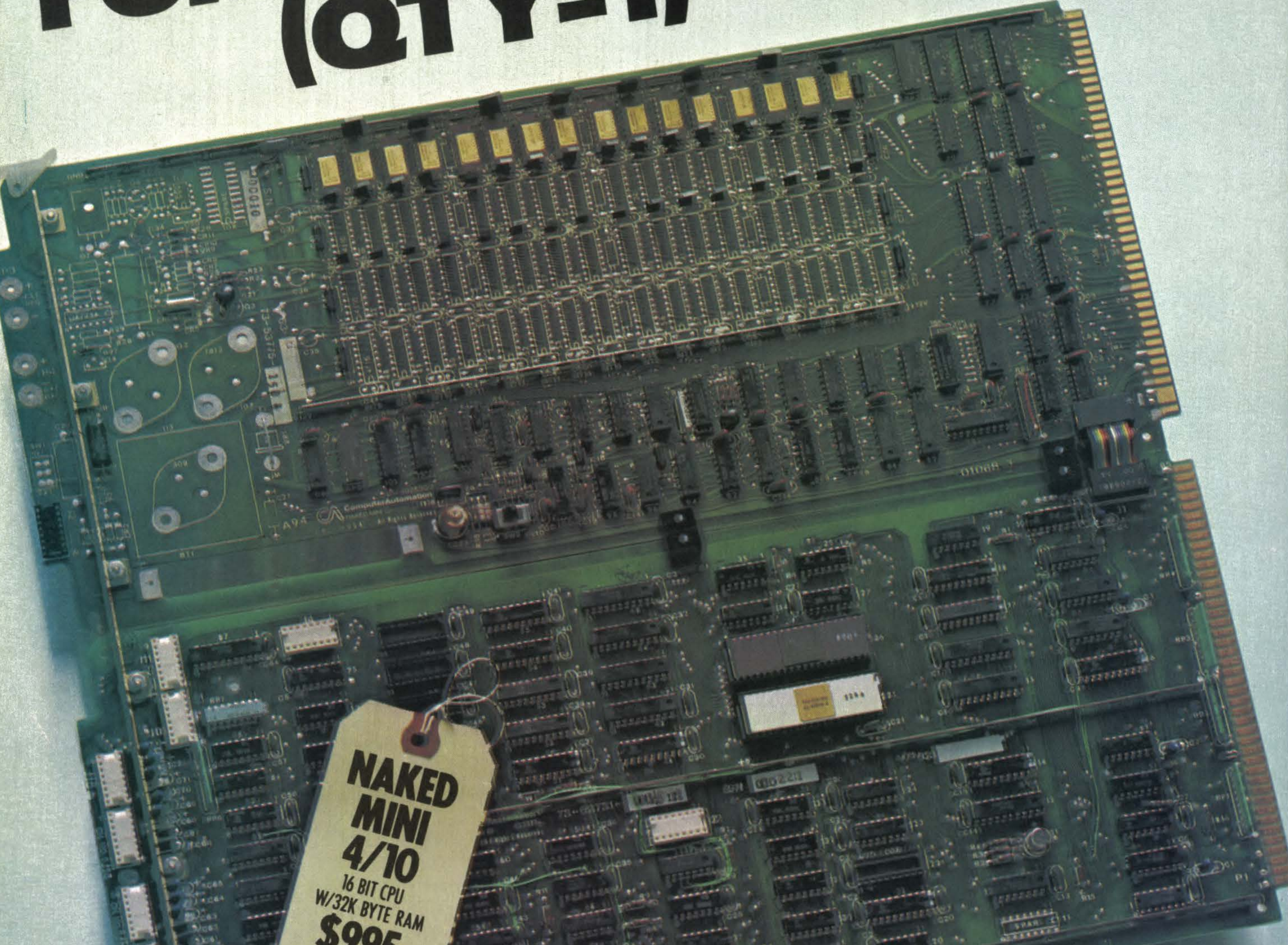

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Top-octave generators make beautiful music

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Bill Schweber, Instron Corp

If you're designing a product that requires audible signals to inform or attract its user, consider using a top-octave generator (TOG) IC as the tone source. Of course, as an alternative you could always use individually tuned oscillators (perhaps made from 555s), but the TOG offers the following advantages:

- A single IC provides up to 12 simultaneous pitches.
- The pitches are musically related and can be joined into pleasing combinations.
- A TOG contains no critical or drift-sensitive components; thus, its tones are always in tune with each other.
- TOG circuitry is easily expanded to produce almost any number of pitches.
- You can interface a TOG to analog and digital controlling circuitry, including μPs.

Top-octave generators divide and conquer

Although a basic understanding of musical pitch helps in applying a TOG (see **box**) the chip itself is simple and easy to use. A TOG divides a master frequency, usually one well above the audible range, by twelve different integers to produce a complete chromatic octave within the audible range. Because these output frequencies must be related by an irrational number ($2^{1/12}$) to match the Western equal-tempered scale, no integer divisors can result in perfect pitch accuracy. In fact, the set of twelve divisors itself is not unique, because different master frequencies can be used. TOGs use the divider set tabulated in **Fig 1.** That set yields an octave with normally inaudible tuning errors and employs the shortest on-chip dividers.

From a practical standpoint, then, only the relative relationships of the pitches, not their absolute accuracy, are critical in determining the "correctness" of the scale as perceived by the ear. In this respect, the TOG excels. Deriving all its pitches from a master oscillator, it produces notes whose relative accuracies depend only on the digital divisors used. The master oscillator need not be especially accurate or stable, unless, for example, you are designing a tuning aid for musical instruments.

Dividers add flexibility to a TOG

A basic TOG circuit (**Fig 2**) consists of a master oscillator and a TOG chip like the Mostek

NOTE	EQUAL-TEMPERED FREQ AT A4 = 440 Hz	TOG DIVISOR	TOG OUTPUT FREQUENCY	PERCENT ERROR	CENTS ERROR
C	261.63 Hz	478	261.54 Hz	−0.034	−0.58
C♯ OR D♭	277.18 Hz	451	277.20 Hz	+0.005	+0.08
D	293.66 Hz	426	293.46 Hz	−0.069	−1.19
D♯ OR E♭	311.13 Hz	402	310.98 Hz	−0.046	−0.80
E	329.63 Hz	379	329.85 Hz	+0.069	+1.19
F	349.23 Hz	358	349.20 Hz	−0.007	−0.12
F♯ OR G♭	369.99 Hz	338	369.87 Hz	−0.034	−0.59
G	391.99 Hz	319	391.89 Hz	−0.025	−0.44
G♯ OR A♭	415.30 Hz	301	415.33 Hz	+0.006	+0.11
A	440.00 Hz	284	440.19 Hz	+0.044	+0.76
A♯ OR B♭	466.16 Hz	268	466.47 Hz	+0.066	+1.15
B	493.88 Hz	253	494.13 Hz	+0.050	+0.87

Fig 1—This TOG-output-frequency error table *assumes a master-oscillator frequency of 125.015 kHz. The cents-error column has been recalculated and might differ from manufacturers' specifications.*

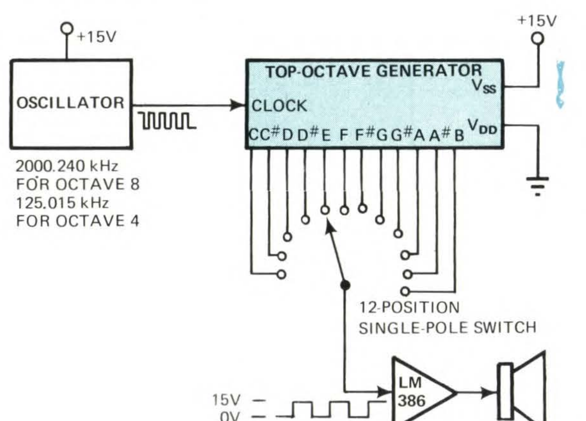


Fig 2—When constructing this basic TOG circuit, *choose the master-oscillator frequency according to the desired output-frequency range.*

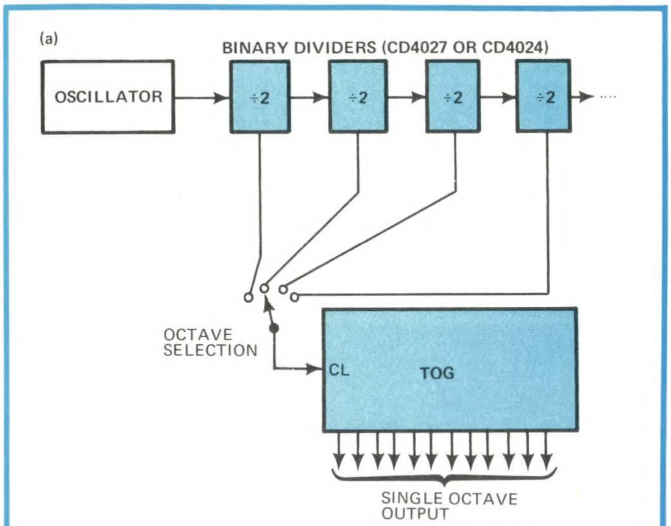
A top-octave generator is never out of tune

MK50240. (As the nearby **table** shows, AMI, GI, SGS-ATES and National Semiconductor also make TOGs.) The circuit uses a single +15V supply and generates 0 to +15V square waves. All twelve pitches are available simultaneously, making system expansion easy. With the addition of a selector switch, amplifier and speaker, the circuit becomes an electronic tuning fork: To use it, match the pitch of the instrument to be tuned to the TOG note.

You can gain additional flexibility by adding a binary divider between the master oscillator and the TOG; selecting different taps of the divider chain in turn selects different octaves **(Fig 3a)**. However, this circuit only provides one octave span at a time. You can overcome this limitation by connecting dividers to the TOG outputs instead of to the master oscillator **(Fig 3b)**. Each stage of division produces the same note in descending octaves, thus making the highest octave and all those below it simultaneously available.

Because TOG pitches are square waves, they can be controlled using ordinary CMOS digital gates—there is no need for more expensive analog switches. As shown in **Fig 4,** a level-shifting transistor implements TTL-level con-

Continued on pg 74



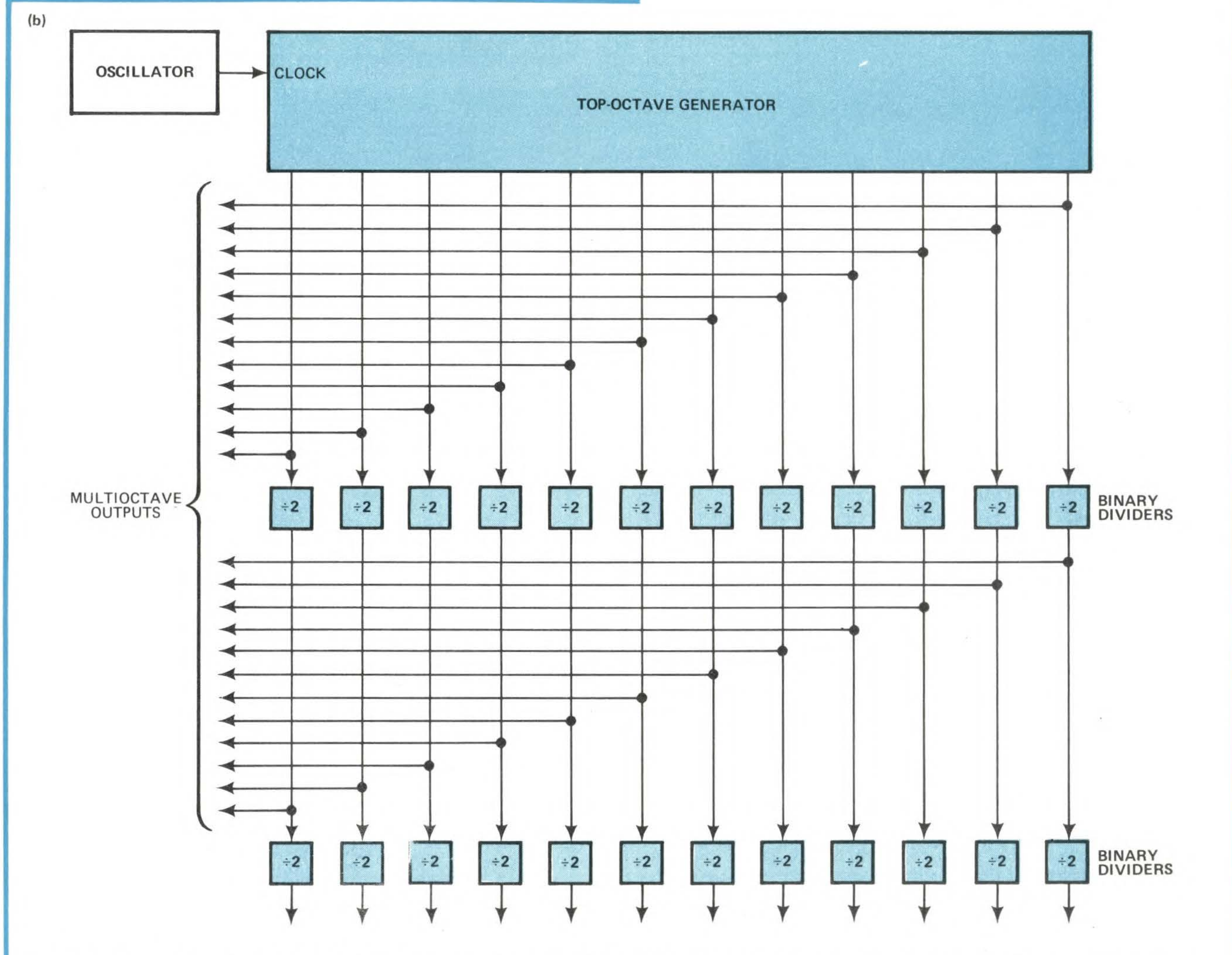
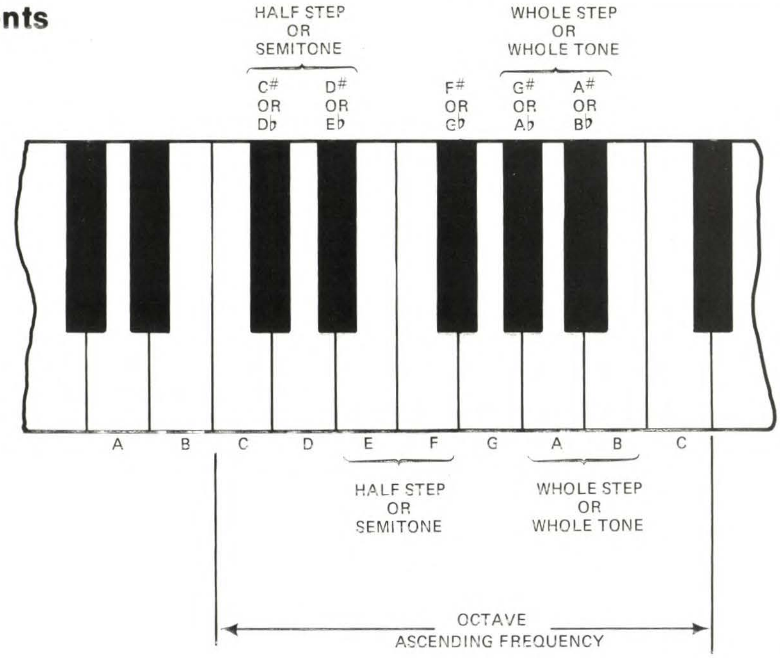


Fig 3—Adding binary dividers *between the oscillator and TOG produces octave-switchable outputs* ***(a)****. Placing the dividers on the TOG outputs makes all notes in all desired octaves available simultaneously* ***(b)****.*

Scales, spectra and common cents

David Ranada, Associate Editor



A section of a piano keyboard *illustrates the basic pitch relationship. Pitches separated by a frequency ratio of $2^{1/12}$ constitute a semitone or half step. Two adjacent semitones make up a whole step (with a frequency ratio of $2^{2/12}$). If the leftmost C were the one nearest the center of the keyboard (middle C), the A above it would have a frequency of 440 Hz.*

In Western music, the scale is based on the division of the octave (a 2:1 frequency ratio) into twelve relatively equally spaced pitches (logarithmically speaking). The equal-tempered system of tuning, predominant since the 18th century, has all pitches separated by the same ratio: $2^{1/12}$. With equal temperament, sharping a note (raising it a half step or semitone; ie, multiplying its frequency by $2^{1/12}$) is musically equivalent to flatting the note above it (dividing that note's frequency by $2^{1/12}$). (Not all systems of tuning, though, retain an audible equivalence between sharped and flatted notes.) Note that there are "natural" half steps between E and F and between B and C (see **figure**).

The frequency standard for musical pitches, promulgated only since the period between the two world wars, makes the A above middle C exactly equal 440 Hz; all other pitches can be derived from this standard. A top-octave generator, however, has no inherent pitch; it simply covers one octave. The octave you choose may start and end on any note at any frequency, depending on the master-oscillator frequency. By convention, however, musical octaves begin and end on Cs.

Almost all music concentrates its fundamental frequencies in the two octaves above and below middle C (261.62 Hz); remember this fact if you don't want your design to sound unnatural.

The musical spectrum of a complex tone is called its timbre. Each note produced by a nonelectronic instrument exhibits a characteristic growth and decay of the amplitudes of its harmonics in relation to each other during the note's first few milliseconds. Differences among these initial spectral fluctuations, more than the following steady-state portion of the note, enable listeners to tell musical instruments apart.

Electronic musical instruments generally have very simple initial spectrum fluctuations, if any. TOGs, being digital devices, usually output only square waves, which contain only odd harmonics (TOGs with non-50% duty cycles do contain some even harmonics, however). In contrast, all nonelectronic instruments generate some even harmonics. Thus, the lack of initial spectral fluctuations and of even harmonics makes imitating an instrument by processing TOG square waves extremely difficult.

To the piano tuner — and the tuner-machine maker—accuracy in tuning is measured in "cents." In this case, a cent divides a semitone into 100 logarithmically spaced increments. A deviation of ±3 cents from the correct pitch is considered barely tolerable; the best tuning machines should have errors below ±1 cent. You can determine how far off a frequency is in cents by using the equation

Deviation (in cents) = (1200/ log 2) (log (frequency ratio)).

A check of many of the TOGs' data sheets reveals that the published error specs are too low; keep this fact in mind. Also, when designing a piano-tuning instrument, include a provision for varying the master-oscillator frequency. All piano strings generate harmonics shifted in varying degrees from their "true" frequencies by the nonideal nature of the strings. Piano technicians compensate for this shift by tuning the harmonics and not the fundamentals. A piano that sounds "in tune" thus has deliberately mistuned fundamental frequencies.

trol. Command signals can come from a μP port or other digital device. With μP control, the software merely *controls* the tone by enabling and disabling it. This me+hod of μP control contrasts with conventional μP tone production, where the μP actually *generates* the tones by toggling an output bit at the note frequency, using software timing loops or software/hardware timers and interruots. Processor control of a TOG considerably reduces software overhead, especially if you desire simultaneous notes.

For chimes and annunciators, hardware sequencers can activate the tones in the required sequences and durations. One sequencing method uses a counter and PROM (**Fig 5**). Here, the counter steps slowly through the addresses of the PROM, whose output data bits then control the tones; different TOG tones are enabled each time the data lines change.

Obviously, PROM width (in bits) determines the number of tones that can be controlled simultaneously, while PROM length (in number of addresses) affects the complete sequence duration. Even a small PROM, though, can generate reasonably long tone sequences, because you can trade off sequence length against tone duration. A 2-Hz clock driving a ?2-word PROM, for example, produces a 16-sec sequence with notes 0.5 sec in duration. And a 512-word PROM driven by a 10-Hz clock generates a sequence 8 min and 32 sec long, yet notes remain controlled to 0.1 sec.

Because TOG square waves contain many odd harmonics, they might sound too "buzzy" for some applications. Filtering the outputs, however, makes a tone's timbre more natural sounding. If you are using only one octave, filtering is straightforward: A simple RC low-pass filter with a −3-dB point about an octave above the highest pitch suffices. Too much filtering, on the other hand, turns the square waves into sine waves, which sound very dull and lack crispness to the ear.

If your application requires more than two or three octaves, it's best to have a filter for each one. A single filter either cuts off too many of the higher frequencies' harmonics or allows too many of the lower frequencies harmonics to pass. Keep in mind that a piano's fundamental frequencies span a 27.5- to 4186-Hz range—7-1/2 octaves. Don't worry about phase shift in the filters; the human ear and brain are relatively insensitive (under many circumstances) to such shifts.

Simulating the sound spectrum (timbre) of a particular instrument presents a much more

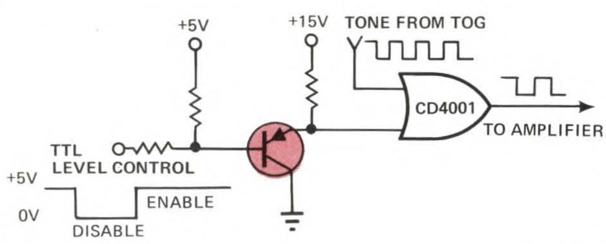


Fig 4—A level-shifting transistor *implements TTL-level control over the CMOS gate that enables and disables the TOG tone.*

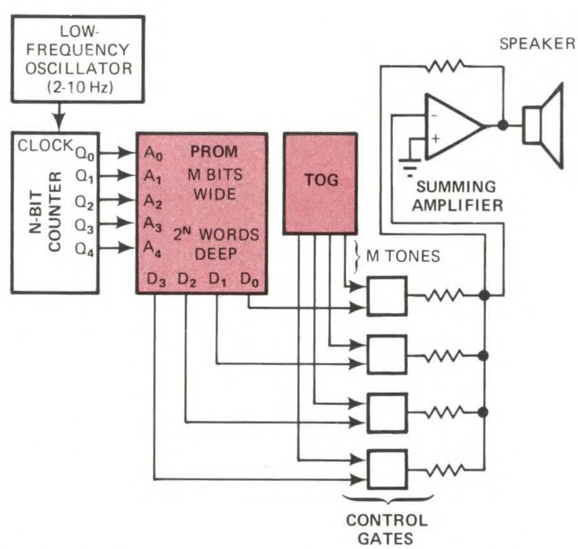


Fig 5—In a tone sequencer, *the PROM is cycled through its addresses, and its output bits control the TOG outputs. The PROM can generate any sequence and combination of tones.*

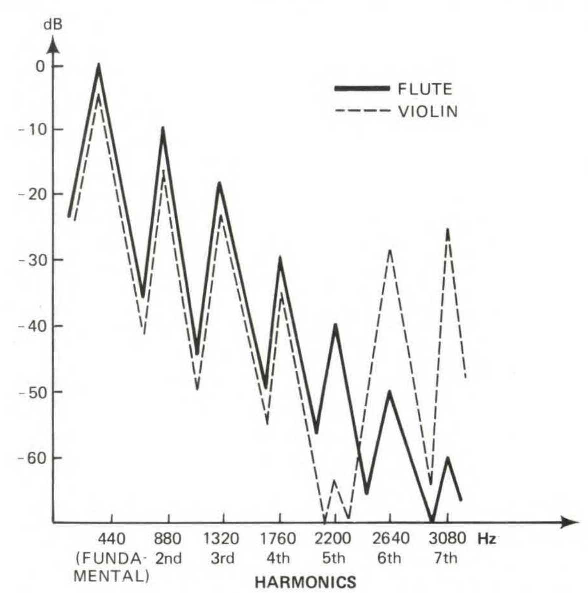


Fig 6—The differing harmonics *of the same fundamental tone (440 Hz) for a flute and a violin illustrate the difficulty involved in filtering TOG output to simulate a specific instrument.*

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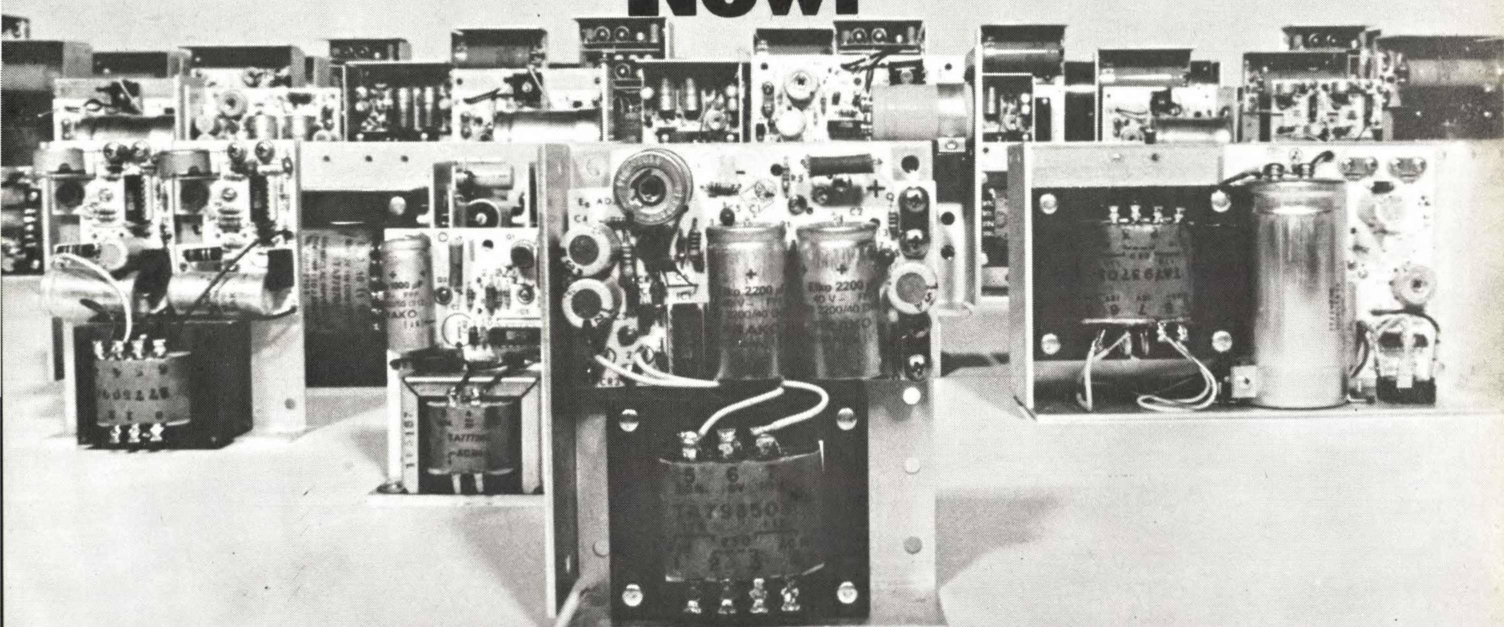

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ETA-515D	5V-6.0A or 6V-5.0A	15V-2.8A or 12V-3.0A
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ETR-142E	5V,6A or 6V,5A	12V,1.5A or 9V,1.2A or 5V,0.8A	12V,1.5A or 15V,1.3A
ETR-113E	5V,6A or6V,5A	5V,3A or 6V,2.5A	18V,1.0A or 20V,1.0A or 24V,1.0A
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	MM5556	7-2200	6	30%	0.51	-27, -14, -10	650	C# TO F#
	MM5832	7-2100	7	30%	1.16	-27, -14, -10	585	G TO C
	MM5833	7-2100	6	30%	1.16	-27, -14, -10	585	C# TO F#
	MM5891AA	100-2500	13	50%	1.16	-11 TO -16	560	5891AB WITH 30% DUTY CYCLE
GENERAL INSTRUMENT	AY-1-0212	250-1500	12	50%	1.16	-12 TO -16, -23 TO -28	750	
	AY-1-0212A	250-2500	12	50%	1.16	-12 TO -16, -23 TO -28	750	
	AY-3-0214	100-4500	12	50%	0.5	+10 TO +16	1.9W	HIGH ACCURACY
	AY-3-0215	100-4500	13	50%	1.16	+10 TO +16	1.9W	
	AY-3-0216	100-4500	13	30%	1.16	+10 TO +16	1.9W	
MOSTEK	MK50240	100-2500	13	50%	1.16	-11 TO -16	600	
	MK50241	100-2500	13	30%	1.16	-11 TO -16	600	
	MK50242	100-2500	12	50%	1.16	-11 TO -16	600	
AMI	550240	100-2500	13	50%	1.16	-11 TO -16	600	
	550241	100-2500	13	30%	1.16	-11 TO -16	600	
	550242	100-2500	12	50%	1.16	-11 TO -16	600	
	550243	100-800	13	50%	1.16	-11 TO -16	600	
	550244	100-800	13	30%	1.16	-11 TO -16	600	
	550245	100-800	12	50%	1.16	-11 TO -16	600	
SGS-ATES	M 087	15-2500	12	NA	1.16	-5, +5, -12	400	

The specifications on these TOGs *come from their manufacturers' data sheets.*

difficult challenge. Because of the different amplitudes of its harmonics, a flute note sounds very different from the same pitch on a violin (Fig 6). Note that for the flute, each harmonic's amplitude decreases about 10 dB from the preceding one. For the violin, the fifth harmonic is negligible, but the sixth and seventh harmonics are louder than the fourth. Piano spectra, incidentally, are extremely complex and difficult to recreate electronically. **EDN**

Author's biography

Bill Schweber, an engineer with Instron Corp, Canton, MA, designs μP-based controls for materials-testing equipment. He received a BS degree from Columbia University and an MS from the University of Massachusetts. Bill's hobbies include bicycling, photography and model railroading.

Article Interest Quotient (Circle One)
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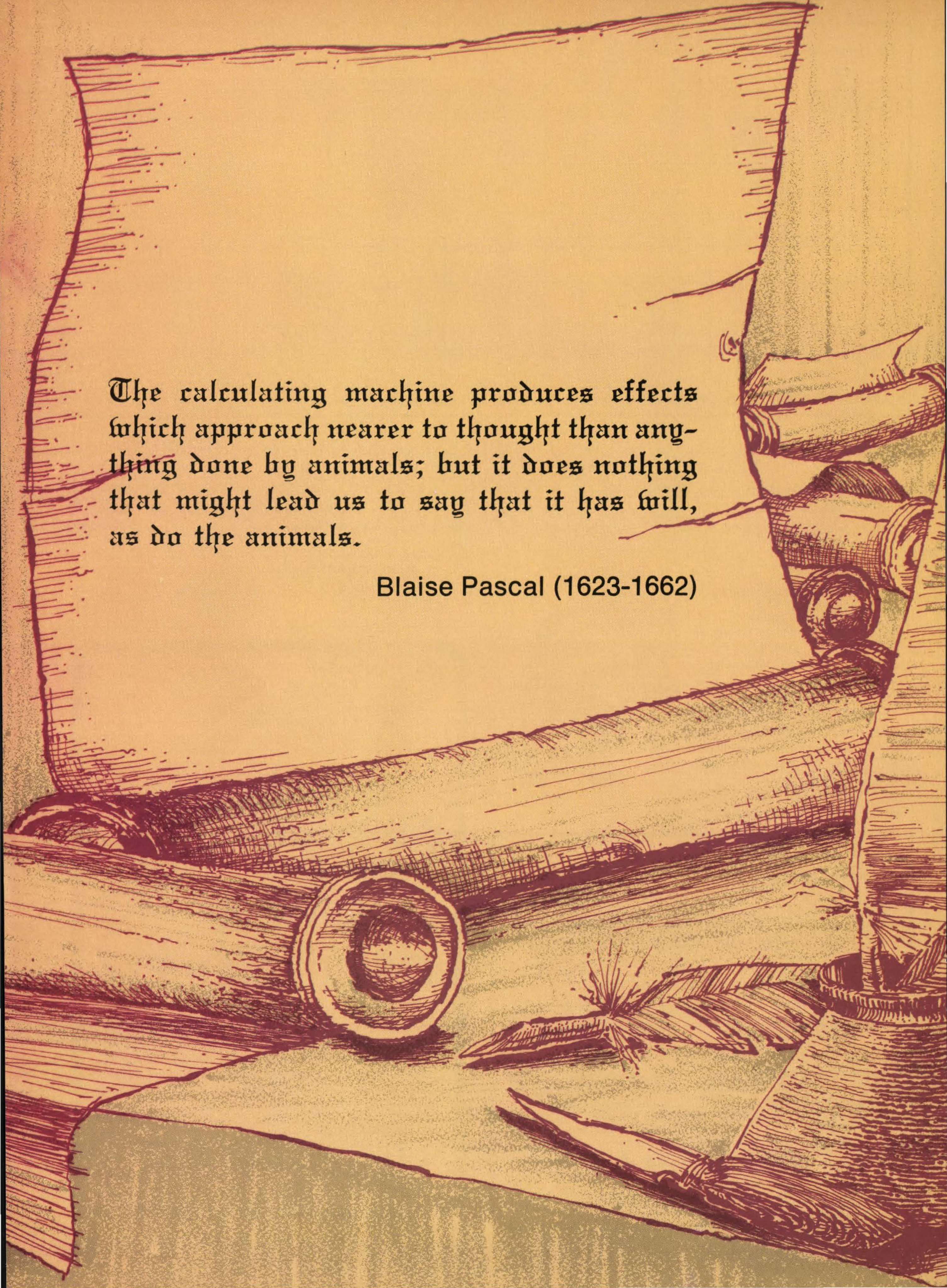

The calculating machine produces effects which approach nearer to thought than anything done by animals; but it does nothing that might lead us to say that it has will, as do the animals.

Blaise Pascal (1623-1662)

PASCAL

With origins in the academic world, PASCAL has now become the darling of commercial computer makers and users. Why this enthusiasm? And what can the language do for you?

Jack Hemenway and **Edward Teja**,
Associate Editors

In the rush to be the first into print with statements and comments about a new language, the obvious facts—what the language offers and what its disadvantages are—often get lost in the shuffle. Here we tune into a description of what PASCAL is, how it is implemented (including the differences of opinion among implementers) and what it offers to programmers.

Pascal wasn't a programmer

Niklaus Wirth drafted the first version of PASCAL in 1968; he designed it as a teaching tool and incorporated into it the valuable features of older languages. PASCAL grew out of the ALGOL family of languages and thus has proved easy to learn, highly readable and easy to compile. Today nearly every manufacturer of computers is either currently selling or promising future availability of a version of the language on its machines.

It's important to stress the words "a version," because there is no one "Version," or even a PASCAL standard. Despite the numerous descriptions extant, PASCAL is not yet officially defined.

In order of popularity, there are three possible standards. Industrial μC users and makers tend to favor the version being sold by the University of California at San Diego (UCSD)—largely because of its $200 price. Both the IEEE PASCAL Standards Committee and the ANSI X3J9 technical committee are considering a document presented to them by the International Standards Organization (ISO)—a document originated by a working group within the British Standards Institution (BSI) and spearheaded by A M Addyman of the University of Manchester. The third standard is simply a referral back to the Wirth book—all proposed versions seem to claim this historical link to some extent.

Nor is this the end of the confusion. UCSD endorses the BSI document as a definition of the basic language, yet not as a complete standard. The PASCAL User's Group (headquartered at the University of Minnesota) is pushing hard to have the BSI document adopted as it stands. And certain corporate representatives present at the recent ANSI meeting expressed serious reservations about letting "academics" such as Wirth and UCSD's Kenneth Bowles play any significant role in the serious matter of defining a commercial-language standard.

Making the world structured

The catch phrase for PASCAL is structured programming—in the sense of block structure in the style of ALGOL. The concept refers to the process of declaring identifiers inside a procedure or function that have no meaning outside that subprogram. Alternatively, identifiers declared outside a subprogram can generally be used inside it. The specific set of rules governing this process constitutes PASCAL's scope rules.

The PASCAL format thus supports

The PASCAL mania

Everywhere you look today, it seems as though there is another article on PASCAL; the interest in the language appears intense enough to classify it as a fad. Posters of Blaise Pascal decorate booths at computer shows; books by Niklaus Wirth and Kathleen Jensen, and more recently by Dr Kenneth Bowles of the University of California at San Diego, turn out to be their publishers' best-selling textbooks; Dr Bowles finds himself facing 350 students in this semester's PASCAL course.

In short, a language written to teach programmers how to program has become the rage outside academia. This Special Report helps resolve the resulting trauma and confusion.

Interpretive versions of PASCAL don't usually support interrupts

a responsive chord in the marketplace.)

Manufacturers find the PASCAL Microengine technique practical in one important respect—the PASCAL it implements is UCSD's; if the industry standardizes on another version, all Western Digital must do is alter the microcode to accommodate that version. An additional benefit arises directly from UCSD's incarnation of the language—the software package that provides the interpreter also furnishes a complete operating system, an editor and BASIC capability.

PASCAL versus disc systems

Lack of I/O capability represents PASCAL's major drawback. Because business-oriented I/O is given short shrift in computer-science classrooms, it accordingly receives similar treatment in the Jensen/Wirth draft. The emphasis in an "ideal" classroom language centers on teaching algorithms, rather than relating a program to its environment (peripherals). Thus, the language places little emphasis on random and indexed-sequential (ISAM) files—these are of serious concern to the commercial programmer and anyone with hopes of competing in a commercial setting.

On the other hand, available PASCAL compilers have given rise to controversy merely because they *attempt* to provide customers with a state-of-the-art I/O package; some PASCAL boosters shriek at any deviance from Jensen and Wirth.

However, the fact remains that Jensen and Wirth did not define adequate I/O capabilities for business applications, and adherents who wish to create a PASCAL standard must thus deal with a complete overhaul of the language's I/O package—which could mean creating extensions. UCSD's version, for example, furnishes both the

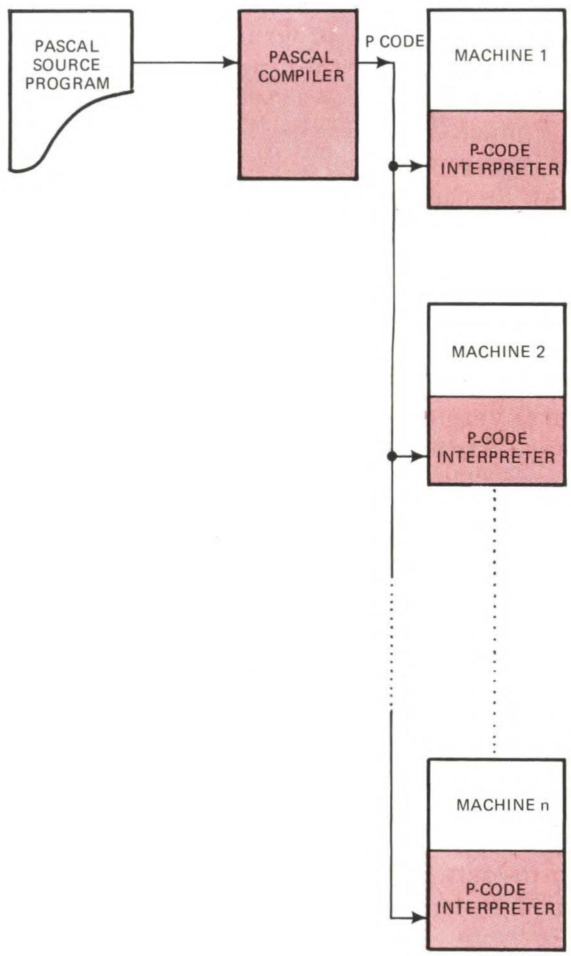

Fig 5—Portability across a range of processors *results from the practice of executing one PASCAL program (P code) on many different machines—interpreting the P code with each machine's own interpreter, which is written in each machine's native code.*

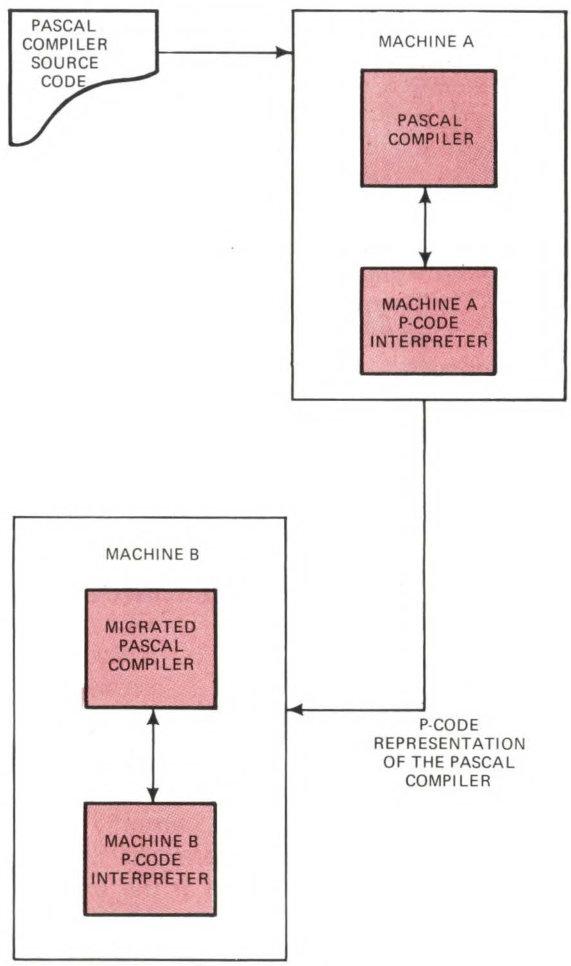

Fig 6—A PASCAL compiler is transferred to another machine *by compiling its source code on machine A, writing a P-code interpreter for machine B and loading the P code produced by machine A into machine B. The remaining system software running on machine A transfers to machine B in the same manner.*

Jensen/Wirth tape-I/O capability and extensions to provide disc I/O; the operating system assumes that I/O is disc-based unless the operator specifies otherwise. According to UCSD's Dr Bowles, this procedure, although it accommodates the commercial user's day-to-day applications, is frowned upon by language purists.

In any event, the question of I/O must be resolved before use of the language makes any sense in a real-world computer system. When you're evaluating various PASCAL compilers, this capability (or the lack of it) can be a good starting point.

