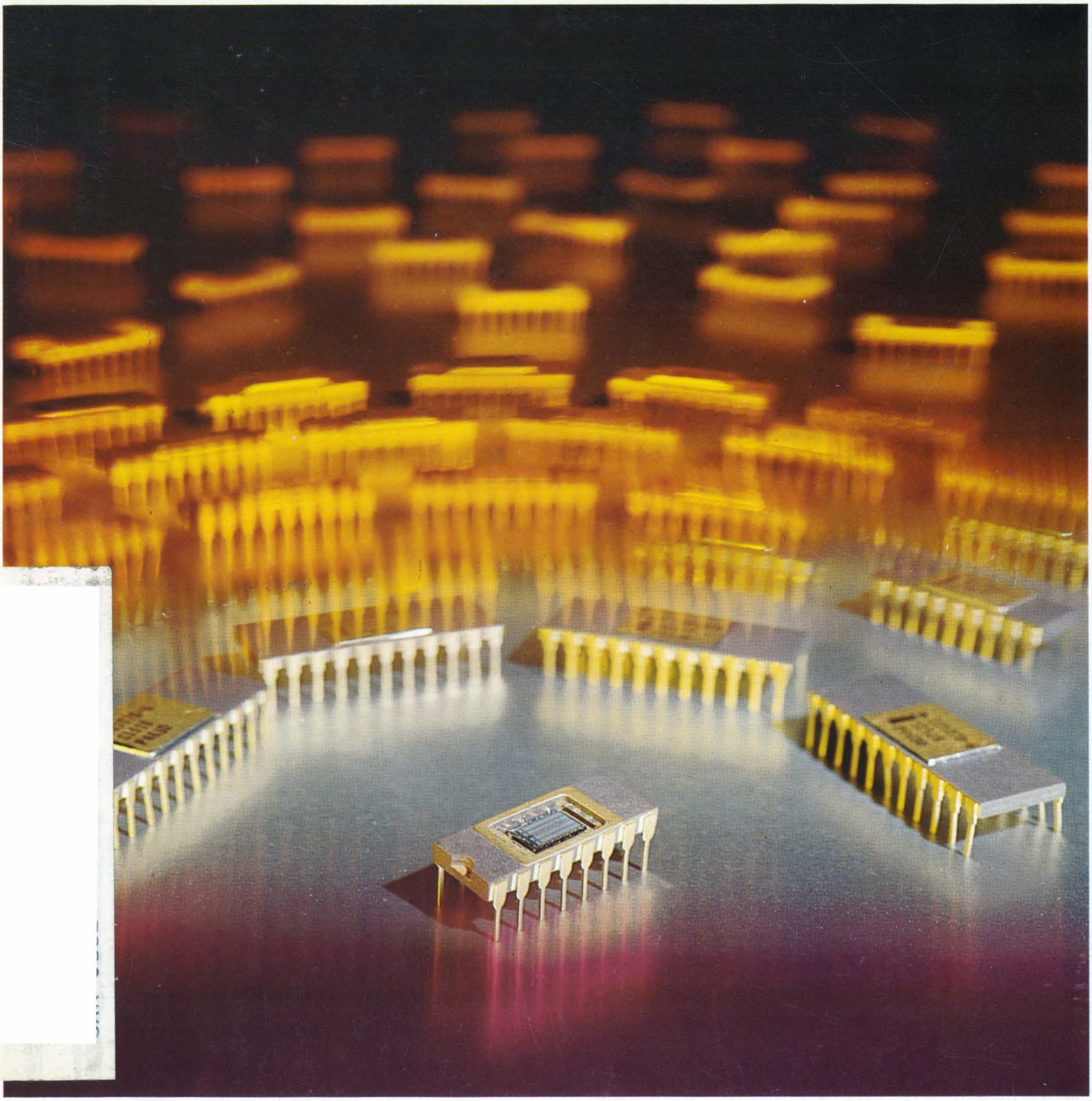
VOL. 24 NO. 7

Electronic Design®

FOR ENGINEERS AND ENGINEERING MANAGERS

MARCH 29, 1976

The first 16-k bit MOS RAM achieves the highest capacity for random-access memories, with no sacrifice in speed. The IC has an access time of 250 ns, or about that of current 4-k bit units. And the new memory uses the 16-pin package of some 4-k versions, simplifying expansion of present systems. See p. 101.



BOURNS®

New, Low-Cost Cermet Trimming Potentiometer outperforms the other "small-change" models!

COMPARE PERFORMANCE

	Model 3352	Beckman Model 91
Power	.75 watts at 40°C	.5 watts at 40°C
Electrical Angle	230°	180°
Adjustability	±0.05%	±0.05%
Torque	5 oz.-in. max.	6 oz.-in.
Shock	100G's max. ±2% VRS	50G's no VRS spec.
Vibration	30G's max. ±2% VRS	10G's no VRS spec.
Contact Resistance Var.	1%	2%
Rotational Life	200 cycles	200 cycles
Temp. Range	−55°C to +125°C	−55°C to +125°C

Bourns super cermet performance delivers again. Our new Model 3352 trimming potentiometer handles more power . . . takes more shock and vibration . . . has a lower CRV . . . and is easier to set than, for example, the "Model 91". Naturally, Bourns super cermet performance is comparably priced. You can depend on it.

The 3352 is a 3/8″ diameter, single-turn device with an easy (but stable) three-way thumbwheel adjust. It can be wave-soldered, and withstands board washing processes with minimal (1%) TR shift. The 3352 is available TODAY in a variety of pin styles to suit your requirements.