PASCAL escalation escalates

And so PASCAL expands its influence. This year alone, Apple Computer, Cromemco and Heath, to name a few firms, will add UCSD PASCAL to their offerings. Responding to market pressure, Intel intends to produce a PASCAL compiler for the 8086, although the firm is also maintaining a definite commitment to PL/M. Furthermore, rumor has it that a UCSD-based compiler will appear on Intel's Intellec system, running under ISIS. Finally, National Semiconductor talks of making PASCAL an in-house standard. In many companies, it already is—standard version or no. **EDN**

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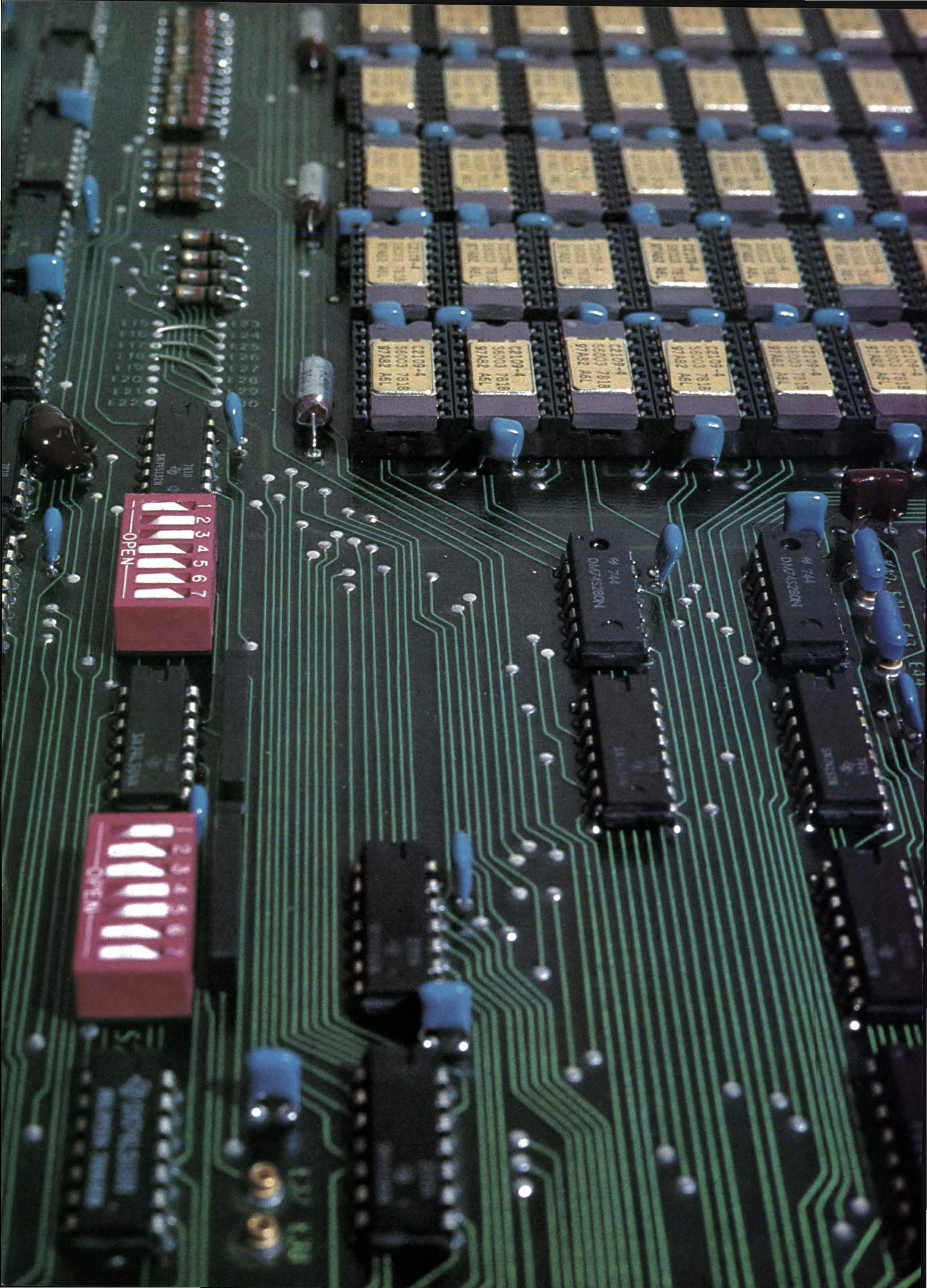

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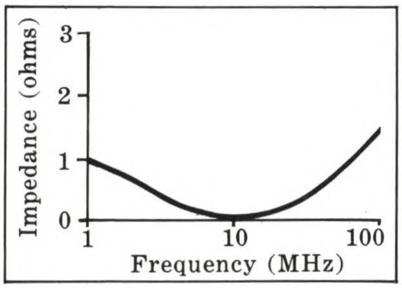

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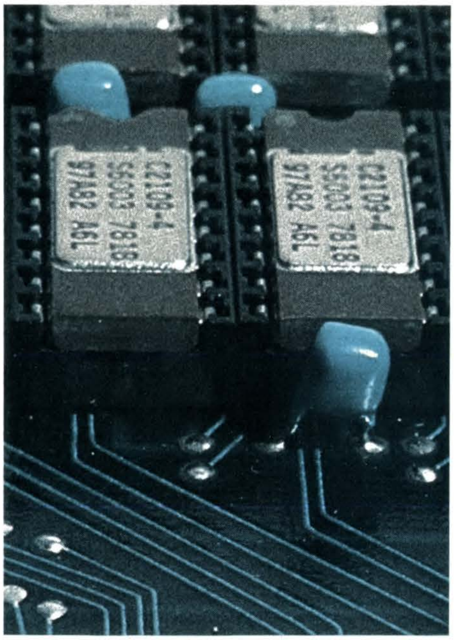

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Measure switcher efficiency without a wattmeter

Although switching power supplies draw pulsed ac currents, you don't need a wattmeter to measure their efficiency. But use of that instrument does yield the most accurate results.

Jeff Wolking, Hewlett-Packard Co

With a dual-trace oscilloscope and a programmable calculator, you can measure the efficiency of a switching power supply to within 8% of the more accurate value obtainable with a wattmeter. And if you're willing to sacrifice even more accuracy for greater convenience, use of a dual-trace scope alone yields results between +5% and −20% of the wattmeter's reading.

The ability to measure power-supply efficiency—and thus optimize it—grows more important as electric utility rates increase. But the measurement task isn't necessarily easy, particularly for switchers. A look at the basics of switching-supply operation reveals why.

Understanding power and efficiency

Power-supply efficiency equals dc output power divided by ac average input power. The latter quantity, in turn, is the time average of the product of instantaneous voltage and current:

$$P_{AVG} = \frac{1}{T}\int_0^T v(t)i(t)dt. \quad (1)$$

Here T is the voltage (or current) waveform period, and v(t) and i(t) are the instantaneous voltage and current magnitudes, respectively. You'll sometimes see average power termed "active" or "real" power.

Another way to calculate average power is to use

$$P_{AVG} = V_{rms} \times I_{rms} \times F_p \quad (2)$$

where V_{rms} and I_{rms} are the root-mean-square values of voltage and current, and F_p is the power factor. For sinusoidal voltage and current, F_p is the cosine of the phase angle between the voltage and current waveforms. The quantity $V_{rms} \times I_{rms}$ is sometimes termed "apparent" power. Unfortunately, though, because switching supplies draw nonsinusoidal input currents, the concept of a simple phase angle is inappropriate.

For the conventional switching regulator diagrammed in **Fig 1**, the ideal input current (**Fig 1b**) instantaneously rises to its maximum value, then decreases cosinusoidally. RFI filters (not shown) and power-line impedance modify this idealization; the actual waveforms appear as in **Fig 1c.**

In a switcher incorporating preregulation (**Fig 2**), the preregulator triac maintains relatively constant voltage across the energy-storage capacitor. This technique simplifies the design of the main regulating control loop but can increase overall power-supply cost. The input current for such a preregulated supply is a combination of sinusoidal and ramp functions.

Measuring efficiency two ways

Fig 3 illustrates the easiest and most accurate way to determine a power supply's efficiency: Measure dc output current and voltage with a DVM, then measure ac input power directly with a wattmeter and calculate the necessary ratio. Conventional electrodynamic wattmeters work well in this application, although the need for increased accuracy could require instruments more responsive to the low power factors and sharp, nonsinusoidal current pulses associated with switchers. Comparison measurements for this article were made with a Bell HPM-501, which capitalizes on the Hall effect to provide voltage-current multiplication and makes power measurements sufficient to determine efficiency to within ±4%.

It's hard to calculate apparent power for a switcher

A second approach permits estimation of ac input power with a dual-trace oscilloscope and a programmable calculator. Arrange the equipment as shown in **Fig 4**, and simultaneously display current and voltage on the oscilloscope as shown in **Fig 5**. Then, from the scope traces, you can directly read values for instantaneous voltage and current. An HP-67/97 calculator program (**Fig 6**) then multiplies and time-averages these values (by using **Eq 1**), producing an estimate of average power. The following list summarizes the approach:

- Enter the program into the calculator.
- Connect the power-supply output to a load of sufficient capacity to operate the supply at the desired output. Realize that efficiency varies with load and line conditions.
- Display both the voltage and current waveforms on the scope. (Use a current shunt,

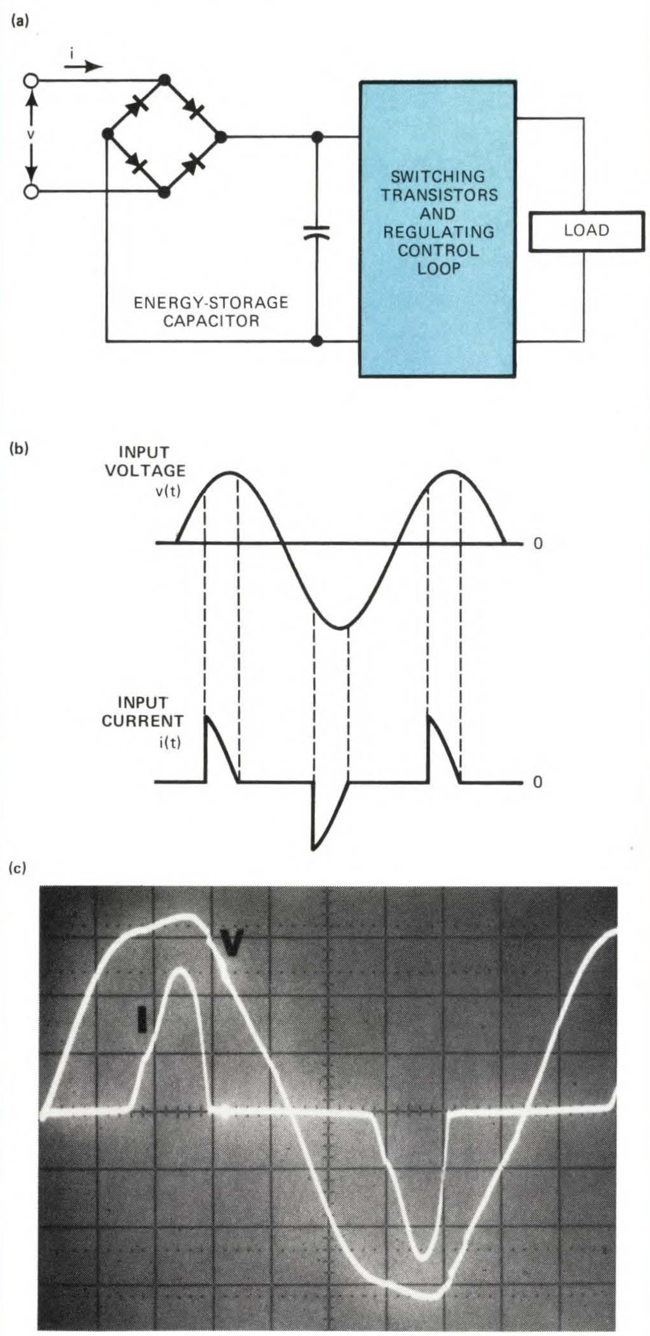


Fig 1—A conventional switching supply (a) *draws pulsed ac input currents. The actual current* ***(c)*** *differs from the ideal or expected current* ***(b)*** *because of power-line and RFI-filter impedances not shown in the diagram.*

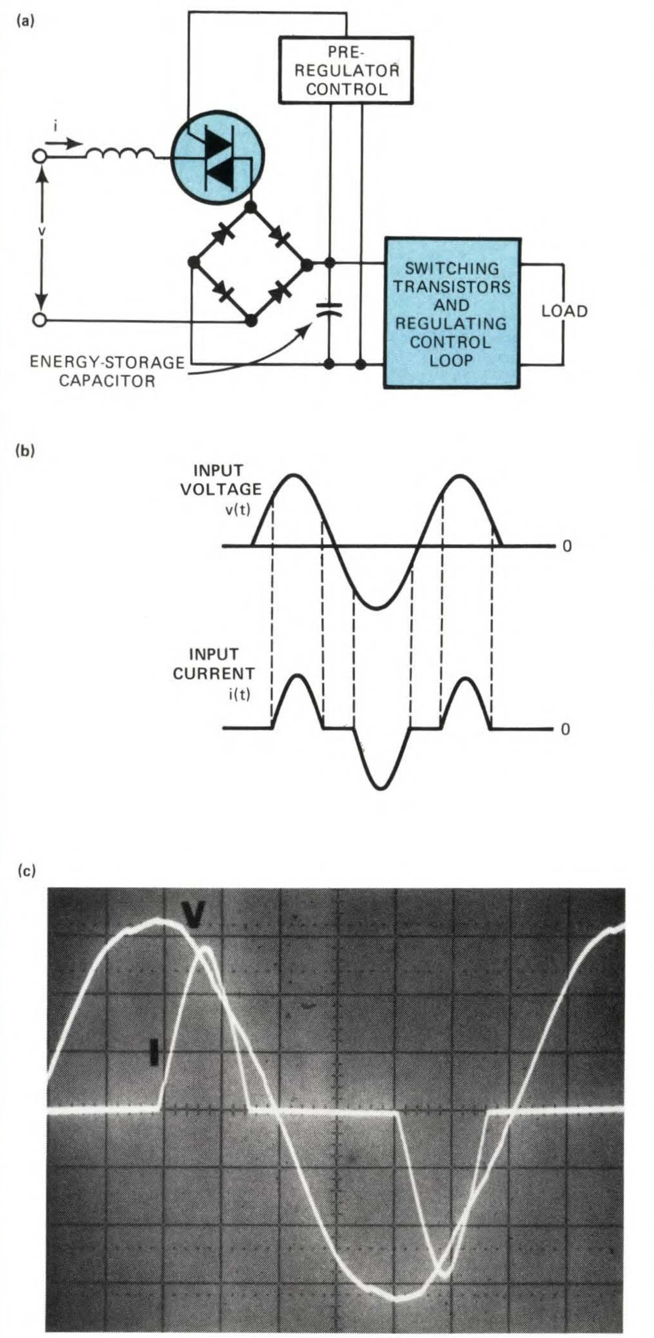


Fig 2—The preregulator triac *in a preregulated switcher* ***(a)*** *maintains relatively constant voltage across the energy-storage capacitor. Expected* ***(b)*** *and actual* ***(c)*** *input waveforms differ.*

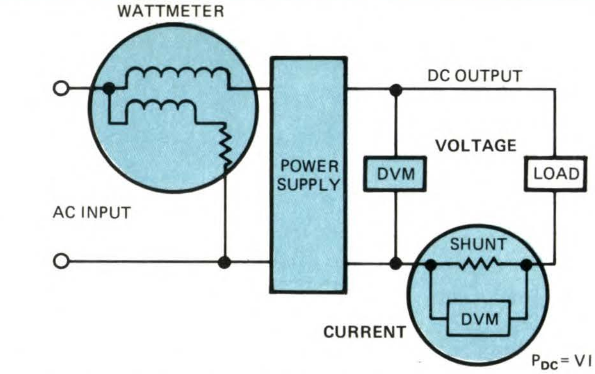


Fig 3—Calculate power-supply efficiency *by dividing dc output power by ac input power. You can measure the former quantity with a DVM and the latter with a wattmeter.*

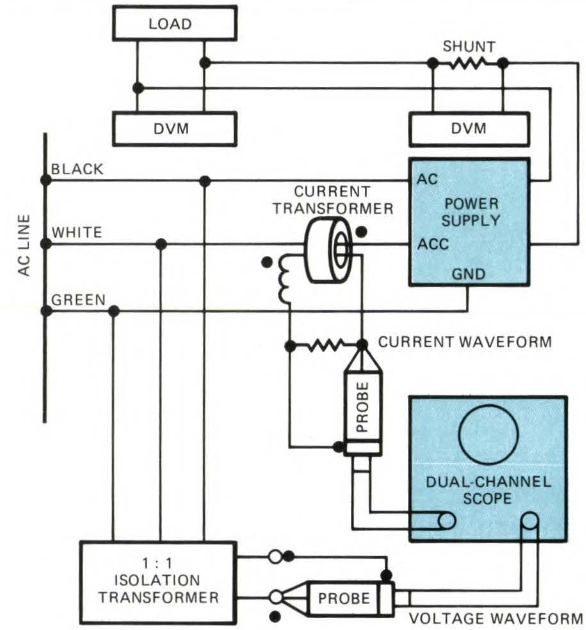


Fig 4—A dual-channel scope *forms the basis of a measurement technique that doesn't require a wattmeter.*

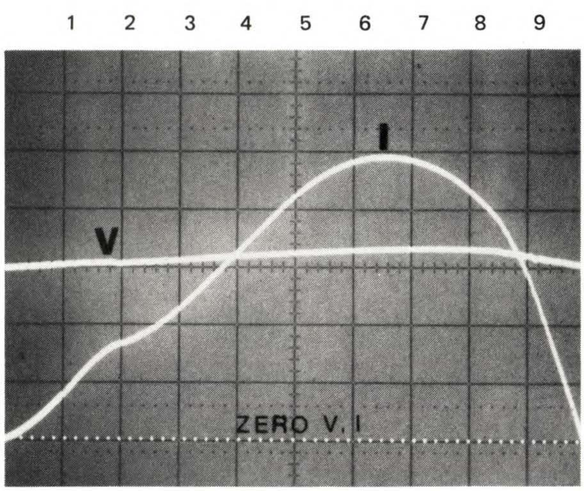
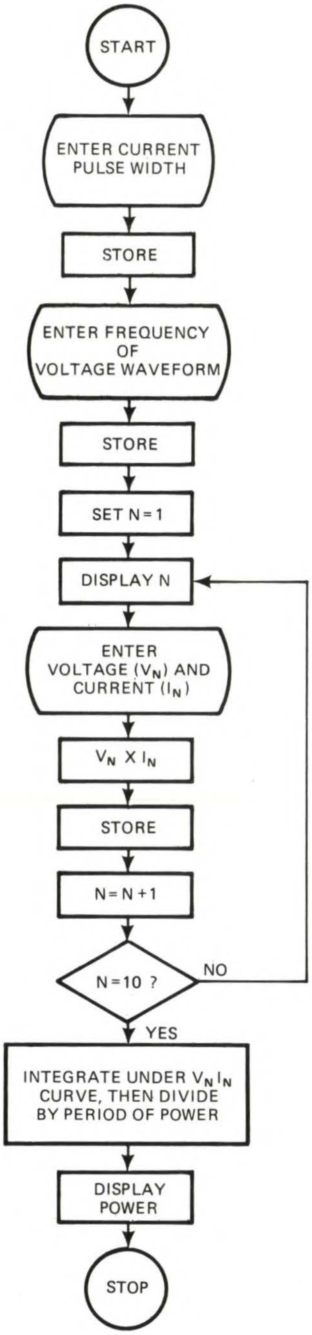


Fig 5—For the oscilloscope + calculator measurement approach, *determine corresponding voltages and currents at nine points along their waveforms.*

(a)



(b)

```
001  *LBLA     21 11
002   CLRG     16-53
003    CF2  16 22 02
004   STO1     35 01
005      9        09
006    CHS       -22
007    X⇄I     16-41
008    RTN        24
009  *LBLC     21 13
010      x       -35
011    F2?  16 23 02
012   GTOa  22 16 11
013    SF2  16 21 02
014      2        02
015      x       -35
016  *LBLa  21 16 11
017      2        02
018      x       -35
019   ST+3  35-55 03
020   ISZI  16 26 46
021   GTOb  22 16 12
022   RCL3     36 03
023   RCL1     36 01
024      x       -35
025   RCL2     36 02
026      x       -35
027      3        03
028      0        00
029      ÷       -24
030    SPC     16-11
031   PRTX       -14
032    RTN        24
033  *LBLb  21 16 12
034   RCLI     36 46
035      1        01
036      0        00
037      +       -55
038    SPC     16-11
039   PRTX       -14
040    RTN        24
041  *LBLB     21 12
042      2        02
043      x       -35
044   STO2     35 02
045      1        01
046    SPC     16-11
047   PRTX       -14
048    RTN        24
049    R/S        51
```

Fig 6—Enter the voltage and current values obtained via Fig 5's scheme *into this HP-67/HP-97 program to obtain average power. For the HP-67, delete steps 30, 31, 38, 39, 46 and 47.*

Display voltage and current, then use measured values to get P_{AVG}

probe, etc, for the current waveform.

- Measure the current pulse's width. Enter this value (in seconds) into the calculator, then press key A.
- Measure the frequency of the voltage waveform. Enter this value (in Hertz) into the calculator, then press key B.
- Expand the waveforms across the scope screen so that the current pulse is exactly 10 div wide (**Fig 5**). Adjust the waveform amplitudes so you can easily measure them simultaneously.
- Record nine corresponding voltage and current measurements at equal time intervals. Note that each pair of readings corresponds to the intersection of the I and V traces with a major vertical division on the scope screen. (These divisions are labeled 1 to 9 in **Fig 5**.)
- Enter the voltage and current readings into the calculator as follows (voltage in volts, current in amps):

Item / Press /	Item / Press /		Calculator Displays
$Volts_1$ ENTER	$amps_1$	C	2
$Volts_2$ ENTER	$amps_2$	C	3
...continue...			4-9
$Volts_9$ ENTER	$amps_9$	C	Power (watts).

After you enter the ninth voltage and current pair, the calculator displays the average input power.

To calculate efficiency, measure the dc output power with a DVM, then compute:

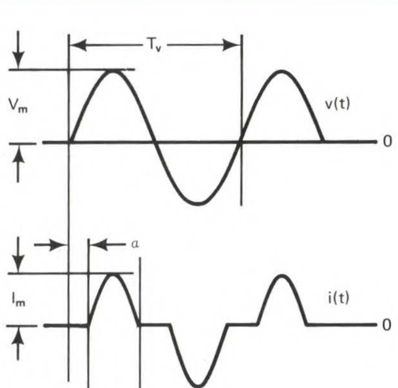


Fig 7—You won't even need a calculator *if you approximate the input waveforms as sine waves. Use of* ***Figs 8a*** *and* ***8b*** *then permits graphical estimation of average power.*

$$\text{EFFICIENCY} = \frac{\text{OUTPUT POWER}}{\text{INPUT POWER}} \times 100\%. \quad \textbf{(3)}$$

A third—less accurate—approach

Another technique for estimating ac average input power requires only a dual-trace oscilloscope. A re-examination of **Figs 1** and **2** reveals that both the voltage and current waveforms appear approximately sinusoidal when the current is nonzero. You can estimate power, then, by using sine waves to represent both current and voltage **(Fig 7)**. You then calculate average power by averaging the current-voltage product over the voltage's period. This double sine-wave procedure is equivalent to integrating the current-voltage product over only a half cycle of the sine approximation of the current (the current is zero elsewhere), then dividing the result by half the voltage-waveform period.

Let

$$i = I_m \sin\left(\frac{2\pi}{2T_p}t\right),\ 0 < t < T_p \quad \textbf{(4)}$$

and

$$v = V_m \sin\left(\frac{2\pi}{T_v}t + \frac{2\pi\alpha}{T_v}\right) \quad \textbf{(5)}$$

where I_m and V_m are the current and voltage maxima. The quantity $2\pi\alpha/T_v$ is the phase difference between the voltage and current half sine waves (see **Fig 7**); T_p defines the current pulse width and T_v the voltage-waveform period, both in seconds. Recall that the average-power calculation comes from **Eq 1**; substituting **Eqs 4** and **5** into **Eq 1** produces

$$P_{AVG} = \frac{V_m I_m}{T_v/2}\int_0^{T_p} \sin\left(\frac{\pi}{T_p}t\right)\sin\left(\frac{2\pi}{T_v}t + \frac{2\pi\alpha}{T_v}\right)dt. \quad \textbf{(6)}$$

Remember, despite the fact that you average over a time interval of length $T_v/2$, you need only integrate from $t=0$ to $t=T_p$ because i is zero elsewhere.

The integral in **Eq 6** is of the form

$$\int \sin(ax)\sin(cx+d)\,dx = \frac{\sin[(a-c)x-d]}{2(a-c)} - \frac{\sin[(a+c)x+d]}{2(a+c)}, \quad \textbf{(7)}$$

where $a^2 \neq c^2$. Thus,

$$P_{AVG} = V_m I_m \left[\frac{\sin\left[\left(\frac{\pi}{T_p}-\frac{2\pi}{T_v}\right)t - \frac{2\pi\alpha}{T_v}\right]}{\left(\frac{\pi}{T_p}-\frac{2\pi}{T_v}\right)T_v} - \frac{\sin\left[\left(\frac{\pi}{T_p}+\frac{2\pi}{T_v}\right)t + \frac{2\pi\alpha}{T_v}\right]}{\left(\frac{\pi}{T_p}+\frac{2\pi}{T_v}\right)T_v}\right]\Bigg|_{t=0}^{t=T_p} \quad (8)$$

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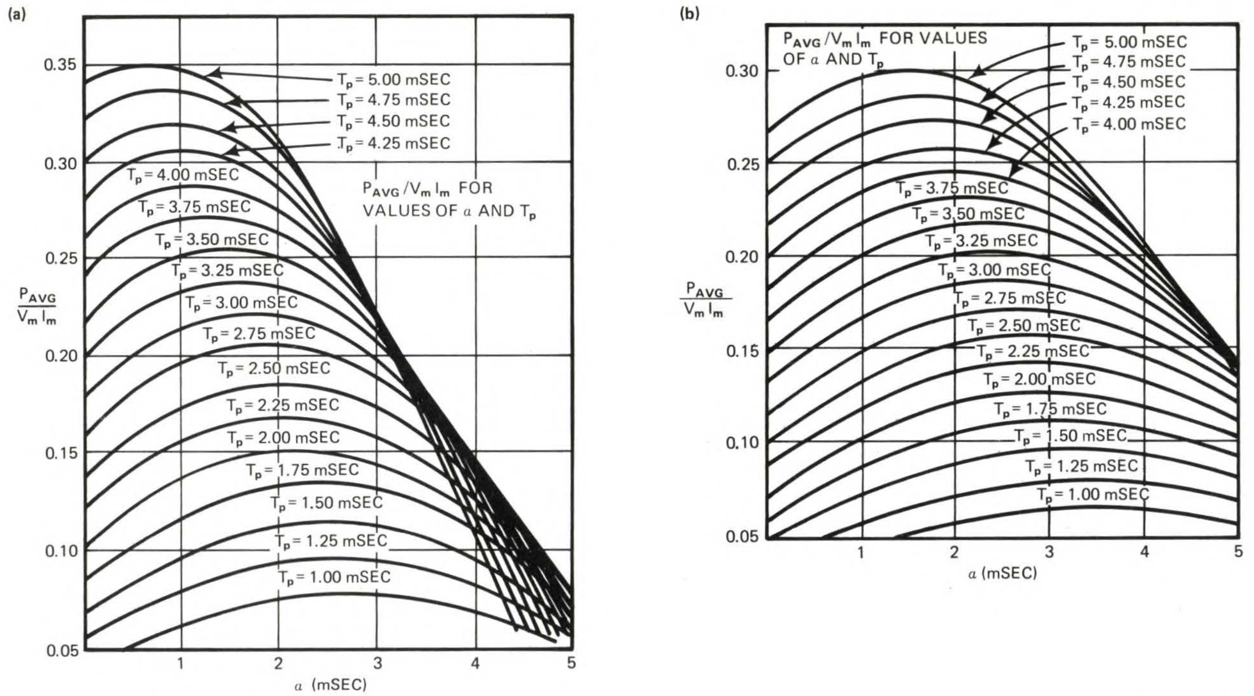
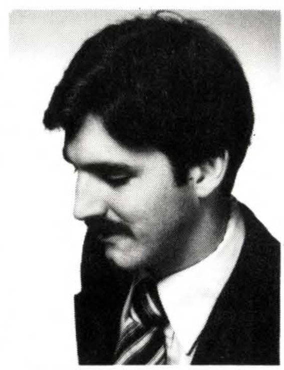


Fig 8—Determine the input waveform parameters *V_m, I_m, T_p, α and T_v from* ***Fig 7****, then estimate average power directly from these graphs. Graph* ***(a)*** *applies to 60-Hz power-line frequencies;* ***(b)****, to 50-Hz cases.*

You can measure V_m, I_m, T_p, α and T_v using the equipment setup shown in **Fig 4**. Find average power directly from **Eq 8**, or alternatively, find the value P_{AVG}/V_mI_m from either **Fig 8a** or **Fig 8b** and multiply that value by V_m and I_m. (Note that the ratio P_{AVG}/V_mI_m on the vertical axes of **Figs 8a** and **8b** is not the power factor (**Eq 2**) because V_m and I_m are peak, not rms, values.) **Figs 8a** and **8b** are derived, of course, from **Eq 8**. The first applies to 60-Hz power-line frequencies ($1/T_v = 60$ Hz); the second, to 50-Hz cases. **EDN**

Author's biography



Jeff Wolking is currently pursuing his MBA degree at the Wharton School. He wrote this article while working as a summer employee in the marketing department of Hewlett-Packard's Rockaway, NJ facility. Jeff earned a BSEE at the Univ of Calif at Irvine and hopes to complete his MBA this May; he has also spent 2 yrs with Rockwell International, working on secure systems and VLF communications. Jeff enjoys tennis, swimming and oenology in his free time.

Article Interest Quotient (Circle One)

High **482** ***Medium*** **483** ***Low*** **484**

Synchronous static CMOS RAMs increase system performance

It's a challenge to design a RAM array with synchronous memories, but an ever-increasing number of μCs can benefit from their use.

Charles Hochstedler, Harris Corp

Synchronous RAMs offer faster access times, lower power dissipation and easier common-bus interfacing than equivalent asynchronous designs. But effectively utilizing these devices in your memory system requires understanding how they operate.

A synchronous RAM derives its name from the fact that the chip-enable signal synchronizes the memory's internal operations with external-system timing demands (**Fig 1**). Because access is initiated by this signal's falling edge, a synchronous RAM's access time is usually 30 to 40% faster than that of an equivalent asynchronous device. Additionally, a synchronous RAM uses the chip-enable HIGH time before every access to prepare itself by presetting (or precharging) the condition of key internal nodes—an operation that allows you to optimize the condition of critical timing paths to ensure the fastest possible access.

By contrast, an asynchronous RAM has no signal available to indicate that an access operation is about to begin. And no precharging operations are possible because the chip-select signal can remain LOW throughout many successive cycles.

Note that synchronous memory operation (often called clocked operation) is not identical to dynamic-memory refresh. Synchronous static memory utilizes the common 6-transistor, fully static, latch-type cell; chip enable is used to increase performance, not to refresh data.

Easier on the draw, too

Lower operating power than asynchronous devices is a second major benefit afforded by synchronous techniques—a comparison that's valid, of course, only between RAMs using identical technologies. (You can't compare the power dissipation of CMOS units with that of NMOS devices.)

Because in synchronous CMOS designs, power consumption becomes a function of the frequency of repetitive accessing plus a small leakage current, the memory consumes power only when it is in active use. It consequently conserves

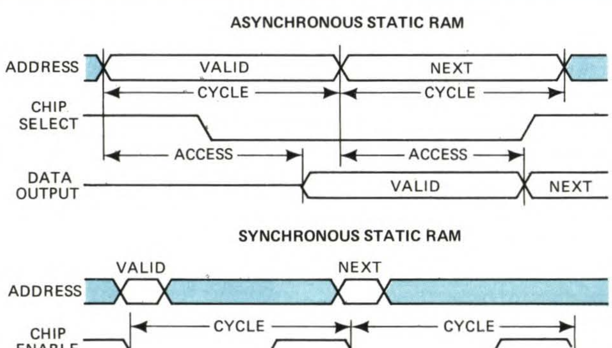


Fig 1—A marked difference in access time *appears in these timing diagrams for typical RAM devices. In addition to exhibiting faster access, the synchronous RAM has less stringent requirements for maintaining valid address inputs.*

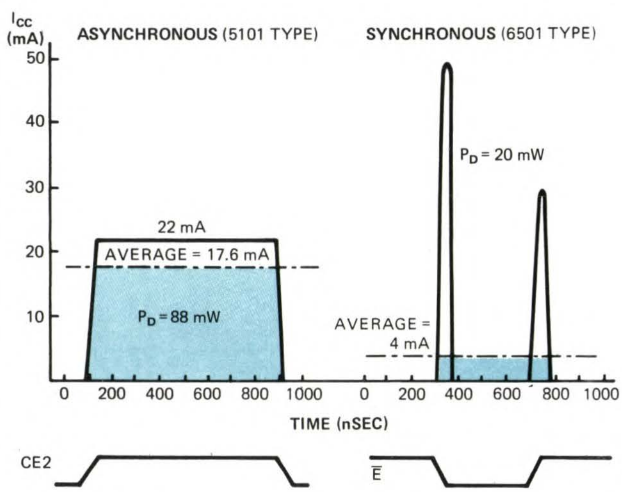


Fig 2—Average power dissipation *is dramatically lower in synchronous RAMs than in equivalent asynchronous memories, despite the fact that peak current demands are much higher.*

Power is lower, even though peak current is higher

power when not being accessed. In contrast, an asynchronous CMOS RAM requires dc current paths and consumes power whenever enabled.

Fig 2 charts the relationship between chip-enable waveforms and supply current for two pin-compatible devices—one synchronous, the other asynchronous. As shown, the synchronous 6501 draws a higher peak current. However, these peaks are so narrow that the asynchronous 5101 has more than four times the power dissipation. The **table** summarizes the speed and power specifications for both standard and prime grades of the 5101 and 6501.

Multiplexed bus structures made easy

The differences in RAM addressing between synchronous and asynchronous units highlight another point in favor of synchronous memories. Because these units require such a short valid-address time, it's easy to implement common address, data-in and data-out bus systems using them. And because in a synchronous-RAM array, valid data output need not be timed to coincide with valid address information, address information and data do not overlap, and it's easy to multiplex these signals on a single bus.

Although at first glance, this type of multiplexed bus structure appears a bit complex, many μP manufacturers are using it to keep pin counts at a reasonable level. And as more μPs appear with common address and data-bus structures, the usefulness of synchronous RAMs with internal address latches will increase. **EDN**

SPEED AND POWER COMPARISONS FOR CMOS STATIC RAMs

	ASYNCHRONOUS 5101[1]		SYNCHRONOUS 6501	
	STANDARD	PRIME	STANDARD	PRIME
MAXIMUM ACCESS (nSEC)	650	450	300	220
MINIMUM CYCLE (nSEC)	650	450	400	320
MAXIMUM STANDBY (μA)	200	10	100	10
MAXIMUM OPERATING (mA)[2]	22	22	4	4
TYPICAL ACCESS (nSEC)[3]	–	–	160	120
TYPICAL CYCLE (nSEC)[3]	–	–	210	170
TYPICAL STANDBY (μA)[3]	–	–	1	0.1
TYPICAL OPERATING (mA)[3]	9	9	1.5	1.5

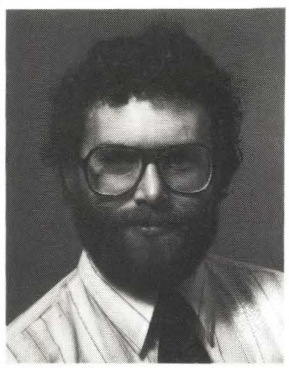
NOTES
(1) 5101 SPECIFICATIONS FROM 1978 INTEL DATA CATALOG
(2) SYNCHRONOUS OPERATING CURRENT SPECIFIED AT REPETITIVE ACCESS RATE OF 1 MHz
(3) TYPICAL PARAMETERS SPECIFIED AT 25°C, 5V

Defining some terms

When using a conventional asynchronous RAM, you must hold its address inputs valid throughout a read or write cycle; this address, together with the device selected, defines the cycle time. If necessary, you can reaccess the RAM while still in this initial select mode.

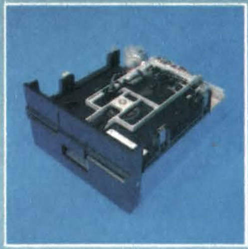
With a synchronous static RAM, on the other hand, you only need a valid address for a short time at the beginning of a cycle. However, cycle initiation requires an edge or transition of the chip-enable signal. Additionally, a finite period of time occurs after access, during which the device must be disabled before the next cycle can begin.

Author's biography



Charles Hochstedler is a memory-applications engineer at Harris' Semiconductor Products Div, Melbourne, FL, where he provides customer applications support and generates information for data sheets and application notes. Charles earned his BS degree in electrical engineering technology at Purdue Univ. His spare-time interests include personal computing, sailing and chess.

Article Interest Quotient (Circle One)
***High* 479 *Medium* 480 *Low* 481**



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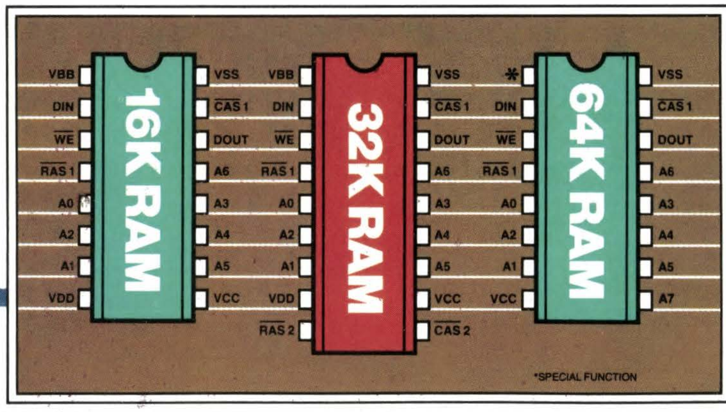

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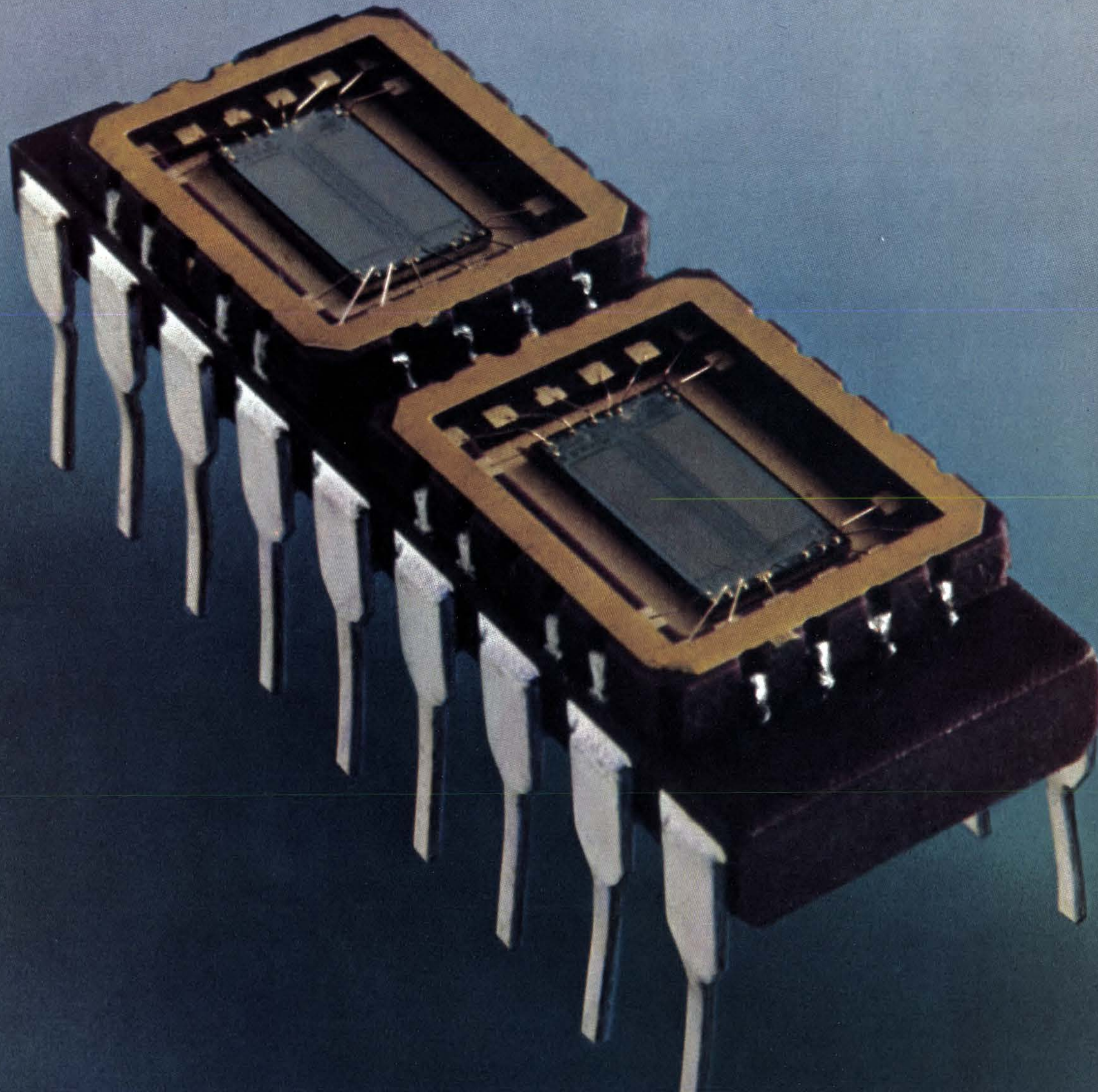

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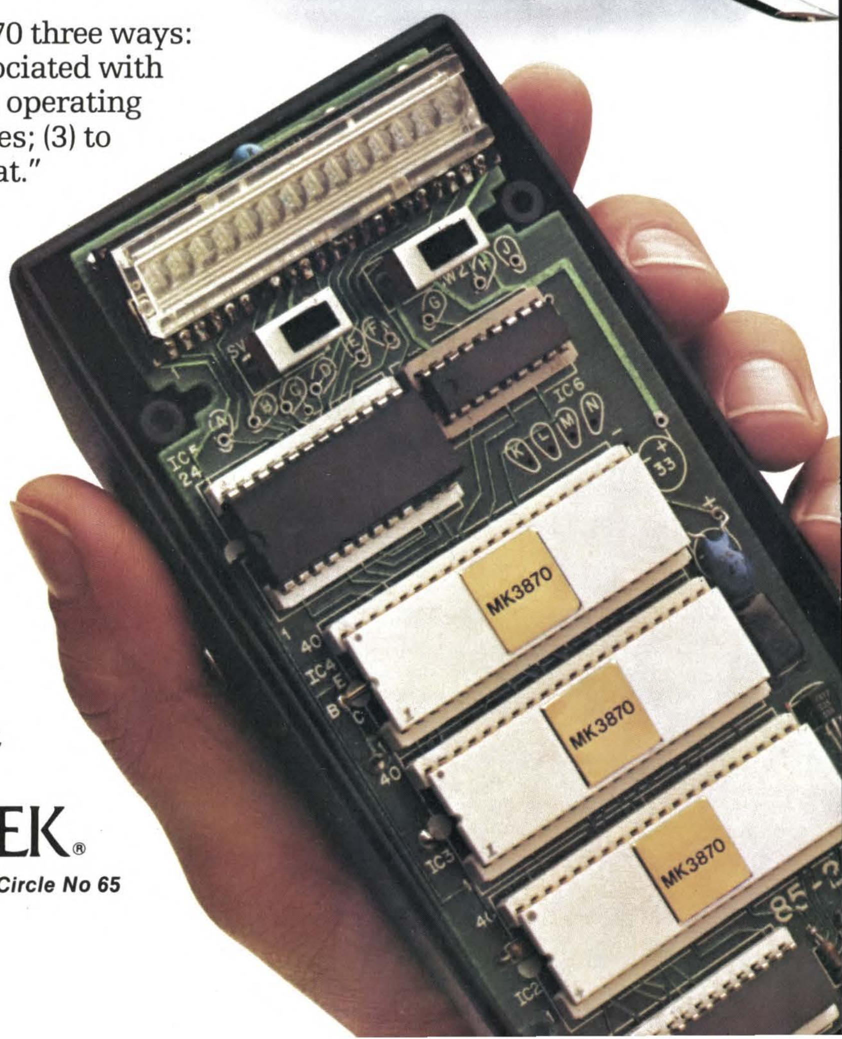

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Learn the peculiarities of low-end-µC architectures

The odd architectures and instruction sets of low-end, calculator-based 1-chip µCs are very cost effective—if you know how to take advantage of them.

Robert H Cushman, Special Features Editor

Because they have so many curious features, today's calculator-like 1-chip µCs demand more individual study than their minicomputer-like, midrange-µP relatives—a realization that grew clearer when we began research for the article originally scheduled for this issue. The advantages of using these versatile low-end devices are lost without adequate groundwork; underestimating the amount of groundwork required can be fatal. And so we have postponed that article—describing an industrial-control application of the National Semiconductor COP402 emulator—until next time. Here we focus on delving more deeply into the architectures and instruction sets of today's low-end 1-chip µCs.

As in previous articles (**Refs 1** and **2**) we'll focus on the Texas Instruments TMS-1000, Rockwell PPS-4/1, National COP400 and AMI S2000. These families are described in capsule form in EDN's annual µP Directory (**Ref 3**), which also lists two Japanese 1-chip-µC families (NEC's µCOM-43 and Panasonic's MN1400) belonging to this calculator-derived category. To a lesser degree, some of the other low-end 1-chip µCs—the Intel 8048, General Instrument PIC1650 and Zilog Z8, for example—have similar features.

Split architectures are the rule

The most obvious architectural feature of the calculator-derived µCs is the way they are split into three distinct parts: program ROM, data RAM and I/O (**Fig 1**). From the perspective of computer history, these split-up organizations would appear to be throwbacks to the early "Harvard" architectures—the opposite of the

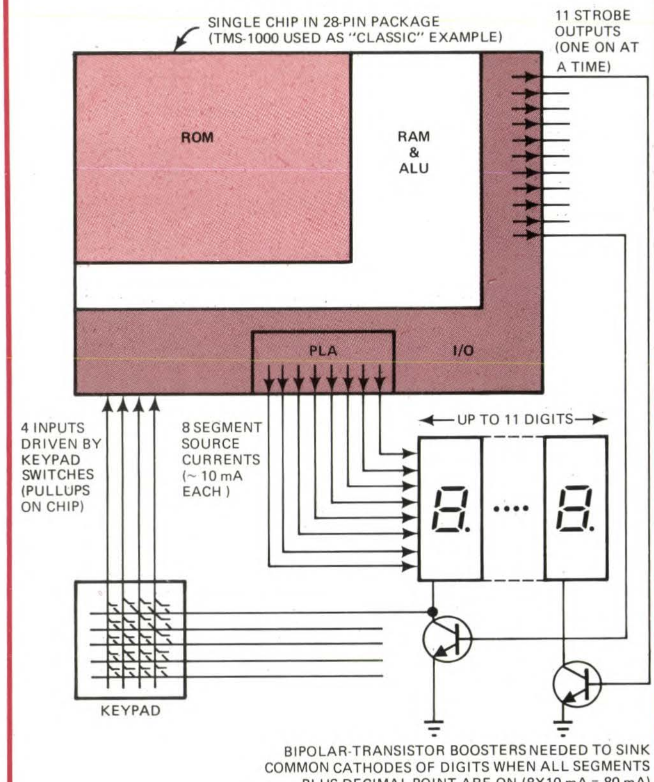


Fig 1—In a typical calculator system, *there is ideally only one semiconductor device: the LSI "µC" itself. Internally, this device divides into three subsystems—program ROM, data RAM and I/O. Externally, the I/O interfaces as directly as possible with a numeric keypad input and a multidigit 7-segment-plus-decimal-point display. Multiplexing via strobe outputs from the LSI device saves pins—an approach that's possible despite the slow clock speeds because the system is used by a human operator. Except when the tiniest LED displays are used, external transistors must sink the displays' common cathodes.*

Low-end 1-chippers optimize RAM, ROM and I/O separately

now-prevailing "Princeton" configurations, in which program and data (and often also I/O) share a common memory space.

A compelling reason for adopting the single memory space of Princeton architectures is that with it, one instruction set can apply uniformly to program, data and I/O. The programmer can freely merge these subsystems in a sophisticated, fluid manner, and the single instruction set is supposedly easier to remember and troubleshoot. Indeed, the advance sales publicity for the forthcoming Z8000 and 68000 "super μPs" has been extolling the benefits of the uniform instruction sets resulting from "clean" Princeton architecture.

As **Fig 2** shows, though, there isn't enough spare silicon in the tiny low-end 1-chip μCs to permit the luxury of treating their subsystems identically. Instead, each subsystem is optimized separately to perform its special tasks without forcing design compromises in the name of uniformity. In fact, the different addressing-register reaches, word widths and circuit performances of the three sections *preclude* uniformity.

The architectural differences in the ROM, RAM and I/O sections in turn are responsible for their instruction-set differences. And before you compare these differences unfavorably with the uniformity prevailing at the higher end of the μP spectrum, we suggest you first examine how much they can contribute to end-product cost effectiveness.

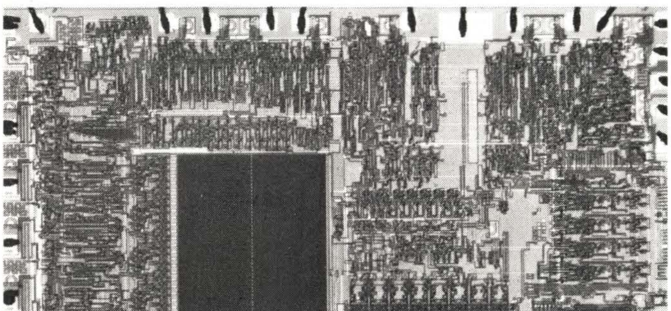


Fig 2—In the latest addition *to AMI's S2000 family—the S2150—ROM and RAM are easily recognized, as are the large I/O devices around the edge. The original S2000 chip measures 162×172 mils, and the S2150 is not much larger (178×173) despite its 50%-larger ROM and 25%-larger RAM. The forthcoming S2200 and S2400, with their 2k and 4k ROMs, will measure 180×180 and 180×218 mils, respectively. Their on-chip, 8-channel, 8-bit A/D converters will occupy only 500 mil²*.

ROMs have regular 8-bit width

In general, the ROM of a low-end 1-chip μC is the least "strange" of its subsystems; RAM is slightly "peculiar," and I/O is very specialized.

Most of the calculator-derived μCs use byte-sized (8-bit) program words—a width adequate for single-word instructions because the addressing spaces involved in these little machines are so restricted. The width also proves handy during prototyping emulation, because it permits use of standard PROMs and RAMs.

The overriding design criterion for the ROM section is maximum effective code capacity. The greater the amount of effective code you can pack into the ROM, the more competitive your end product. As far as users are concerned, this emphasis on ROM code capacity translates into an emphasis on short, 1-byte instructions. Because an 8-bit byte isn't wide enough to contain the address operand for full-length "long" jumps through the basic 1k ROMs used in the 1-chip μCs, various types of "short" jump instructions are provided, typically with 6-bit address operands (and thus 64-byte reaches). Thus, a low-end 1-chip μC's basic 1k ROM is typically broken up into 16 64-byte pages. The instruction set of the COP400 family (**Fig 3**) provides an example.

The compartmentalization of the ROM-address space necessitated by the emphasis on single-byte instructions also leads to a number of "nuisance" rules and restrictions for jump and call instructions. Here's an overview of these restrictions for the TMS-1000, COP400 family, S2000 and PPS-4/1:

- The earliest of the designs, the TMS-1000 is also the most primitive; it has only six bits in its PC (program counter). Thus the PC can only fetch instructions within one of the 64-byte ROM pages; when it reaches the end of the page, it wraps around and fetches the next instruction from the page's beginning. Unaided, then, the TMS-1000's jump and call instructions only branch execution within a page. If you want the execution to jump to another page, you must insert an LDP (load page buffer immediate) instruction to select that page from among the other 15. In addition, because all branches are conditional and might not occur, you must remember to insert a second LDP before a branch whenever a subroutine-call instruction directs execution to another page. That way, the page buffer will be restored to the original page.

- The COP420 has a full 10-bit PC but nevertheless also uses 64-byte paging to provide short jumps and calls (**Fig 4**). A further complication: Pages 2 and 3 of the 16 ROM pages are treated as "subroutine pages"; the short-form JP (jump) instruction, which normally can only initiate a jump within a 64-byte page, can also cause a jump to one of these subroutine pages from the other. (Because the COP's PC preincrements before the instruction fetch, you must remember to treat the last address on a page as part of the next page.) The COP400 family's short-form subroutine call, JSRP, is a 1-byte instruction that permits jumping to subroutines in pages 2 or 3 from any other page. It's an efficient way of moving program execution to the subroutine pages; once execution is there, though, any further levels of subroutining must be called by the long-form, 2-byte JSR instruction. This requirement is unfortunate, because unlike the TMS-1000 (which is restricted to just one level of subroutine call), the COP400 family can nest up to three levels (if no interrupt is expected).
- The S2000 resembles the COP400 devices in that it has a full 10-bit PC and three levels of subroutine stack. But this μC achieves short-form program jumps in a manner more akin to that used by the TMS-1000. Jumps must be preceded by a PP (prepare page) instruction. If, in addition to jumping within the internal 1k ROM, you wish to jump to one of up to seven externally addressed 1k banks, you must insert two PP instructions in tandem—the first to prepare the bank address and the second to select the page address. The S2000 architecture treats page 15 (in any of the 1k banks) as the subroutine page. The μC's JMS (jump to subroutine) instruction automatically sets the page register to 15 unless it is overridden by a preceding PP instruction.
- The PPS-4/1's ROM architecture resembles those of the COP400 and S2000 families. However, it has a wider PC (11 bits) for directly addressing up to 2k of ROM, and some of its long jumps are a full three bytes long. It also has two levels of subroutine stack. Problems can arise with the multibyte jump instructions, though, because the PPS-4/1 coding rules don't permit placing skip instructions ahead of these multibyte codes.

Do all these details of ROM addressing for the calculator-derived μCs sound confusing? They are at first, but after you've worked with these machines, you quickly catch on and learn to make their idiosyncrasies work for you. Originally, the manufacturers of these chips were forced to do much of the programming for their customers, but now they say most of those customers are doing their own programming. Based on the number of development systems sold for the calculator-derived μCs, we estimate that there could be as many as 10,000 engineers familiar with the techniques of programming them.

RAMs are really CPU-register arrays

Only occasionally are low-end 1-chip μCs required to act on 4-bit words. More typically, they either process numbers in the form of strings of BCD digits or set and reset individual flag bits. This operation contrasts with that of larger machines, where the computer's word length is more likely to prove adequate for the data processed.

The tiny RAMs in the calculator-derived μCs are therefore organized less like regular memory RAMs than like CPU-register arrays and groups of flag bits. As shown in **Fig 4**, the two parts of their split address registers typically map these RAMs into four long 16-word strings. The strings' individual words or "digits" are addressed by a 4-bit lower ("d") register (to use COP-family terminology); the usual four strings of 16 digits are then selected by short 2-bit upper ("r") registers.

The 4-bit d register is usually intimately associated with the accumulator (and, as you'll see later, with one of the I/O ports). The two r bits are treated somewhat like the upper bits of the PC addressing the ROM; they should ideally be initialized only occasionally, although they might, in reality, get flipped-about frequently during program execution.

This split-up RAM-addressing scheme nicely suits the design goals for low-end 1-chip μCs: It produces maximum ROM-code density, because it permits packing RAM-addressing operands into 1-byte instructions. And because many of these RAM-referencing instructions are constantly used in typical application programs, it is essential that they be short. Further, because they are typically used in program loops, they can have a critical effect upon program execution speed—again, shortness pays off.

A look at the COP instruction set (**Fig 3**) shows why the μC's architecture permits short, fast instructions. Consider the bit patterns for the XDS and XIS instructions, for example; these complementary commands are the key instructions found in so many numerical data-processing loops. They are single-byte entities, yet they contain the necessary RAM addressing as well as loop housekeeping. Two short software examples illustrate their power.

Suppose first that you want to bring the digits of a numerical string in RAM into the accumula-

Is a multiple-μC 1-chip device next?

tor one by one, clear them, and return them to RAM. For this purpose, you can use the very short, tight, fast loop shown in **Fig 5**.

The string of interest in this case comprises the digits 0 to 12 of string 1. An LBI (load RAM-address register B immediate), which initializes both the r and d sections of the RAM-address register B, sets up the operation. The r=01 of this instruction's operand field points at RAM-register string 1, and the d=1011 points at the number 12 digit of that string. The loop itself consists of just three 1-byte instructions:

- The CLRA clears the accumulator.
- The XDS is a multifunction instruction that does practically all the loop's work. It exchanges contents with the pointed-to RAM location, loading in the ZEROs that clear that location. It exclusive-ORs the r address with the r field in the operand—an act that has no effect in this case because the r field is 00. Finally, it decrements the d address to shift the RAM address to the next digit and checks to see if the d part of the address has gone past 0000. If so, it causes the μC to skip the next instruction.
- The final JP is a short 1-byte jump to the start of the loop. It is skipped when the last digit of the string has been processed because then the d address has gone past 0000. Note that the writer of this program has purposely mapped the string against the right-hand boundary of the RAM so that the XDS skip occurs after the last digit of the

RAM (& ALU) SECTION

Mnemonic	Operand	Hex Code	Machine Language Code (Binary)	Data Flow	Skip Conditions	Description
MEMORY REFERENCE INSTRUCTIONS						
CAMQ		33 3C	0011 0011 0011 1100	A → $Q_{7:4}$ RAM(B) → $Q_{3:0}$	None	Copy A, RAM to Q
CQMA		33 2C	0011 0011 0010 1100	$Q_{7:4}$ → RAM(B) $Q_{3:0}$ → A	None	Copy Q to RAM, A
LD	r	-5	00 r 0101	RAM(B) → A Br ⊕ r → Br	None	Load RAM into A, Exclusive-OR Br with r
LDD	r, d	23 --	0010 0011 00 r d	RAM(r,d) → A	None	Load A with RAM pointed to directly by r, d
LQID		BF	1011 1111	ROM($PC_{9:8}$, A, M) → Q SB → SC	None	Load Q Indirect
RMB	0 1 2 3	4C 45 42 43	0100 1100 0100 0101 0100 0010 0100 0011	0 → $RAM(B)_0$ 0 → $RAM(B)_1$ 0 → $RAM(B)_2$ 0 → $RAM(B)_3$	None	Reset RAM Bit
SMB	0 1 2 3	4D 47 46 4B	0100 1101 0100 0111 0100 0110 0100 1011	1 → $RAM(B)_0$ 1 → $RAM(B)_1$ 1 → $RAM(B)_2$ 1 → $RAM(B)_3$	None	Set RAM Bit
STII	y	7-	0111 y	y → RAM(B) Bd + 1 → Bd	None	Store Memory Immediate and Increment Bd
X	r	-6	00 r 0110	RAM(B) ↔ A Br ⊕ r → Br	None	Exchange RAM with A, Exclusive-OR Br with r
XAD	r, d	23 --	0010 0011 10 r d	RAM(r,d) ↔ A	None	Exchange A with RAM pointed to directly by r, d
XDS	r	-7	00 r 0111	RAM(B) ↔ A Bd – 1 → Bd Br ⊕ r → Br	Bd decrements past 0	Exchange RAM with A and Decrement Bd, Exclusive-OR Br with r
XIS	r	-4	00 r 0100	RAM(B) ↔ A Bd + 1 → Bd Br ⊕ r → Br	Bd increments past 15	Exchange RAM with A and Increment Bd, Exclusive-OR Br with r
REGISTER REFERENCE INSTRUCTIONS						
CAB		50	0101 0000	A → Bd	None	Copy A to Bd
CBA		4E	0100 1110	Bd → A	None	Copy Bd to A
LBI	r, d	-- 33 --	00 r (d – 1) (d = 0, 9:15) or 0011 0011 10 r d (any d)	r,d → B	Skip until not a LBI	Load B Immediate with r, d
LEI	y	33 6-	0011 0011 0110 y	y → EN	None	Load EN Immediate
XABR		12	0001 0010	A ↔ Br (0,0 → A_3,A_2)	None	Exchange A with Br
ARITHMETIC INSTRUCTIONS						
ASC		30	0011 0000	A + C + RAM(B) → A Carry → C	Carry	Add with Carry, Skip on Carry
ADD		31	0011 0001	A + RAM(B) → A	None	Add A to RAM
ADT		4A	0100 1010	A + 10_{10} → A	None	Add Ten to A
AISC	y	5-	0101 y	A + y → A	Carry	Add Immediate, Skip on Carry (y ≠ 0)
CASC		10	0001 0000	$\bar{A}$ + RAM(B) + C → A Carry → C	Carry	Complement and Add with Carry, Skip on Carry
CLRA		00	0000 0000	0 → A	None	Clear A
COMP		40	0100 0000	$\bar{A}$ → A	None	Ones complement of A to A
NOP		44	0100 0100	None	None	No Operation
RC		32	0011 0010	"0" → C	None	Reset C
SC		22	0010 0010	"1" → C	None	Set C
XOR		02	0000 0010	A ⊕ RAM(B) → A	None	Exclusive-OR A with RAM

Fig 3—The instruction set *for the COP420 illustrates the separate instruction groups for each of the chip's three subsections. Although you won't be able to fully decipher these instructions because we haven't included important supplemental notes and provisos, you should be able to understand their general structure.*

ROM SECTION

Mnemonic	Operand	Hex Code	Machine Language Code (Binary)	Data Flow	Skip Conditions	Description
TRANSFER OF CONTROL INSTRUCTIONS						
JID		FF	1111 1111	ROM ($PC_{9:8}$, A, M) → $PC_{7:0}$	None	Jump Indirect
JMP	a	6–	0110 00 $a_{9:8}$	a → PC	None	Jump
		--	$a_{7:0}$			
JP	a	--	1 $a_{6:0}$ (pages 2, 3 only)	a → $PC_{6:0}$	None	Jump within Page
			or			
		--	11 $a_{5:0}$ (all other pages)	a → $PC_{5:0}$		
JSRP	a	--	10 $a_{5:0}$	PC + 1 → SA → SB → SC 0010 → $PC_{9:6}$ a → $PC_{5:0}$	None	Jump to Subroutine Page
JSR	a	6–	0110 10 $a_{9:8}$	PC + 1 → SA → SB → SC a → PC	None	Jump to Subroutine
		--	$a_{7:0}$			
RET		48	0100 1000	SC → SB → SA → PC	None	Return from Subroutine
RETSK		49	0100 1001	SC → SB → SA → PC	Always Skip on Return	Return from Subroutine then Skip
TEST INSTRUCTIONS						
SKC		20	0010 0000		C = "1"	Skip if C is True
SKE		21	0010 0001		A = RAM(B)	Skip if A Equals RAM
SKGZ		33	0011 0011		$G_{3:0}$ = 0	Skip if G is Zero (all 4 bits)
		21	0010 0001			
SKGBZ		33	0011 0011	1st byte		Skip if G Bit is Zero
	0	01	0000 0001	2nd byte	G_0 = 0	
	1	11	0001 0001		G_1 = 0	
	2	03	0000 0011		G_2 = 0	
	3	13	0001 0011		G_3 = 0	
SKMBZ	0	01	0000 0001		$RAM(B)_0$ = 0	Skip if RAM Bit is Zero
	1	11	0001 0001		$RAM(B)_1$ = 0	
	2	03	0000 0011		$RAM(B)_2$ = 0	
	3	13	0001 0011		$RAM(B)_3$ = 0	
SKT		41	0100 0001		A time-base counter carry has occurred since last test.	Skip on Timer

I/O SECTION

Mnemonic	Operand	Hex Code	Machine Language Code (Binary)	Data Flow	Skip Conditions	Description
INPUT/OUTPUT INSTRUCTIONS						
ING		33	0011 0011	G → A	None	Input G ports to A
		2A	0010 1010			
ININ		33	0011 0011	IN → A	None	Input IN Inputs to A
		28	0010 1000			
INIL		33	0011 0011	IL_3, CKO, "0", IL_0 → A	None	Input IL Latches to A
		29	0010 1001			
INL		33	0011 0011	$L_{7:4}$ → RAM(B) $L_{3:0}$ → A	None	Input L Ports to RAM, A
		2E	0010 1110			
OBD		33	0011 0011	Bd → D	None	Output Bd to D Outputs
		3E	0011 1110			
OGI	y	33	0011 0011	y → G	None	Output to G Ports Immediate
		5–	0101 y			
OMG		33	0011 0011	RAM(B) → G	None	Output RAM to G Ports
		3A	0011 1010			
XAS		4F	0100 1111	A ↔ SIO, C → SK	None	Exchange A with SIO

INSTRUCTION SET SYMBOLS

Symbol	Definition
INTERNAL ARCHITECTURE SYMBOLS	
A	4-bit Accumulator
B	6-bit RAM Address Register
Br	Upper 2 bits of B (register address)
Bd	Lower 4 bits of B (digit address)
C	1-bit Carry Register
D	4-bit Data Output Port
EN	4-bit Enable Register
G	4-bit Register to latch data for G I/O Port
IL	Two 1-bit Latches associated with the IN_3 or IN_0 Inputs
IN	4-bit Input Port
L	8-bit TRI-STATE I/O Port
M	4-bit contents of RAM Memory Pointed to by B Register
PC	10-bit ROM Address Register (program counter)
Q	8-bit Register to latch data for L I/O Port
SA	10-bit Subroutine Save Register A
SB	10-bit Subroutine Save Register B
SC	10-bit Subroutine Save Register C
SIO	4-bit Shift Register and Counter
SK	Logic-Controlled Clock Output
INSTRUCTION OPERAND SYMBOLS	
d	4-bit Operand Field, 0–15 binary (RAM Digit Select)
r	2-bit Operand Field, 0–3 binary (RAM Register Select)
a	10-bit Operand Field, 0–1023 binary (ROM Address)
y	4-bit Operand Field, 0–15 binary (Immediate Data)
RAM(s)	Content & RAM location addressed by s
ROM (t)	Content & ROM location addressed by t
OPERATIONAL SYMBOLS	
+	Plus
–	Minus
→	Replaces
↔	Is exchanged with
=	Is equal to
$\bar{A}$	The ones complement of A
⊕	Exclusive-OR
:	Range of values

string has been cleared. Such clever RAM mapping is essential in 1-chip μCs (**Refs 4 and 5**).

At this point we should mention a handy feature found in several of the calculator-derived μCs. You can create multiple-entry subroutines by starting off with a string of LBIs, with each one setting up a different starting point in RAM. When a subroutine is called, only the first LBI landed upon is executed—all following LBIs are ignored. With this dodge, you could extend this clear routine to clear any number of different strings in RAM; the main program calls the desired clear by having the jump-to-subroutine command vector to the desired LBI.

Now suppose (as a second example) that you want to add two BCD strings. The code sequence shown in **Fig 6** uses the XIS instruction because this example involves working up from the least significant digit. You map the two arguments to be added one above the other, with their most significant digits up against the high end of the RAM strings.

To make the XIS operate alternately on both

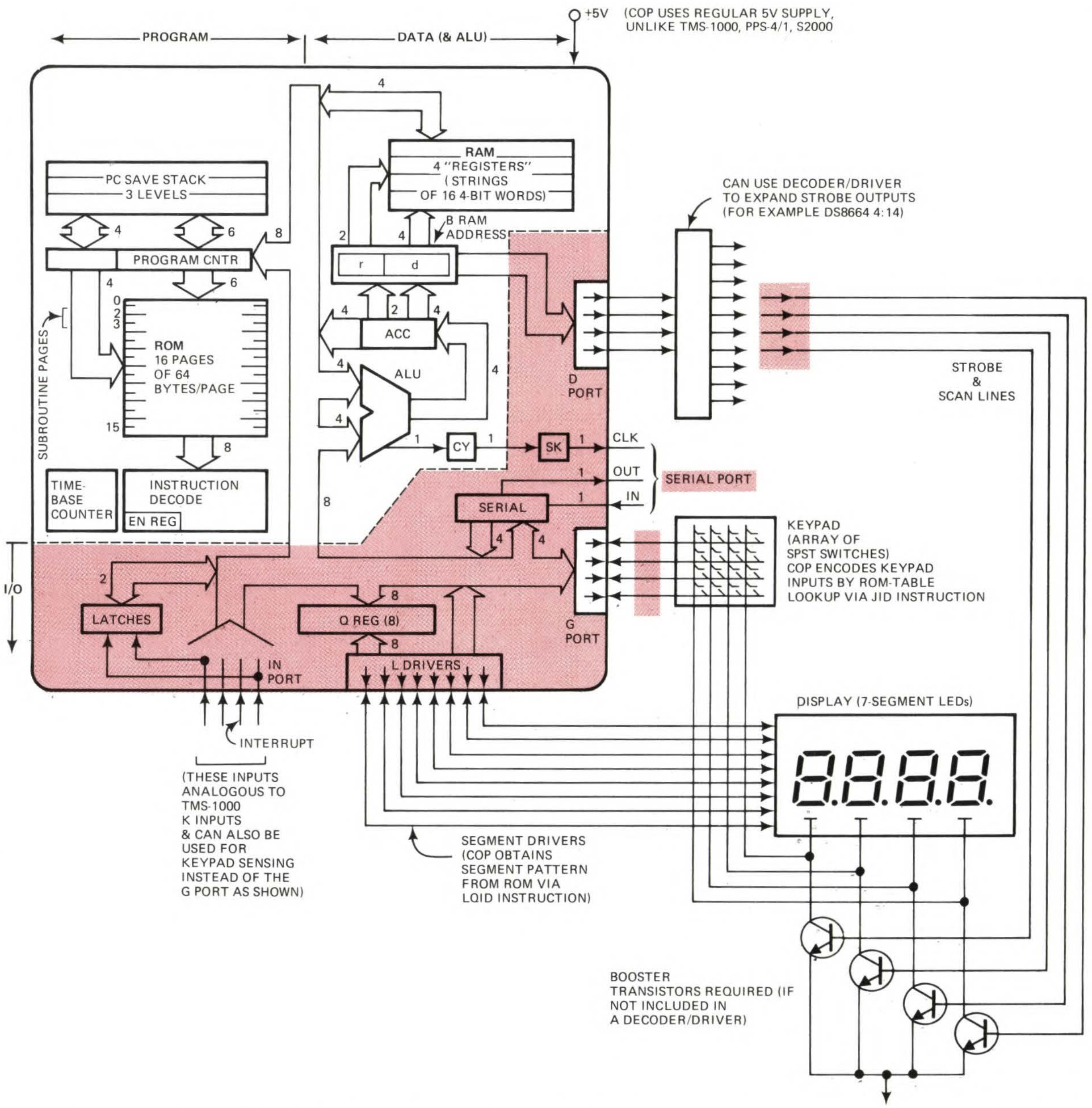


Fig 4—Architecture *of the COP420 shows how the chip expands on the basic calculator configuration. Instead of using the same number of I/O pins for the strobes, as most calculators and the TMS-1000 do, National cut the number of strobe outputs to four. The seven freed pins implement another 4-bit parallel port and a 3-line serial port. Note how many of the pins that were single-function unidirectional lines in the TMS-1000 are now multifunctional and bidirectional, and note the addition of true vectored interrupt on one of the IN pins.*

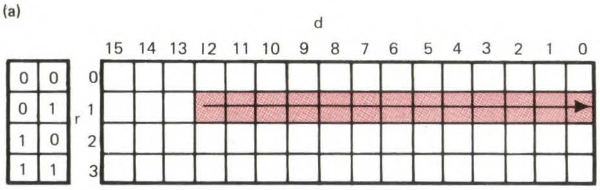
arguments, you need only initialize the RAM-address register once (with the first LBI), and from then on you use the exclusive-ORing feature of XIS's r field to keep flipping back and forth between one string and the other. In the example, the r address for argument 1 is 00, while the r address for argument 2 is 01. Because there is a ONE in the operand field's least-significant-bit position, the exclusive-OR operation causes the least significant bit of the r address to flip back and forth, from ZERO to ONE and then ONE to ZERO. It's hard to imagine a more compact form of relative addressing.

Like the COP400 family, the PPS-4/1 and S2000 also have combined RAM-addressing and loop-control instructions. But the earlier TMS-1000 doesn't, and consequently it suffers in benchmark tests with respect to code compactness and execution speed. However, the TMS-1000 offers users the option of creating more powerful commands through mask-programmed microinstructions; knowledgable users might thus be able to make it catch up in capability to the newer 1-chip devices.

When low-end 1-chip μCs aren't handling BCD strings, they are usually handling individual bits used as flags to remember states of an application's system. All the devices cited here, including the TMS-1000, have instructions that can set, reset and test individual bits in the 4-bit machine words (**Fig 3**).

However, the bit-manipulation instructions assume that the RAM-address register points at the word containing the desired bit. If that isn't the case (as, for example, with a less inspired arrangement of the RAM-location assignments and program flow), an instruction like the COP LBI must initialize the RAM pointer. (Note that there are two LBIs in the COP instruction set: a short 1-byte LBI and a long 2-byte LBI. Obviously you should try to place the flag bits in words that the short instruction can point to.)

(a)



(b)

LABEL	INSTRUCTION	OPERAND	COMMENTS
ENTER	LBI	r = 01, d = 1011	POINT RAM-ADDRESS REGISTER PAIR TO HIGH-ORDER DIGIT OF STRING
CLR	CLRA		CLEAR ACCUMULATOR
	XDS	r = 00	EXCHANGE PUTS 0000 IN RAM DIGIT, DECREMENTS THE DIGIT ADDRESS AND SKIPS NEXT INSTRUCTION IF DIGIT ADDRESS GOES PAST 0000. (BECAUSE r = 00, THERE IS NO EFFECT ON r ADDRESS)
	JP	CLR	LOOP TILL SKIPPED OVER
	RET		RETURN FROM SUBROUTINE

Fig 5—RAM mapping and software *clear a COP420 digit string and illustrate how little ROM space is needed if you organize RAM mapping in "calculator" fashion (all instructions are single bytes).*

I/O evolved from trials of calculators

To appreciate the peculiar architecture of the calculator-based μCs' I/O sections, you must recall what happened in the calculator marketplace during the brutal price wars of the early 1970s. The name of the game then for US manufacturers was combatting the advantage of cheap Asian assembly labor by reducing the number of parts the US products required; it was the only way a US manufacturer could stay in business as retail calculator prices tumbled from $100 to $10.

The goal was to have only three essential components:

- The calculator chip itself
- The output display
- The input keyboard.

All of these components would ideally mount on one pc board—and that' s about all you see inside today's pocket calculators besides the batteries.

The TMS-1000 directly reflects this bare-bones calculator heritage, and part of its immense popularity arises from the way it has brought the economies of $10 calculator chips within the reach of all product designers.

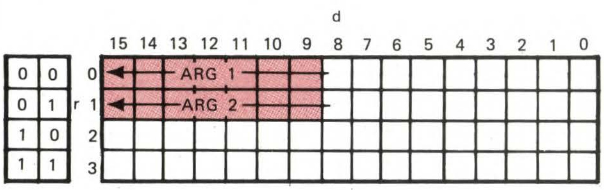
A diagram in one of our previous articles—**Fig 1** of **Ref 1**—illustrated how closely the TMS-1000's I/O subsystem meets the calculator-market criterion of minimum off-chip parts; **Fig 1** in this article shows an I/O configuration that's a capsule rendition of that earlier figure. You can see that the TMS-1000 fails to meet the goal only insofar as it needs external transistors to sink the collective common-cathode currents of the display digits. Each LED is sourced with 10 mA (directly from the TMS-1000), so if all seven segments plus the decimal point are ON, the digit strobe must sink 80 mA—too much to expect of a reasonably sized LSI-device I/O driver. (However, some calculator chips can directly handle the collective digit currents of small displays—for example, the General Instrument C-6XXD/C to C-16XXD Series).

The TMS-1000's 28-pin package has 11 strobe outputs, so the μC can service 11 digits without external multiplexing. In calculators, these same strobes are used to scan the keyboard matrix, but in most units, except for the most complex

I/O subsystems permit use of a minimum number of parts

scientific calculators (and some of the newer alphanumeric language translators), some strobes are usually left over and are utilized by product designers to expand the TMS-1000's functions beyond mere calculation.

(a)



(b)

LABEL	INSTRUCTION	OPERAND	COMMENTS
ENTER	LBI	r = 00, d = 0100	SET RAM-ADDRESS REGISTER TO LSD OF ARGUMENT 1
	RC		INITIALIZE CARRY TO RESET STATE
ADD	LD	r = 01	ARGUMENT 1 TO ACCUMULATOR AND FLIP UPPER RAM ADDRESS TO ARGUMENT 2
	AISC	y = 0110	ASSUME BCD CORRECTION WILL BE NEEDED, SO PRECORRECT BY ADDING DECIMAL 6. (NOTE: NO CARRY AND THUS NO SKIP SHOULD OCCUR IF ACCUMULATOR STARTS WITHIN BCD LIMITS)
	ASC		ADD ARGUMENT 2 TO ACCUMULATOR, AND SKIP IF CARRY-OUT SHOWS BCD CORRECTION NEEDED
	ADT	[IMMEDIATE VALUE OF DECREMENT; 10 IS IMPLIED]	IF NO BCD CORRECTION NEEDED, UNCORRECT PREVIOUS BCD CORRECTION (BY ADDING DECIMAL 10)
	XIS	r = 01	STORE RESULT DIGIT BACK IN RAM (IN ARGUMENT 2 SPACE) AND FLIP UPPER RAM ADDRESS BACK TO ARGUMENT 1. INCREMENT DIGIT ADDRESS AND CHECK FOR END OF STRING, d = 0000
	JP	ADD	NOT DONE, SO REPEAT
	RET		

Fig 6—BCD addition of large numbers *is something that any calculator should do well, and this COP420 program indicates how few precious ROM bytes the procedure can tie up if coded well. Note the decimal correction, implemented via a "precorrection-then-uncorrect-if-not-needed" process; several of the calculator-derived machines use this technique. An important advantage of the data-RAM section's 4-bit-wide words, compared with RAM in 8-bit machines, is that there is no wasted memory space used to accommodate numbers with an odd* number of digits.

Internally, the I/O section's logic helps the TMS-1000 handle the calculator-type servicing of the display and keyboard in several ways. The strobe outputs are driven from the same addressing that accesses digits in the RAM strings. (In terms of the diagram of the COP-420 1-chip μC architecture—**Fig 4**—this would be the d part of the B register.) As a result, the digit addressed in the RAM is the same one being refreshed in the display. A PLA associated with the segment outputs in the TMS-1000 aids the process by automatically translating each BCD digit into a 7-segment (or other) pattern.

The TMS-1000 has only four inputs. Many designers now consider that too few, but four are all that most calculator applications require, and the 4-bit-wide port matches up nicely with the 4-bit-wide data words on the RAM side of the machine. While the TMS-1000 can handle more inputs than shown in the illustration by means of further input multiplexing with the available leftover strobe outputs, these extra inputs—if they are other than the simple spst switches of keyboards—demand further external devices. Furthermore, the TMS-1000 has no interrupts, so it is usually restricted to handling external events within the rhythm of its basic repeating keyboard- and display-scanning loop.

The I/O sections of the newer μCs—the PPS-4/1, COP400 and S2000—are all variations and elaborations upon the TMS-1000 structure. These μCs' designers have tried to strengthen the strong points of the TMS-1000 architecture while adding flexibility and generality.

An I/O variation

Like the TMS-1000, the COP420 also comes in a small 28-pin package National has attempted to redistribute the μC's I/O resources to make it a more general-purpose controller; the firm has traded off some of the strobe outputs in favor of a 4-bit bidirectional port and a 3-line (one input, one output, one clock) serial I/O port. Thus, whereas the TMS-1000 has 11 strobe outputs, the COP420 has only four.

If a COP420 user wants to strobe more display digits than just four, he must add an external 4-to-16 decoder. This addition isn't necessarily a disadvantage, because available low-cost TTL decoders provide both the decoding and the high-current sinking for display digits.

The COP's serial I/O isn't too flexible—it only operates synchronously with the COP clock—but it provides (among other things) a handy means for communicating with low-cost shift-register devices and other COP units. For example, you could tie an inexpensive 8-pin miniDIP CMOS shift register to this port for additional nonvolatile RAM. If you don't need a serial port, you can software-program this same shift register to act

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COP 400 family is to retain the economies of a TMS-1000-class device but also broaden the device's general-purpose usefulness by offering a wide range of hardware and software options. The most extreme of these options, device-mask, permits direct connection to the midrange 8080's 8-bit bus—an action that uses up most of the I/O that would normally serve for calculating the classic calculator-type keyboard-display scan. But the COP device still has enough remaining ports to be used—with external logic or another COP device linked to it via the serial port—for a surprising variety of applications. Computer-system manufacturers are utilizing this part as an intelligent link to peripherals, according to National. The firm is also producing a preprogrammed version that services an alphanumeric keyboard and display.

In the S2000, AMI has taken a somewhat different tack in I/O-subsystem implementation than National has. Rather than trying to maintain the smallest possible chip sizes and thereby keep cost low, the firm has sought to produce a Cadillac version of the TMS-1000, even if that approach uses more chip area and puts the μC at the high end of the 1-chip calculator-based-μC marketplace. For example, AMI uses a special though the AMI chip is NMOS. The firm also includes I/O to directly handle capacitive touch-keyboard inputs (the type popular in microwave ovens). Part of this I/O capability is an input that detects analog thresholds. And future S2000-family chips will incorporate 8-bit A/D converters and up to 4k of ROM.

Before we began to get hands-on experience with the low-end, calculator-derived 1-chip μCs, we had assumed they were just a passing fad—a case of calculator suppliers' trying to cash in on the μP bonanza. Now we've reversed our opinion. Far from being makeshift, hand-me-down expedients, calculator-derived architectures appear to be nearly optimum for use in low-end markets.

Actually, the 1-chip μC's multiplexed-I/O structure should also suit many electromechanical and simple electronic interfaces as well. A system's keyboard matrix's spst switches could be replaced by any similar device, from reed switches to snap-action limit units; any of the many variable-resistance, 2-terminal electronic devices, from photocells to thermistors, could also substitute for these keyboard switches. Similarly, the display's LEDs could be replaced by a whole host of output actuators.

The Microbus option and the serial I/O of National's COP family also portend how the $1 to $3 chips could be linked into the larger multiprocessing systems of the future, adding credibility to our thesis that 1-chip μCs will evolve into the equivalents of TTL building blocks. One National source has even predicted that you'll be seeing multiples of these computers on single chips. **EDN**

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Design Ideas

Conversion circuit handles binary or BCD

R Srinivasan, R Ramesh and **D K Murthi**
National Aeronautical Lab, Bangalore, India

Systems requiring arithmetic operations on data usually perform those operations in binary form. As a result, they must convert the data to BCD form for display purposes. Address-selection information from digit switches, on the other hand, must be converted to binary form for use in memory-addressing operations.

For applications not requiring fast conversion, a single circuit that can perform both conversions proves adequate. One such circuit (see **figure**) utilizes up/down counters to obtain the desired results. To perform binary-to-BCD conversion, preset the binary value in the binary counter and clear the BCD counter. The binary counter counts down while the BCD counter counts up, and when the binary counter reaches zero, the BCD counter holds. For BCD-to-binary operation, the BCD counter counts down from the BCD value while the binary counter counts up. **EDN**

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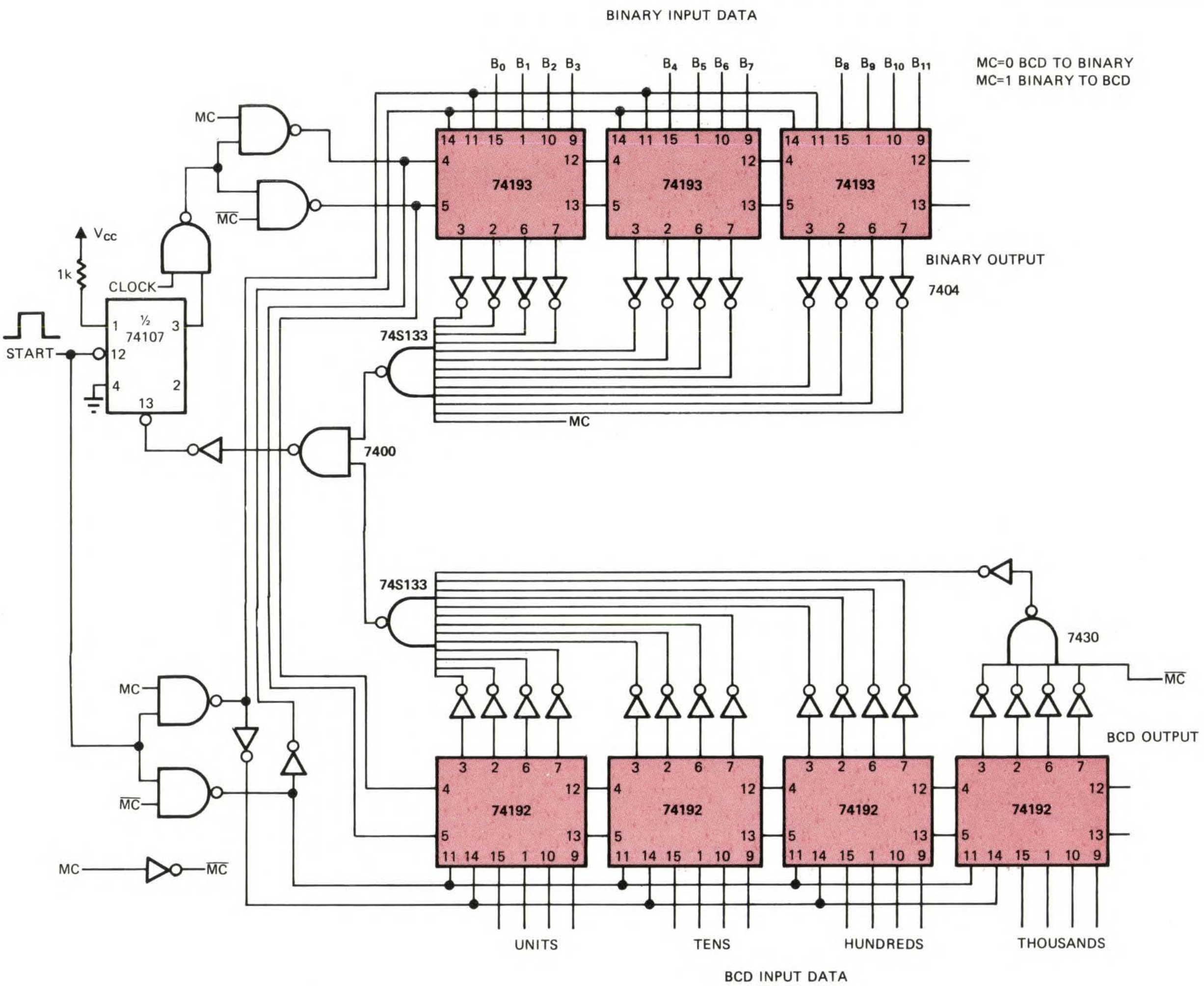

Separate binary and BCD up/down counters *permit both binary-to-BCD and BCD-to-binary conversion in one circuit.*

Comparator detects frequency

Robert Pease
National Semiconductor, Santa Clara, CA

A quad comparator forms the basis of a frequency detector (**figure**) that is faster and less expensive than more complex versions designed around F/V-converter chips.