Compare performance . . . specify Bourns Model 3352. For complete details, contact your local Bourns representative . . . or the factory direct.

Nobody knows more about trimming potentiometers than we do

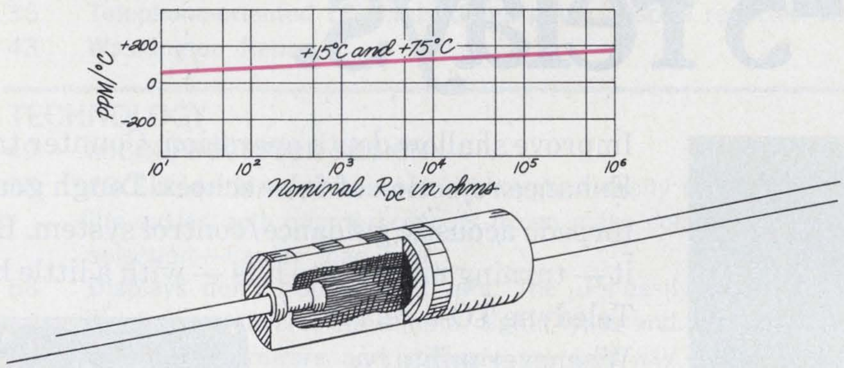
BOURNS INC

TRIMPOT PRODUCTS DIVISION • 1200 COLUMBIA AVE., RIVERSIDE, CALIF. 92507

CIRCLE NUMBER 284

Hot-molded resistors provide low temperature coefficient and unmatched reliability.

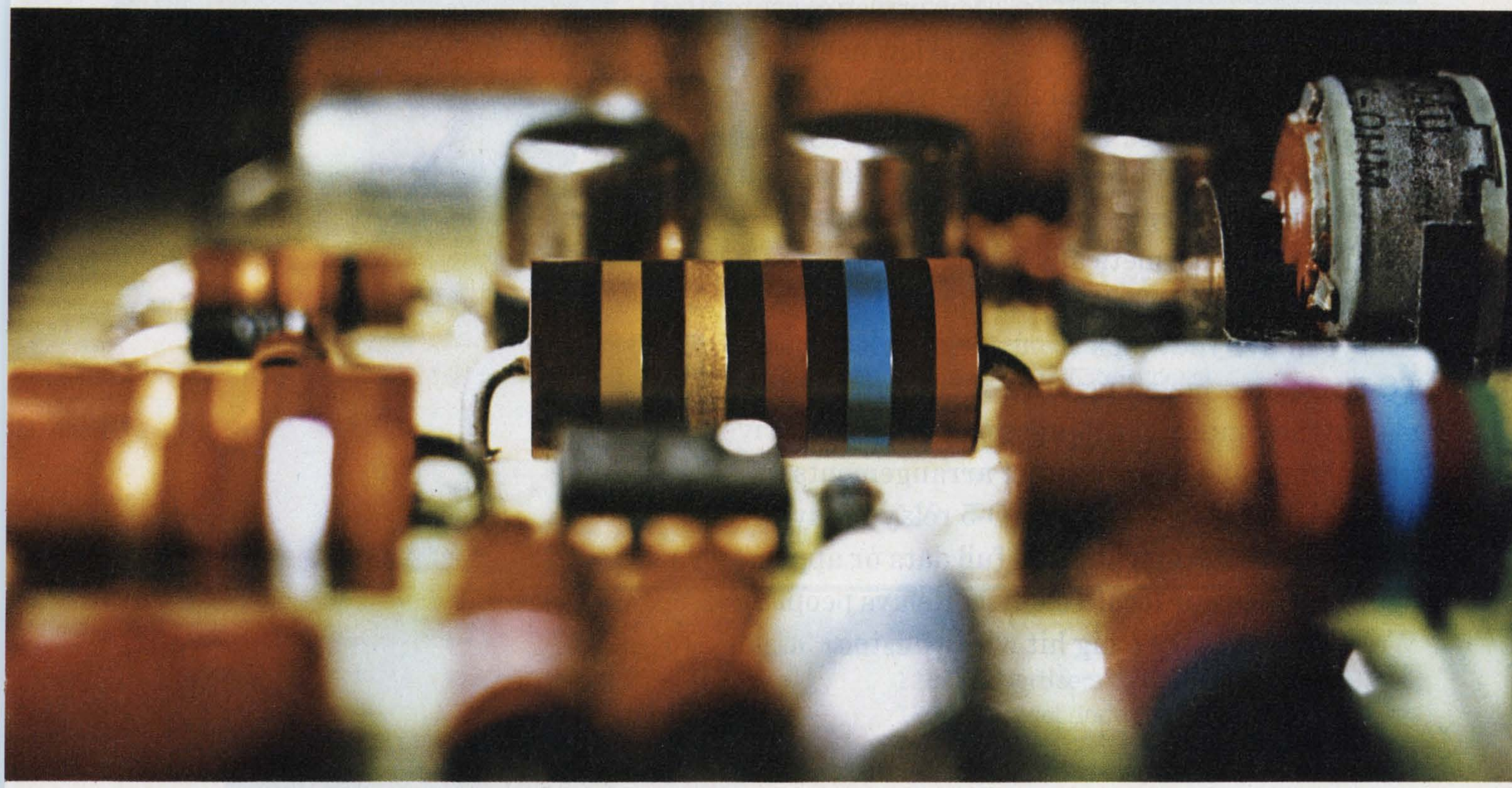
The Resistance Temperature Coefficient of Allen-Bradley hot-molded fixed resistors is typically less than 200 PPM over the entire resistor range shown in the normal equipment operating temperature of +15°C to +75°C. Excellent RTC ratings have always been an Allen-Bradley benefit. And consistency of Allen-Bradley resistors means repeatable results and tight performance patterns. Allen-Bradley resistors offer the **lowest cost—on the board**—where it counts!



Reliability is unsurpassed. Over 700 million unit test hours without a single failure.

No coatings Insulation and resistance element integrally molded into one solid structure.

Pulse handling characteristics offer outstanding protection against surges and transients.



Quality in the best tradition.

A-B QUALITY

ALLEN-BRADLEY
Electronics Division
Milwaukee, Wisconsin 53204

EC113

CIRCLE NUMBER 2


We unknot wire problems
BELDEN
...new ideas for moving electrical energy

Across the Desk

Bit-error rate analysis needed

The article "Squeeze More Data into Mag Tape," by Messrs. Bentley and Varsos (ED No. 21, Oct. 11, 1975, p. 76) should have included a more substantial analysis of the high bit-error rate associated with Miller encoding in a bandwidth-limited (tape recording) application. Such an exhaustive analysis is included in a paper by W. N. Waggener of EMR-Schlumberger titled "Optimum Detection of Delay Modulation."

The introduction of the paper states, "The performance of delay modulation (DM) has been widely misunderstood. The small low-frequency content and a sharply peaked spectrum at about 0.4 bit rate has led potential users to conclude that DM is an efficient coding technique.

Such a conclusion is unwarranted and, in fact, the performance of DM is 3.5 dB poorer than NRZ using an optimum detection bandwidth of twice that of NRZ. If the bandwidth of DM is limited to the spectral region less than the bit rate, a considerable penalty in bit error performance is paid. This seems to contradict the article by Messrs. Bentley and Varsos.

W. D. Lewis
Computer Systems Specialist
General Dynamics
Data Systems Services

Authors reply

The analytical paper referred to by Mr. Lewis has been reviewed with interest and appears to be highly pertinent to the subject material. We greatly appreciate his letter, especially in directing our attention to this analytical study.

Our article, though, in no way contradicts or confirms the result of Mr. Waggener's study. For recording applications, where output signal-to-noise ratios greater than 20 dB are experienced in practice, bit-error rates (BERs) better than 10^{-6} are attainable even under the most pessimistic performance curve of Waggener's analysis. This is in agreement with the claims of BER performance, as stated in our article.

The 10^{-6} BER performance has been previously reported in reference 2 of our article, and in other new references that have been published more recently. These are listed here for your information:

1. Breikss, Ivars P., "High-Density Data Recording," *IEEE Spectrum*, May, 1975, pp. 58-62.
2. Jensen, T. A., and Starkey, M., "80 MBPS Recording," *Digital Design*, September, 1974, pp. 28-35.

S. G. Varsos
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16811 El Camino Real
Houston, TX 77058

Beating the standard set for HP-25

The programmable pocket calculator truly provides the scientist and engineer of today with a personal computer. The presently available calculators are comparable in computing power to the early full-scale computers. It will be interesting to watch for parallelisms in development.

The absolute machine language

(continued on page 8)

Electronic Design welcomes the opinions of its readers on the issues raised in the magazine's editorial columns. Address letters to Managing Editor, Electronic Design, 50 Essex St. Rochelle Park, N.J. 07662. Try to keep letters under 200 words. Letters must be signed. Names will be withheld on request.

(continued from page 7)

programming in the early computer days emphasized minimization of the number of machine cycles and storage locations used. As execution and storage got faster and cheaper, especially relative to the labor component of programming, economic considerations changed the factors to be minimized. As a result, higher level languages became popular.

Modern programmable pocket calculators have limited speed, limited program and data storage, and are programmed in machine language. We are back to counting and minimizing the number of locations used and instructions executed. Since these programs are often entered from the keyboard by highly trained personnel, the number of keystrokes needed to enter the program should also be minimized.

The HP-25 is a popular calculator of this class, and since a book of application programs comes with it, there is a standard to try to beat. Here is a program that calculates the factorial and that is used the same way as the one in the book, but consists of fewer instruction entered in fewer keystrokes—and runs faster. Both versions use one data storage register.

```
STO    0
 1
 —
STO × 0
 1
f × ≠ y
GTO 03
RCL 0
GTO 00
```

Can some other reader beat this?

Henry E. Schaffer
Professor of Genetics
North Carolina State University
Box 5487
Raleigh, NC 27607

D for diode is recommended

Reference Mr. Thomas' letter "An 'Excellent' Guide to Miniature Relays" (ED No. 22, Oct. 25, 1975, p. 7), perhaps I might express the hope that the use of the designation CR be abandoned for diodes.

Not only does it suffer from the disadvantage of obscurity in this context (D is admirably clear and not used, so far as I am aware, for any other circuit element) but CR is needed for "contactor," for which it is regularly used by electrical engineers to distinguish contactors from low-power supervisor-and-control relays (RL).

Please therefore continue to use the common sense D for diode and perhaps we may hope that one day the American National Standards Institute terminology will be amended to conform to what is a natural and therefore preferable usage.

W. Lyons
Jt. Managing Director
Claude Lyons Ltd.
Ware Rd., Hoddesdon
Herts, EN11 9DX
United Kingdom

Misplaced Caption Dept.