Positive feedback through a 5-MΩ resistor allows the circuit to resolve changes as small as 2%; the output responds to those changes in about one cycle. When the input frequency is high, V_2 is pulled LOW, it's never allowed to exceed $2/3V_S$. When the input frequency is lower than the limit, V_2 exceeds $2/3V_S$ once each cycle, but V_3 is held below that limit.

The trip frequency is defined by

$$F = 1/(1.1R_2C_2).$$

You can adjust R_2 to permit trimming of the trip point, but R_3 must remain larger than R_2.

EDN

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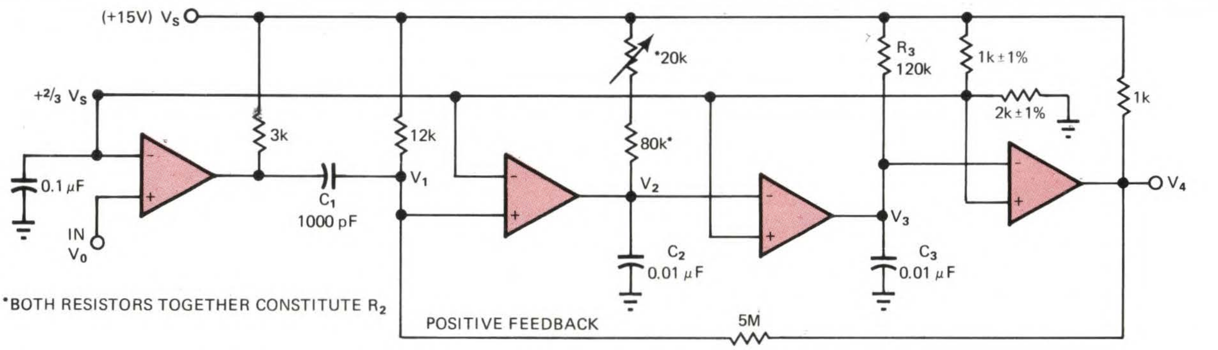

A single quad comparator *finds use in a fast and simple frequency-detector circuit.*

Op amp provides linear current source

Donald E Hall
Tektronix Inc, Beaverton, OR

A common 2-transistor differential amplifier provides a simple voltage-controlled method for driving circuits requiring such inputs. This approach, however, suffers from irregularities over much of the source's dynamic range, producing the familiar characteristic shown in **Fig 1.** Notice in this example that for operation with less than 1% nonlinearity, differential base voltage must remain within a ±26-mV range—leaving a large portion of the dynamic range unused.

An improved circuit (**Fig 2**) uses a 741 op amp to overcome nonlinearity. With ideal op-amp response, the transfer function is described by

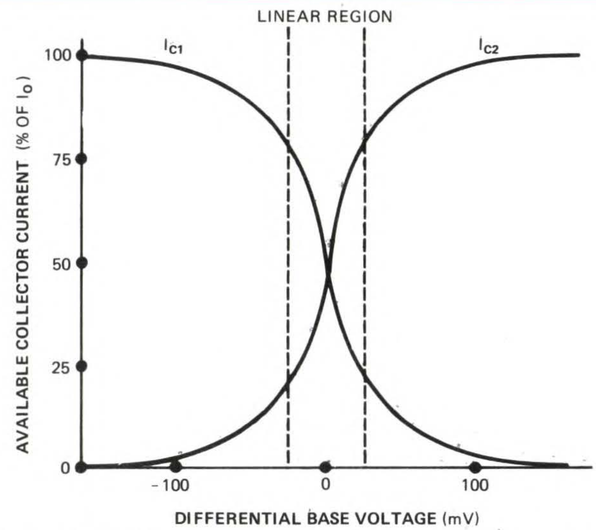

Fig 1—A typical 2-transistor differential amplifier *proves linear only within a narrow range of base voltages.*

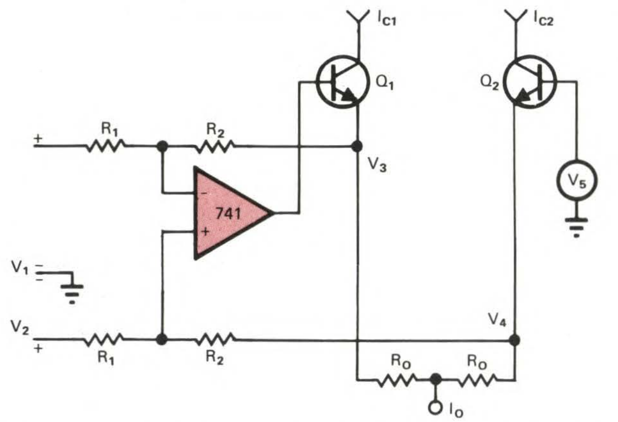

Fig 2—Adding an op amp *linearizes the output of the current source.*

$$(V_3-V_4)/(V_2-V_1)= R_2/R_1.$$

Because

$$I_{C1}-I_{C2}=(V_3-V_4)/R_O,$$

then

$$(I_{C1}-I_{C2})/(V_2-V_1)= R_2/R_OR_1.$$

This relationship indicates that even though transconductance of individual transistors can change, the op amp maintains a linear relationship in the current source. Linear operation continues until I_{C1} or I_{C2} equals I_O, as shown in **Fig 3.** **EDN**

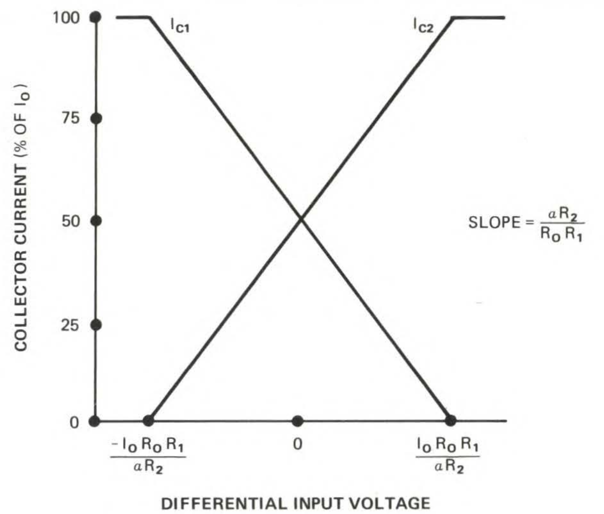

Fig 3—The improvement in linearity *effects a significant increase in the circuit's dynamic range.*

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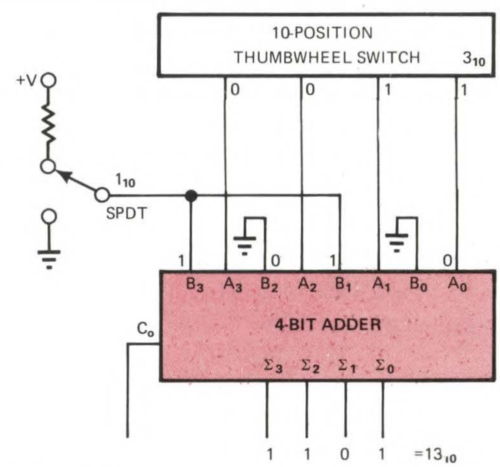
Single chip converts BCD to binary

Vaughn Martin
ITT Aerospace/Optical, Ft Wayne, IN

One 4-bit full adder with a carryout and a spdt switch can convert any BCD number up to 19 into its binary equivalent. The adder's A inputs accept the number's least significant digits from a 10-position BCD thumbswitch; the spdt switch provides the tens-place information. Held HIGH, the switch represents a 10; LOW, a zero. The **figure** illustrates conversion of the number 13.

The first binary addition of a logic ONE (A_0) and a logic ZERO (B_0) yields a logic ONE (Σ_0); the addition of two logic ONEs (A_1 and B_1) yields a logic ZERO (Σ_1) and a carry. The third binary addition of two logic ZEROs (B_2 and A_2) and the carry yield a logic ONE (Σ_2). The last addition, a logic ONE (B_3) plus a logic ZERO (A_3), yields a logic ONE (Σ_3). For numbers greater than 15, the last addition causes a carry out (C_0). **EDN**



To convert BCD numbers less than 20 into binary form, *this simple circuit uses only a 4-bit adder.*

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.039	.09	.18	.40	650B1A393–*	26
.047	.09	.18	.40	650B1A473–	26
.056	.09	.18	.40	650B1A563–	26
.068	.09	.18	.40	650B1A683–	26
.082	.09	.18	.40	650B1A823–	26
.10	.09	.18	.40	650B1A104–	26
.12	.09	.18	.40	650B1A124–	26
.15	.10	.20	.40	650B1A154–	26
.18	.09	.18	.53	650B1A184–	26
.22	.09	.18	.53	650B1A224–	26
.27	.10	.19	.53	650B1A274–	26
.33	.11	.21	.53	650B1A334–	26
.39	.13	.22	.53	650B1A394–	24
.47	.14	.24	.53	650B1A474–	24
.56	.16	.25	.53	650B1A564–	24
.68	.18	.27	.53	650B1A684–	24
.82	.20	.29	.53	650B1A824–	24
1.0	.22	.32	.53	650B1A105–	24
1.2	.20	.29	.68	650B1A125–	24
1.5	.22	.32	.68	650B1A155–	24
1.8	.23	.32	.78	650B1A185–	24
2.0	.24	.34	.78	650B1A205–	24
2.5	.28	.37	.78	650B1A255–	24
3.0	.31	.41	.78	650B1A305–	22
3.5	.34	.43	.78	650B1A355–	22
4.0	.31	.40	.95	650B1A405–	22
4.5	.33	.42	.95	650B1A455–	22
5.0	.25	.42	1.17	650B1A505–	22
6.0	.28	.45	1.17	650B1A605–	22
8.0	.34	.50	1.17	650B1A805–	22
10.0	.39	.56	1.17	650B1A106–	20
12.0	.43	.60	1.17	650B1A126–	20
15.0	.49	.66	1.17	650B1A156–	20
18.0	.47	.64	1.45	650B1A186–	20
20.0	.50	.67	1.45	650B1A206–	20
30.0	.56	.73	1.70	650B1A306–	20
40.0	.66	.83	1.70	650B1A406–	20
50.0	.75	.91	1.70	650B1A506–	20

100 VOLT

MFD	DIMENSIONS T ±.05"	W ±.05"	L ±.05"	CATALOG PART NUMBER	LEAD SIZE (AWG)
For .0010 thru .015 MFD – See Higher Voltages					
.018	.09	.18	.40	650B1B183–*	26
.022	.09	.18	.40	650B1B223–	26
.033	.09	.18	.40	650B1B333–	26
.039	.09	.18	.40	650B1B393–	26
.047	.09	.18	.40	650B1B473–	26
.056	.10	.19	.40	650B1B563–	26
.068	.11	.21	.40	650B1B683–	26
.082	.09	.18	.53	650B1B823–	26
.10	.10	.19	.53	650B1B104–	26
.12	.11	.20	.53	650B1B124–	26
.15	.12	.22	.53	650B1B154–	24
.18	.14	.23	.53	650B1B184–	24
.22	.16	.25	.53	650B1B224–	24
.27	.18	.28	.53	650B1B274–	24
.33	.20	.30	.53	650B1B334–	24
.39	.23	.32	.53	650B1B394–	24
.47	.20	.30	.68	650B1B474–	24
.56	.23	.32	.68	650B1B564–	24
.68	.23	.32	.78	650B1B684–	24
.82	.25	.35	.78	650B1B824–	24
1.0	.28	.38	.78	650B1B105–	24
1.2	.31	.41	.78	650B1B125–	22
1.5	.31	.40	.95	650B1B155–	22
1.8	.34	.43	.95	650B1B185–	22
2.0	.27	.44	1.17	650B1B205–	22
2.5	.31	.48	1.17	650B1B255–	22
3.0	.35	.51	1.17	650B1B305–	20
3.5	.38	.55	1.17	650B1B355–	20
4.0	.41	.58	1.17	650B1B405–	20
4.5	.44	.61	1.17	650B1B455–	20
5.0	.47	.63	1.17	650B1B505–	20
6.0	.52	.68	1.17	650B1B605–	20
8.0	.53	.69	1.45	650B1B805–	20
10.0	.54	.70	1.70	650B1B106–	20
12.0	.54	.70	1.90	650B1B126–	20
15.0	.61	.78	1.90	650B1B156–	20
18.0	.68	.84	1.90	650B1B186–	20
20.0	.72	.88	1.90	650B1B206–	20

200 VOLT

MFD	DIMENSIONS T ±.05"	W ±.05"	L ±.05"	CATALOG PART NUMBER	LEAD SIZE (AWG)
For .0010 thru .0033 MFD – See Higher Voltages					
.0039	.09	.18	.40	650B1C392–*	26
Thru	.09	.18	.40	650B1C –	26
.015	.09	.18	.40	650B1C153–	26
.018	.10	.19	.40	650B1C183–	26
.022	.11	.20	.40	650B1C223–	26
.027	.09	.18	.53	650B1C273	26
.033	.09	.18	.53	650B1C333–	26
.039	.10	.20	.53	650B1C393–	26
.047	.11	.21	.53	650B1C473–	26
.056	.13	.22	.53	650B1C563–	24
.068	.15	.24	.53	650B1C683–	24
.082	.16	.26	.53	650B1C823–	24
.10	.18	.28	.53	650B1C104–	24
.12	.21	.30	.53	650B1C124–	24
.15	.23	.33	.53	650B1C154	24
.18	.21	.30	.68	650B1C184–	24
.22	.23	.33	.68	650B1C224–	24
.27	.24	.33	.78	650B1C274–	24
.33	.27	.36	.78	650B1C334–	24
.39	.30	.40	.78	650B1C394–	22
.47	.33	.43	.78	650B1C474–	22
.56	.32	.41	.95	650B1C564–	22
.68	.25	.42	1.17	650B1C684–	22
.82	.28	.45	1.17	650B1C824–	22
1.0	.32	.49	1.17	650B1C105–	22
1.2	.36	.52	1.17	650B1C125–	20
1.5	.41	.58	1.17	650B1C155–	20
1.8	.46	.62	1.17	650B1C185–	20
2.0	.49	.65	1.17	650B1C205–	20
2.5	.47	.64	1.45	650B1C255–	20
3.0	.47	.63	1.70	650B1C305–	20
3.5	.51	.67	1.70	650B1C355–	20
4.0	.50	.66	1.90	650B1C405–	20
4.5	.53	.70	1.90	650B1C455–	20
5.0	.57	.73	1.90	650B1C505–	20
6.0	.63	.79	1.90	650B1C605–	20
8.0	.74	.90	1.90	650B1C805–	20
10.0	.84	1.00	1.90	650B1C106–	20

Epoxy Case

50 VOLT

MFD	DIMENSIONS T ±.01"	H (MAX.)	L ±.01"	S ±.015"	CATALOG PART NUMBER	LEAD SIZE (AWG)
For .0010 thru .068 MFD – See Higher Voltages						
.082	.18	.30	.42	.300	652A1A823 *	22
Thru	.18	.30	.42	.300	652A1A	22
.15	.18	.30	.42	.300	652A1A154	22
.18	.18	.30	.55	.400	652A1A184	22
.22	.18	.30	.55	.400	652A1A224	22
.27	.18	.30	.55	.400	652A1A274	22
.33	.18	.30	.55	.400	652A1A334	22
.39	.18	.30	.55	.400	652A1A394	22
.47	.24	.37	.55	.400	652A1A474	22
.56	.24	.37	.55	.400	652A1A564	22
.68	.24	.37	.55	.400	652A1A684	22
.82	.30	.43	.55	.400	652A1A824	22
1.0	.30	.43	.55	.400	652A1A105	22
1.2	.30	.43	.67	.500	652A1A125	22
1.5	.30	.43	.67	.500	652A1A155	22
1.8	.30	.43	.82	.600	652A1A185	22
2.0	.30	.43	.82	.600	652A1A205	22
2.5	.40	.55	.82	.600	652A1A255	22
3.0	.40	.55	.82	.600	652A1A305	22
3.5	.40	.55	.82	.600	652A1A355	20
4.0	.40	.55	1.04	.800	652A1A405	20
4.5	.40	.55	1.04	.800	652A1A455	20
5.0	.40	.55	1.24	1.100	652A1A505	20
6.0	.40	.55	1.24	1.100	652A1A605	20
8.0	.40	.55	1.24	1.100	652A1A805	20
10.0	.57	.73	1.24	1.100	652A1A106	20
12.0	.57	.73	1.24	1.100	652A1A126	20
15.0	.57	.73	1.24	1.100	652A1A156	20
18.0	.57	.73	1.75	1.600	652A1A186	20
20.0	.57	.73	1.75	1.600	652A1A206	20

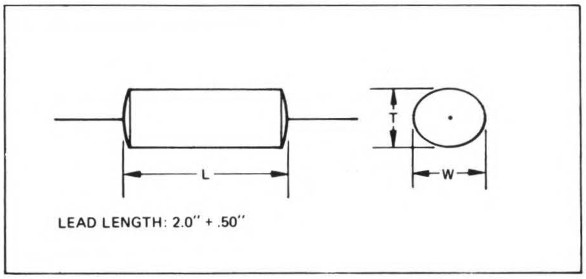
100 VOLT

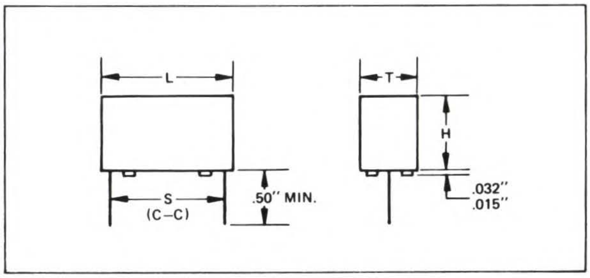
MFD	DIMENSIONS T ±.01"	H (MAX.)	L ±.01"	S ±.015"	CATALOG PART NUMBER	LEAD SIZE (AWG)
For .0010 thru .022 MFD – See Higher Voltages						
.027	.18	.30	.42	.300	652A1B273–*	22
.033	.18	.30	.42	.300	652A1B333	22
.039	.18	.30	.42	.300	652A1B393	22
.047	.18	.30	.42	.300	652A1B473–	22
.056	.18	.30	.42	.300	652A1B563	22
.068	.18	.30	.42	.300	652A1B683	22
.082	.18	.30	.55	.400	652A1B823	22
.10	.18	.30	.55	.400	652A1B104–	22
.12	.18	.30	.55	.400	652A1B124	22
.15	.18	.30	.55	.400	652A1B154–	22
.18	.24	.37	.55	.400	652A1B184	22
.22	.24	.37	.55	.400	652A1B224	22
.27	.24	.37	.55	.400	652A1B274	22
.33	.30	.43	.55	.400	652A1B334–	22
.39	.30	.43	.55	.400	652A1B394–	22
.47	.30	.43	.67	.500	652A1B474	22
.56	.30	.43	.67	.500	652A1B564	22
.68	.30	.43	.82	.600	652A1B684	22
.82	.40	.55	.82	.600	652A1B824	20
1.0	.40	.55	.82	.600	652A1B105	20
1.2	.40	.55	.82	.600	652A1B125	20
1.5	.40	.55	1.04	.800	652A1B155	20
1.8	.40	.55	1.04	.800	652A1B185	20
2.0	.40	.55	1.24	1.100	652A1B205–	20
2.5	.40	.55	1.24	1.100	652A1B255	20
3.0	.40	.55	1.24	1.100	652A1B305	20
3.5	.57	.73	1.24	1.100	652A1B355	20
4.0	.57	.73	1.24	1.100	652A1B405	20
4.5	.57	.73	1.24	1.100	652A1B455	20
5.0	.57	.73	1.24	1.100	652A1B505	20
6.0	.57	.73	1.24	1.100	652A1B605–	20
8.0	.57	.73	1.75	1.600	652A1B805	20

200 VOLT

MFD	DIMENSIONS T ±.01"	H (MAX.)	L ±.01"	S ±.015"	CATALOG PART NUMBER	LEAD SIZE (AWG)
For .0010 thru .0047 MFD – See Higher Voltages						
.0056	.18	.30	.42	.300	652A1C562–*	22
Thru	.18	.30	.42	.300	652A1C –	22
.015	.18	.30	.42	.300	652A1C153–	22
.018	.18	.30	.42	.300	652A1C183–	22
.022	.18	.30	.42	.300	652A1C223–	22
.027	.18	.30	.55	.400	652A1C273–	22
.033	.18	.30	.55	.400	652A1C333–	22
.039	.18	.30	.55	.400	652A1C393–	22
.047	.18	.30	.55	.400	652A1C473–	22
056	.24	.37	.55	.400	652A1C563–	22
068	.24	.37	.55	.400	652A1C683–	22
082	.24	.37	.55	.400	652A1C823–	22
.10	.24	.37	.55	.400	652A1C104–	22
.12	.30	.43	.55	.400	652A1C124–	22
.15	.30	.43	.55	.400	652A1C154–	22
.18	.30	.43	.67	.500	652A1C184–	22
.22	.30	.43	.67	.500	652A1C224–	22
.27	.30	.43	.82	.600	652A1C274–	22
.33	.40	.55	.82	.600	652A1C334–	20
.39	.40	.55	.82	.600	652A1C394–	20
.47	.40	.55	.82	.600	652A1C474–	20
.56	.40	.55	1.04	.800	652A1C564–	20
.68	.40	.55	1.24	1.100	652A1C684–	20
.82	.40	.55	1.24	1.100	652A1C824–	20
1.0	.40	.55	1.24	1.100	652A1C105–	20
1.2	.57	.73	1.24	1.100	652A1C125–	20
1.5	.57	.73	1.24	1.100	652A1C155–	20
1.8	.57	.73	1.24	1.100	652A1C185–	20
2.0	.57	.73	1.24	1.100	652A1C205–	20
2.5	.57	.73	1.75	1.600	652A1C255–	20
3.0	.57	.73	1.75	1.600	652A1C305–	20
3.5	.57	.73	1.75	1.600	652A1C355–	20

*Add suffix letter to part number for capacitance tolerance desired: ±20% = None ±10% = K ±5% = J ±2% = G ±1% = F.
**Higher voltages and other case styles (round wrap and fill, rectangular epoxy, round and rectangular metal hermetically sealed) are available.





electrocube capacitors

Metallized Mylar* Wrap/Fill

100 VOLT

MFD	DIMENSIONS T ±.05"	W ±.05"	L ±.05"	CATALOG PART NUMBER	LEAD SIZE (AWG)
	For .0010 thru .015 MFD – See Higher Voltages				
.018	.09	.18	.40	230B1B183–*	26
.022	.09	.18	.40	230BIB223–	26
.033	.09	.18	.40	230BIB333–	26
.039	.09	.18	.40	230B1B393–	26
.047	.09	.18	.40	230B1B473–	26
.056	.09	.18	.40	230B1B563–	26
.068	.10	.19	.40	230B1B683–	26
.082	.11	.20	.40	230B1B823–	26
.10	.09	.18	.53	230B1B104–	26
.12	.09	.18	.53	230B1B124–	26
.15	.09	.18	.53	230B1B154–	26
.18	.09	.18	.53	230B1B184–	26
.22	.10	.20	.53	230B1B224–	26
.27	.12	.22	.53	230B1B274–	24
.33	.14	.23	.53	230B1B334–	24
.39	.15	.25	.53	230B1B394–	24
.47	.17	.27	.53	230B1B474–	24
.56	.19	.28	.53	230B1B564–	24
.68	.22	.31	.53	230B1B684–	24
.82	.18	.27	.68	230B1B824–	24
1.0	.20	.29	.68	230B1B105–	24
1.2	.22	.32	.68	230B1B125–	24
1.5	.21	.30	.78	230B1B155–	24
1.8	.23	.33	.78	230B1B185–	24
2.0	.25	.34	.78	230B1B205–	24
3.0	.31	.41	.78	230B1B305–	22
4.0	.32	.41	.95	230B1B405–	22
5.0	.26	.42	1.17	230B1B505–	22
6.0	.29	.45	1.17	230B1B605–	22
8.0	.35	.51	1.17	230B1B805–	20
10.0	.46	.63	1.17	230B1B106–	20
12.0	.51	.68	1.17	230B1B126–	20
15.0	.50	.67	1.45	230B1B156–	20
18.0	.56	.72	1.45	230B1B186–	20
20.0	.52	.68	1.70	230B1B206–	20
30.0	.59	.75	1.90	230B1B306–	20
40.0	.72	.88	1.90	230B1B406–	20
50.0	.79	.95	1.90	230B1B506–	20

200 VOLT

MFD	DIMENSIONS T ±.05"	W ±.05"	L ±.05"	CATALOG PART NUMBER	LEAD SIZE (AWG)
	For .0010 thru .0047 MFD – See Higher Voltages				
.0068	.09	.18	.40	230B1C682–*	26
.010	.09	.18	.40	230B1C103–	26
.012	.09	.18	.40	230B1C123–	26
.015	.09	.18	.40	230B1C153–	26
.018	.10	.20	.40	230B1C183–	26
.022	.09	.18	.53	230B1C223–	26
.027	.09	.18	.53	230B1C273–	26
.033	.09	.18	.53	230B1C333–	26
.039	.09	.18	.53	230B1C393–	26
.047	.09	.18	.53	230B1C473–	26
.056	.11	.20	.53	230B1C563–	26
.068	.12	.22	.53	230B1C683–	24
.082	.14	.23	.53	230B1C823–	24
.10	.16	.25	.53	230B1C104–	24
.12	.17	.27	.53	230B1C124–	24
.15	.20	.29	.53	230B1C154–	24
.18	.22	.32	.53	230B1C184–	24
.22	.18	.28	.68	230B1C224–	24
.27	.20	.29	.68	230B1C274–	24
.33	.24	.33	.68	230B1C334–	24
.39	.21	.30	.78	230B1C394–	24
.47	.24	.33	.78	230B1C474–	24
.56	.26	.36	.78	230B1C564–	24
.68	.29	.39	.78	230B1C684–	24
.82	.33	.42	.78	230B1C824–	22
1.0	.32	.41	.95	230B1C105–	22
1.2	.25	.42	1.17	230B1C125–	22
1.5	.29	.45	1.17	230B1C155–	22
1.8	.32	.49	1.17	230B1C185–	22
2.0	.35	.51	1.17	230B1C205–	20
3.0	.44	.61	1.17	230B1C305–	20
4.0	.44	.61	1.45	230B1C405–	20
5.0	.45	.61	1.70	230B1C505–	20
6.0	.49	.65	1.70	230B1C605–	20
8.0	.53	.70	1.90	230B1C805–	20
10.0	.70	.87	1.90	230B1C106–	20
15.0	.87	1.04	1.90	230B1C156–	20
20.0	1.01	1.18	1.90	230B1C206–	20

Epoxy Case

100 VOLT

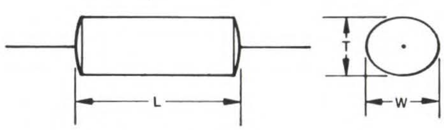
MFD	DIMENSIONS T ±.01"	H (MAX.)	L ±.01"	S ±.015"	CATALOG PART NUMBER	LEAD SIZE (AWG)
	For .0010 thru .018 MFD – See Higher Voltages					
.022	.18	.30	.42	.300	232A1B223–*	22
.027	.18	.30	.42	.300	232A1B273–	22
.033	.18	.30	.42	.300	232A1B333–	22
.039	.18	.30	.42	.300	232A1B393–	22
.047	.18	.30	.42	.300	232A1B473–	22
.056	.18	.30	.42	.300	232A1B563–	22
.068	.18	.30	.42	.300	232A1B683–	22
.082	.18	.30	.42	.300	232A1B823–	22
.10	.18	.30	.55	.400	232A1B104–	22
.12	.18	.30	.55	.400	232A1B124–	22
.15	.18	.30	.55	.400	232A1B154–	22
.18	.18	.30	.55	.400	232A1B184–	22
.22	.18	.30	.55	.400	232A1B224–	22
.27	.18	.30	.55	.400	232A1B274–	22
.33	.24	.37	.55	.400	232A1B334–	22
.39	.24	.37	.55	.400	232A1B394–	22
.47	.24	.37	.55	.400	232A1B474–	22
.56	.30	.43	.55	.400	232A1B564–	22
.68	.30	.43	.55	.400	232A1B684–	22
.82	.30	.43	.67	.500	232A1B824–	22
1.0	.30	.43	.67	.500	232A1B105–	22
1.2	.30	.43	.67	.500	232A1B125–	22
1.5	.30	.43	.82	.600	232A1B155–	22
1.8	.30	.43	.82	.600	232A1B185–	22
2.0	.40	.55	.82	.600	232A1B205–	20
3.0	.40	.55	.82	.600	232A1B305–	20
4.0	.40	.55	1.04	.800	232A1B405–	20
5.0	.40	.55	1.24	1.100	232A1B505–	20
6.0	.40	.55	1.24	1.100	232A1B605–	20
8.0	.57	.73	1.24	1.100	232A1B805–	20
10.0	.57	.73	1.24	1.100	232A1B106–	20
15.0	.57	.73	1.75	1.600	232A1B156–	20

200 VOLT

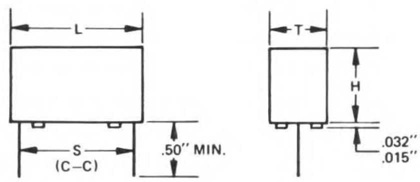
MFD	DIMENSIONS T ±.01"	H (MAX.)	L ±.01"	S ±.015"	CATALOG PART NUMBER	LEAD SIZE (AWG)
	For .0010 thru .0068 MFD – See Higher Voltages					
.0082	.18	.30	.42	.300	232A1C822–*	22
.010	.18	.30	.42	.300	232A1C103–	22
.012	.18	.30	.42	.300	232A1C123–	22
.015	.18	.30	.42	.300	232A1C153–	22
.018	.18	.30	.42	.300	232A1C183–	22
.022	.18	.30	.55	.400	232A1C223–	22
.027	.18	.30	.55	.400	232A1C273–	22
.033	.18	.30	.55	.400	232A1C333–	22
.039	.18	.30	.55	.400	232A1C393–	22
.047	.18	.30	.55	.400	232A1C473–	22
.056	.18	.30	.55	.400	232A1C563–	22
.068	.18	.30	.55	.400	232A1C683–	22
.082	.24	.37	.55	.400	232A1C823–	22
.10	.24	.37	.55	.400	232A1C104–	22
.12	.24	.37	.55	.400	232A1C124–	22
.15	.30	.43	.55	.400	232A1C154–	22
.18	.30	.43	.55	.400	232A1C184–	22
.22	.30	.43	.67	.500	232A1C224–	22
.27	.30	.43	.67	.500	232A1C274–	22
.33	.30	.43	.67	.500	232A1C334–	22
.39	.30	.43	.82	.600	232A1C394–	22
.47	.30	.43	.82	.600	232A1C474–	22
.56	.40	.55	.82	.600	232A1C564–	20
.68	.40	.55	.82	.600	232A1C684–	20
.82	.40	.55	.82	.600	232A1C824–	20
1.0	.40	.55	1.04	.800	232A1C105–	20
1.2	.40	.55	1.24	1.100	232A1C125–	20
1.5	.40	.55	1.24	1.100	232A1C155–	20
1.8	.40	.55	1.24	1.100	232A1C185–	20
2.0	.57	.73	1.24	1.100	232A1C205–	20
3.0	.57	.73	1.24	1.100	232A1C305–	20
4.0	.57	.73	1.75	1.600	232A1C405–	20
5.0	.57	.73	1.75	1.600	232A1C505–	20

*Add suffix letter to part number for capacitance tolerance desired: ±20% = None ±10% = K ±5% = J ±2% = G ±1% = F.
**Higher voltages and other case styles (round wrap and fill, rectangular epoxy, round and rectangular metal hermetically sealed) are available.

*Mylar is a registered TM of DuPont



LEAD LENGTH: 2.0" + .50"



electrocube capacitors®

Miniature High Voltage

1000 VOLT

MFD	DIMENSIONS T ±.05"	W ±.05"	L ±.05"	CATALOG PART NUMBER	LEAD SIZE (AWG)
.001	.12	.32	1.0	520B1G102–*	20
.002	.16	.36	1.0	520B1G202–	20
.003	.19	.39	1.0	520B1G302–	20
.005	.21	.41	1.0	520B1G502–	20
.01	.33	.53	1.0	520B1G103–	20
.02	.33	.53	1.3	520B1G203–	20
.03	.41	.61	1.3	520B1G303–	20
.05	.43	.63	1.5	520B1G503–	20
.10	.64	.84	1.5	520B1G104–	20
.20	.79	.99	1.8	520B1G204–	20
.30	1.01	1.21	1.8	520B1G304–	20
.50	.75	1.05	3.3	520B1G504–	20
1.0	.93	1.23	4.3	520B1G105–	20

2000 VOLT

MFD	DIMENSIONS T ±.05"	W ±.05"	L ±.05"	CATALOG PART NUMBER	LEAD SIZE (AWG)
.001	.12	.35	1.0	520B1J102–*	20
.002	.19	.39	1.0	520B1J202–	20
.003	.25	.45	1.0	520B1J302–	20
.005	.23	.43	1.3	520B1J502–	20
.01	.34	.54	1.3	520B1J103–	20
.02	.40	.60	1.5	520B1J203–	20
.03	.52	.72	1.5	520B1J303–	20
.05	.45	.65	2.3	520B1J503–	20
.10	.55	.75	3.3	520B1J104–	20
.20	.60	.90	4.3	520B1J204–	20
.30	.76	1.06	4.3	520B1J304–	20
.50	1.02	1.32	4.3	520B1J504–	18
1.0	1.50	1.80	4.3	520B1J105–	18

3000 VOLT

MFD	DIMENSIONS T ±.05"	W ±.05"	L ±.05"	CATALOG PART NUMBER	LEAD SIZE (AWG)
.001	.20	.40	1.0	520B1L102–*	20
.002	.26	.46	1.0	520B1L202–	20
.003	.33	.53	1.0	520B1L302–	20
.005	.31	.51	1.3	520B1L502–	20
.01	.46	.66	1.3	520B1L103–	20
.02	.55	.75	1.5	520B1L203–	20
.03	.68	.88	1.5	520B1L303–	20
.05	.61	.81	2.3	520B1L503–	20
.10	.68	.88	3.3	520B1L104–	20
.20	.78	1.08	4.3	520B1L204–	20
.30	1.00	1.30	4.3	520B1L304–	18
.50	1.33	1.63	4.3	520B1L504–	18
1.0	1.95	2.25	4.3	520B1L105–	18

5000 VOLT

MFD	DIMENSIONS T ±.05"	W ±.05"	L ±.05"	CATALOG PART NUMBER	LEAD SIZE (AWG)
.001	.20	.40	1.3	520B1N102–*	20
.002	.27	.50	1.3	520B1N202–	20
.003	.35	.55	1.3	520B1N302–	20
.005	.45	.65	1.3	520B1N502–	20
.01	.52	.72	1.5	520B1N103–	20
.02	.67	.87	1.8	520B1N203–	20
.03	.67	.87	2.3	520B1N303–	20
.05	.88	1.08	2.3	520B1N503–	20
.10	.98	1.18	3.3	520B1N104–	18
.20	1.13	1.43	4.3	520B1N204–	18
.30	1.42	1.72	4.3	520B1N304–	18
.50	1.87	2.17	4.3	520B1N504–	18

8000 VOLT

MFD	DIMENSIONS T ±.05"	W ±.05"	L ±.05"	CATALOG PART NUMBER	LEAD SIZE (AWG)
.001	.35	.55	1.8	520B1Y102–	20
.002	.50	.70	1.8	520B1Y202–	20
.003	.60	.80	1.8	520B1Y302–	20
.005	.65	.85	2.0	520B1Y502–	20
.01	.78	.98	2.5	520B1Y103–	20
.02	.78	.98	3.5	520B1Y203–	20
.03	.99	1.19	3.5	520B1Y303–	20
.05	1.02	1.32	4.5	520B1Y503–	18
.10	1.50	1.80	4.5	520B1Y104–	18
.20					
.30					
.50					

10,000 VOLT

MFD	DIMENSIONS T ±.05"	W ±.05"	L ±.05"	CATALOG PART NUMBER	LEAD SIZE (AWG)
.001	.40	.60	1.8	520B1S102–*	20
.002	.60	.80	1.8	520B1S202–	20
.003	.60	.80	2.0	520B1S302–	20
.005	.66	.86	2.5	520B1S502–	20
.01	.98	1.18	2.5	520B1S103–	20
.02	.98	1.18	3.5	520B1S203–	20
.03	1.23	1.43	3.5	520B1S303–	20
.05	1.29	1.59	4.5	520B1S503–	18
.10	1.87	2.17	4.5	520B1S104–	18
.20					
.30					
.50					

*Add suffix letter to part number for capacitance tolerance desired: ±20% = None ±10% = K ±5% = J ±2% = G ±1% = F.
**Higher voltages and other case styles (round wrap and fill, rectangular epoxy, round and rectangular metal hermetically sealed) are available.