Come seven, we spec it at 7 dB.

Sorry. That's Bartolomé Esteban Murillo's "Street Arabs," which hangs in the Alte Pinakothek in Munich.

Need for kits with an understandable program

I want to commend ELECTRONIC DESIGN for bringing out two fine articles relating to microprocessors. In the January 5, 1976 issue (ED No. 1), on page 46 there is the ED special report on microprocessors, and the even more interesting article on page 96, "Incorporate a Calculator Chip," relating to use of a calculator chip in a number-processing data system.

It is certain that both of these articles will go far to advance the microprocessor concept, not only for controlling systems, but for mathematical calculations involved in doing so.

For example, a calculator-microprocessor combination could be designed to orient a flat-plate mirror, one of many to be used for concentrating solar heat onto a boiler to generate megawatts of electrical energy. Solar energy thus should go a long way toward solving the energy crisis now facing humanity.

The Altair system, as pointed out in the microprocessor article, is operable using Basic. Many of us engineers know how to use Basic but have difficulties understanding assembly languages as offered in the simple microprocessor kits. Hence, there is an urgent need for putting these kits together with understandable programs for ease in arranging I/O interfaces.

For that reason, the article on the calculator chip was particularly appealing. For instance, calculator kits are available from a number of sources. One could assemble such a "pocket calculator," modify it in the direction of process controlling, and at the same time learn some very good fundamentals of microprocessor use.

Robert H. Weitbrecht
Vice President, Research & Development
Applied Communications Corp.
P.O. Box 555
Belmont, CA 94002

A matter of fact

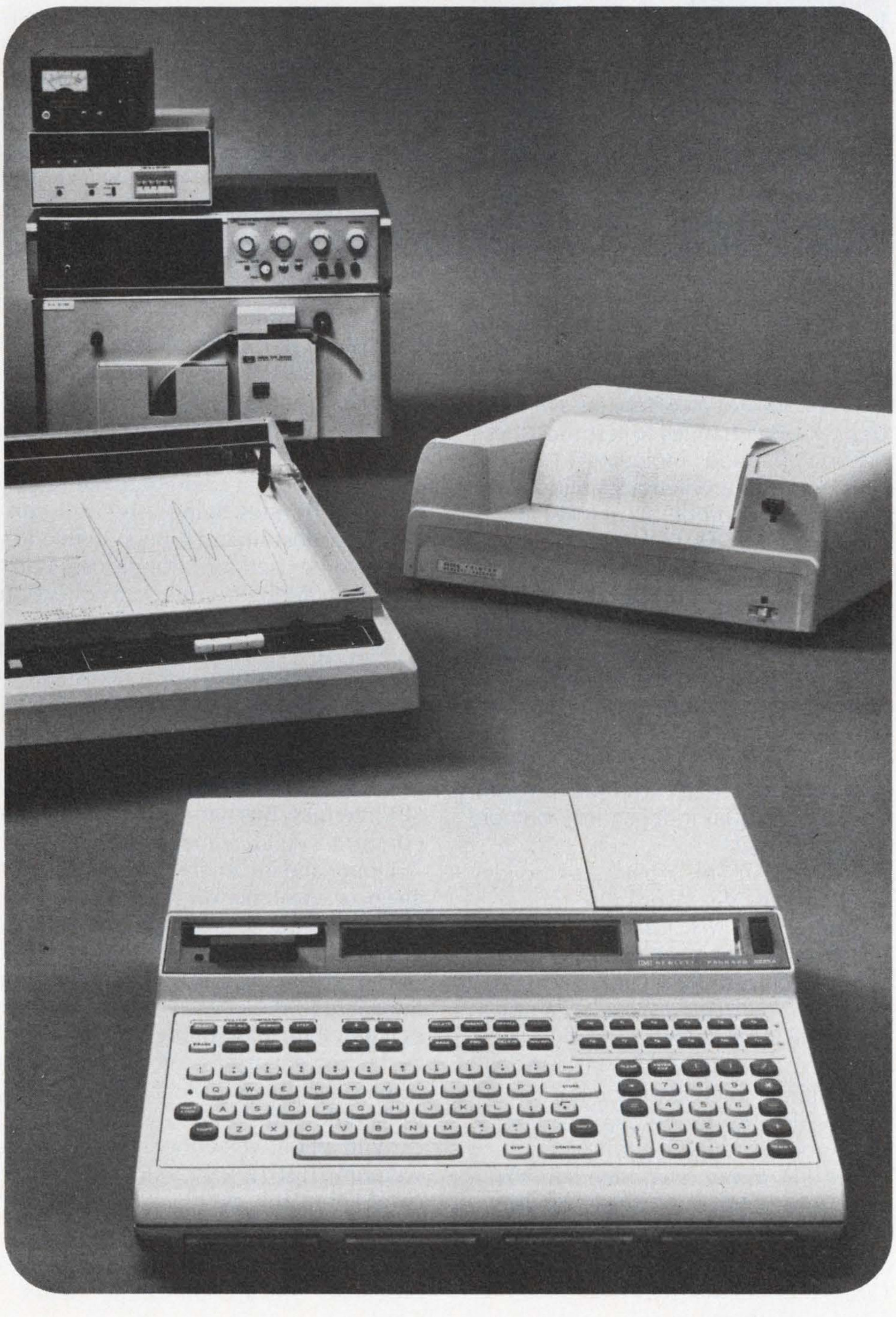
Thank you for your enlightening editorial in the January 5, 1976 issue of ELECTRONIC DESIGN. Irrespective of whether a different consultant would have altered the course of history, I would like to know if the progency of the Czar and the Czarina should in fact have been identified as Czardines.