Mylar*/Foil

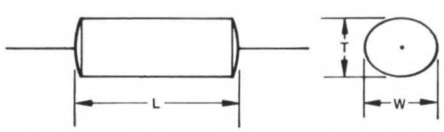
250B OVAL

Cap. Mfd.	200 WVDC Dash Number	T	W	L	400 WVDC Dash Number	T	W	L	600 WVDC Dash Number	T	W	L
.001	(See Higher Voltages)				(See Higher Voltage)				1F102	.11	.20	.53
.0015									1F152	.11	.20	.53
.0022									1F222	.11	.20	.68
.0033					1E332	.11	.20	.53	1F332	.11	.20	.68
.0047					1E472	.11	.20	.68	1F472	.14	.23	.68
.0068					1E682	.11	.20	.68	1F682	.14	.23	.81
.01	1C103	.11	.20	.53	1E103	.14	.23	.68	1F103	.19	.28	.81
.015	1C153	.11	.20	.68	1E153	.14	.23	.81	1F153	.20	.29	.81
.022	1C223	.14	.23	.68	1E223	.18	.28	.81	1F223	.25	.34	.90
.033	1C333	.16	.26	.68	1E333	.20	.29	.81	1F333	.26	.35	.90
.047	1C473	.17	.27	.81	1E473	.26	.35	.90	1F473	.33	.42	.90
.068	1C683	.18	.28	.81	1E683	.31	.40	.90	1F683	.39	.48	1.17
.10	1C104	.21	.31	.81	1E104	.33	.42	.90	1F104	.41	.57	1.17
.15	1C154	.26	.35	.90	1E154	.39	.48	1.17	1F154	.45	.62	1.45
.22	1C224	.26	.43	.90	1E224	.41	.57	1.17	1F224	.47	.63	1.45
.33	1C334	.28	.45	1.17	1E334	.41	.57	1.45	1F334	.59	.75	1.68
.47	1C474	.35	.52	1.17	1E474	.47	.63	1.68	1F474	.66	.82	1.90
.68	1C684	.41	.57	1.17	1E684	.54	.70	1.90				
1.0	1C105	.41	.57	1.45	1E105	.66	.82	1.90				
1.5	1C155	.54	.70	1.45								
2.0	1C205	.59	.75	1.68					TOLERANCE ±.050			

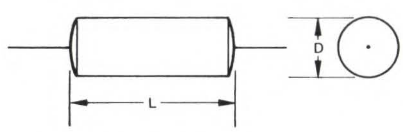
TYPE 250D ROUND

Cap. Mfd.	200 WVDC Dash Number	D	L	400 WVDC Dash Number	D	L	600 WVDC Dash Number	D	L
.001	1C102	.14	.53	1E102	.14	.53	1F102	.14	.53
.0015	1C152	.14	.53	1E152	.14	.53	1F152	.17	.53
.0022	1C222	.14	.53	1E222	.14	.53	1F222	.17	.68
.0033	1C332	.14	.53	1E332	.17	.53	1F332	.17	.68
.0047	1C472	.14	.53	1E472	.17	.68	1F472	.20	.68
.0068	1C682	.14	.53	1E682	.17	.68	1F682	.20	.81
.01	1C103	.17	.53	1E103	.20	.68	1F103	.24	.81
.015	1C153	.17	.68	1E153	.20	.81	1F153	.25	.81
.022	1C223	.20	.68	1E223	.24	.81	1F223	.31	.90
.033	1C333	.22	.68	1E333	.26	.81	1F333	.32	.90
.047	1C473	.23	.81	1E473	.32	.90	1F473	.39	.90
.068	1C683	.24	.81	1E683	.37	.90	1F683	.45	1.17
.10	1C104	.26	.81	1E104	.39	.90	1F104	.51	1.17
.15	1C154	.32	.90	1E154	.45	1.17	1F154	.55	1.45
.22	1C224	.35	.90	1E224	.51	1.17	1F224	.57	1.45
.33	1C334	.38	1.17	1E334	.51	1.45	1F334	.69	1.68
.47	1C474	.45	1.17	1E474	.57	1.68	1F474	.76	1.90
.68	1C684	.51	1.17	1E684	.64	1.90			
1.0	1C105	.51	1.45	1E105	.76	1.90			
1.5	1C155	.64	1.45						
2.0	1C205	.75	1.68	LEAD LENGTH 2 ± ½ INCHES					

*Mylar is a registered TM of DuPont



LEAD LENGTH: 2.0" + .50"



LEAD LENGTH: 2.0" + .50"

electrocube capacitors

Metallized Polypropylene

135V (RMS)

MFD	DIMENSIONS T ±.05"	DIMENSIONS W ±.05"	DIMENSIONS L ±.05"	PNRP *** mA	POWER (MAX.) mW	CATALOG PART NUMBER	LEAD SIZE (AWG)
.0010	.09	.18	.40	20	80	910B1C102-*	26
.0015	.09	.18	.40	20	80	910B1C152-	26
.0022	.09	.18	.40	20	80	910B1C222-	26
.0033	.09	.18	.40	20	80	910B1C332-	26
.0047	.09	.18	.40	20	80	910B1C472-	26
.0068	.09	.18	.40	55	80	910B1C682-	26
.0082	.09	.18	.40	67	80	910B1C822-	26
.010	.09	.18	.40	81	80	910B1C103-	26
.015	.09	.18	.53	52	98	910B1C153-	26
.022	.09	.18	.53	77	98	910B1C223-	26
.033	.12	.21	.53	115	126	910B1C333-	26
.047	.15	.24	.53	164	157	910B1C473-	24
.068	.18	.28	.53	237	190	910B1C683-	24
.082	.20	.30	.53	286	214	910B1C823-	24
.10	.23	.32	.53	349	253	910B1C104-	24
.15	.22	.32	.68	333	273	910B1C154-	24
.22	.23	.33	.78	358	310	910B1C224-	24
.33	.30	.39	.78	537	424	910B1C334-	24
.47	.32	.41	.95	650	511	910B1C474-	22
.68	.29	.45	1.17	616	598	910B1C684-	22
.82	.32	.49	1.17	742	686	910B1C824-	22
1.0	.36	.53	1.17	906	780	910B1C105-	20
2.0	.47	.64	1.45	1395	1161	910B1C205-	20
5.0	.64	.81	1.90	2400	1968	910B1C505-	20
10.0	.94	1.11	1.90	4800	3305	910B1C106-	20

270V (RMS)

MFD	DIMENSIONS T ±.05"	DIMENSIONS W ±.05"	DIMENSIONS L ±.05"	PNRP *** mA	POWER (MAX.) mW	CATALOG PART NUMBER	LEAD SIZE (AWG)
.0010	.12	.21	.68	20	147	910B1E102-*	26
.0015	.12	.21	.68	20	147	910B1E152-	26
.0022	.12	.21	.68	20	147	910B1E222-	26
.0033	.12	.21	.68	20	147	910B1E332-	26
.0047	.12	.21	.68	57	147	910B1E472-	26
.0068	.12	.21	.68	83	147	910B1E682-	26
.0082	.12	.21	.68	100	147	910B1E822-	26
.010	.12	.21	.68	122	147	910B1E103-	26
.015	.16	.25	.68	183	193	910B1C153-	24
.022	.20	.29	.68	270	245	910B1E223-	24
.033	.17	.26	.95	204	255	910B1E333-	24
.047	.21	.30	.95	288	316	910B1E473-	24
.068	.26	.35	.95	417	400	910B1E683-	24
.082	.28	.38	.95	501	436	910B1E823-	24
.10	.32	.41	.95	602	511	910B1E104-	22
.15	.28	.45	1.17	612	598	910B1E154-	22
.22	.36	.52	1.17	897	756	910B1E224-	20
.33	.46	.62	1.17	1344	1009	910B1E334-	20
.47	.47	.64	1.45	1437	1191	910B1E474-	20
.68	.46	.63	1.90	1386	1363	910B1E684-	20
.82	.52	.69	1.90	1674	1566	910B1E824-	20
1.0	.58	.75	1.90	2040	1781	910B1E105-	20
2.0	.86	1.03	1.90	4080	2931	910B1E205-	20

Polypropylene & Foil

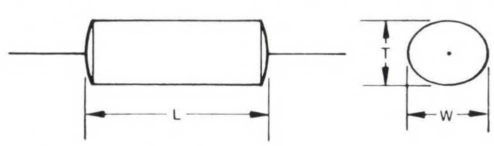
135V (RMS)

MFD	DIMENSIONS T ±.05"	DIMENSIONS W ±.05"	DIMENSIONS L ±.05"	PNRP *** AMP	POWER (MAX.) mW	CATALOG PART NUMBER	LEAD SIZE (AWG)
.0010	.09	.18	.63	2	97	950B1C102-*	26
.0015	.09	.18	.63	2	97	950B1C152-	26
.0022	.09	.18	.63	2	97	950B1C222-	26
.0033	.09	.18	.63	2	97	950B1C332-	26
.0047	.09	.18	.63	2	97	950B1C472-	26
.0068	.09	.19	.63	7	97	950B1C682-	26
.0082	.10	.20	.63	8	97	950B1C822-	26
.010	.11	.21	.63	10	97	950B1C103-	26
.015	.14	.24	.63	15	126	950B1C153-	24
.022	.18	.28	.63	22	167	950B1C223-	24
.033	.17	.27	.78	33	214	950B1C333-	24
.047	.21	.31	.78	28	209	950B1C473-	24
.068	.21	.31	.88	41	287	950B1C683-	24
.082	.24	.34	.88	35	280	950B1C823-	24
.10	.27	.37	.88	43	310	950B1C104-	24
.15	.29	.39	1.05	65	407	950B1C154-	22
.22	.26	.43	1.27	75	510	950B1C224-	22
.33	.33	.50	1.27	78	620	950B1C334-	22
.47	.41	.58	1.27	111	780	950B1C474-	20
.68	.39	.56	1.80	160	1009	950B1C684-	20
.82	.43	.60	1.80	192	1147	950B1C824-	20
1.0	.49	.66	1.80	180	1221	950B1C105-	20
2.0	.66	.83	2.0	244	1744	950B1C205-	20
5.0	1.09	1.26	2.0	611	3402	950B1C505-	20

270V (RMS)

MFD	DIMENSIONS T ±.05"	DIMENSIONS W ±.05"	DIMENSIONS L ±.05"	PNRP *** AMP	POWER (MAX.) mW	CATALOG PART NUMBER	LEAD SIZE (AWG)
.0010	.12	.21	.68	4	147	950B1E102-*	26
.0015	.12	.21	.68	4	147	950B1E152-	26
.0022	.12	.21	.68	4	147	950B1E222-	26
.0033	.12	.21	.68	11	147	950B1E332-	26
.0047	.12	.21	.68	16	147	950B1E472-	26
.0068	.13	.23	.68	23	158	950B1E682-	24
.0082	.15	.24	.68	28	181	950B1E822-	24
.010	.17	.26	.68	34	206	950B1E103-	24
.015	.22	.31	.68	52	273	950B1E153-	24
.022	.17	.27	.95	36	255	950B1E223-	24
.033	.22	.32	.95	54	332	950B1E333-	24
.047	.27	.37	.95	76	418	950B1E473-	24
.068	.23	.39	1.17	72	475	950B1E683-	24
.082	.26	.42	1.17	87	535	950B1E823-	24
.10	.29	.46	1.17	106	620	950B1E104-	22
.15	.38	.54	1.17	159	804	950B1E154-	20
.22	.47	.64	1.17	234	1077	950B1E224-	20
.33	.50	.67	1.45	260	1281	950B1E334-	20
.47	.48	.65	2.0	244	1430	950B1E474-	20
.68	.60	.77	2.0	354	1855	950B1E684-	20
.82	.67	.83	2.0	426	2084	950B1E824-	20
1.0	.75	.91	2.0	520	2408	950B1E105-	20
2.0	1.09	1.26	2.0	1041	4060	950B1E205-	20

*Add suffix letter to part number for capacitance tolerance desired: ±20% = None ±10% = K ±5% = J ±2% = G ±1% = F.
**Higher voltages and other case styles (round wrap and fill, rectangular epoxy, round and rectangular metal hermetically sealed) are available.
***Peak Non-Repetitive Pulse



LEAD LENGTH: 2.0" ± .50"

electrocube capacitors

Metallized Polysulfone

100 VOLT

MFD	DIMENSIONS T ±.05"	DIMENSIONS W ±.05"	DIMENSIONS L ±.05"	CATALOG PART NUMBER	LEAD SIZE (AWG)
.0010	.09	.18	.40	810B1B102-*	26
.0012	.09	.18	.40	810B1B122-	26
.0015	.09	.18	.40	810B1B152-	26
.0018	.09	.18	.40	810B1B182-	26
.0022	.09	.18	.40	810B1B222-	26
.0027	.09	.18	.40	810B1B272-	26
.0033	.09	.18	.40	810B1B332-	26
.0039	.09	.18	.40	810B1B392-	26
.0047	.09	.18	.40	810B1B472-	26
.0056	.09	.18	.40	810B1B562-	26
.0068	.09	.18	.40	810B1B682-	26
.0082	.09	.18	.40	810B1B822-	26
.010	.09	.18	.40	810B1B103-	26
.012	.09	.18	.40	810B1B123-	26
.015	.09	.18	.40	810B1B153-	26
.018	.09	.18	.40	810B1B183-	26
.022	.09	.18	.40	810B1B223-	26
.027	.09	.18	.40	810B1B273-	26
.033	.09	.18	.40	810B1B333-	26
.039	.10	.20	.40	810B1B393-	26
.047	.12	.21	.40	810B1B473-	26
.056	.09	.18	.53	810B1B563-	26
.068	.09	.18	.53	810B1B683-	26
.082	.10	.19	.53	810B1B823-	26
.10	.11	.20	.53	810B1B104-	26
.12	.12	.22	.53	810B1B124-	24
.15	.14	.24	.53	810B1B154-	24
.18	.16	.25	.53	810B1B184-	24
.22	.18	.27	.53	810B1B224-	24
.27	.20	.30	.53	810B1B274-	24
.33	.23	.32	.53	810B1B334-	24
.39	.19	.29	.68	810B1B394-	24
.47	.22	.31	.68	810B1B474-	24
.56	.20	.29	.78	810B1B364-	24
.68	.22	.32	.78	810B1B684-	24
.82	.25	.34	.78	810B1B824-	22
1.0	.28	.38	.78	810B1B105-	22
1.2	.32	.41	.78	810B1B125-	22
1.5	.31	.40	.95	810B1B155-	22
1.8	.23	.40	1.17	810B1B185-	22
2.0	.26	.43	1.17	810B1B205-	22
2.5	.30	.47	1.17	810B1B255-	20
3.0	.34	.51	1.17	810B1B305-	20
3.5	.37	.54	1.17	810B1B355-	20
4.0	.41	.57	1.17	810B1B405-	20
4.5	.43	.60	1.17	810B1B455-	20
5.0	.46	.63	1.17	810B1B505-	20
6.0	.44	.61	1.45	810B1B605-	20
8.0	.46	.63	1.70	810B1B805-	20
10.0	.48	.64	1.90	810B1B106-	20
12.0	.53	.70	1.90	810B1B126-	20
15.0	.60	.77	1.90	810B1B156-	20
20.0	.71	.88	1.90	810B1B206-	20

200 VOLT

MFD	DIMENSIONS T ±.05"	DIMENSIONS W ±.05"	DIMENSIONS L ±.05"	CATALOG PART NUMBER	LEAD SIZE (AWG)
.0010	.09	.18	.40	810B1C102-*	26
.0012	.09	.18	.40	810B1C122-	26
.0015	.09	.18	.40	810B1C152-	26
.0018	.09	.18	.40	810B1C182-	26
.0022	.09	.18	.40	810B1C222-	26
.0027	.09	.18	.40	810B1C272-	26
.0033	.09	.18	.40	810B1C332-	26
.0039	.09	.18	.40	810B1C392-	26
.0047	.09	.18	.40	810B1C472-	26
.0056	.09	.18	.40	810B1C562-	26
.0068	.09	.18	.40	810B1C682-	26
.0082	.09	.18	.40	810B1C822-	26
.010	.09	.18	.40	810B1C103-	26
.012	.09	.18	.40	810B1C123-	26
.015	.09	.18	.40	810B1C153-	24
.018	.09	.18	.53	810B1C183-	24
.022	.09	.18	.53	810B1C223-	24
.027	.09	.18	.53	810B1C273-	24
.033	.10	.20	.53	810B1C333-	24
.039	.11	.21	.53	810B1C393-	24
.047	.13	.22	.53	810B1C473-	24
.056	.14	.24	.53	810B1C563-	24
.068	.16	.26	.53	810B1C683-	24
.082	.18	.27	.53	810B1C823-	24
.10	.21	.30	.53	810B1C104-	24
.12	.23	.32	.53	810B1C124-	24
.15	.20	.29	.68	810B1C154-	24
.18	.22	.32	.68	810B1C184-	22
.22	.21	.30	.78	810B1C224-	22
.27	.24	.33	.78	810B1C274-	22
.33	.27	.36	.78	810B1C334-	22
.39	.29	.39	.78	810B1C394-	22
.47	.33	.43	.78	810B1C474-	22
.56	.31	.41	.95	810B1C564-	22
.68	.25	.42	1.17	810B1C684-	22
.82	.28	.45	1.17	810B1C824-	20
1.0	.32	.49	1.17	810B1C105-	20
1.2	.36	.52	1.17	810B1C125-	20
1.5	.41	.58	1.17	810B1C155-	20
1.8	.46	.63	1.17	310B1C185-	20
2.0	.49	.65	1.17	810B1C205-	20
2.5	.48	.64	1.45	810B1C255-	20
3.0	.47	.63	1.70	810B1C305-	20
3.5	.47	.63	1.90	810B1C355-	20
4.0	.50	.67	1.90	810B1C405-	20
4.5	.54	.71	1.90	810B1C455-	20
5.0	.57	.74	1.90	810B1C505-	20
6.0	.64	.80	1.90	810B1C605-	20
8.0	.75	.92	1.90	810B1C805-	20
10.0	.85	1.01	1.90	810B1C106-	20

Combination Film

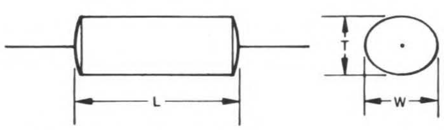
100 VOLT

MFD	DIMENSIONS T ±.05"	DIMENSIONS W ±.05"	DIMENSIONS L ±.05"	CATALOG PART NUMBER	LEAD SIZE (AWG)
0010	09	18	40	730B1B102-*	26
0012	09	18	40	730B1B122-	26
0015	09	18	40	730B1B152-	26
0018	09	18	40	730B1B182-	26
0027	09	18	40	730B1B272-	26
0033	09	18	40	730B1B332-	26
0039	09	18	40	730B1B472-	26
0047	09	18	40	730B1B392-	26
0056	09	18	40	730B1B562-	26
0068	09	18	40	730B1B682-	26
0082	09	18	40	730B1B822-	26
010	09	18	40	730B1B103-	26
012	09	18	40	730B1B123-	26
015	09	18	40	730B1B153-	26
018	09	18	40	730B1B183-	26
022	09	18	40	730B1B223-	26
027	09	18	40	730B1B273-	26
033	09	18	40	730B1B333-	26
039	09	19	40	730B1B393-	26
047	10	20	40	730B1B473-	26
056	11	21	40	730B1B563-	26
068	13	23	40	730B1B683-	24
082	11	20	53	730B1B823-	24
10	13	23	53	730B1B104-	24
12	14	24	53	730B1B124-	24
15	16	26	53	730B1B154-	24
18	19	28	53	730B1B184-	24
22	22	31	53	730B1B224-	24
27	24	34	53	730B1B274-	24
33	27	37	53	730B1B334-	24
39	30	40	53	730B1B394-	22
47	24	34	68	730B1B474-	22
56	29	38	68	730B1B564-	22
68	25	35	78	730B1B684-	22
82	28	38	78	730B1B824-	22
1.0	31	41	78	730B1B105-	22
1.2	35	45	78	730B1B125-	22
1.5	35	45	95	730B1B155-	22
1.8	39	48	95	730B1B185-	22
2.0	29	46	1.17	730B1B205-	22
2.5	33	50	1.17	730B1B255-	22
3.0	37	53	1.17	730B1B305-	20
3.5	41	58	1.17	730B1B355-	20
4.0	44	62	1.17	730B1B405-	20
4.5	47	64	1.17	730B1B455-	20
5.0	50	67	1.17	730B1B505-	20
6.0	56	73	1.17	730B1B605-	20
8.0	57	74	1.45	730B1B805-	20
10.0	57	74	1.70	730B1B106-	20
12.0	57	74	1.90	730B1B126-	20
15.0	65	82	1.90	730B1B156-	20
18.0	72	88	1.90	730B1B186-	20
20.0	76	93	1.90	730B1B206-	20

200 VOLT

MFD	DIMENSIONS T ±.05"	DIMENSIONS W ±.05"	DIMENSIONS L ±.05"	CATALOG PART NUMBER	LEAD SIZE (AWG)
0010	09	18	40	730B1C102-*	26
0012	09	18	40	730B1C122-	26
0015	09	18	40	730B1C152-	26
0018	09	18	40	730B1C182-	26
0027	09	18	40	730B1C272-	26
0033	09	18	40	730B1C332-	26
0039	09	18	40	730B1C392-	26
0047	09	18	40	730B1C472-	26
0056	09	18	40	730B1C562-	26
0068	09	18	40	730B1C682-	26
0082	09	18	40	730B1C822-	26
010	09	18	40	730B1C103-	26
012	09	18	40	730B1C123-	26
015	09	18	40	730B1C153-	26
018	10	19	40	730B1C183-	26
022	11	20	40	730B1C223-	26
027	09	18	53	730B1C273-	26
033	09	18	53	730B1C333-	26
039	10	20	53	730B1C393-	26
047	11	21	53	730B1C473-	26
056	13	22	53	730B1C563-	24
068	15	24	53	730B1C683-	24
082	16	26	53	730B1C823-	24
10	18	28	53	730B1C104-	24
12	21	30	53	730B1C124-	24
15	23	33	53	730B1C154-	24
18	21	30	68	730B1C184-	24
22	23	33	68	730B1C224-	24
27	24	33	78	730B1C274-	24
33	27	36	78	730B1C334-	24
39	30	40	78	730B1C394-	22
47	33	43	78	730B1C474-	22
56	32	41	95	730B1C564-	22
68	25	42	1.17	730B1C684-	22
82	28	45	1.17	730B1C824-	22
1.0	32	49	1.17	730B1C105-	22
1.2	36	52	1.17	730B1C125-	20
1.5	41	58	1.17	730B1C155-	20
1.8	46	62	1.17	730B1C185-	20
2.0	49	65	1.17	730B1C205-	22
2.5	47	64	1.45	730B1C255-	20
3.0	47	63	1.70	730B1C305-	20
3.5	51	67	1.70	730B1C355-	20
4.0	50	66	1.90	730B1C405-	20
4.5	53	70	1.90	730B1C455-	20
5.0	57	73	1.90	730B1C505-	20
6.0	63	79	1.90	730B1C605-	20
8.0	74	90	1.90	730B1C805-	20
10.0	84	1.00	1.90	730B1C106-	20

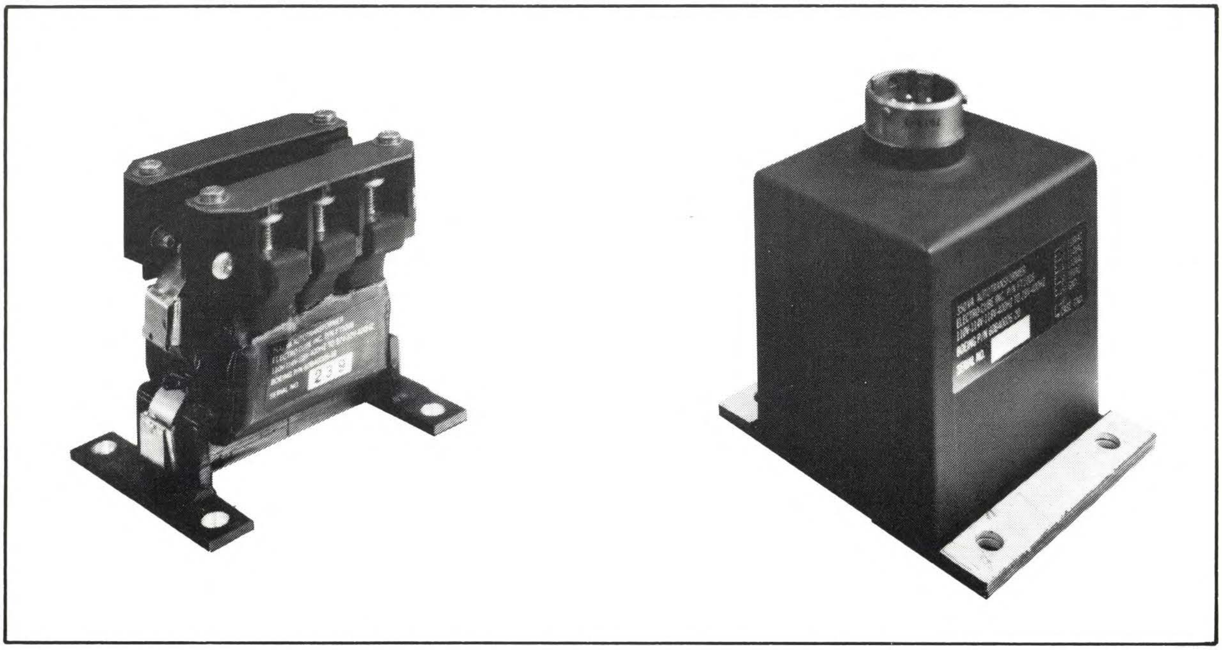
*Add suffix letter to part number for capacitance tolerance desired: ±20% = None ±10% = K ±5% = J ±2% = G ±1% = F.
**Higher voltages and other case styles (round wrap and fill, rectangular epoxy, round and rectangular metal hermetically sealed) are available.



LEAD LENGTH: 2.0" + .50"

electrocube transformers

Aluminum Foil Wound



Electro Cube aluminum foil wound transformers are available in the standard models listed on the reverse and also to customer requirements as isolation or auto transformers for frequencies from 25 cycles into the kilocycle range. Units may be single or multi-phase. Open frame, shell enclosure and hermetically sealed configurations can be furnished.

Advantages of these foil wound transformers over conventional wire wound units include:

- higher operating efficiency
- reduced weight
- improved thermal efficiency
- higher temperature operation
- improved regulation
- internal losses
- improved volume efficiency

The ability of a transformer to dissipate heat affects its maximum rating. Electro Cube foil wound coils have the ability to dissipate large amount of heat because there is a direct metallic path to each end of the coil from any point within the coil. Special end treatment of the coil including attachment to a heat sink, can make possible significantly reduced operating temperatures.

Wire wound coils, by comparison, are more difficult to cool. As a result of a limited heat path a lower coefficient of heat transfer and increased resistance due to heat and vice versa, the heat is greatest in that part of the coil least capable of dissipating it. Heat generated by conductors deep within the coil must pass through many thermal barriers of the insulation between the wires.

In addition to thermal efficiency, the materials in Electro Cube foil transformers permit use with higher operating temperatures than are possible with wire coils with equivalent insulation ratings. This also contributes to reduced weight and volume.

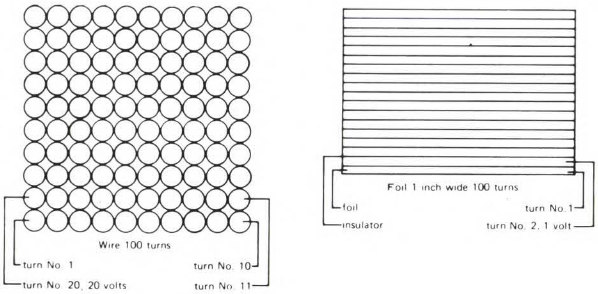


Figure 1. Typical coil sections with 100 volts excitation.

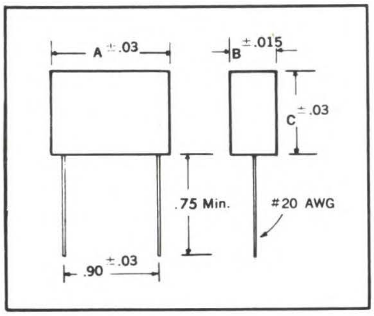
Figure 1 shows the relative difference in volume required for a 100 turn wire coil and an equivalent foil coil, and the relative use of space for insulation and conductors. It also shows voltage stress and insulation requirements for the two configurations. At 1 volt per turn there would be 20 volts between the 20th and first turn of the wire coil. When the top layer is finished, the last turn may lay against one of the first, resulting in a voltage difference of up to 100 volts. The foil coil never has more than 1 volt between any two conductors, or a 100 to 1 advantage over the wire coil, in this example.

The physical arrangement of the foil windings promotes a lower leakage reactance or power loss in the transformer, which contributes to efficiency and regulation. Together with the lower I^2R loss of the windings, this allows the use of fewer circular mils of conductor area to meet required efficiency and regulation requirements.

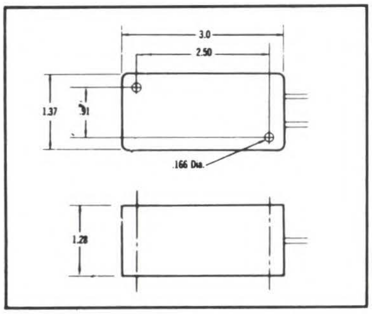
electrocube

UL Recognized

RC Networks

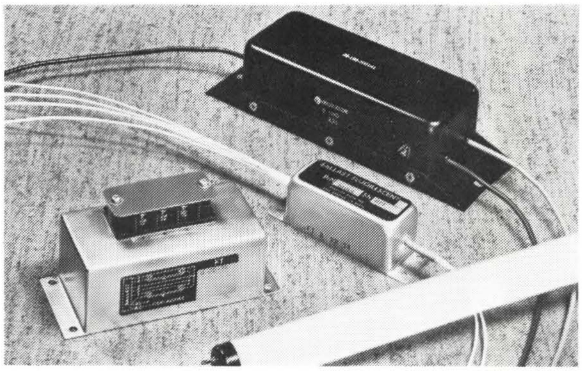


Capacity MFD	Resistance Ohms ±10%	Rated Voltage	Peak Pulse Voltage	Dimensions A in.	Dimensions B in.	Dimensions C in.	Electro Cube Part Number
0.5 ± 10%	22	200 VDC or 125 VAC	300 V	1.00	.38	.63	RG 1780 — 1
0.5 ± 10%	33		300 V	1.00	.38	.63	RG 1780 — 2
0.5 ± 10%	47		300 V	1.00	.38	.63	RG 1780 — 3
1.0 ± 10%	22		300 V	1.00	.50	.75	RG 1781 — 1
1.0 ± 10%	33		300 V	1.00	.50	.75	RG 1781 — 2
1.0 ± 10%	47		300 V	1.00	.50	.75	RG 1781 — 3
0.1 ± 20%	22	600 VDC or 250 VAC	900 V	1.00	.38	.63	RG 1782 — 1
0.1 ± 20%	33		900 V	1.00	.38	.63	RG 1782 — 2
0.1 ± 20%	47		900 V	1.00	.38	.63	RG 1782 — 3
0.25 ± 20%	22		900 V	1.00	.50	.75	RG 1783 — 1
0.25 ± 20%	33		900 V	1.00	.50	.75	RG 1783 — 2
0.25 ± 20%	47		900 V	1.00	.50	.75	RG 1783 — 3
0.5 ± 10%	22		900 V	1.25	.58	.83	RG 1784 — 1
0.5 ± 10%	33		900 V	1.25	.58	.83	RG 1784 — 2
0.5 ± 10%	47		900 V	1.25	.58	.83	RG 1784 — 3



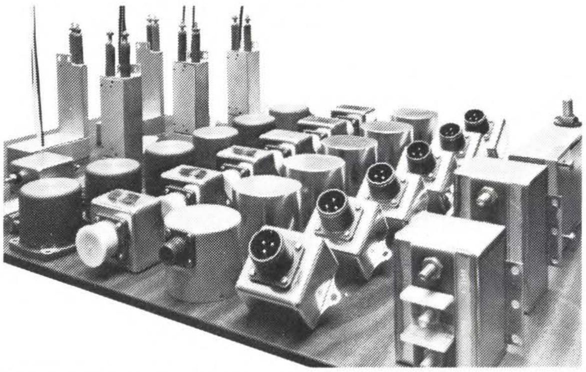
Part #	Resistance Ohms	Tolerance %	Power Watts	Capacity MFD	Tolerance %	VDC Volts	VAC Volts	Thyrector Part #	Lead Length Inches	Circuit #
RG 1676-1	100	10	10	1.0	10	1000	480	N/A	24	1
-148	100	10	10	1.0	10	1000	480	N/A	48	1
-2	100	10	10	.5	10	1000	480	N/A	24	1
-3	10	10	2	1.0	10	600	250	N/A	25	1
-10	220	10	5	2.0	10	600	250	N/A	25	1
-12	220	10	2	.5	10	1000	480	N/A	24	1
-13	220	10	1	.47	10	1000	480	N/A	24	1
-1848	220	10	5	.47	10	1000	480	N/A	48	1
-19	220	10	2	1.0	10	400	120	N/A	24	1
-20	100	10	2	2.0	20	600	250	N/A	18	1
-21	10	10	5	1.0	10	1000	480	N/A	24	1

Ballasts



Electrocube has designed and produced a wide variety of fluorescent ballasts for airborne and ground systems installation, as well as selected commercial applications where size and weight are considerations. These lightweight units are offered in 60 Hz and 400 Hz versions, for operation on DC and to 15 KHz, for fixed or dimmable circuits. Either leading or lagging power factors may be specified, and burnout protection can be provided against tube rectification. For cold weather applications, ballasts have been designed for normal operation in temperatures to −10°C.

Filters



Electrocube has developed literally thousands of EMI filters, to meet military, aerospace and commercial applications. Versions have been designed with current carrying capacities from 0.1 to 500 amps, voltages to 5000 VDC and 600 VAC, and for DC to 1000 Hz and intermittent or continuous duty. Single and multi-circuit configurations are also offered, including L, Pi (also with feed-through capacitors) and T. Models include low pass, high reject, noise, interstage and line, screen room, and heavy duty industrial filters.

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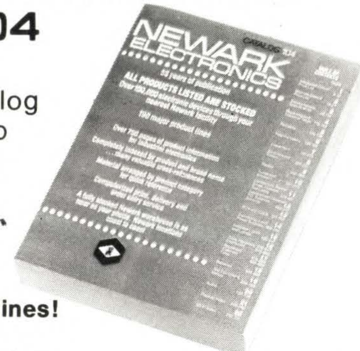

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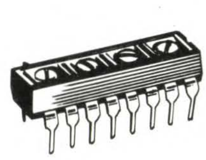

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Flip flop provides long delay

Haresh Shah
Bunting Steri System, Bridgeport, CT

You can extend the delay of a D flip flop with the 3-transistor circuit shown in the **figure.** The unijunction transistor (Q_1) remains OFF until the voltage across C_1 exceeds its threshold voltage. This hold-off time can be determined from

$$T = R_1 C_1 \ln(1/(1-(V_T+0.6)/V_{DD}))$$

and ranges from a few milliseconds to a few minutes. **EDN**

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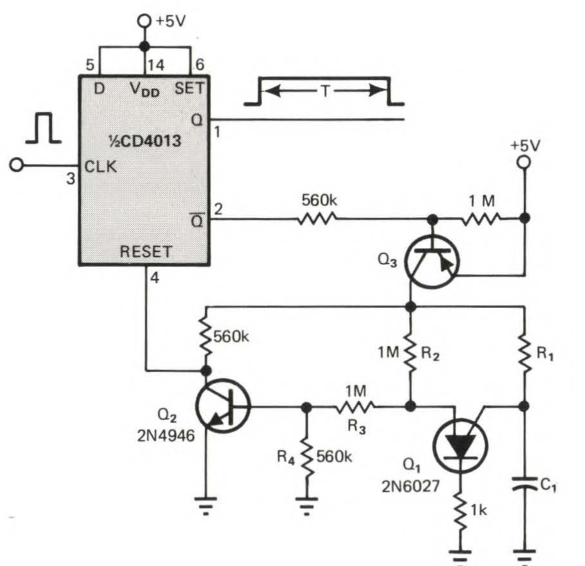
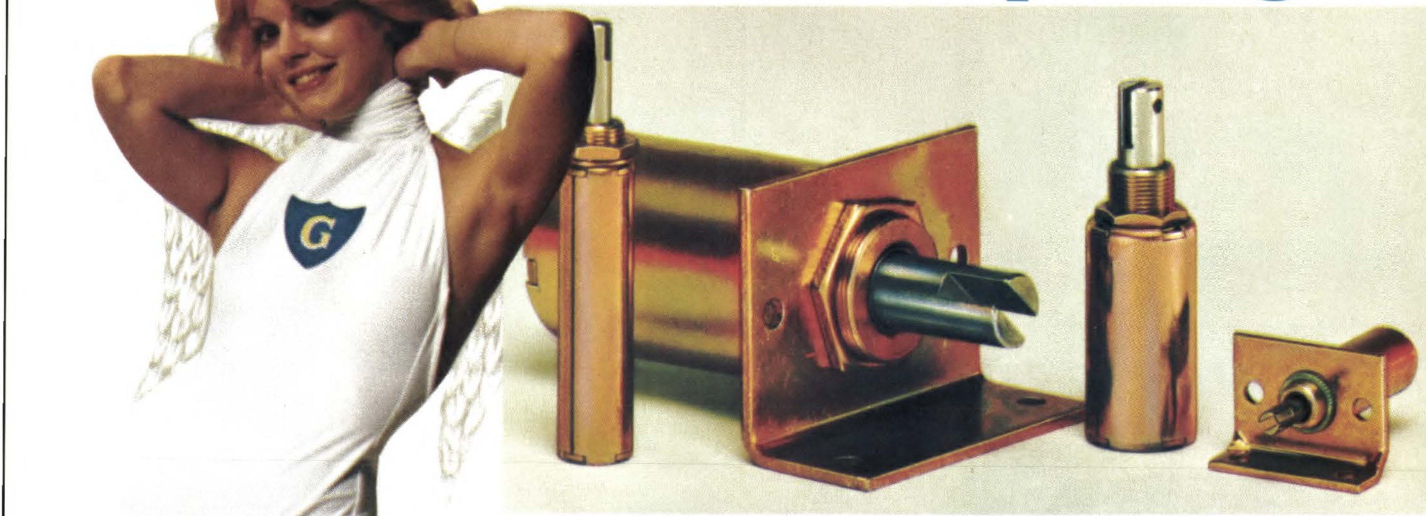
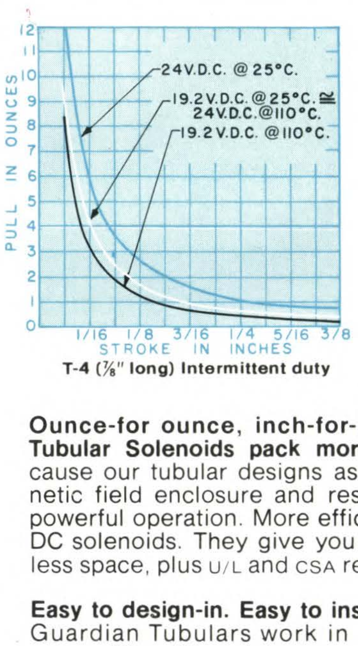


Delay circuitry *stretches an output pulse to a length dependent on the charge rate of C_1 through R_1. For the component values shown, the pulse period T is $0.8R_1C_1$.*

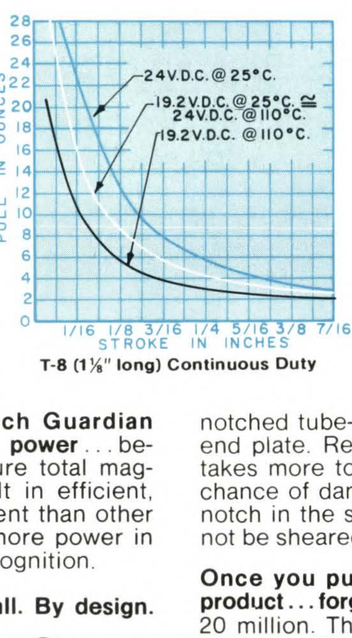
MORE PULL in a smaller package?



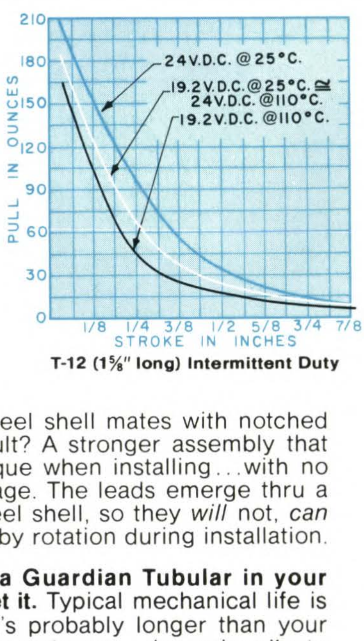
Check these curves.



T-4 (⅞" long) Intermittent duty



T-8 (1⅛" long) Continuous Duty



T-12 (1⅝" long) Intermittent Duty

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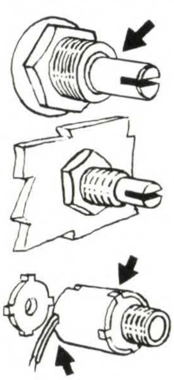
Easy to design-in. Easy to install. By design. Guardian Tubulars work in any position. Close tolerance between plunger and bobbin means no possibility of double seating. So they work in your product just the way *you* want them to work.

Mount them directly into panel by inserting threaded bushing thru installation hole and tightening nut on lock washer. Or, mount with standard bracket.

Either way, Guardian Tubulars install without damage to the solenoid. Look how the notched tube-steel shell mates with notched end plate. Result? A stronger assembly that takes more torque when installing...with no chance of damage. The leads emerge thru a notch in the steel shell, so they *will* not, *can* not be sheared by rotation during installation.



Once you put a Guardian Tubular in your product...forget it. Typical mechanical life is 20 million. That's probably longer than your product's life expectancy...due primarily to the unique Valox® 420 molded bobbin.

Variations and specials? Guardian's got 'em. Any DC voltage from 6 to 240. Push type or pull type operation. Return springs, silencers, termination variations, special mountings ... you name it and we'll deliver it with the high quality craftsmanship and low prices that have made Guardian Number 1 in Solenoids—and that keeps us here on top.

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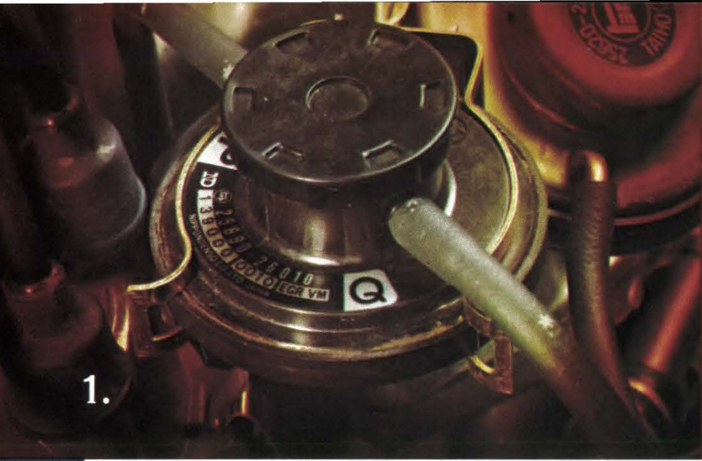
For more information, Circle No 74



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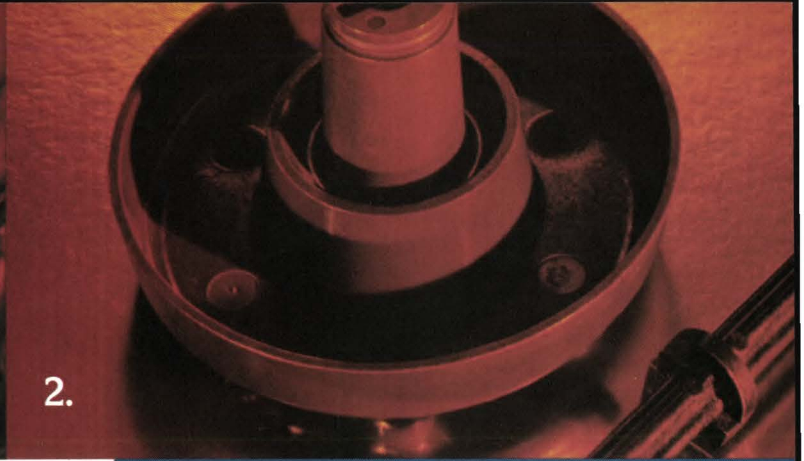


2.

5 ways to make a better product–and Ryton® does them all.

1. Keep it heat-resistant—Ryton® polyphenylene sulfide resins have UL 94 V-O and 5V flammability ratings, without additives.

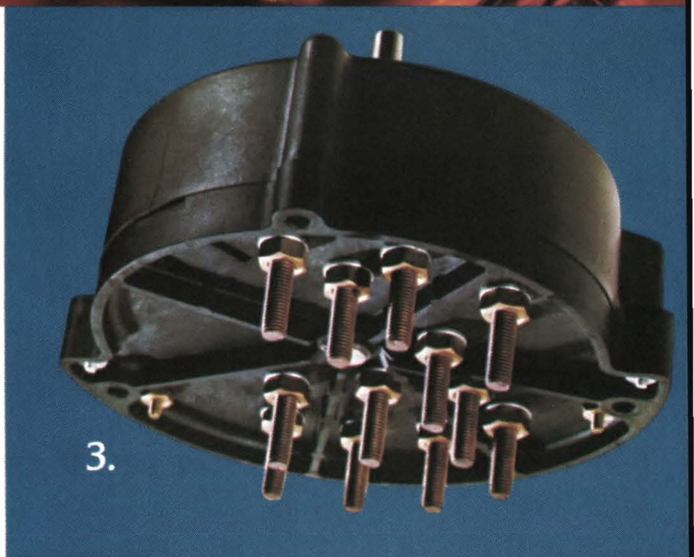
2. Keep it stable—Ryton engineering plastics have excellent dimensional stability—the only thermoplastic molding compounds with a UL Temperature Index as high as 240°C. (and documented performance in temperatures to 260°C.).

3. Keep it arc-resistant—Where high voltages are a requirement, Ryton resins with high arc resistance and low tracking rate are available.

4. Keep it chemical resistant—Ryton has no known solvents under 200°C.

5. Keep it all—There is no waste to Ryton. Simply recycle your sprues and runners. You save many dollars in raw materials costs. Dollars you can reinvest in R&D or further product refinements.

Ryton engineering plastics are available in 5 standard colors and an unlimited number of custom variations. And, as always, Ryton technicians stand ready to help you make the most out of your Ryton applications. *For quick action from the Ryton Sales Engineer nearest you call our Phillips Engineering Plastics Office toll free . . .* **800 231-3630** *(In Texas* **800 392-3716**).



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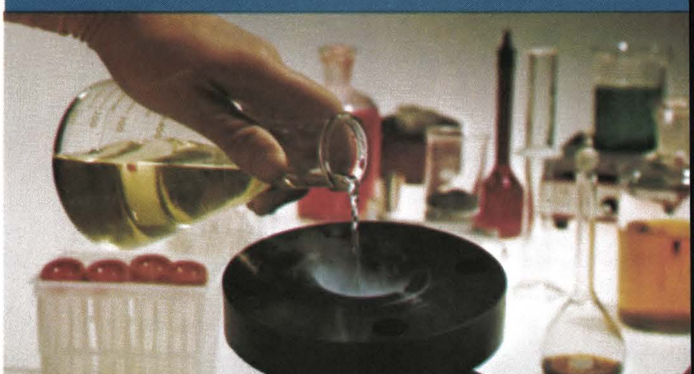

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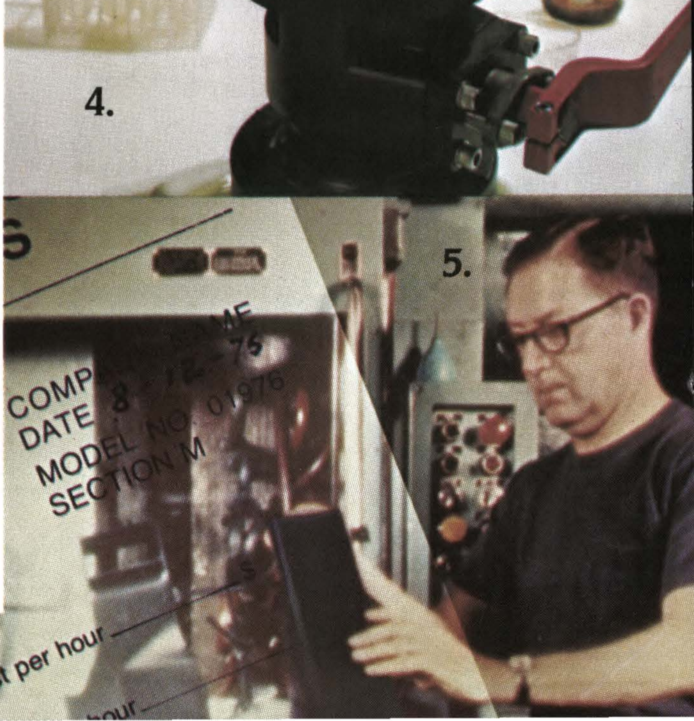

5.

Ryton® engineering plastics perform.

Phillips also produces K-Resin® butadiene styrene polymers and Marlex® polyolefin resins. Call toll free 800 231-1212 (In Texas 800 392-2078).