Robert E. Bilby
Manager Marketing Services
Weston Instruments
614 Frelinghuysen Ave.
Newark, NJ 07114

MEASUREMENT COMPUTATION NEWS
innovations from Hewlett-Packard

MARCH 1976

in this issue



HP's 9825A powerful new desktop computing system

Because of special features and high speed, the 9825A can compute, handle peripherals, and control instruments, all effectively at the same time.

Combining calculator and minicomputer features, HP's new 9825A offers you a "personal" computer oriented toward the solution of problems in the fields of engineering, research and statistics.

The 9825A has a combination of features never before found on a desktop calculator. With the *live keyboard*, the user can examine and change program variables, perform complex calculations, call subroutines, and record and list programs while the 9825 is performing other operations.

A few more exciting features of this new calculator: *Multidimensional arrays*

(continued on second page)

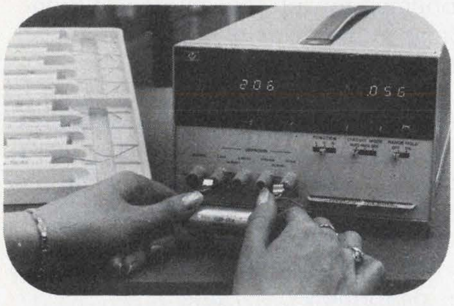
New fully automatic LCR meter measures inductance, capacitance, and resistance over wider range

Measurements of capacitors, inductors and resistors have been speeded up to rates as high as one reading per second with HP's new 4261A LCR Meter. Autoranging and automatic selection of measurement equivalent circuits in C/D, L/D and R modes makes the 4261A LCR meter ideal for testing components used in electronic equipment ranging from stereophonic gear to lab-grade test instrumentation.

Applications such as the measurement of stray capacitance of cables, printed circuit board materials and other components become routine with the 4261A. To facilitate the wide variety of applications, the 4261A will be available with three options: BCD, remote control, and an interface for HP 9800 series calculators via the HP Interface Bus (HP-IB) (IEEE Standard 488-1975).

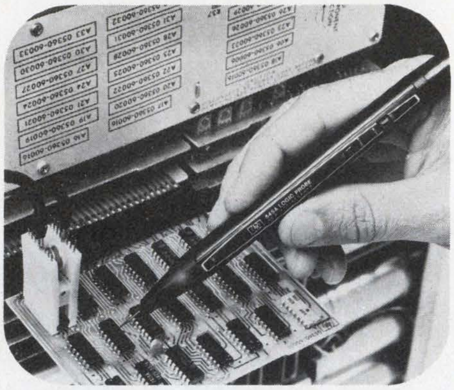
Capacitance measurement capability is in eight ranges from 0.1 pF to 19.00 mF. Inductance can be measured in seven ranges from 0.1 μH to 1900 henries; resistance in eight ranges from 1 milliohm to 19 megohms. Dissipation factors of 0 to approximately 1.900 can be made with the 4261A. Measurements are made at 1 kHz for general applications and at 120 Hz for electrolytic capacitors. Accuracy is typically 0.2% of reading.

For details, check D on the HP Reply Card.



Automatic measurement is now possible for the parameters of semiconductors, pulse transformers, filter coils, electrolytic and film capacitors, or to determine the internal resistance of a dry cell or an electrolysis liquid.

New multi-family Logic Probe has built-in pulse memory, low price



Easy-to-use, simple, and rugged, the probe provides a highly effective solution to digital troubleshooting problems.

Troubleshooting of mixed logic families is now faster and more economical than ever before, thanks to HP's new 545A multi-family Logic Probe.

At the flick of a switch, the HP 545A Logic Probe changes to test most positive logic families including TTL and CMOS. An unambiguous single lamp display in the probe tip quickly indicates logic HIGH, LOW, bad level, pulses or pulse trains. Yet, this rugged overload-protected probe costs one-half the price of previous multi-family probes.

The 545A also has a separate built-in pulse memory with its own indicator lamp to catch those elusive pulses and transitions that occur when you're not there to watch. Use of the pulse memory in no way interferes with probe operation as there's an independent memory display circuit.

The 15μA/15pF input hardly loads your circuits, yet gives pulse train response to 80 mHz for TTL, 40 mHz for CMOS, and pulse width response to 10 ns.

HP's versatile new "grabber" connectors are provided so you can power the probe using IC test clips, test pins, or you can connect to power pins on an IC with little chance of shorting to an adjacent pin. The probe operates from a wide voltage range—3 to 18 Vdc—and in the TTL mode offers standard TTL logic thresholds over supply ranges from 4.5 to 15 Vdc.

Circle B on the HP Reply Card for your 545A data sheet.

New calculator/controller with outstanding interface capability

(continued from first page)

allow you to organize data logically, thus saving program space and execution time. *Memory load and record* allows you to suspend processing, store the complete contents of memory on tape—including programs, data, and pointers—for continuation later on.

Direct memory access (DMA) is yours with input speeds up to 400,000 16-bit words per second. Memory is expandable in 8K bytes to 32K bytes. Each bidirectional tape cartridge can store 250K bytes with an average access time of 6 seconds.

Accuracy to 12 digits with a dynamic range of 10^{-99} to 10^{99} and an internal calculation range of 10^{-511} to 10^{511} provides you with outstanding arithmetical capabilities.

Because of the 9825's *vectored priority* interrupt capability, available in the Extended I/O ROM, the calculator can act as a controller for several instruments or peripherals which require attention at unpredictable rates or times. Besides being used as a controller for instrumentation systems, it can also be used for pilot process control applications, remote data collection and production control.

As a controller, the 9825 can handle up to 45 measuring instruments simultaneously through its three I/O slots.

Three optional interface cards are available: one for 16-bit parallel data, one for BCD devices, and a third—the HP-Interface Bus—for instruments that conform to IEEE Standard 488-1975.

Upper and lower case alphanumerics are now available on both the 32-character LED display and the 16-character thermal printer.

The 9825's high level programming language (HPL) offers you power and efficiency for handling complex formulas and equations. HPL handles subroutine nesting and flags, and allows 26 simple and 26 array variables.

With all this versatility and speed and weighing just 12 kg. (26 lbs), the 9825 can legitimately be considered a portable computer.

For your free copy of the 16-page 9825A brochure, check O on the HP Reply Card.

Economical pulse generators for TTL, CMOS, ECL, and educational applications

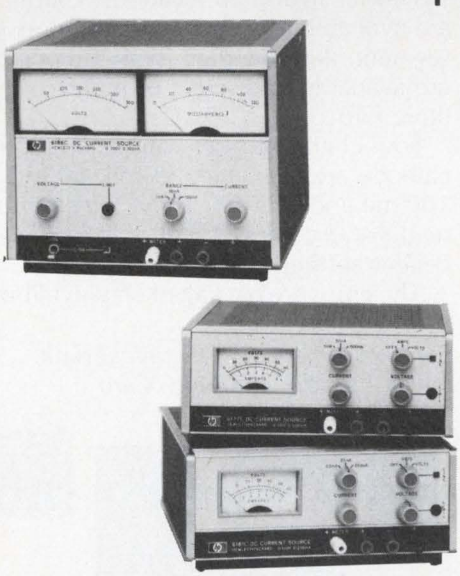
Meeting the requirements of digital logic laboratories, these pulse generators are extremely flexible with panel controls designed for easy operation.

HP's broad family of high quality pulse generators includes a cost-effective pulser for every performance level and application. Model 8011A, for example, is HP's lowest cost pulse generator. It's 16V amplitude and 20 MHz repetition rate are perfect for the requirements of CMOS and TTL logic design. The pulse burst option (001) helps you speed logic debugging by letting you rapidly generate a precise pulse burst just by dialing the desired length on thumbwheel switches. The 8011A's low cost of ownership also makes it an ideal choice for education applications. The logical, easy-to-use panel control layout, and short circuit proof output minimize familiarization and down time—important benefits in student labs.

Models 8012B and 8013B are versatile, general-purpose units which provide you additional pulse parameter control for more complex testing applications. The 50 MHz, ±10V performance of these models is ideal for TTL and basic ECL applications. The 8012B is HP's lowest cost 50 Hz pulser with variable rise and fall times. The 8013B has fixed transition times less than 3.5 ns and also provides simultaneous positive and negative outputs useful in analog applications.

For literature, check L on the HP Reply Card.

Precision Constant Current sources give output useful to microampere region



Precision performance, low price, small size, and light weight combine to make these supplies useful as general purpose laboratory constant current sources for semiconductor circuit development and component evaluation.

With a constant current source in the lab, you can:

- Evaluate reverse breakdown and forward V-I characteristics of PN junctions
- Measure silicon wafer resistivity and contact resistance
- Test relays, meters, potentiometers, and electrolytic capacitors
- Aid in coulometric titration and precision electroplating
- Determine dynamic and incremental impedance of devices

HP constant current sources supply precisely-regulated (30 ppm) dc current. Three models cover a range of ratings from 1 μA to 0.5A.

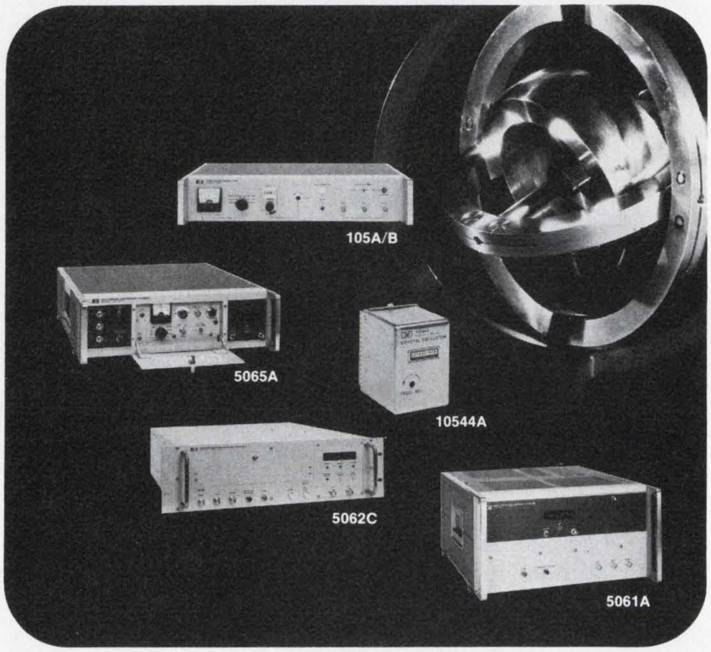
You can adjust the constant current output with the high resolution (0.02%) front panel control, or you can program the output current anywhere over an entire range with an external voltage or resistance. The maximum voltage compliance can also be set with a voltage limit control or by external programming.