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A DIVISION OF PHILLIPS PETROLEUM COMPANY

PHILLIPS 66

For more information, Circle No 75

Feature Products

Electronic load handles 300A, features no-guess digital readout

Power supplies are getting bigger and bigger, and whether you build them or buy them, you must also be able to test them. Lectra-Load II meets this need; it's programmable, dissipates up to 1250W, specs a 0 to 300A constant-current capability and a 0.01 to 100Ω constant-resistance range, and accepts inputs ranging from 1.5 to 50V dc.

Unlike its competitors, the instrument sports a 4-digit readout and a *true* short-circuit test, controlled by a pushbutton. Its flexibility is further enhanced by a built-in pulse generator that can simulate dynamic loads. And for direct, constant sampling of these tests, the unit provides a front-panel 1-mV/A scope output.

Programmable *from front-panel controls or remotely via resistance or voltage inputs (IEEE-488 capability is optional), the portable Lectra-Load II operates over 0 to 40°C. Its dynamic loading capability permits switching between two current levels, and its built-in pulse generator provides both amplitude and duty-factor adjustment over a 1- to 1000-Hz range.*

Varied uses

If you're not familiar with electronic loads, you might not appreciate the Lectra-Load II's full capabilities. So consider the following potential applications of the device:

- In its constant-current mode, you can connect it in series with a constant-voltage dc power supply to form a variable constant-current source.
- It can test capacitor banks and batteries by acting as a constant-current discharge; it also tests dc voltage regulators.
- Because its voltage range extends down to 1.5V, it can test ECL power supplies.
- In its constant-resistance mode, the wide range frees you from the need to stock power rheostats among your test components.
- By using its built-in pulse generator, you can create many useful tests. For example, with duty factor set at 100%, you can program the unit to exercise a power supply at three levels—no load plus two preprogrammed values.

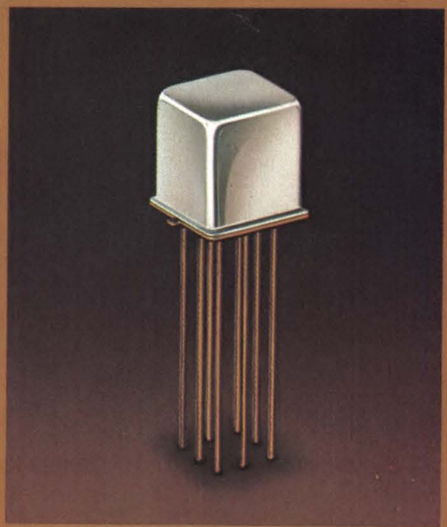
Human engineering

To make the Lectra-Load II easier to operate, designers engineered its front panel with well-spaced vernier controls and smooth push-push mode and range switches. They also added a built-in bale that tilts the instrument to the desired viewing angle.

Inside the electronic load's 5×10×16-in. case, all-copper heat sinks and bus bars attest to quality construction. Service problems are further minimized by the use of plug-in-type pc boards and cables, socket-mounted heat-dissipating elements and hermetically sealed semiconductors. Two 4-in. cooling fans eliminate hot spots. $1100; available in August.

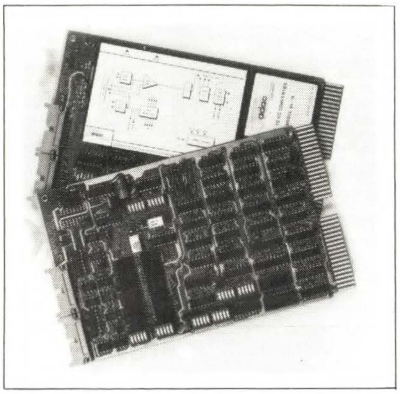
Power/Mate Corp, 514 S River St, Hackensack, NJ 07601. Phone (201) 343-6294.

Circle No 455



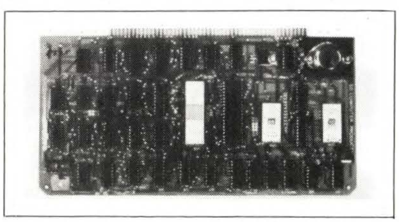
New Products

COMPUTER-SYSTEM SUBASSEMBLIES



I/O CARDS. These two dual-width boards furnish I/O capabilities to DEC LSI-11, LSI-11/2 and PDP-11/03 μCs, as well as the manufacturer's Series 1000 and 2000 systems. One of the boards, the Model 1750 asynchronous serial-line I/O card, contains sockets for 512×16 bits of PROM. Each of this dual-port board's I/O channels performs serial to parallel (and vice versa) conversion in 5-, 6-, 7- or 8-bit format.

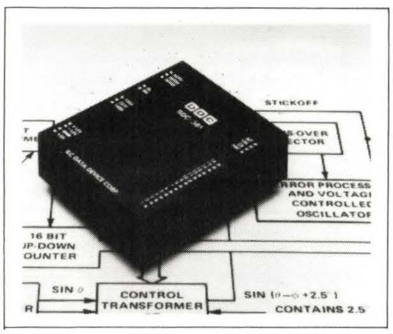
The other board, the Model 1014 A/D converter, features 14-bit resolution and a 10-kHz throughput rate. This unit allows random- or sequential-mode access, vector addressing, and selection of full-scale ranges and register addressing. You can increase its 16-channel capacity to 64 channels with a Model 1012-EX expander board. Model 1750, $395; Model 1014, $1195. Delivery, 30 days ARO. **ADAC Corp,** 70 Tower Office Park, Woburn, MA 01801. Phone (617) 935-6668. **Circle No 166**



VIDEO-DISPLAY BOARD. The Z80 μP-based VDB-8024 offers 80-character×24-line display (7×10-dot character matrix), composite video output (in addition to separate TTL-level sync and video outputs), 2k bytes of RAM and an I/O-mapped interface. Display features include full cursor control, forward and reverse scrolling, variable-speed display rate and enhancements such as blinking and underlining. $499 ($349, kit). **SD Systems,** Box 28810, Dallas, TX 75228. Phone (214) 271-4667. **Circle No 167**

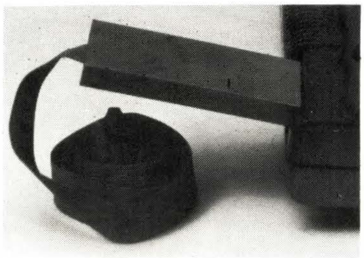
ANALOG I/O BOARDS. Compatible with PDP-11 Unibus systems, the DT1711 Series of 1-card analog-I/O and input systems offers four hex-height models. Standard features of units in this family include a channel capacity of up to 64 analog inputs and a choice of high- or low-level signal capability with 12-bit A/D conversion. These boards can also perform logic-controlled 3-axis point plotting via high-current outputs from two 12-bit DACs and an on-board Z-axis pulse generator. From $1240. **Data Translation Inc,** 4 Strathmore Rd, Natick, MA 01760. Phone (617) 655-5300. **Circle No 168**

PRINTER INTERFACE. Containing two separate interfaces, the PRI card handles either dot-matrix or daisy-wheel printers. One interface utilizes the "Centronics parallel" convention for dot-matrix operation, the other employs the "daisy-wheel parallel" convention and includes ribbon-lift and ribbon-lowering circuitry. $195. **Cromemco Inc,** 280 Bernardo Ave, Mt View, CA 94043. Phone (415) 964-7400. **Circle No 169**



S/D CONVERTER MODULE. Featuring internal transformer isolation, the SDC-361 synchro-to-digital converter module operates over a 47-to-1000-Hz range. This 2-speed (1:36 ratio) converter provides accuracy to within 20 seconds of angle and accommodates all standard synchro and resolver input formats. Tracking rates are 1000°/sec for 400 Hz and 250°/sec for 60 Hz. $695. **ILC Data Device Corp,** Airport International Plaza, Bohemia, NY 11716. Phone (516) 567-5600. **Circle No 170**

New Products



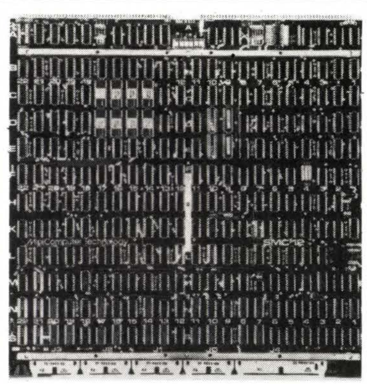
PRINTER INTERFACE. Plugging directly into the back of a TRS-80 computer keyboard, the Print Module eliminates the need for an expansion interface when driving printers such as Centronics (P1, 779, 703), Telpar and Axium models. This parallel line-printer interface is compatible with line-print commands in Level II BASIC. $99.95. **American Micro Products,** 6550 Tarnef, MS 11, Houston, TX 77074. Phone (713) 777-2759.

Circle No 171

UNIBUS I/O BOARD. Acting as a general-purpose interface, the DUAL I/O board provides the logic for program-controlled parallel transfers of 16-bit data between two external devices and a Unibus system. The quad-height unit is the hardware and software equivalent of two DR11-C interfaces. $900. **Able Computer Technology Inc,** Box 18162, Irvine, CA 92714. Phone (714) 979-7030.

Circle No 172

DAC BOARD FOR LSI-11. Residing on a half-quad-size board, the ST-LSI-DA4 4-channel DAC interfaces with LSI-11 μCs. Jumper-selectable addressing allows you to cascade any number of boards. These 12-bit units offer 4-μsec settling time, ±1/2-LSB max nonlinearity and a choice of four full-scale output-voltage ranges: 0 to +5, 0 to +10, −5 to +5 and −10 to +10V. $535; $475 without dc/dc converter. **Datel Systems Inc,** 11 Cabot Blvd, Mansfield, MA 02048. Phone (617) 828-8000. **Circle No 173**



DISC CONTROLLER. With a transfer rate up to 1.2M bytes/sec, the SM12 interfaces Data General minicomputers to as many as four storage-module disc drives in any mix of capacities up to 1200M bytes. Two computers with these controllers can share dual-ported drives. Dual, full-sector RAM buffers allow single-command contiguous-sector transfers up to 64k words. $3580. Delivery, 45 days ARO. **Minicomputer Technology,** 2470 Embarcadero Way, Palo Alto, CA 94303. Phone (415) 321-7400.

Circle No 174

GROWING UP TOGETHER

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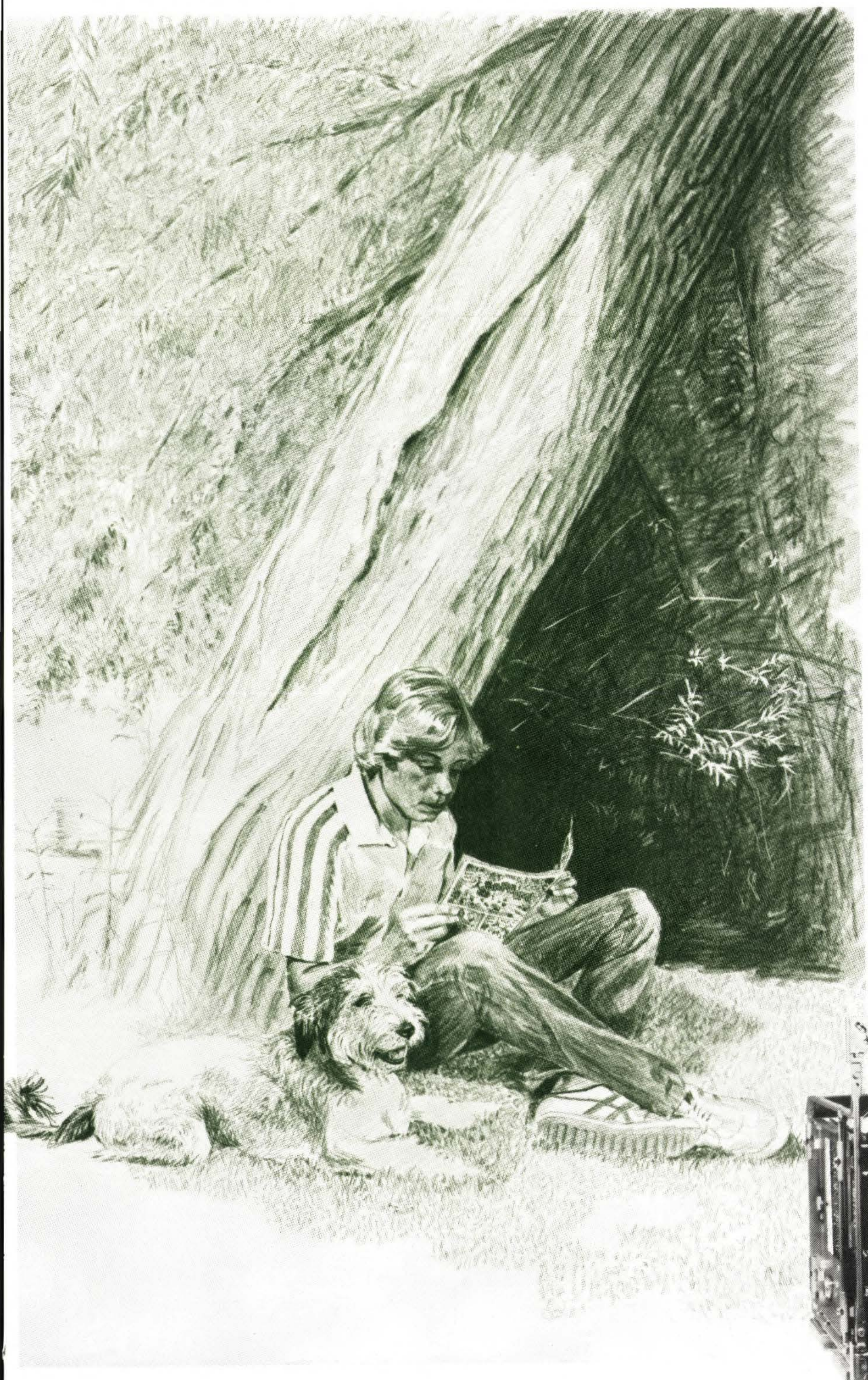

The years we've spent growing up with the alphanumeric terminal industry—years of working closely with the designers and makers of the final product—have given us the insight and understanding of the industry's needs that could have come no other way.

This relationship has helped Motorola grow to be a leading supplier of CRT display modules to the industry. Leading not only in terms of sales, but also in terms of quality, reliability and technology; leading in terms of performance vs. price.

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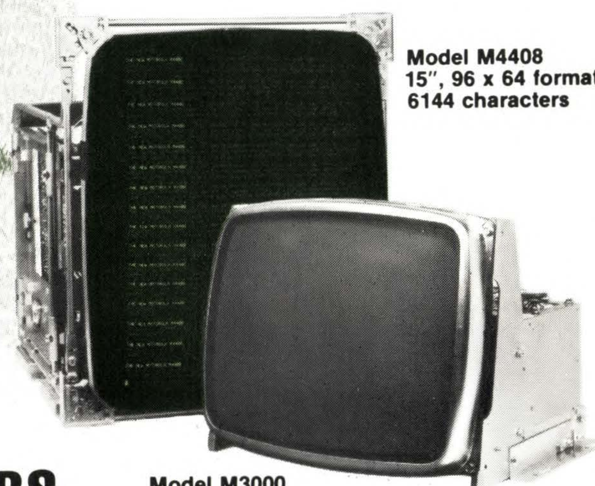

Model M4408
15", 96 x 64 format
6144 characters

Model M3000
12", 80 x 24 format
1920 characters

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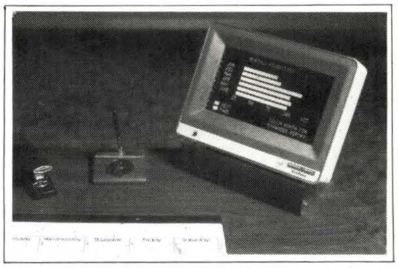
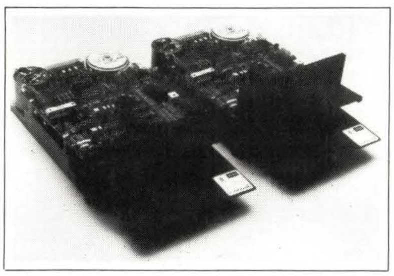
New Products

COMPUTERS & PERIPHERALS



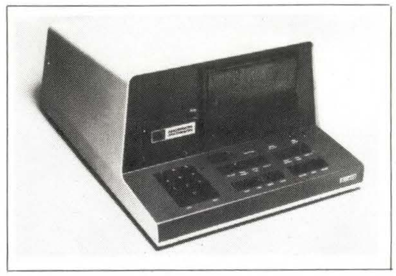
TOUCH PANEL. Communicating at 300 to 19,200 baud over an RS-232 interface, Vuepoint serves as a direct replacement for a CRT terminal. Only 2.5 in. thick, the unit's 12-line×40-character panel accepts touch input. Wall-mount, rack-mount, printer and keyboard options configure the panel for a variety of applications. $3500. **General Digital Corp,** 700 Burnside Ave, East Hartford, CT 06108. Phone (203) 289-7391. **Circle No 211**



MINI-FLOPPY DRIVE. Offering 40-track capacity in a small package, Model 6106 5.25-in. floppy drive furnishes track-to-track access time of 12 msec. The drive operates in both FM and MFM recording modes, providing up to 250k bytes (unformatted) storage on one side of a diskette. $450; $225 (500). **BASF Systems,** Crosby Dr, Bedford, MA 01730. Phone (617) 271-4064. **Circle No 212**

MODULAR TERMINALS. By combining the separately packaged display screens, keyboards, printers, magnetic card readers and memory subsystems included in BMT Series electronic terminals, you can tailor them to specific applications. Each terminal furnishes its own intelligence, eliminating the need for separate terminal controllers. From $2500. **Burroughs Corp,** Box 418, Detroit, MI 48232. Phone (313) 972-7267. **Circle No 213**

FLOPPY-DISC EXECUTIVE. Suitable for most popular 6800 systems, INDEX (*in*terrupt-*d*riven *ex*ecutive) services the console and I/O devices by interrupt requests rather than polling. You can write your own utility commands and driver routines to expand the versatility of the operating system. The software comes on two mini diskettes. $99.95. **Percom Data Company,** 318 Barnes, Garland, TX 75042. Phone (214) 272-3421. **Circle No 214**

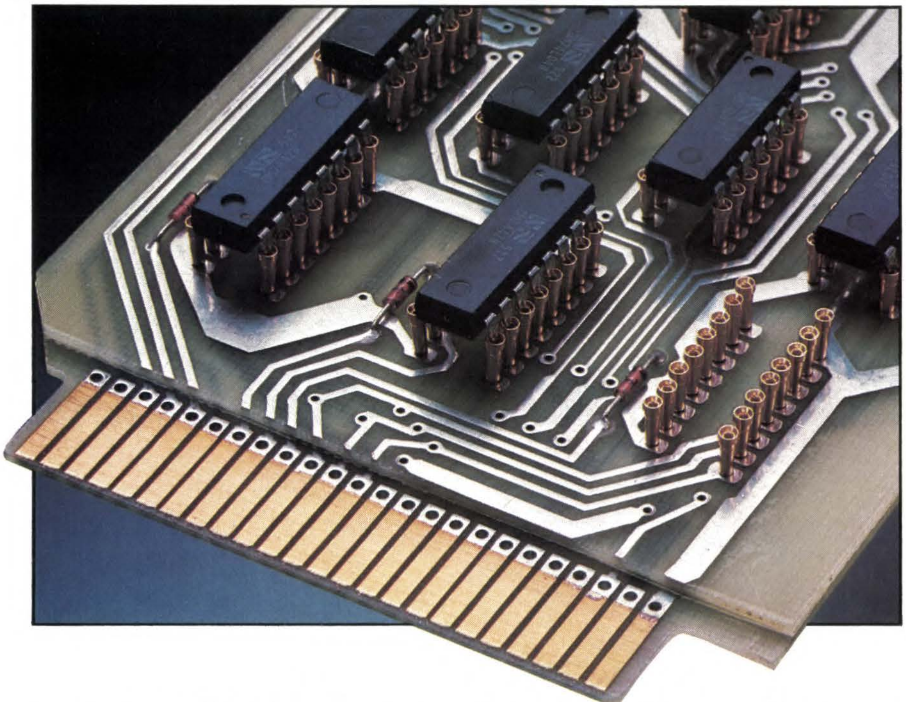


COMMUNICATIONS DISC. Designed to efficiently replace paper-tape, cassette or magnetic-tape units, Model AJ 460 diskette system operates at higher transmission rates than those devices and furnishes over 204k of storage. You can record data in binary, which allows the system to be transparent to control characters, or in packed mode for maximum storage efficiency. $1995. **Anderson Jacobson Inc,** 521 Charcot Ave, San Jose, CA 95131. Phone (408) 263-8520. **Circle No 215**

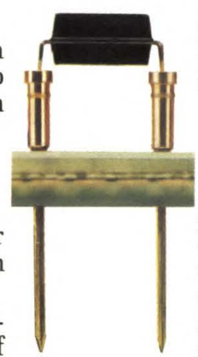
MODEM MULTIPLIER. MM-4 is designed to replace multiple modems interfaced to individual terminals in polled communications systems. The multiplier supports four terminals and each terminal can be located up to 50 ft from the unit. The units can also be linked to support more than four terminals. $450. **Wizard Associates,** 1019 S Noel, Wheeling, IL 60090. Phone (312) 541-6803. **Circle No 216**

CRT TERMINAL. Offering switch-selectable software compatibility with four leading terminals, Act-V provides a separate numeric keypad, and software-selectable screen formats of 80×24 or 48×39. $865. **Micro-Term Inc,** 1314 Hanley Industrial Ct, St Louis, MO 63144. Phone (314) 968-8151. **Circle No 217**

Expanding the parameters of press-fit technology



New press-fit I.C. socket offers lower cost, higher density and cooler operation.



Low Cost
Using a conventional precision screw machine contact, press-fit into the circuit board, this new socket is a major improvement over time-proven packaging methods. This innovative conversion to press-fit techniques greatly increases cost effectiveness by reducing need for external wiring and the elimination of soldering.

Characteristics of the new socket allow us to selectively plate a portion of the tails with significant savings in gold plating.

High Density—Greater Design Freedom
The new socket stands rather high on the board (.190″)—but with good reason.

The .062 pad now allows a trace to be run between contact holes for greater circuit density. This should allow a drop from a 3-wrap tail to a 2-wrap—or no tail at all. The 2-wrap offers about the same spacing as a conventional low profile socket with 3-wrap tail. Used in an Elfab Multi-Pac® system, you can get up to six planes of circuitry on a modular daughter board or backpanel. You eliminate the need for complex and expensive multilayered boards.

Cooler Operation
Since the socket stands up off the board, air flow aids in heat dissipation giving you much cooler operating temperatures. This is especially significant with higher pin count IC's.

Oriented Contact — both clip and contact tail.
Clip is so oriented that the four contact tines are in perfect alignment with the IC lead. Each tail is oriented square and parallel with the others to accept a mating connector when desired.

An Elfab exclusive!

For additional information contact:

ELFAB
The Leader in Press-fit Technology
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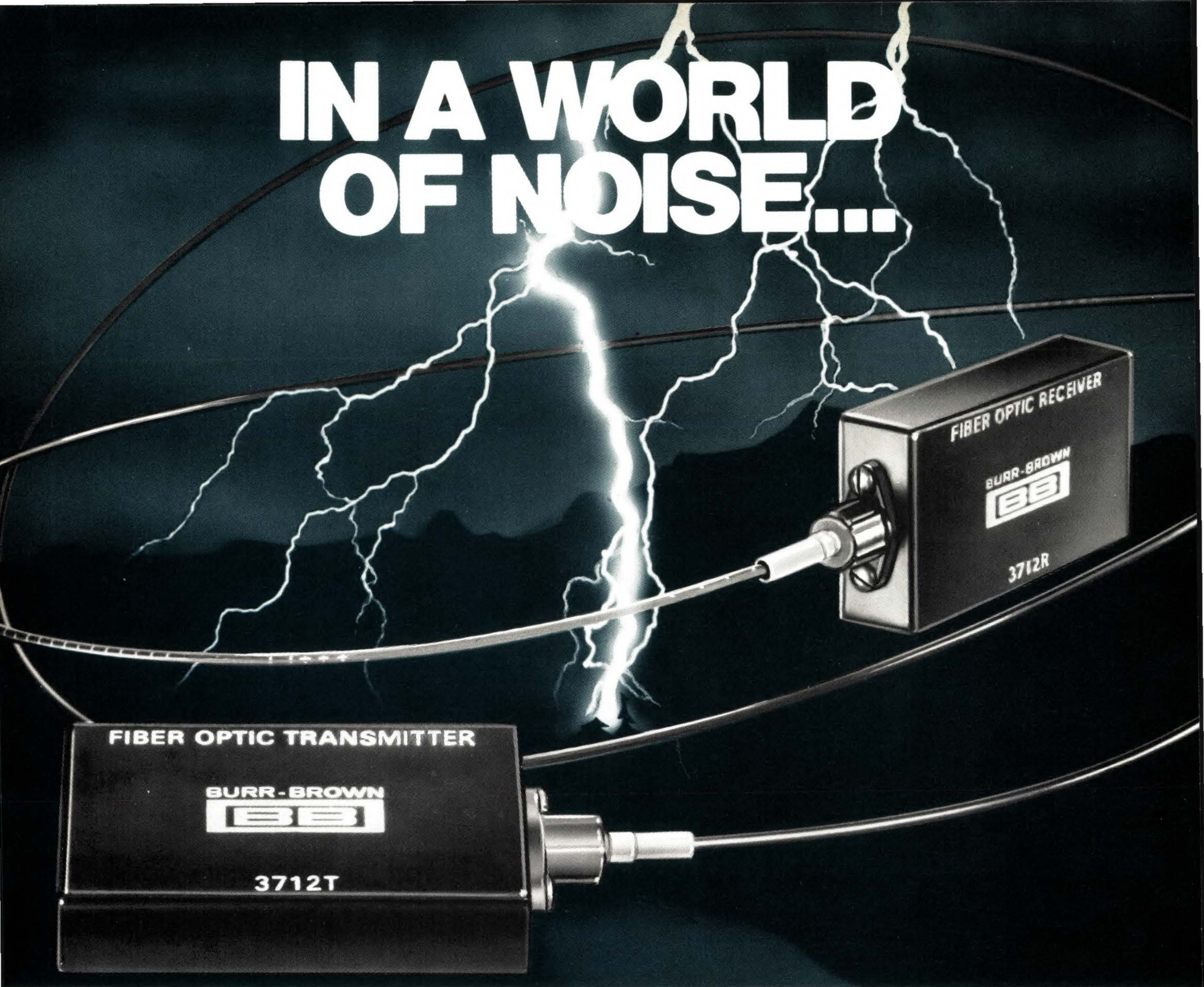

* 100's, cable not included.

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This fiber optic data link offers the lowest cost alternative to achieve total electrical isolation and noise immunity. 3712T transmitter (TTL In/Light Out) and 3712R receiver (Light In/TTL Out), coupled by fiber optic cable, form a simplex data link. You're assured of reliable, error-free 20k bit data transmission through hostile, noisy environments.

Maximum transmission length depends on the type of fiber optic cable you select. Lengths exceed 1.5km with 10^{-9} BER when low loss 200μm silica fiber is used. Units use the popular AMP single fiber connector.

DC coupled, 3712R is designed for low noise, low drift and maximum sensitivity. It requires only 5nW optical power and ±15VDC (±20mA). 3712T requires +5VDC (+60mA max) and launches 3.5μW of optical power into a 40mil, 0.53 N.A. fiber.

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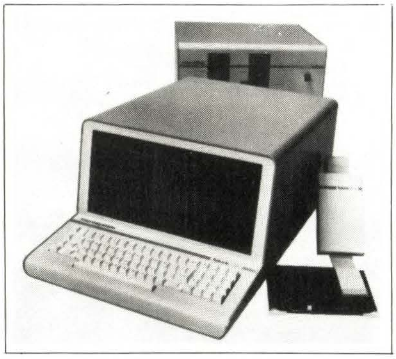
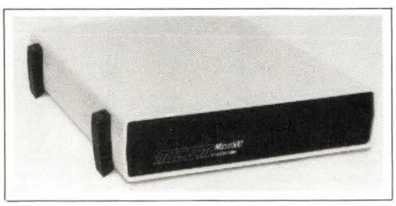
New Products



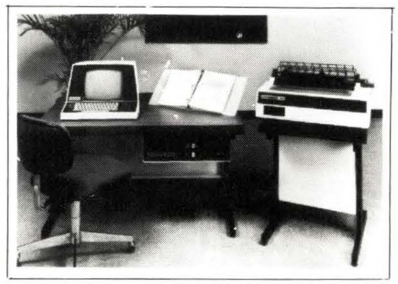
DEVELOPMENT SYSTEM. Providing the necessary tools for developing 8080-, 8085-, 6800-, 6802- or Z80-based products, the AMDS system furnishes real-time, in-circuit emulation up to 5 MHz. A 48-channel logic analyzer provides three hardware-break registers and a 256-state trace buffer. Software includes a screen-based editor and macro assembler. $16,500, with choice of CPU. **Futuredata Computer Corp,** 11205 S La Cienega Blvd, Los Angeles, CA 90045. Phone (213) 641-7700. **Circle No 218**



ERROR CONTROLLER. Eliminating the risk of undetected transmission errors by providing retransmission on error, Micro500 suits data communications over dial-up or dedicated lines at speeds up to 9600 bps. The unit also furnishes asynchronous to synchronous conversion. $895. Delivery, 45 days ARO. **Micom Systems Inc,** 9551 Irondale Ave, Chatsworth, CA 91311. Phone (213) 882-6890. **Circle No 219**

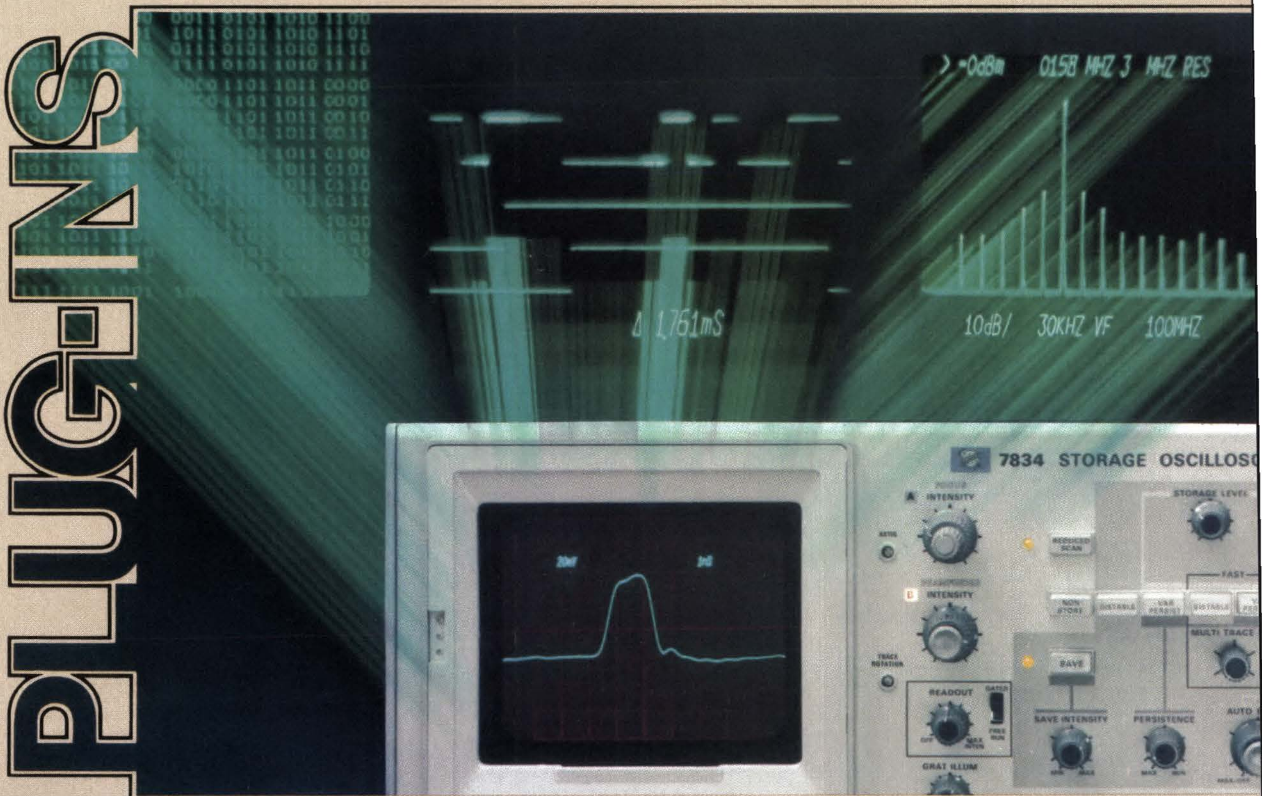
PRINT MECHANISM. Model AP-20M provides up to 20 columns of nonimpact thermal printing. The 5×7 alphanumeric characters output at 2.5 lines per sec, and the unit's fixed-head design requires only one moving part—the paper-roll drive. $275. **Gulton Industries Inc,** Gulton Industrial Park, East Greenwich, RI 02818. Phone (401) 884-6800. **Circle No 220**

MULTIUSER MICRO. Based on an 8085A computer, Microstar adds a floppy-disc operating system with interactive BASIC, multiuser and multitasking capability and a report writer to furnish complete software support. File access methods supported include direct, sequential and index sequential (ISAM). **Micro V Corp,** 17777 S E Main St, Irvine, CA 92714. Phone (714) 957-1517. **Circle No 221**



μC SYSTEM. Configured around the Z80 μP and a 12-in. Mindless terminal, System B utilizes both the manufacturer's disc operating system and CP/M. The system incorporates a 48k dynamic-RAM board; a Flashwriter video board displays 80×24 characters in an 8×10 matrix. $4750. **Vector Graphic Inc,** 31364 Via Colinas, Westlake Village, CA 91361. Phone (213) 991-2302. **Circle No 222**

FLEXIBILITY



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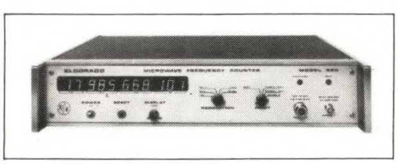
10^{-17}A ELECTROMETER. In Model 642, MOSFET technology enables you to make measurements to 60 electrons/sec. Resolution approaches 0.005% of the input signal, so one range covers 200× the span of an equivalent analog instrument's—one range thus replaces six analog ranges.

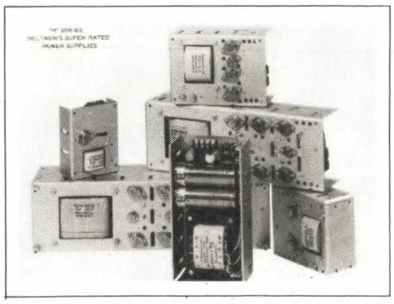
The instrument provides direct readings of voltage, current or charge, spanning 10 μV to 10V ($10^{16}\Omega$ input resistance), 10^{-13} to 10^{-7}A FS (4-1/2-digit resolution) and 10^{-11} coulombs (0.1, 1 or 10 ranges).

Innovations in the electrometer's design include a drift-compensated input stage; a lead(PB)-free input-terminal that minimizes surrounding air volume and thus reduces ionization; elimination of the need for switching devices with OFF resistances in the order of $10^{17}\Omega$; and minimized-insulation contact points, guarded and made of sapphire to reduce their contribution to leakage currents.

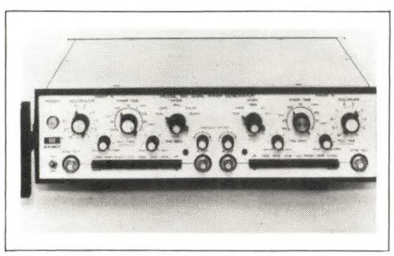
Analog inputs permit recording of large signals and allow high-gain observation of low signals. Dessicant paper, BCD output, BNC input connector, an air-line input connector, a test box and a battery adapter (to allow external 12V powering) are available as accessories. $3395. Delivery, 60 to 90 days ARO. **Keithley Instruments Inc,** 28775 Aurora Rd, Cleveland, OH 44139. Phone (216) 248-0400. **Circle No 175**



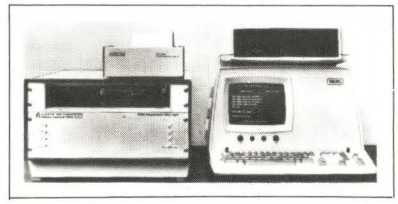
μWAVE FREQUENCY COUNTER. Model 990 performs completely automatic measurements under μP control. A frequency-only device, it utilizes automatic heterodyning to cover from 20 Hz to 18 GHz in two ranges. Sensitivity specs at −25 dBm; overload at +25 dBm. Options provide −30-dBm sensitivity, 26-GHz response, GPIB (IEEE 488-1975) interface and 2W input protection. $3800. **Eldorado Instruments Co,** 2945 Estand Way, Pleasant Hill, CA 94523. Phone (415) 682-2100. **Circle No 176**



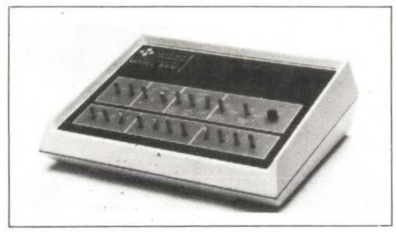
OPEN FRAMES. Claimed to deliver 25% more output than competitive units with the same case size, R Series supplies feature socketed semis and protection against reversed voltage or loss of sense. Forty two single-output models span 5 to 24V at 1.5 to 33.7A. All have a shielded split primary, 0.1% regulation and 1.5-mV rms noise. OVP comes as an option. From $37. **Deltron Inc,** Wissahickon Ave, North Wales, PA 19454. Phone (215) 699-9261. **Circle No 177**



DUAL RAMP GENERATOR. Model 180 effectively combines dual-ramp raster and delay generation. Its two complete 1-μsec to 1000-sec ramp generators (independently operable) can be synchronized for 1:1, 2:1 and 4:1 interlace. Rasters can easily be generated by using the unit's position and size controls, reverse sweeps, single-shot frames and fields, composite blanking pulses and 2:1 and 4:1 vertical sweeps for interlace. $995. **Exact Electronics Inc,** Box 347, Tillamook, OR 97141. Phone (503) 842-8441. **Circle No 178**



DAS. Included in Model 7251B are a BASIC-language computer with CRT, printer and mini-floppy disc; 8k of RAM (in addition to 42k of BASIC ROM); a scanner/mainframe with capacity for 14 I/O cards; a 4-1/2-digit DVM and a 10-channel low-level MUX. You can display bar charts and quasi-graphics on the CRT. Little or no programming experience is required of system users. $12,700, including the computer. **FI Electronics,** 968 Piner Rd, Santa Rosa, CA 95401. Phone (707) 527-0410. **Circle No 179**



BUS-FAULT ANALYZER. Using the portable Model 4810 you can view or control IEEE-488-bus data, handshake and control lines. The analyzer acts as a manual bus driver, controlled either from front-panel switches or the switch-programmed memory. For fault analysis, an internal memory permits review of up to 100 characters of bus transmissions; a memory loop bypasses unused memory space and repeats only the programmed segment. $1595. **ICS Electronics Corp,** 1450 Koll Circle, Suite 105, San Jose, CA 95112. Phone (408) 298-4844. **Circle No 180**

DIGITAL PATTERN GEN. Model 710A's hex keypad and display permit easy data entry. The unit generates patterns from 8 to 64 bits wide and 1024 bits deep, at a 10-MHz rate. It features programmability through keyboard or IEEE-488 controller, nonvolatile storage of digital patterns and expansion to 64-channel×1024-bit capability. $2400. Delivery, 60 days ARO. **Moxon Inc,** 2222 Michelson Dr, Irvine, CA 92715. Phone (714) 833-2000. **Circle No 181**

Product Managers: The best things in life are *FREE*

And that includes the exposure your newest products receive in EDN's Product Showcase. Twice yearly, in December and July, EDN's editors screen the previous six months' product introductions and publish the cream of the crop. Our over 200,000 readers save and constantly use this valuable reference issue, which in July will be organized into six comprehensive product categories. Reader service cards are valid for six months, so this issue keeps working for you.

Send us your candidates for this July Product Showcase *NOW*. Deadline is May 14, 1979. To qualify for initial consideration, an input

- *Must* have been introduced or be slated for introduction between January 1, 1979 and July 20, 1979. (Naturally, we pledge to keep any information about products not yet introduced *strictly confidential.)*
- *Must* be accompanied by a black-and-white photo and full pricing and availability information.
- *Must* be fully spec'd. Please tell us *why* the product is noteworthy. Brag about it. Give us enough information on which to adequately judge its merits.

Don't delay! Send us your inputs *NOW!* Clearly mark the envelope "PRODUCT SHOWCASE" and, *depending on product category,* mail to one of the following addresses:

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- Computers and peripherals — all computer equipment, packaged and board level, including interfaces and software
- Power sources — All types of power supplies, including batteries
- Hardware and interconnect devices — wire, cable, connectors, pc boards, enclosures, fiber-optic links, etc
- ICs and semiconductors — All types of solid-state devices, discrete to LSI, hybrid and monolithic, that come in DIPs or smaller packages. Includes μPs, RAMs, ROMs, power transistors, all function *chips* (A/D, D/A, V/F), fiber-optic sources and detectors, etc

2.