These supplies have no output capacitor. Output capacitance is minimized to reduce stored energy at the high impedance output, which along with specialized circuitry, reduces current transients in rapidly changing loads.

A separate monitoring terminal allows external voltage measurement without degrading constant current performance.

For technical data sheet, check J on the HP Reply Card.

The "Time Standard" Company offers a wide choice of proven precision frequency standards



Hewlett-Packard frequency/time standards in the HP Measurement Standards Lab in Santa Clara, Calif. contribute timekeeping data regularly to both the U.S. Naval Observatory and the U.S. Bureau of Standards.

As a leading manufacturer of cesium, rudibium and quartz standards, we at Hewlett-Packard offer you 35 years of frequency standards experience to help you make an optimum choice.

We can be of special help since many of our several thousands of frequency standards in the field are used in the most reliability demanding areas. These include LORAN C and OMEGA navigation, space vehicle tracking and guidance, satellite communication and basic timekeeping in numerous standards labs and observatories throughout the world.

One of the following precision frequency standards should meet your applications needs.

HP 5061A Cesium Standard

- Primary frequency standard with 7×10^{-12} accuracy (with high performance tube, 0° to 50°C)
- Proven reliability (MTBF in excess of 40,000 hours)

Your best choice for superior performance and reliability.

HP 5062C Cesium Standard

- Primary frequency standard with 3×10^{-11} accuracy (−28° to +65°C)
- Fast warmup (20 min. at −28°C)
- Rugged construction (passed 400 lb. hammer blow test)

Your best choice for harsh environments such as mobile navigation and communications systems.

HP 5065A Rubidium Standard

- Compact and light weight
- Long term stability less than 1×10^{-11}/month
- Short term stability less than 5×10^{-13}, 100 sec. averaging

Your best choice for a secondary atomic standard at a considerably lower price.

HP 105A/B Quartz Oscillator

- High performance economical frequency standard
- Excellent short term stability and spectral purity
- Aging rate less than 5×10^{-10}/day

Your best choice when excellent stability and versatility are needed at lowest cost.

HP 10544A Ovenized Component Oscillator

- Fast warmup
- Excellent aging rate at low cost (less than 5×10^{-10}/day)
- Rugged, compact, reliable

Your best choice for integrating into test and measurement equipment or communication and navigation systems.

For data sheets on all of these instruments, please check F on the HP Reply Card.

New Application Note for Low Input Current, High Gain Isolators

Optically coupled isolators are useful in applications where large common mode signals are encountered. Examples are: line receivers, logic isolation, power lines, medical equipment and telephone lines. This Application Note 951-1 has at least one example in each of these areas for the 5082-4370 series high CTR isolators.

HP's 5082-4370 series isolators contain a high gain, high speed photodetector that provides a minimum current transfer ratio (CTR) of 300% at input currents of 1.6 mA for the −4370 and 400% at 0.5 mA for the −4371. The excellent low input current CTR enables these devices to be used in applications where low power consumption is required and those applications that do not provide sufficient input current for other isolators.

For your free copy, check Q on the HP Reply Card.

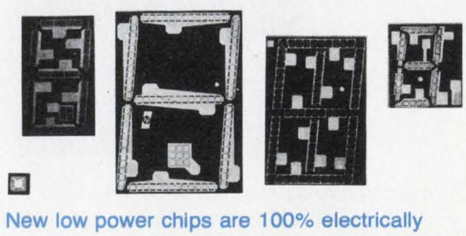
HP offers new monolithic LED chips for watch industry

The HP 5082-7800 series are common cathode monolithic chips designed for hybrid applications. Chips are available in seven segment, nine segment, and one digit fonts. Colons are available in discrete or monolithic form.

Four character sizes with a common cathode are available: 53 mil, 80 mil, 100 mil and 120 mil. These are easy to read, MOS compatible and offer an excellent aesthetic appearance.

The chips are packaged on vinyl film or in waffle packages.

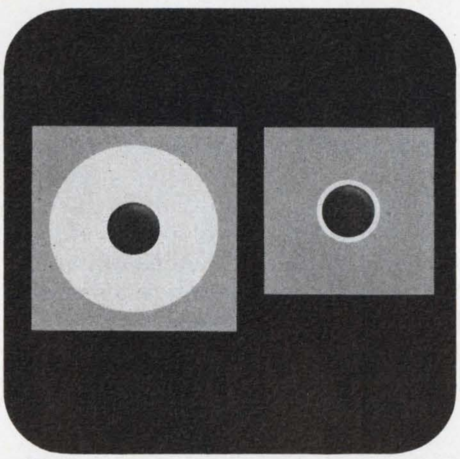
For detailed specific technical data, check I on the HP Reply Card.



New low power chips are 100% electrically tested, before shipment, to a high HP standard criteria.

HEWLETT-PACKARD COMPONENT NEWS

New Metal-Insulator-Semiconductor capacitors for microwave IC's



Magnified view of new MIS chip capacitor with oxide-nitride insulator yielding superior reliability.

These new 5082-0900 MIS chip capacitors have been designed for shunt rf bypassing and series dc blocking in amplifiers, oscillators, switches, limiters, mixers and modulators.

Eleven units are offered in the 0.5 to 45 pF range. Capacitance tolerance is ±15%. Tolerances to ±5% and values in the 45 to 100 pF range are available on special order. Minimum breakdown voltage for units from 0.5 to 2.0 pF is 250 V; 5.0 to 15 pF—150V; units from 20 to 45 pF—100 volts.