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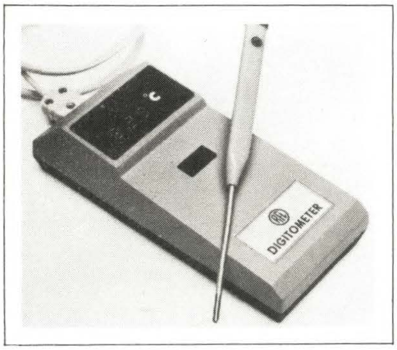
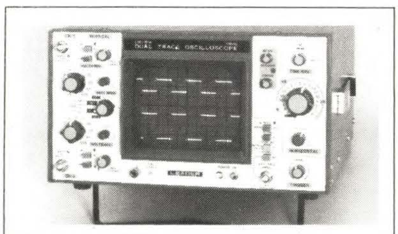
New Products

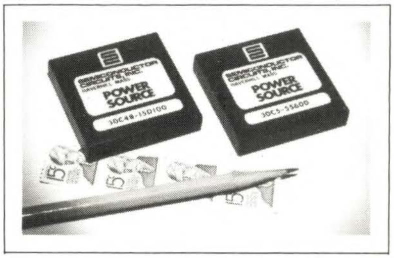


DIGITAL THERMOMETERS. Unlike many competitive units, LED-readout Digitometers come complete with probe and batteries. The standard Type-K liquid-immersible thermocouple probe covers −25 to +250°C (Model BDK-450) or −25 to +482°F (Model BDK-1000), with accuracy of ±0.2% of reading ±1 digit; optional probes extend these ranges. An internal element provides cold-junction compensation. Four 1.5V AA alkaline cells give 10 hrs of continuous operation or 10,000 readings. $340 for either model. **RFL Industries Inc,** Boonton, NJ 07005. Phone (201) 334-3100. **Circle No 182**



10-MHz SCOPES. Both the single-trace Model LBO-53 and the dual-trace Model LBO-514 furnish 8×10-cm display, Z-axis modulation, ×5 magnifier and complete trigger controls. Sensitivity reaches 1 mV on both units. Extensive use of ICs reduces instrument parts count and permits design simplification. Model LBO-514 also features X-Y operation, CH-1/CH-2 trigger selection and alternate or chopped display modes. $499 for LBO-53; $649 for LBO-514. **Leader Instruments Corp,** 151 Dupont St, Plainview, NY 11803. Phone (516) 822-9300. **Circle No 183**

TINY SWITCHERS. Able to hide under a penny, units in the 0.5×0.5×0.5-in. μS-A Series of switching-mode power supplies deliver up to 30 mW of output. Available models output 1.5 to 15V, regulated or unregulated, and operate from 47- to 440-Hz input. Full-output models accept either 120 or 240V input, while a reduced-output version operates from 90 to 255V without switching. I/O isolation specs at 2500V. $2.86 (100). **Microsource Corp,** 7330 Rogers Ave, Chicago, IL 60626. Phone (312) 465-8420. **Circle No 184**



DC-DC CONVERTERS. Series 30 units' low output noise (5 mV p-p max for dual-output models, 8 mV p-p max for single-output models) fits them for demanding applications. Common specs for the 12 devices in the line show full output to 71°C ambient, <1% reflected input ripple, 55 to 75% efficiency, a 2×2×0.4-in. case and 300V I/O isolation. Available input can be 4.5 to 5.5, 10.8 to 15, 21.6 to 30 or 42 to 56V dc; output, 5V/600 mA, ±12V/125 mA or ±15V/100 mA. $74.75. **Semiconductor Circuits Inc,** 218 River St, Haverhill, MA 01830. Phone (617) 373-9104. **Circle No 185**

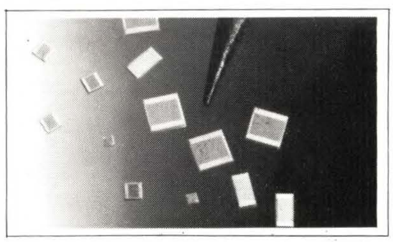
PROGRAMMABLE SUPPLIES. Four quarter-rack models (10V/3A, 20V/2A, 50V/1A, 100V/0.5A) and four half-rack 150W models (10V/10A, 20V/6A, 50V/3A and 100V/1.5A) make up the series. Each unit can have its output voltage, current and voltage limit controlled by IEEE-488 bus, external analog signals or manually. Outputs respond to programmed changes in 1 to 2 msec; current-sink circuitry discharges load capacitance. $495 to $625. **Systron-Donner,** 10 Systron Dr, Concord, CA 94518. Phone (415) 676-5000. **Circle No 186**

COMPONENTS & PACKAGING

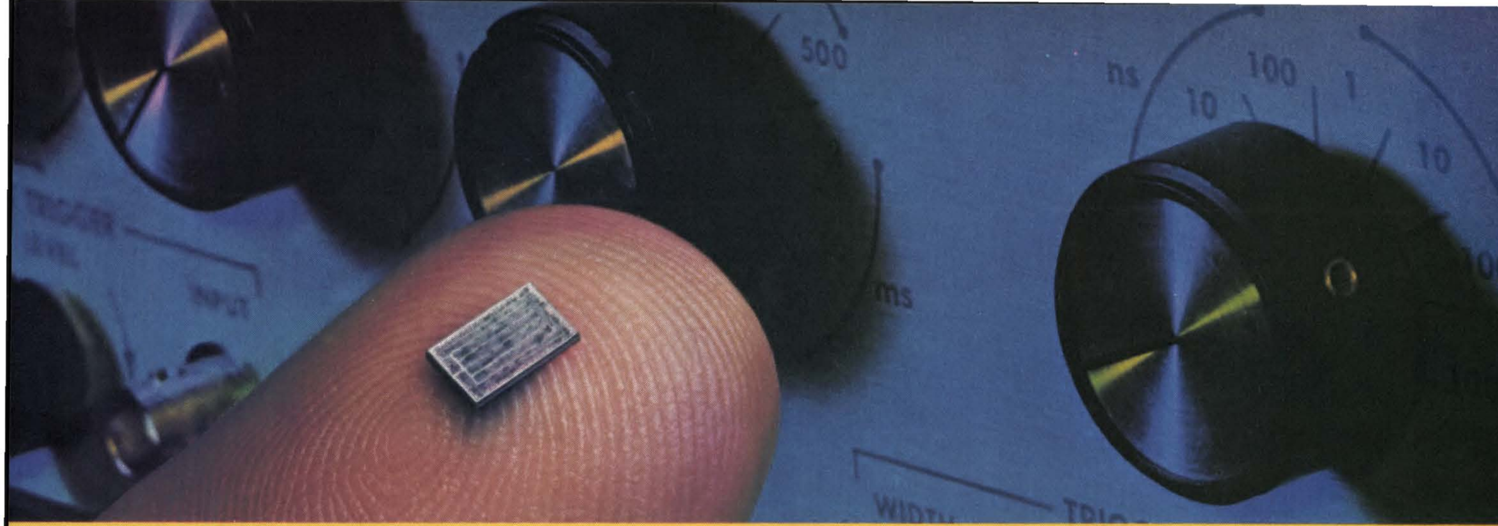
KEYBOARD. Designed specifically for personal, business and educational μC systems, Model 771 includes 56 alphanumeric keys which provide the full ASCII set (including lower case) and a separate 15-key numeric/cursor control keypad.

Four encoding modes, including an upper-case-only mode, combine convenient entry of data with high throughput. Standard features include auto-repeat, 2-key rollover and fully buffered outputs. The unit is equipped with a parallel interface and D-series connector for easy interconnection.

The options allow users to tailor the keyboard to their specific application. Four power-supply options suit almost any available voltage source. A versatile interface permits user selection of data, strobe and parity sense. An optional adapter converts the keyboard to a self-contained transmitter with 110 to 9600 baud RS-232 or current-loop serial-data output. From $150. **George Risk Industries Inc,** GRI Plaza, Kimball, NB 69145. Phone (308) 235-4645. **Circle No 187**



R NETWORKS. Designed for precision linear, digital and microwave circuits, this line of thin-film-on-ceramic chip resistors provides 20Ω to 500-kΩ resistance and 15- to 400-mW power ratings. The chips range in size from 0.02×0.04 to 0.1×0.1 in. and are laser-trimmed to standard tolerances of 1 and 5% (0.05% on special order). Long-term stability is typically 0.1%/1000 hrs at 125°C. The standard terminations are gold, nickel-gold or nickel-solder. **Electro Films Inc,** 100 Meadow St, Warwick, RI 02886. Phone (401) 738-9150. **Circle No 188**



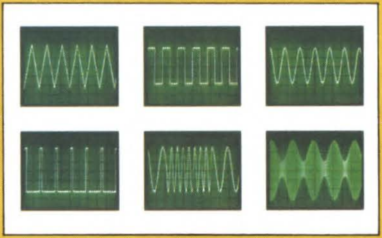
Gain huge savings–in dollars and inches–by replacing bulky conventional oscillators with tiny IC circuits.

WHILE CONVENTIONAL OSCILLATORS (FUNCTION GENERATORS, WAVEFORM GENERATORS, VCO'S, ETC.) COST UP TO SEVERAL HUNDRED DOLLARS, A SINGLE-CHIP IC OSCILLATOR CAN LITERALLY DO THE SAME JOB...AND FOR AS LITTLE AS $1.72. All you give up for this tremendous reduction in cost and size is a certain degree of regulation in the output, and a variety of knobs and controls. But let's be realistic—for most applications, the IC oscillator is perfectly adequate. Its small size and low price makes the alternate approach quite impractical.

Nothing left out in the process.

Despite its small size, an IC chip really does contain every operating section of a traditional function generator. Consider a typical semiconductor oscillator, the XR-2206. On-chip you find the oscillator circuit (to generate the basic periodic waveform); the wave shaper to give you a clean sinewave; the modulator section (for AM capability); and an output drive amplifier. Basically the selfsame circuitry you'd receive if you bought a standard oscillator or benchtop function generator hundreds, even thousands of times as big as the IC.

But the real payoff comes in the outputs of these oscillators, and here too you lose nothing by going solid-state. The IC oscillator will generate a combination of eight different types of output waveforms: triangle, ramp, sawtooth, squarewave, sinewave, pulse and FSK (frequency-shift keying) outputs, each with its own appropriate range of applications.



Just the item for sweep generators and sweep modulators.

The sweep generator, with its output hodgepodge of frequencies, can be a complex device. Yet it's a circuit easily built with ICs. A triangle-, ramp- or sawtooth-wave generator (XR-2207) modulates another oscillator (XR-2206) set up for voltage-to-frequency conversions. And presto! You have a functioning pocket-size sweeper.

Digital test equipment and stable phase-locked loop design.

Where space is at a premium, the solid-state precision voltage-controlled oscillator (XR-2209) comes to the rescue with banners flying. It more than meets the functional accuracies required, saves pounds and inches, and shaves dollars too.

Audio test equipment too.

Low cost is the prime requisite here, and once again the IC oscillator comes through for the design engineer. Solid-state sinewave generators (XR-2206 or XR-8038) are ideal, low-cost, simple solutions that often can offer a size and power advantage perfect for the test or hobby market.

Electrical Characteristics	EXAR Device Type				
	205	8038	2206	2207	2209
Output Waveforms	Triangle, Square, Sine			Triangle, Square	
Upper freq. limit (MHz)	4	1	1	1	1
Sweep range	7:1	1000:1	2000:1	2000:1	2000:1
Typ. temp. Drift (PPM/°C)	300	50	20	20	20
Typ. sinewave distortion	2.5	0.5	0.5	—	—

Table 1. Exar's line of IC Oscillators.

Digital communications, including data-interface or acoustical-coupled MODEMs.

The FSK oscillator is tailor made to solve this design dilemma. Modern designers, particularly those dealing with computer and data-processing systems, are continually put upon to squeeze more capability into ever decreasing amounts of space. Where board space is tight, the IC FSK oscillator (XR-2206 or XR-2207) is magnificently effective in compressing a complex function into a nutshell. You wind up with inches of real estate for really important things such as more memory.

Digital testers, logic circuits, on/off gating.

Naturally, there's an IC oscillator for the purpose. This time one with a pulse output (XR-2206 or XR-2207). All the same advantages you find in other applications—size, cost, low power requirements—apply here as well. In short, regardless of where you need to use an oscillator or function generator, there's an outstanding chance you can find a solid-state device to do the job and make you a hero in the bargain.

Beware. Only one company produces a complete line of IC oscillators.

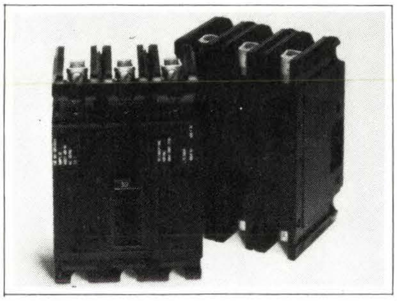
With a stable of five different circuits, Exar boasts by far the industry's broadest choice of IC oscillators. From low cost, easy-to-use devices to high performance function generators, the line is summarized in Table 1. Check them out, find the one best suited for your use, then make the shrewd move to solid state.

Exar's Function Generator Data Book contains technical articles and application notes. To request your copy, write on your company letterhead to your nearest Exar representative or to Exar, 750 Palomar Avenue, Sunnyvale, California 94086.

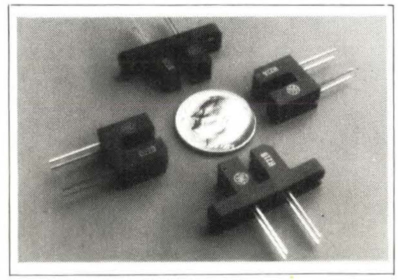
EXAR LINEAR

FOR THE EXAR DISTRIBUTOR OR REP NEAREST YOU, CALL EXAR AT (408) 732-7970.

New Products



CIRCUIT BREAKERS. Accommodating 250V at each pole, GH Series units feature three time-delay choices, ratings of 15 to 100A and a 10,000A interrupt capacity. These fully magnetic breakers carry 100% of rated load without derating; changes in temperature have no effect on current rating, must-trip point (125% rated load) or instantaneous-trip point. An inverse time delay protects against nuisance trips caused by normal starting surges. **Heinemann Electric Co,** Magnetic Dr, Trenton, NJ 08650. Phone (609) 882-4800. **Circle No 189**



INTERRUPTER MODULES. H21/H22 Series devices are compatible with logic systems from CMOS to relays. The units provide a consistent light beam with maximum dimensions of 1×1.5 mm, up to 25-mA minimum output and 55V blocking capability. The line includes 24 types: 12 transistor detectors feature low saturation voltage (<0.4V at 1.8 mA), and 12 darlingtons feature high output current (≥50 mA at 1.5V). **General Electric Co,** W Genesee St, Auburn, NY 13021. Phone (315) 253-7321. **Circle No 190**

MIXERS. Model MHP-106 operates over a 1- to 2500-MHz range with an IF of 1 to 2000 MHz. This medium-power-level device (17-dBm LO power) has a 1-dB compression point of 10 dBm min from 1 to 1000 MHz and 8 dBm min from 1000 to 2500 MHz. Full MIL-STD-202E performance is guaranteed. Contained in a hermetically-sealed 8-pin plug-in or solder-pin package, the MHP-106 measures 0.4×0.4×0.8 in. $50. **Engelmann Microwave Co,** Skyline Dr, Montville, NJ 07045. Phone (201) 334-5700. **Circle No 191**

MIXER. Model MD-159 is a 5- to 1000-MHz double-balanced mixer that provides a typical VSWR of 1.1:1. Other typical specs include 45-dB LO-to-RF isolation, 6-dB midband conversion loss and SSB NF within 1 dB of conversion loss. Typical two-tone IM ratio (with a −10-dBm input for each tone at 10-MHz separation) is 50 dB at 500 MHz. All specs apply with 50Ω source and local impedance and 7-dBm available LO power. $55. **Anzac Electronics,** 39 Green St, Waltham, MA 02154. Phone (617) 899-1900. **Circle No 192**

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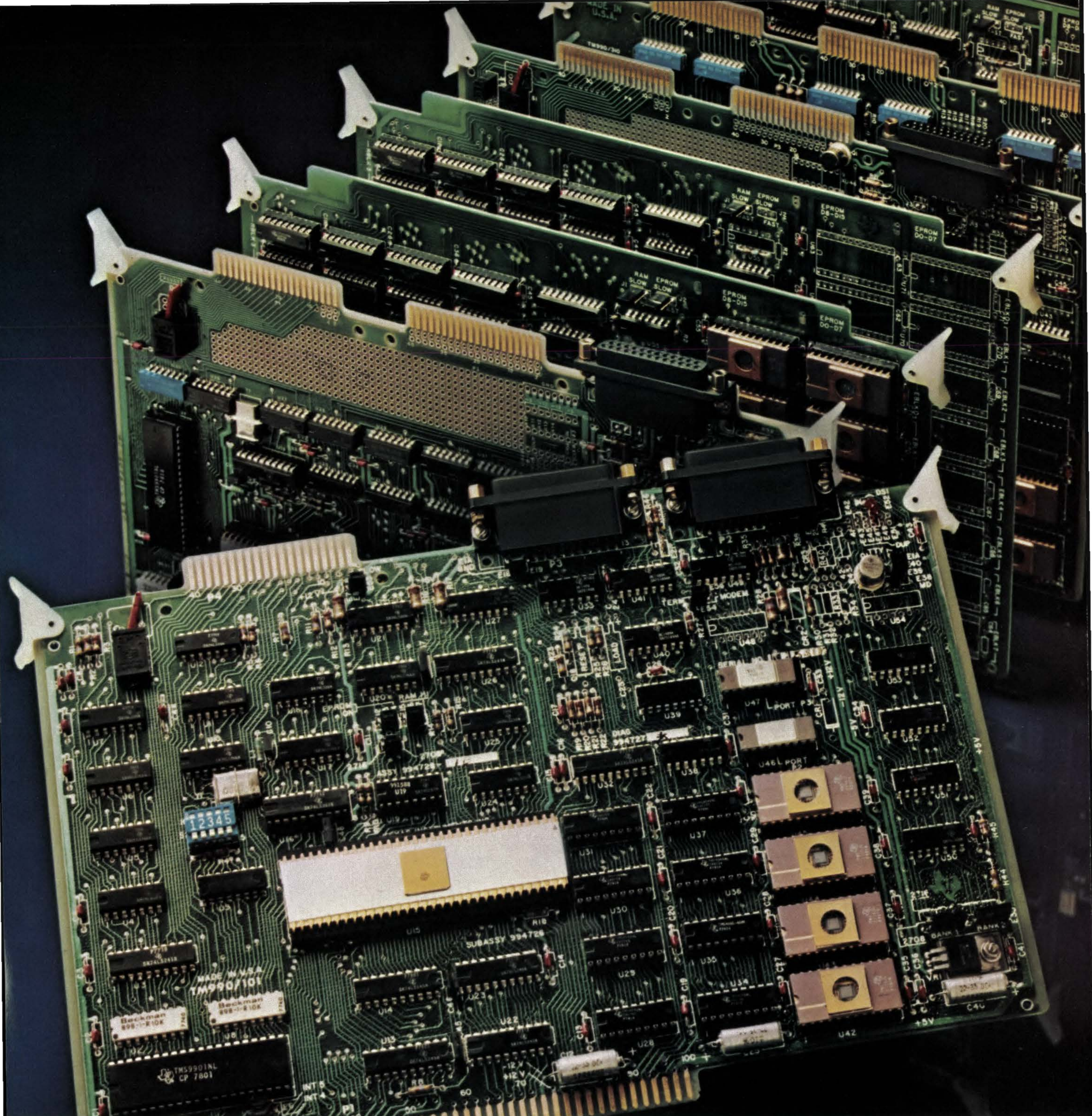

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First 16-bit microcomputer with BASIC. Easier to program. More capability to store. Remember. Communicate.

Now available from your local TI distributor, true single-board computers. TI's new TM 990/101M microcomputer modules. More memory than ever before. Simultaneous dual communication. With communication protocol on the board and POWER BASIC* high-level language on the TM 990/101M-10 to make programming faster, easier.

These new modules from TI save you design and development time. Cut the number of system components. Reduce costs and improve reliability.

They're preassembled. Pretested. Ready to plug in.

Four times the memory

The TM 990/101M microcomputers come with as much as four times the static RAM on board: up to 2K by 16 bits. The EPROM is either 2K by 16 bits or 4K by 16 bits.

Double the communication capability

Also on board: two serial communication ports. One for "remote" usage such as a terminal or modem. The other for "local" usage with an EIA terminal, a teletype, or TI's TM 990/301 microterminal.

The most in microcomputers

In TI's TM 990 Series, you have the widest available choice of cost-effective, 16-bit microcomputers to meet your system needs. Ideal for microprocessor evaluation. To speed your microprocessor-based design to market. Or as a production alternative. And all are instruction-set compatible with other members of TI's 990/9900 First Family.

For evaluation and OEM applications:

- TM 990/100M – Utilizes TI's NMOS 16-bit TMS 9900 microprocessor. Includes 1024 bytes of static RAM, 2K bytes of EPROM, and programmable serial and parallel I/O to form a powerful, single-board microcomputer.
- TM 990/180M – Provides 2.5 MHz operation. Incorporates an 8-bit memory interface.
- TM 990/189M – A self-contained, assembled, single-board 16–Bit Microcomputer System complete with integral keyboard, system monitor, symbolic assembler, 500 page Tutorial Text and 200 page User's Guide.

For memory expansion:

- TM 990/201 – 8K bytes of EPROM and 4K bytes of static RAM. Expandable to 32K bytes of EPROM and 16K bytes of RAM.
- TM 990/203 – Dynamic memory module with up to 64K bytes capacity with parity.
- TM 990/206 – 8K bytes of RAM expandable to 16K bytes.

For data entry and display:

- TM 990/301 – Provides hexadecimal entry of program data, as well as display and modification of internal registers and memory under software (TIBUG*) control.

For I/O expansion:

- TM 990/310 – A 48-bit input/output expansion module.
- TM 990/305 – Up to 32K bytes memory capacity using pin compatible static RAMS and/or EPROMS. Plus 32 optically isolated I/O lines, 16 dedicated parallel input lines and 16 user-configurable parallel I/O lines.

For A/D, D/A and digital I/O industrial interfaces:

- 16 new TM 990 Bus Compatible Modules – 7 A/D and D/A modules – 9 AC and DC input and output modules.

For development and production:

- TM 990/302 Software Development Module – Includes ROM resident symbolic assembler, text editor, loader, debug package. EPROM programming, dual audio cassette interface, and POWER BASIC development options.
- TM 990/401 – Interactive debug monitor (TIBUG) preprogrammed into EPROM.
- TM 990/402 – Line-by-line assembler preprogrammed into the EPROM.
- TM 990/450 – 8K POWER BASIC preprogrammed into ROM.
- TM 990/451 – 12K POWER BASIC preprogrammed into ROM.
- TM 990/452 – POWER BASIC option – EPROM programming and audio cassette interface.
- Configurable Basic – TMS W510F floppy based Industrial Basic allowing minimum memory configuration.

OEM card cages, cables, connectors, extender and prototyping boards are available.

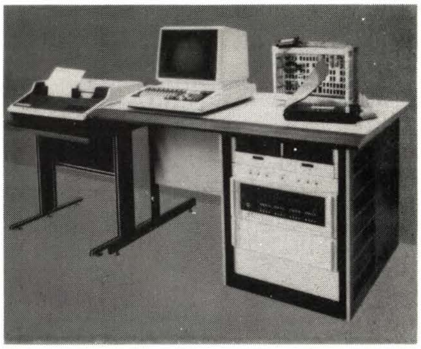
Time-saving software support

The TM 990 microcomputers are fully supported by TI's Advanced Microprocessor Prototyping Laboratory. AMPL* features 10 MHz trace capability and universal emulation for the TMS 9900, SBP 9900, TMS 9980, and TMS 9940 microprocessors as well as others to come.

*Trademark Texas Instruments Incorporated

AMPL is available as a floppy diskette system or as a disk system that accommodates multiple users. Programs can be edited, assembled, linked, loaded, and executed much faster than conventional paper tape or cassette based systems.

The 9900/9980 emulation allows development and debugging of software directly on a TM 990 module while monitoring and controlling the operation from the AMPL prototyping system.



For today and tomorrow: the 16-bit First Family

The TM 990 Series microcomputers and AMPL are integral members of TI's pace-setting 990/9900 First Family. A mature, proven family already providing the power and performance of 16 bits that many others are just beginning to imitate.

It's a broad, readily available selection of compatible microprocessors, microcomputers and minicomputers using the same advanced memory-to-memory architecture. Same instruction set. Same development system. All software supported and software compatible.

The 990/9900 Family gives you flexibility and economy to meet today's specific needs. And provides the base to improve and innovate as your needs change while protecting both your hardware and software investments.

For technical assistance on the TM 990 Series microcomputers, call your TI Field Sales Office. For more information, call your TI distributor or write: Texas Instruments, P.O. Box 1443, M/S 6404, Houston, Texas 77001.

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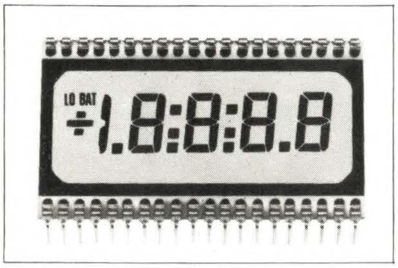
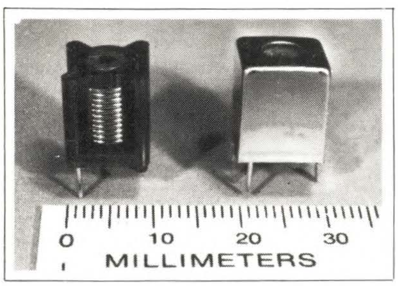
For more information, Circle No 86

New Products



DISPLAY. The 4-1/2-digit Model FE0206 liquid-crystal display features a 0.4-in. digit height, four decimal points, "low-battery" annunciator, +/− sign and two colons. The unit is available in transmissive, reflective and transflective modes and can be purchased with DIP pins or in a leadless version for use with elastomeric connectors. Crystal materials are available in two operating ranges: −10 to +55°C and −5 to +90°C. Red, blue and green readouts are available on special order. $11.25 (100). **AND,** 770 Airport Blvd, Burlingame, CA 94010. Phone (415) 347-9916.
Circle No 193



COILS. Tuneable Uni-10 devices employ a precision winding in a single molded piece of polypropylene plastic to assure mechanical and electrical stability. Nominal inductance for a 1-1/2-turn coil with a 0.25-in.-long carbonyl E core is 0.059 μH; a 10-1/2-turn unit yields 0.429 μH. Typical Q for the latter is 100 at 40 MHz. The coils' hex-hole core tunes more easily than slotted cores. $0.10 (5000). **Coilcraft,** 1102 Silver Lake Rd, Cary, IL 60013. Phone (312) 639-2361.
Circle No 194

SWITCHES. Series TH lighted pushbuttons convert from alternate to momentary action through movement of a lever accessible through a window in the switch body. Three available models include: TH01 with tapered bezel, TH31 with straight bezel and TH42 with covered bezel. Wipe-and-roll gold-plated-silver contacts handle loads to 5A at 250V ac. Most units come with round, square or rectangular lenses (translucent or transparent) and up to 4-pole switching capability. $3.55 (1000) for TH01. **Unimax Switch Corp,** Ives Rd, Wallingford, CT 06492. Phone (203) 269-8701. **Circle No 195**

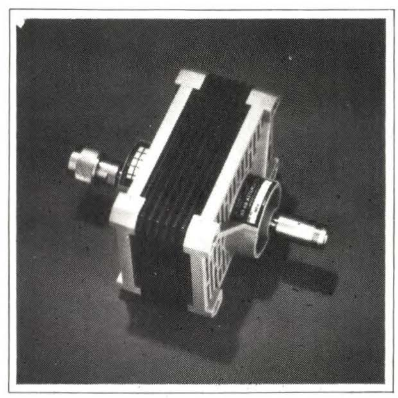
POSITION SENSORS. This line of contactless linear and rotary sensors serves industrial applications; the linear units have two ferrite-tube inductors connected in series and mounted between a movable plunger assembly containing two ceramic permanent magnets. When a unit is driven with an ac signal, its output is an ac voltage with amplitude proportional to the plunger position. Output of the similarly constructed rotary units varies linearly with shaft angle. Approx $20. **Licon Div/ITW Inc,** 6615 W Irving Park Rd, Chicago, IL 60634. Phone (312) 282-4040. **Circle No 196**

ASSEMBLY PANELS. Mountable on 0.5-in. centers, W9302 hex wire-wrapping modules accommodate up to 96 DIP ICs or sockets; 55 positions are dedicated to 16-pin devices and 11 to 20-pin units. These dedicated positions are prewired for ground and power. In addition, power and ground pads accommodate ceramic decoupling capacitors at 55 locations. Two I/O positions serve ribbon-cable edge connectors with up to 50 conductors, and 2-level wrapping posts are installed on the boards' component side. **MDB Systems Inc,** 1995 N Batavia St, Orange, CA 92665. Phone (714) 998-6900. **Circle No 197**

SOCKET BOARDS. The metric DMPS series of packaging panels offers a 160×233-mm board with an I/O area compatible with European right-angle wire-wrappable, 96-pin connectors. The Schottky-TTL construction combines two outside ground planes with a sandwiched V_{CC} plane. Socket/terminals have brass sleeves with gold-plate over nickel or a 200-μin. electro-tin finish. The four-tine spring-socket members are gold-plated beryllium copper and are available with three lengths of wire-wrapping or rectangular-post terminations. $150 to $350. Delivery, 4 to 6 wks ARO. **Garry Mfg Co,** 1010 Jersey Ave, New Brunswick, NJ 08902. Phone (201) 545-2424. **Circle No 198**

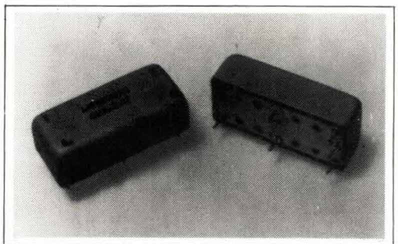
HEAT SINKS. Series 6075 components feature a universal hole pattern for 2-, 3- and 4-lead TO-3, TO-127 and TO-220 plastic power devices. For a 75° rise, thermal resistance specs at 6.25 (6077B), 7.4 (6076PB) and 11 (6075PB) °C/W. The sinks' U-shaped stampings require little board space; the components are a good choice in applications where vertical space is plentiful. The heat sinks come in pre-black-anodized aluminum material. $0.08 to $0.15 (1000). **Thermalloy Inc,** Box 34829, Dallas, TX 75234. Phone (214) 243-4321. **Circle No 199**

SWITCHES. 39000 Series thumbwheels are only 0.315 in. wide and include an isolated switching chamber for extra protection against dust and debris. Units are available with 10, 11, 12 or 16 positions (with field-installable dial stops) in a wide variety of output codes. The front-mounted modules feature 0.2-in.-high characters, a gold contact system and G-10 circuit board. The units assemble without tools and come with solder or optional pin terminations. $3.15/module (100). **Digitran Co,** 855 S Arroyo Parkway, Pasadena, CA 91105. Phone (213) 449-3110. **Circle No 201**

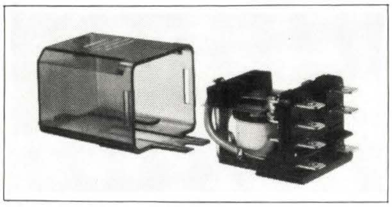


ATTENUATOR. Intended for broadband coaxial measurements at medium power, the 8498A offers 30-dB attenuation and covers a dc to 18-GHz range. It has a standing wave ratio of 1.3 at 18 GHz, and its attenuator pad is bilateral so that either end accepts 25W inputs. No adapters are needed because the standard connector configuration uses one Type-N male and one Type-N female. $475. Delivery, 8 wks ARO. **Hewlett-Packard Co,** 1507 Page Mill Rd, Palo Alto, CA 94304. Phone (415) 493-1501.
Circle No 202

DPM. Model 3362 features a full-scale capability of ±5999 counts with a bright 0.55-in. gas-discharge display. External control signals include hold, trigger, blank, read-rate and decimal point. Output signals include polarity and overrange; read-rates to 8 samples/sec are available. Options include parallel BCD output and offset for process applications. The unit is housed in a standard NEMA-size case. $118 (OEM qty). **Data Tech,** 2700 S Fairview, Santa Ana, CA 92704. Phone (714) 546-7160. **Circle No 206**



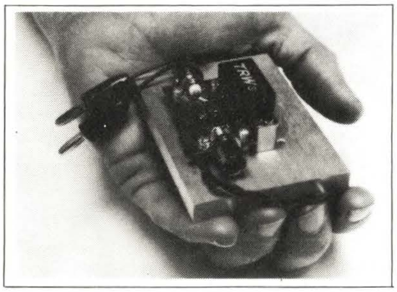
HYBRIDS. Series QHS-6 quadrature 90° hybrids are aimed at amplifier-combining, SSB-generator, image-reject mixer and radio direction-finding applications. Three units make up the line: QHS-6-17, 2 to 32 MHz; QHS-6-42, 3.5 to 80 MHz; and QHS-6-225, 50 to 400 MHz. All units have a 3-dB coupling loss, 20-dB isolation (15 dB for the −225), 1-dB amplitude balance and 1.5-dB insertion loss. VSWRs are 1.3, 1.35 and 1.5, respectively. The units are housed in a miniature pc-board plug-in package. $195 to $245. **Merrimac Industries Inc,** 41 Fairfield Pl, West Caldwell, NJ 07006. Phone (201) 575-1300. **Circle No 207**



RELAYS. Type 188 relays are rated for 30A at 28V dc, 120/240V ac (80% power factor) and 1 hp at 120V ac. They are available in Form X, Y and Z contact arrangements. Standard input-coil voltages range from 6 to 100V dc and 6 to 220V ac. The relays provide 0.25-in. combination quick-connect/solder terminals and are offered with either a standard or open-style, stud-mounted, plastic-flanged dust cover. $3.56 (2500) for Form Z, 120V-ac-coil unit. Delivery, stock to 6 wks ARO. **MidTex Inc,** 1650 Tower Blvd, North Mankato, MN 56001. Phone (507) 625-6521. **Circle No 208**

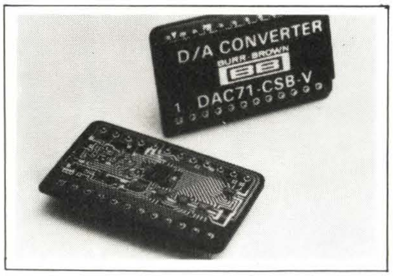
I/O SWITCHES. S442 and S443 solid-state ac-output switches provide an electrically clean, photoisolated, noise-free interface between sensitive controls and their load-field elements. Both units have a load-current rating of 2A at 40°C and 1.3A at 70°C. The S442 features a 30 to 140V-ac rms range, while the S443 is rated at 60 to 280V-ac rms. The devices are fully potted and have an internal heat spreader for optimum thermal management. S442, $12.25 (50); S443, $12.85. Delivery, stock to 6 wks. **International Rectifier Corp,** 1521 E Grand Ave, El Segundo, CA 90245. Phone (213) 322-3331. **Circle No 209**

New Products



TEST PACKAGE. The Demonstrator consists of an evaluation fixture and one high-power hybrid amplifier. Two amplifiers—both having a 30-dB gain and operating over a 1- to 520-MHz range with ±1-dB flatness—are offered: CA2820 which operates on 16 to 28V and delivers 0.5W, and CA2812 which operates on 8 to 15V and outputs 0.3W. The test fixture includes a base plate for the heat sink, pc board with BNC connectors, banana jacks for connecting a power supply and gold-plated pin sockets for terminating the amplifier. **TRW Semiconductors,** 14520 Aviation Blvd, Lawndale, CA 90260. Phone (213) 679-4561. **Circle No 210**

ICs & SEMICONDUCTORS



16-BIT DAC. Offering 16-bit, 4-digit resolution and ±0.003% linearity error, Model DAC71 settles in 10 μsec to ±0.003% FS. Six models give a choice of complementary straight-binary, complementary offset-binary and complementary decimal input codes, as well as voltage (0 to 10V or ±10V) or current (0 to −2-mA or ±1-mA) outputs. Gain drift is limited to ±15 ppm/°C over 0 to 70°C. The 24-pin ceramic hybrid DIP requires ±15 and +5V supplies. $39 (100). **Burr-Brown,** Box 11400, Tucson, AZ 85734. Phone (602) 746-1111. **Circle No 223**

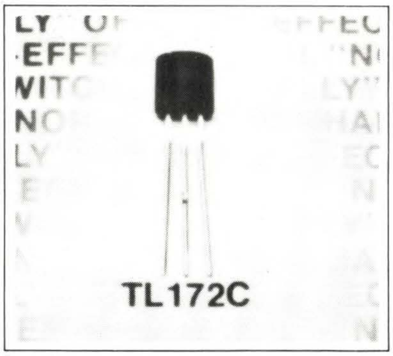
DC-MOTOR SPEED CONTROL. Essentially a phased-locked-loop IC, the CS-175 is intended primarily for use with ac tachometer signals from dc motors. With this circuit in operation, the external compensation required to ensure motor stability dominates motor-speed errors. For multiple-speed requirements, pin-programmed speed ratios of 1.333:1, 1.5:1 and 2:1 are included. The 14-pin DIP contains a tachometer input comparator, a voltage-controlled one-shot, a phase comparator, a current-limited output amp and a reference voltage. Nominal supply voltage equals 6V dc. $0.79 (1000). **Cherry Semiconductor Corp,** 99 Bald Hill Rd, Cranston, RI 02920. Phone (401) 463-6000. **Circle No 224**

4-1/2-DIGIT COUNTER/DRIVERS. Featuring guaranteed counting up to 15 MHz (25 MHz typ), ICM7224 and 7225 use CMOS technology to achieve low-power operation (1 μA at 10 kHz, 2 mA at 20 MHz). The devices operate as decade counters to 19999 or as timers to 15959; Schmitt-trigger input assures accurate counting. The 7225 LED-driver has direct, nonmultiplexed, common-anode 8-mA segment drivers. The 7224 LCD version has an on-board backplane RC oscillator. Minimum operating voltages are 3V (7224) and 4V (7225). ICM7224, $7 (100); ICM7225, $5.30. **Intersil Inc,** 10710 N Tantau Ave, Cupertino, CA 95014. Phone (408) 996-5000. **Circle No 225**

POWER MOSFETs. VN12 n-channel devices come with 40, 60, 80 and 90V ratings. Housed in a TO-3 package, the transistors supply 16A continuously or 32A pulsed. ON resistance of 0.25Ω and switching speed of <50 nsec make these devices interchangeable with IRF 100 units, and a gate threshold-voltage range of 0.8 to 2.5V simplifies TTL or MOS interfacing. A companion p-channel series, the VP12, offers the same voltage ratings. Units in this family supply 10A continuously or 30A pulsed; gate threshold voltage ranges from 1.0 to 3.0V. 80V VN12, $12 (1000); 80V VP12, $15. **Supertex Inc,** 1225 Bordeaux Dr, Sunnyvale, CA 94086. Phone (408) 744-0100. **Circle No 226**

10-BIT DAC IC. Accepting TTL-compatible inputs, the DAC-IC10B features ±1/2-LSB worst-case linearity error. An external reference current programs the device's scale factor and can be varied over a 4:1 range for multiplying operation. Output currents of 0 to 4 mA settle in 250 nsec to 1/2 LSB. Output compliance is −2.5V to +0.2V, and gain TC is 20 ppm/°C. The 16-pin ceramic DIP requires +5V at 18 mA and −15V at 20 mA. From $14.50. Delivery, 4 wks. **Datel Systems Inc,** 11 Cabot Rd, Mansfield, MA 02048. Phone (617) 828-8000, Ext 124. **Circle No 227**

LOW-EMI SWITCHING NPNs. Combining the economy of the TO-3 package with the versatility of an isolated-collector design, this family of transistors addresses problems encountered in high-voltage switching circuits. A reduction of collector-to-base capacitance reduces conducted interference by 20 to 30 dB; other benefits include reduced ground-loop currents, lowered assembly costs (no insulators required) and reduced shock hazards. V_{CEO} specs range from 200 to 450V; I_Cs, from 10 to 30A. $7.10 to $18.40 (100). **General Semiconductor Industries Inc,** Box 3078, Tempe, AZ 85281. Phone (602) 968-3101. **Circle No 228**



HALL-EFFECT SWITCH. Containing a Hall-effect sensor, signal-conditioning and hysteresis functions and an output transistor, the TL172C senses the presence of a magnetic field. A field of sufficient strength causes the output to switch from a high-impedance to a low-impedance state. $0.43 (100). **Texas Instruments Inc,** Box 225012, MS 308, Dallas, TX 75265. Phone (214) 238-5908. **Circle No 229**

LOW-COST ADC. For use with TMS-1000-type μCs, the TL507C contains a 7-bit synchronous counter, a binary-weighted resistor ladder, a summing amp, two comparators, a buffer amp, an internal regulator and logic circuitry. Using a single-slope conversion technique, the 7-bit-resolution, 8-pin DIP outputs a pulse whose duration is proportional to the analog input. Conversion speed equals about 1 msec. The unit operates on 8 to 18V from unregulated supplies or 3.5 to 6V from regulated supplies. $0.65 (100). **Texas Instruments Inc,** Box 225012, MS 308, Dallas, TX 75265. Phone (214) 238-5908. **Circle No 230**

Tired of Reruns?

Fluke counters with a new series in the 5 Hz-520 MHz/time slot.

If you're paying over $345 for a counter and getting frequency only, tune in on our new 1900-series of priced-right multicounters.

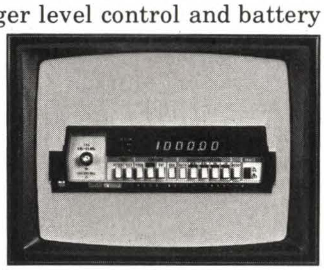
Five different models offer both time *and* frequency, with award-worthy performance and features; the ratings are terrific!

New Time and Frequency.

Last year's hit, the model 1900A, set the stage for this new series of multicounters by offering frequency, period, period average and totalize *standard* in one great counter.

Now all models in the series offer comparable features and value, with autoranging and autoreset as well.

Most models feature a trigger level control and battery option for reliable field use or line-cord-free bench operation. All typically have a 15 mV sensitivity (guaranteed on most!), plus a 0.5 ppm/month time base for long-term stability.

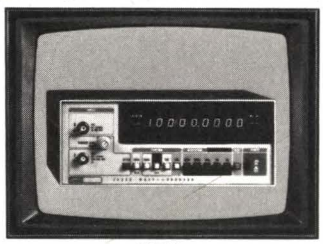


1900A

The Price is Right.

From this shared base of solid performance features, we've built a series of counters with one model just right for your needs.

The new **1912A**, with a 520 MHz range and an extensive package of standard features, offers more capability for $620 than you're likely to find anywhere. For 250 MHz measurement perfection, the **1911A** multicounter is a best-buy for only $495.



1925A

For lower frequency (125 MHz) applications, specify the **1910A** for $395. The **1900A**, years ahead in value, has been reduced to $345 for even more cost-effective 80 MHz measurement.

All models include true ±1 count for improved resolution, and the 1911A and 1912A have "clean drop-out" implemented on the high frequency inputs. Most models include internal RFI shielding.

Tune In and Count.

Call (800) 426-0361*, toll free, for the location of the closest office or for complete technical literature. Then stop in for the great family picture, and review the extensive option list for better TCXOs, data outputs, and more. John Fluke Mfg. Co., Inc., P.O. Box 43210, Mountlake Terrace, WA 98043.

Prices U.S. only.

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EDN
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LSI REGULATOR WITH OVER 1000 CIRCUITS.

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LAMBDA SEMICONDUCTORS

LAMBDA LAS 3905, 8 AMP, 80 WATT MONOLITHIC POSITIVE VOLTAGE REGULATORS

Description

8 amp positive regulator

The LAS-3900 series voltage regulators are monolithic integrated circuits designed for use in applications requiring a well regulated positive output voltage. Outstanding features include full power usage up to 8.0 amperes of load variation, internal current limiting, thermal shutdown, and safe area protection on the chip, providing protection of the series pass Darlington, under most operating conditions. In addition, a sense terminal is provided for elimination of voltage drop problems at high currents. Hermetically sealed copper TO-3 packages are utilized for high reliability and low thermal resistance when used with an appropriate heat sink. A low-noise temperature-stable diode reference is the key design factor insuring excellent temperature regulation of the LAS-3900 series. This coupled to a very low output impedance insures superior performance and load regulation.

The LAS-3900 series of four terminal regulators is available in a fixed output voltage tolerance of ±5% with a nominal output voltage of +5 volts.

ABSOLUTE MAXIMUM RATINGS

PARAMETER	SYMBOL	MINI-MUM	MAXI-MUM	UNITS
Input Voltage	V_{IN}	0	25 (1)	VOLTS
Input/Output Differential	$V_{IN}-V_{OUT}$	0	20 (1)	VOLTS
Power Dissipation @$T_C \leq 94°C$	P_D		80 (1) (2) (3)	WATTS
Thermal Resistance Junction To Case	θ_{JC}		0.7	°C/WATT
Operating Junction Temperature Range	T_J	-55	150	°C
Storage Temperature Range	T_{STG}	-65	150	°C
Lead Temperature (Soldering, 60 Seconds Time Limit)	T_{LEAD}		300	°C

(1) The maximum input voltage of the LAS-3900 Series is limited by the maximum input-output differential, maximum power dissipation, or the maximum current limit safe operating area, whichever is less.

(2) For operation above 94°C T_{CASE}, derate @1.42 watt/°C.

(3) In case of a short circuit, the second breakdown protection designed in this regulator may require the removal of the input voltage to re-start the regulator.

Regulator Performance Specifications

Input voltage test condtions are as follows: V_1 = Vo + 3 Volts, V_2 = Vo + 10 Volts, V_3 = Vo + 150 volts, or the maximum input whichever is less.

PARAMETER	SYMBOL	TEST CONDITIONS V_{IN}	I_o	T_J	MIN	MAX	UNITS
Input Voltage	V_{IN}		10MA		Vo+2.6	25(5)	Volts
Output Voltage	V_O	V1 to V2	10MA to 8.0 Amp	25°C	0.95[Vo] (1)	1.05[Vo]	Volts
Input-Output	$V_{IN}-V_O$		8.0 Amp	0°C to +125°C	2.6		Volts
Differential	$V_{IN}-V_O$		0.5 Amp	0°C to +125°C		20.	Volts
Output Current	I_O	V1		25°C	0	8.0	Amps
Line Regulation(2)	$REG_{(LINE)}$	V1 to V3	5A	25°C		2.0	$\%V_O$
Load Regulation(2)	$REG_{(LOAD)}$	V1	10MA to 8.0 Amp	25°C		0.6	$\%V_O$
Quiescent Current	I_Q	V1	Output/Open	25°C		20.	MA
Quiescent Current Line	$I_{Q(LINE)}$	V1 to V2	10MA	25°C		5.	MA
Quiescent Current Load	$I_{Q(LOAD)}$	V1	10MA to 8.0 Amp	25°C		5.	MA
Current Limit	I_{LIM}	Vo+5V		25°C		14.	Amps
Short Circuit Current	I_S	Vo+5V		25°C		14.	Amps
Temperature Coefficient	T_C	V1	0.1 Amp	0°C to +125°C		0.03	%Vo/°C
Output Noise Voltage	V_N	V1	0.1 Amp	0°C to +125°C		10(3)	uVrms/V
Ripple Attenuation	R_A	V1	2.0 Amp	0°C to +125°C	60(4)		dB

(1) Nominal output voltages are specified under ordering information.

(2) Instantaneous regulation, average chip temperature changes must be accounted for separately.

(3) BW=10Hz — 100 Hz.

(4) Ripple attenuation is specified for a 1 VRMS, 120 Hz input ripple. Ripple attenuation is a minimum of 60 dB at a 5 volt output.

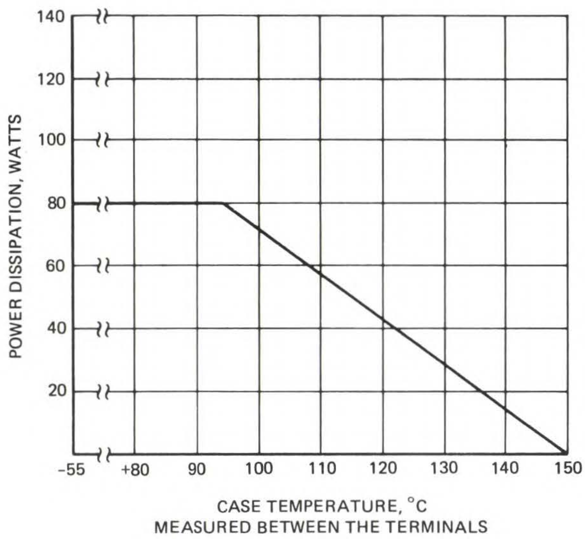
(5) The maximum input voltage of the LAS-3900 series is limited by maximum input-output differential voltage, maximum power dissipation, or the current limit-SOA, whichever is less.

Price List

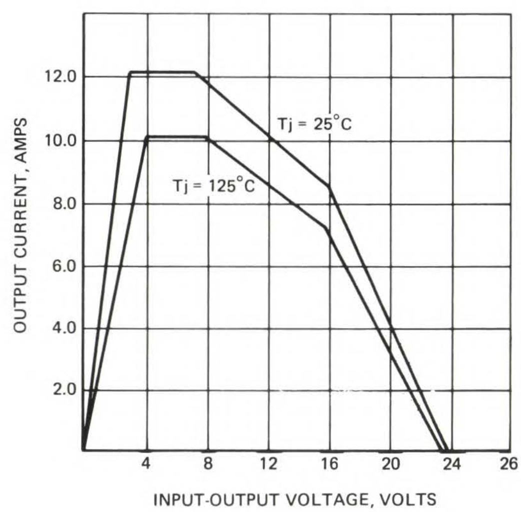
NOMINAL Vo VOLTS	DEVICE PART NO.	QTY 1-24	QTY 25-49	QTY 50-99	QTY 100-249	QTY 250-499	QTY 500-999	QTY 1000-2499	QTY 2500-4999
5	LAS-3905	$18.00	$16.50	$15.75	$14.75	$13.00	$11.90	$10.65	$10.00

CONTACT THE FACTORY FOR HIGHER QUANTITY PRICES. DEVICE CONFIGURATIONS, SPECIFICATIONS, AND PRICES SUBJECT TO CHANGE WITHOUT NOTICE

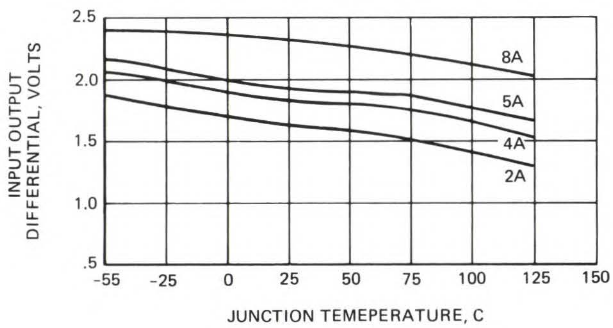
Operational Data



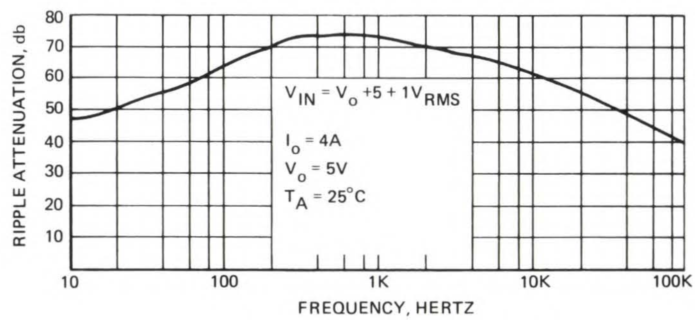
POWER DERATING



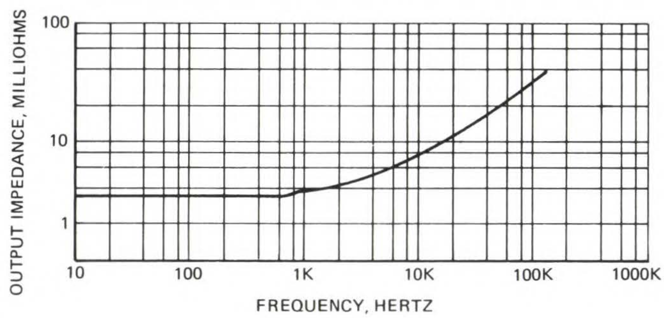
TYPICAL CURRENT LIMIT VS INPUT OUTPUT VOLTAGE DIFFERENTIAL



TYPICAL INPUT-OUTPUT DIFFERENTIAL VOLTAGE vs JUNCTION TEMPERATURE

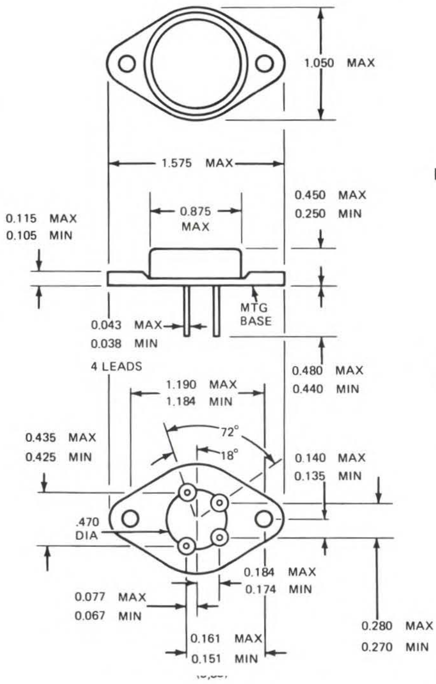


TYPICAL RIPPLE ATTENUATION vs FREQUENCY

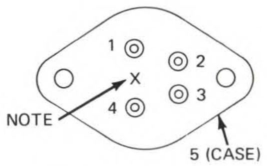


TYPICAL OUTPUT IMPEDANCE vs FREQUENCY

Outline Drawing



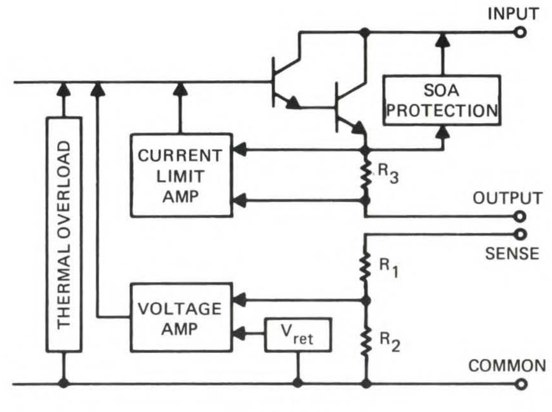
COPPER
4 TERMINAL/TO-3



NOTE (X) = Case temperature measured at this point.

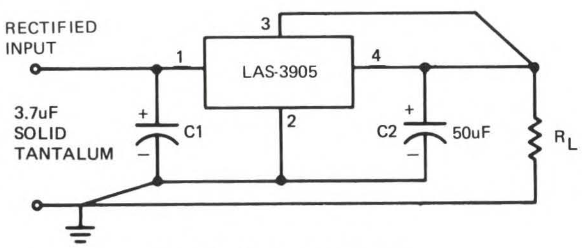
PIN	FUNCTION
1	INPUT
2	COMMON (ELEC)
3	SENSE
4	OUTPUT
5	COMMON

Functional Block Diagram



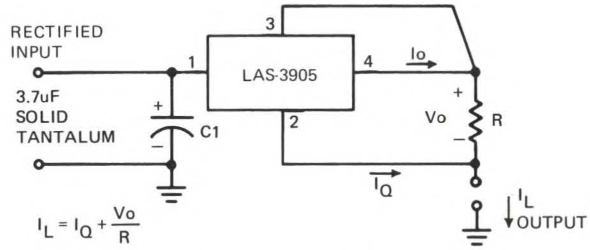
LAS-3905

Typical Applications



PIN 2 IS CONNECTED TO CASE.
C 1 TO BE PLACED AS CLOSE TO THE DEVICE AS POSSIBLE
FILTER CAPACITOR = 2000uF/AMP

8 AMP POSITIVE REGULATOR CIRCUIT



PIN 2 IS CONNECTED
TO CASE.
C1 TO BE PLACED AS CLOSE TO THE DEVICE AS POSSIBLE.
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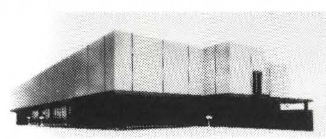

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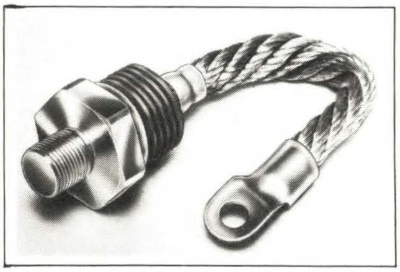
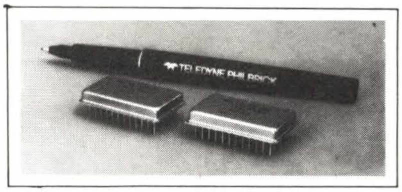
New Products

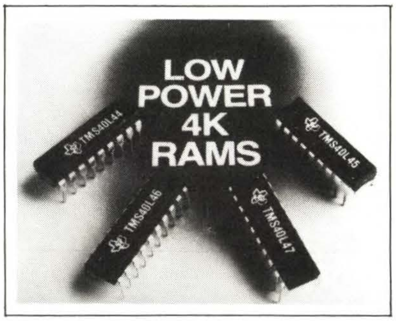


HIGH-POWER RECTIFIER. Capable of withstanding a single-cycle surge current of 9000A, Model SKN-40 also passes an average forward current of 400A (900A max). The unit features a reverse voltage in the 1800 to 3000V range and a V_F of 1.45V max. Each part comes with a ribbed isolator, which allows .ault-free operation in high-pollution atmospheres. Junction-to-case thermal resistance equals 0.11 °C/W. **Semikron International Inc,** Box 83, Hudson, NH 03051. Phone (603) 883-8102. **Circle No 231**

SEVEN-SEGMENT DRIVER. Pin compatible with 7447, 9374 and 8674 drivers, the NE 586 common-anode LED decoder/driver features 25-mA constant-current outputs; LOW-loading, bus-compatible, latched BCD inputs; and ripple blanking on leading/trailing zeros. You can specify alternative fonts because ROM implements the segment decoding. The chip requires a 4.75 to 5.25V (7V max) supply, but its inputs withstand 15V. $1.78 (100). **Signetics,** Box 9052, Sunnyvale, CA 94086. Phone (408) 739-7700. **Circle No 232**



HI-REL V/F CONVERTERS. Processed to MIL-STD-883, Models 4731 (10 kHz) and 4733 (100 kHz) have a full-scale nonlinearity of less than ±0.005% over the −25 to +125°C range. These hybrid units handle positive, negative and differential input signals, using ±9 to ±18V supplies. Guaranteed specs include TC of ±50 ppm/°C, V_{OS} TC of ±100 µV/°C and 100-dB dynamic range. A current input resolves levels as low as 1 nA, making possible operation with full-scale V_{in}s of <250 mV to >100V. 4731, $125; 4733, $135. **Teledyne Philbrick,** Allied Dr at Rte 128, Dedham, MA 02026. Phone (617) 329-1600. **Circle No 233**



LOW-POWER RAMs. Models TMS40L44 and TMS40L46 (4k×1) and TMS40L45 and TMS40L47 (1k×4) come in three speed ranges—450-, 250- and 200-nsec maximum access times. Fully static units, they operate from single +5V supplies and are TTL compatible. Typical power dissipations for the 200-nsec 40L44 and 40L45 units are 200 and 250 mW, respectively. The 40L46 and 40L47 units have a power-down feature providing 6-mW typical dissipation. The 40L44 and 40L45 units come in 18-pin DIPs, the others in 20-pin packages. 200-nsec units, $11.40 (100); 450-nsec units, $6.90. **Texas Instruments Inc,** Box 1443, MS 669, Houston, TX 77001. Phone (713) 494-5115. **Circle No 234**

TEMPERATURE CONTROLLER. Accepting inputs directly from a thermistor, the AY-3-1270 measures temperatures arising in domestic and commercial equipment and displays them on either LED or LCD panels. Its 40-pin DIP includes a power-failure detector and warning indicator for out-of-range conditions. Two control outputs can be used for external alarm circuitry or compressor control. One output operates at the temperature setpoint plus hysteresis (0, 0.2, 0.4, 0.8, 2, 4 or 8°C), the other at setpoint minus hysteresis. Accuracy of temperature sensing is ±1°C, while the temperature range depends on the thermistor chosen. The chip requires one supply voltage between 7.2 and 10.8V. $8 (100). **General Instrument Corp,** 600 W John St, Hicksville, NY 11802. Phone (516) 733-3606. **Circle No 235**

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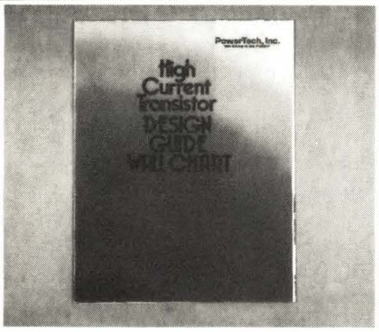


Power-transistor wall chart

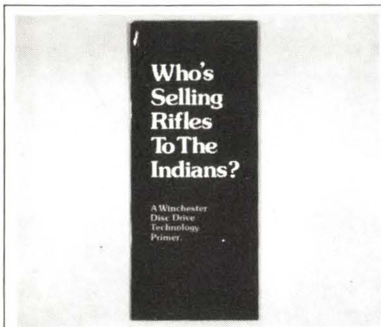
This design-guide chart unfolds to colorfully illustrate the performance of 53 of the company's high-current power transistors. The chart depicts power-transistor and module anatomy, along with package options. It also provides specs and a list of applications. **PowerTech Inc,** 0-02 Fair Lawn Ave, Fair Lawn, NJ 07410.

Circle No 236

New products highlight data-comm catalog

This latest "Black Box" edition features descriptions of the company's data communication devices including test sets, switches, interfaces, converters, stunt boxes, modems and modem eliminators, as well as cables and connectors. Along with coverage of 25 new products, the catalog presents specs, features, applications and prices of each device listed. **Expandor Inc,** 400 Sainte Claire Plaza, Upper Saint Clair, PA 15241.

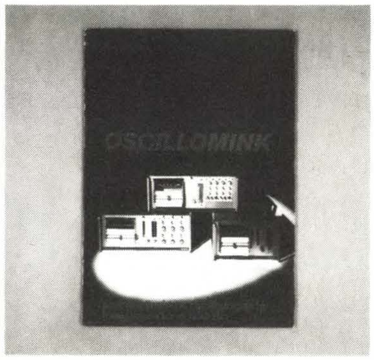
Circle No 237



Winchester-disc-drive technology primer

"Who's Selling Rifles to the Indians?" explains the evolution of the Winchester disc drive and covers the differences between that technology and earlier innovations. A brief history traces development from IBM's RAMAC 305, with its 50 discs and 5M-byte capacity to today's single-disc Winchester drives having as much as 33M bytes of data storage. The pamphlet describes both track- and bit-density gains and improvements to disc-drive reliability. **Priam Corp,** 20730 Valley Green Dr, Cupertino, CA 95014.

Circle No 238



Liquid-jet oscillographs: Principles, applications

Through diagrams, photos and text, this 24-pg booklet explains the liquid-ink-jet printing principle used in the company's line of portable and benchtop oscillographs. Comprehensive specs for instruments employed in industrial maintenance and monitoring applications complete the brochure. **Siemens Corp,** Measuring & Scientific Instruments Div, 2 Pin Oak Lane, Cherry Hill, NJ 08034.

Circle No 239

Note describes resistor pulse-handling capabilities

"Pulse Handling Capability of Wirewound Resistors," a 24-pg application booklet, explains how to pick the right wirewound resistor to withstand short-duration pulses. For pulses from 0.5 to 5 sec long, the pamphlet explains how to calculate the maximum energy that can be safely applied to the resistor. For pulses lasting less than 0.5 sec, the brochure offers a series of charts to help you determine if the calculated pulse energy is greater or less than a given resistor's rated energy. **TRW/IRC Resistors,** Box 1860, Boone, NC 28607.

Circle No 240

A potpourri of offerings for kit builders

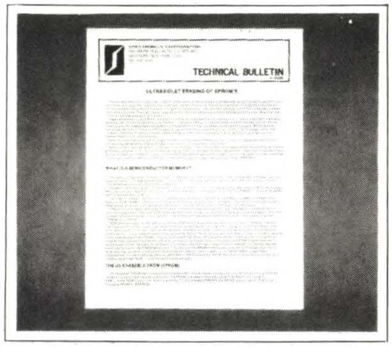
The 96-pg Winter 1979 Heathkit catalog describes a variety of electronic kits in such areas as color TV, hi-fi components, amateur radio, test instruments, personal computers and weather instruments. New products in this issue include a dc to 35-MHz dual-trace, delayed-sweep scope; a rack-mounted AM/FM stereo tuner; and a solid-state heat/cool setback unit for home energy saving. **Heath Co,** Benton Harbor, MI 49022.

Circle No 241

Extend storage capability with digital scopes

Bulletin 449-5 illustrates the advantages of digital-storage oscilloscopes compared with storage-tube models. The 6-pg publication presents specs on two of the company's portable dual-trace units, which are designed for flicker- and fade-free viewing of both long-term events and transients. **Gould Inc,** Instruments Div, 3631 Perkins Ave, Cleveland, OH 44114.

Circle No 242



EPROM bulletin shows erase times

Spectronics Corp's "Ultraviolet Erasing of EPROMs" (A-78286) offers an in-depth discussion of erase times and contains tables listing the nominal erasing energy required for various popular EPROM types. A pair of charts show the erasing times required for simultaneous erasure of several EPROMs using the company's UV sources. Also described are the advantages of EPROMs and how they work. **Adco Electronics,** 2182 DuPont, Suite 222, Irvine, CA 92715.

Circle No 243

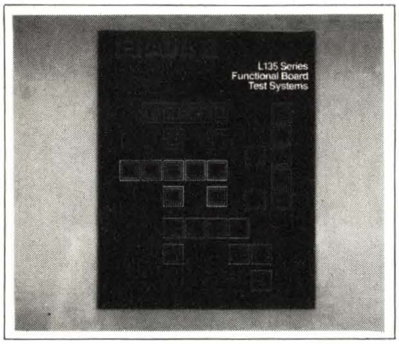
Learn what's new in electrical contacts

In addition to describing the company's electrical contacts, this 21-pg brochure lists properties of powder-metal contact materials, copper-base contact-support materials and the silver-braze alloys used for attaching contact tips to contact supports. Publication P102 also relates the particle sizes of tungsten and

Literature

tungsten-carbide powders to the wear characteristics of silver-tungsten and silver-tungsten carbide contacts. The brochure provides weight-system conversion factors (troy, avoirdupois and metric), a table of crown heights for given contact diameters and face radii, application factors and an explanation of how order prices are adjusted to the market price of silver. **Advanced Metallurgy Inc,** 1011 E Smithfield St, McKeesport, PA 15135.

Circle No 244

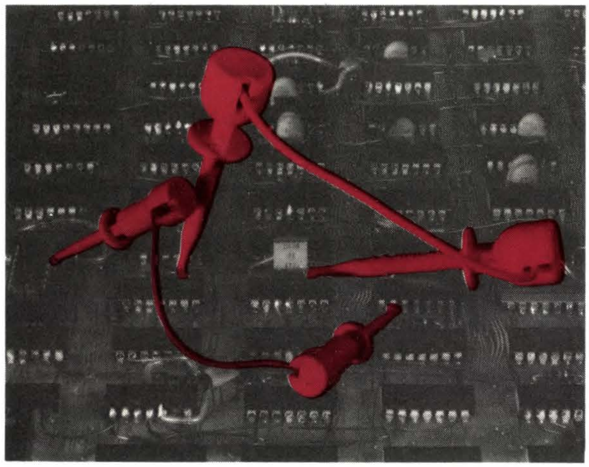


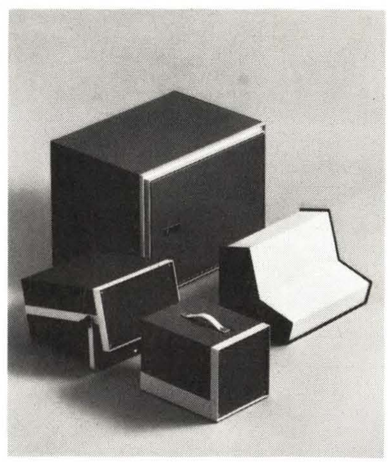
System expands into a series of board testers

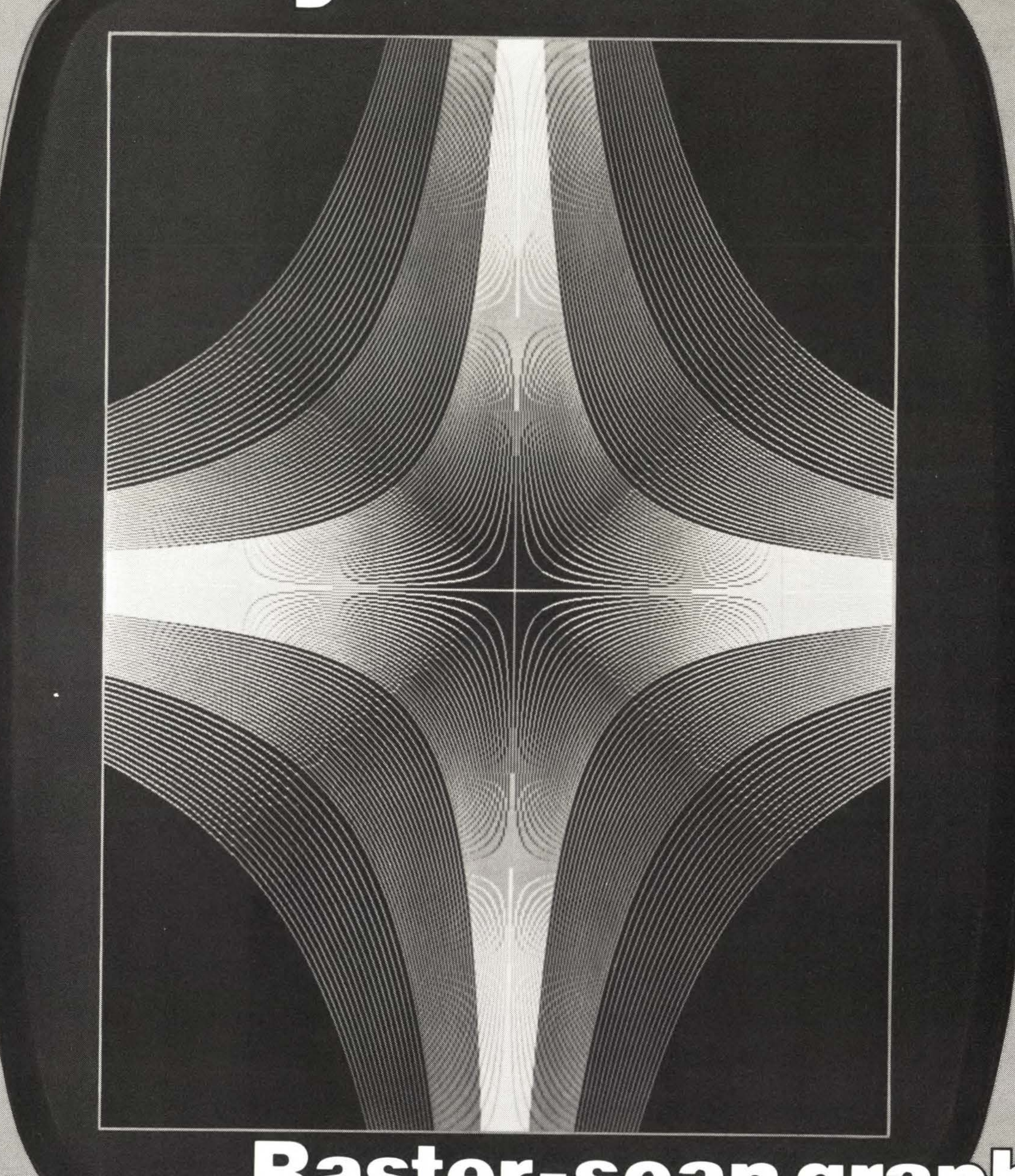
A 4-pg brochure illustrates the L135 functional board-test systems, which serve a variety of production-line testing needs. The folder details the family's modular system architecture that permits users to move up to larger configurations and increase the number of testing modes with virtually no production-schedule disruptions. **Teradyne Inc,** 183 Essex St, Boston, MA 02111. **Circle No 245**

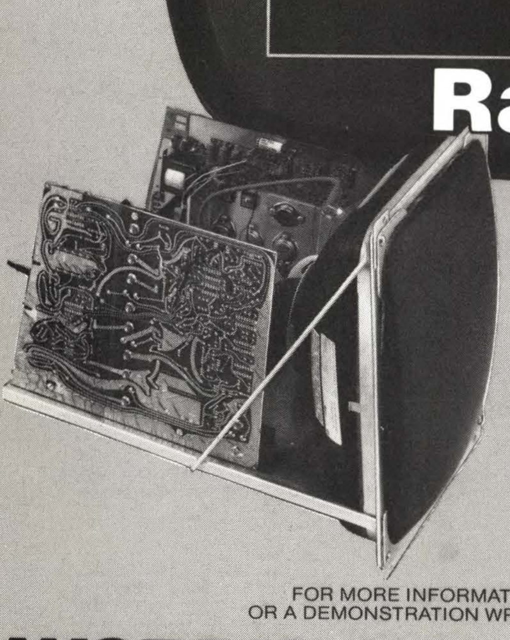
You can specify and order with instrumentation note

Catalog I highlights a line of instrumentation for the measurement, analysis and/or recording of power-line disturbances and power-system parameters. Other general-purpose instruments measure phase/gain, impedance, current voltage, Q and time/frequency. The brochure also describes the company's SERs (Sequence-of-Event recorders). Each product section lists features, supplies comprehensive details of the instruments and plug-ins, and, where applicable, performance curves. The last page lists company technical literature available upon request. **Dranetz Engineering Laboratories Inc,** 2385 S Clinton Ave, South Plainfield, NJ 07080. **Circle No 246**









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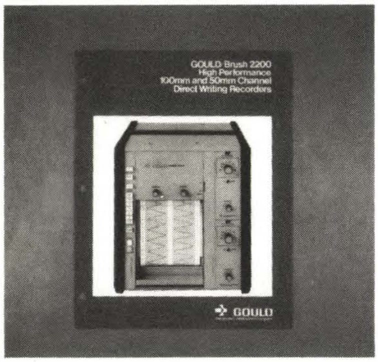


One- and 2-channel high-performance recorders

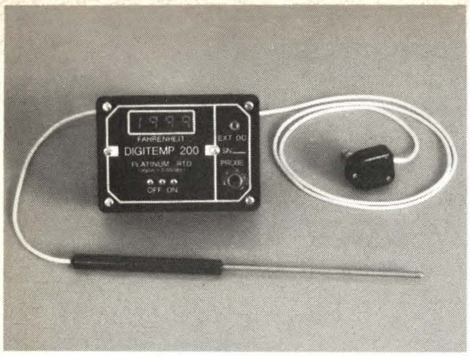
A photo in this 6-pg bulletin points out the major features of the 2200 Series of direct-writing recorders, and an actual chart sample depicts the recorders' resolution and trace fidelity. The brochure also supplies complete specs and options for the series. **Gould Inc**, Instruments Div, 3631 Perkins Ave, Cleveland, OH 44114. **Circle No 247**

Low-pass filter offers 230 dB per octave

Providing information on the Model 752 programmable, dual low-pass anti-aliasing filter, this 4-pg data sheet describes the device as the closest approach to the ideal "brickwall" filter allowable by the present state of the art. Listed features include a rolloff rate, in each of two identical channels, of better than 115 db/octave (cascading permits 230 db/octave)—illustrated by three CRT traces. The brochure briefly describes such typical applications as band-limiting of analog signals before A/D conversion; signal conditioning; waveform analysis; noise studies; distortion measurement and data recording and playback. **Rockland Systems Corp,** Rockleigh Industrial Park, Rockleigh, NJ 07647. **Circle No 248**

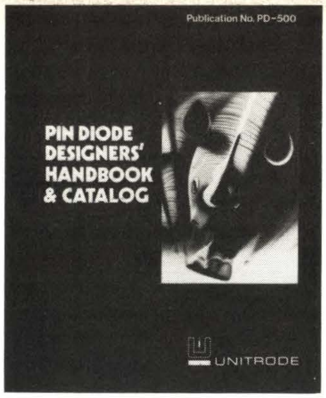
Varied applications for telemetry products

Twenty data sheets constitute this package, which details a complete line of receivers, transmitters, amplifiers, multiplexers and synthesizers. Each sheet begins with a short description of a product and its typical applications, then lists complete specs. **Communitronics Ltd,** 1324 Motor Parkway, Hauppauge, NY 11787. **Circle No 249**



DIGITEMP 200 PLATINUM RTD DIGITAL THERMOMETER spans −328°F to +1562°F with 0.2% accuracy and 1°F resolution. Also available is the DIGITEMP 100 digital meter which uses a Semiconductor Type sensor and spans −55°C to +150°C with 0.5°C accuracy and 0.1°C resolution. A variety of probes are available for either meter, and both may be ordered in either Fahrenheit or Centigrade. Prices start at $155. **MID-CONTINENT COMMUNICATIONS CORP., 3618A Noland Court, Independence, Mo. 64055. (816) 461-1334.**

For more information, Circle No 106



PIN Diode Handbook and Catalog For RF Engineers

Complete catalog of Unitrode's PIN Diode data. Including selection guide relating PIN Diode types to applications such as: common RF switches, attenuators, transmit-receive switches, and phase shifters. Bias, thermal conditions, and distortion are discussed. For your copy: contact Unitrode Corporation, 580 Pleasant St., Watertown, MA 02172, (617) 926-0404.

For more information, Circle No 107

Literature

Handbook explains workings of mag-tape recorders

"Modern Instrumentation Tape Recording" discusses: the physics of magnetic-tape recording; media, means and mechanisms for recording and reproduction; direct, FM and digital recording of analog signals; tape-movement systems; tape and tape heads; and selection and specification of instrumentation tape recorders. The last chapter of the 140-pg opus highlights comprehensive applications. $6. **EMI Technology Inc,** 100 Research Dr, Stamford, CT 06906.

INQUIRE DIRECT

Catalog chock full of test accessories

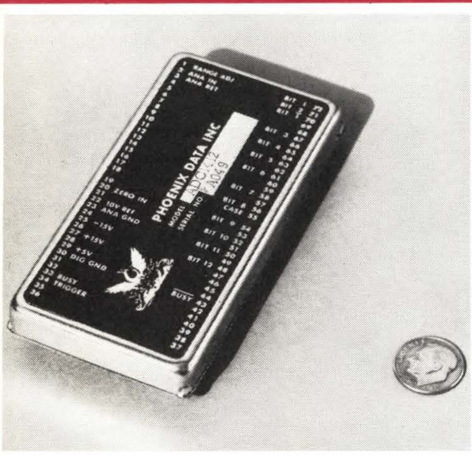
New product descriptions combine with details of previously offered electronic-test-accessory families in this 100-pg document. Accessories described include molded patch cords, cable assemblies, test-socket adapters, molded test leads, plugs, connecting cords, probes and holders. Photographs and drawings accompany ordering information, BNC- and triaxial-cable assembly procedures and two tables for metric and temperature conversions. **ITT Pomona Electronics,** 1500 E Ninth St, Pomona, CA 91766.

Circle No 250

A power supply for every need

Containing 32 pages of helpful application hints and a design tutorial, this 144-pg catalog also describes the company's power supply line. The booklet groups the products by shared characteristics: modular/linear, modular/ferroresonant, modular/switching, laboratory/systems, high speed/unipolar, high speed/bipolar, and programmer and interfaces. It lists accessories and hardware, and also offers a glossary of power-supply terms. **Kepco Inc,** 131-38 Sanford Ave, Flushing, NY 11352.

Circle No 251



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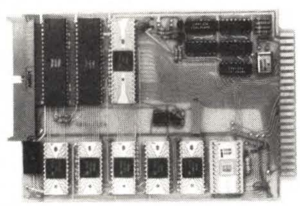
For more information, Circle No 108



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Crossed signals

Dear Editor:
As a busy EE, although I find EDN invaluable, I do not have the time to read it all the way through. Therefore, it would be a great service to your readers if you would supply them with special glasses that would make the essential points stand out in red, the medium-interest passages appear yellow and the non-essential lines disappear altogether.

Sincerely,
J R Vague
JRV Associates
Blue Forks, MI

Organic memory is a slice of life

HAL Corp has announced that scientists at its de'Hormel research facility in Paramus, NJ, have succeeded in storing up to 40 bytes of unformatted data on a single 5-1/4-in. slice of bologna. Dubbed a "really-floppy disc" by its developer, Dr Otto Oikenheimer, the pork platter attains its outrageous storage capacity by whirling around and around and around at 33-1/3 rpm until little grease specs fly off. Each spec represents one bit of digital data.

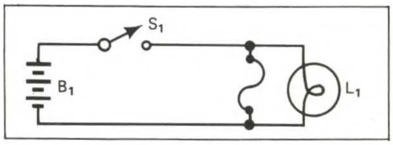
The port sports a 4-port EIE I/O bus on rye. Mustard is optional; kosher versions will soon be announced.—***BP***

TWD International's part premiers

In a bold move sure to send shock waves through the electronics industry, TWD International has announced its fourth significant revolutionary breakthrough of the year—the Termodigitrator (Mark I).

Industry sources say the new component is bigger than a breadbox, faster than a speeding bullet, the key to peace in our time and the potential savior of all life as we know it on earth.

TWD International (formerly Teeny Weeny Devices Inc) is a 7-yr-old firm specializing in the manufacture of high-noise op amps, lenient voltage regulators and 10%-tolerance timer chips.—***JB***



Fuse tester for all seasons

Need a simple, portable fuse tester that doesn't require extensive operator training? The one shown provides a complete test—if the light comes on, the fuse is bad. The circuit suits all types of fuses, both metric and English; color-coded units work with it, too.—***ET***

To Vote For This Design
Circle No 6-7/8

Check out this disposable μP

Model 80808080 sports many features that make it suitable for no applications whatsoever. Fabricated with ECSST (English-Channel silicone semiconscious technology) water gates, the device implements systems which would have cost $40G, filled Grand Central Station and consumed all the power it took to run North America just 20 yrs ago. To permit the ruggedized, glass-passivated chip to handle power in the kilowatt region, a RIP (rarely in-line package) contains space for seven standard MIL-TFD-41S ice cubes. For specialized applications, an output-fuss-free RIP leadless package permits greater packing density (Model 80808080 RIP-OFF). Chip versions are also available. Price: High. Delivery: How long can you tread water? **National Texsil Interolachild Hemiconductor Inc,** 2^{16-1} E Rte 2^{8-1}, Revlon-on-Avon, Taxachusetts 31415.—***DR***

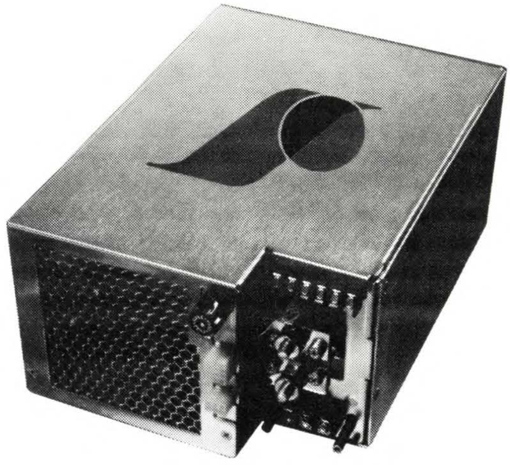
Circle No π

When you hate to remember

This versatile, super-volatile Model 20/140 random-access forgetter (RAF) enables you to forget the things you wish you never knew (and goes OFF even when the lights stay ON). The names of friends you wish you never had, the time of appointments you never wanted to keep and the sum of the tax bill you never intended to run up, once entered into this device, disappear forever. With an infinite access time and infinite capacity, the unit comes in special expanded-capability Presidential (-PFIB), Senatorial (-SFIB) and Special Advisor (-SAFIB) Models for testimony before congressional committees. **Anacreon Memory Co,** 1023 Morpheus St, Last Chance, SN.—***JV***

Circle No 3.3333

For 21 years we've quietly built Switchers.



Now it's time to let the World in on it.

ack in 1958, Pioneer Magnetics built its first switch-ng power supply. We've been quietly pioneering the esign of switching supplies ever since.

oday we offer the system designer a complete fam-y of standard models providing output voltages anging from 2 to 48 VDC with output power to 000 Watts. Single and multiple output configura-ions with a wide range of options are available.

EATURES:

.C. Input: 92 to 138 or 184 to 250V single phase 47 to 63 Hz.
.C. Input: 24, 48, 120 or 240 VDC standard.
rownoutproof: Supplies ignore most line variations and con-inue to supply specified regulated outputs at full load if in-ut voltage drops as low as 80 or 140 VAC.
otal Error Band: Output deviations will not exceed ±2% due o line changes, static and dynamic load changes, ripple and oise spikes, temperature variations and drift.
ower Loss Holdup: Output will remain within regulation 30 nsec after loss of AC input at full load and nominal line.
afety Standards: Standard models are recognized to UL478.

SINGLE OUTPUT SUPPLIES

AC INPUT MODEL / DC INPUT MODEL			PM2496A / PM2721	PM2497A / PM2722	PM2498B / – – –	PM2499 / – – –
OUTPUT VOLTAGE	TYPE NUMBERS (Add Amps in Blanks) AC MODELS	DC MODELS	OUTPUT CURRENT	OUTPUT CURRENT	OUTPUT CURRENT	OUTPUT CURRENT
2	2D ____	2F ____	100	200	400	300
3	3D ____	3F ____	60	100	200	200
5	5D ____	5F ____	50	100	200	200
5	5D ____	5F ____	60	120	–	–
5	5D ____	5F ____	–	150	300	300
12	12D ____	12F ____	25	60	120	120
15	15D ____	15F ____	25	50	100	100
18	18D ____	18F ____	22	45	90	90
21	21D ____	21F ____	18	38	76	76
24	24D ____	24F ____	16	33	66	66
28	28D ____	28F ____	13	27	54	54
48	48D ____	48F ____	8	16	32	32
SIZE (INCHES) (CENTIMETERS)			5x8x11 12.7x20.3x27.9	5x8x11 12.7x20.3x27.9	5x16x11 12.7x40.6x27.9	5x8x15 12.7x20.3x38.1
WEIGHT (POUNDS) (KILOGRAMS)			16 7.3	18 8.2	35 15.9	25 11.4

MULTIPLE OUTPUT SUPPLIES

AC INPUT MODEL / DC INPUT MODEL		PM2675A / PM2775		PM2676A / PM2776		PM2677A		PM2678A
MAX. TOTAL OUTPUT POWER IN WATTS		375W		600W		750W		850W
MAIN CHANNEL	OUTPUT VOLTAGES AVAILABLE	2, 3, 5, 12, 15, 18, 21, 24, 28, 48						
	MAX. POWER IN WATTS	250W		500W		600W		750W
SECOND CHANNEL	OUTPUT VOLTAGE	5	12	15	18	21	24	28
	OUTPUT CURRENT MAX. (see note 1)	7	7	7	CHECK FACTORY			
THIRD CHANNEL	OUTPUT VOLTAGE	5	12	15	18	21	24	28
	OUTPUT CURRENT MAX. (see note 1)	10	10	10	CHECK FACTORY			
FOURTH CHANNEL	OUTPUT VOLTAGE	5	12	15	18	21	24	28
	OUTPUT CURRENT MAX.	4	4	4	4	4	3	3
SIZE (INCHES) (CENTIMETERS)		5 x 8 x 11¾ 12.7 x 20.3 x 29.8 (see note 2)						
WEIGHT (POUNDS) (KILOGRAMS)		20 9						

Note 1: Higher currents available to 30 Amperes.
Note 2: Add 1-9/16" (4 cm.) for external fan on Models PM2677A, PM2678A.

For more information, Circle No 111

The Pioneers in Switching Supplies

Pioneer Magnetics

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