In the MIS structure, the metal is gold, the insulator is silicon nitride over silicon dioxide, and the semiconductor material is silicon.

For a technical data sheet, check G on the HP Reply Card.

Low V_F Schottky mixer diodes for better matching and lower noise

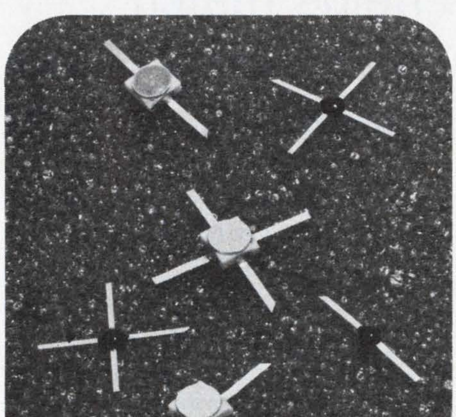
Low forward-voltage equivalents of HP's microwave Schottky diode line are now available. A rating of 200 to 300 millivolts forward drop versus the conventional millivolt droppage of 400 to 500 millivolts is now available in a total of 23 devices including chips, beam leads and quad configurations.

Intended primarily for mixer applications, the low V_F diodes are closer to a 50 ohm impedance than standard Schottky mixer diodes, resulting in lower VSWR over the band. At lower levels of l.o. power, the impedance is equivalent to standard units, a property useful in starved local oscillator mixers.

This new forward voltage rating applies to the following series of components:

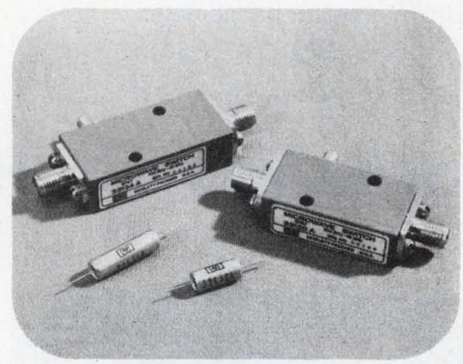
5082-2229 beam lead mixer diodes
5082-2231 hermetic microstrip quads
5082-2271 broadband microstrip quads
5082-2285 hermetic single chip coax packages
5082-2765 hermetic single chip microstrip packages
5082-2774 broadband single chip microstrip packages

For data sheets describing the above products, check H on the HP Reply Card.



Noise figure of low V_F diodes is typically less than 6 dB at 9 GHz for power levels ranging from −5 dBm to +5 dBm.

Insertion loss reduced by 20% in new SPST microwave switches



These SPST switches use PIN diodes in shunt across a 50 ohm transmission line. Control current for the 33132A/33632A is 30 mA for the 33134A/33634A is 200 mA.

Two new SPST microwave switches reduce insertion loss in X-Band and Ku-Band by 20% over currently available types. The HP 33130 series are complete switches, with RF connector, bias circuits, and built-in dc returns. Model 33132A is a complete 2-diode switch with insertion loss of 1.8 dB max from 12.0 to 18.0 GHz.

The Model 33134A is a complete 4-diode switch with insertion loss of 2.3 dB maximum over the same frequency range.

The basis of the HP SPST switch product line is the coaxial module. The 33600 series module is optimized for low insertion loss with high isolation. The modules are available with either two or four diodes. Three diode units are available on special order.

For a technical data sheet on the 33130 and 33630 Series switches, check P on the HP Reply Card.

A new ultra-low distortion analyzer gives you readings to −90 dB

The Hewlett-Packard 4333A Distortion Analyzer measures total harmonic distortion down to 0.01% full scale at 41 spot frequencies, each variable over a range of more than ±8%.

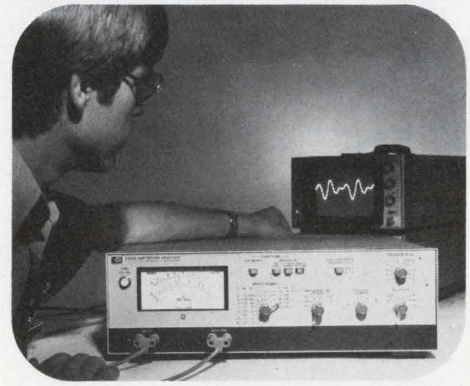
The new 4333A gives you ±3% accuracy over its entire 10 Hz to 100 kHz range.

The 4333A is easy to use. Automatic fundamental nulling reduces critical manual nulling operations. Select your measurement range in 10 dB steps and read distortion directly on the large, clearly marked panel meter. A front-panel monitor output lets you conveniently analyze the harmonic distortion using a scope or recorder.

A high sensitivity voltmeter mode offers 13 ranges in 10 dB steps; range is from 100 μV to 100 V rms full scale.

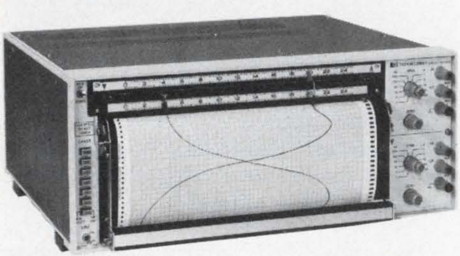
When you need believable amplifier or oscillator distortion measurements, rely on the 4333A.

For more information, check E on the HP Reply Card.



New distortion analyzer with distortion input sensitivity of 1 Vrms for 100% set level reference.

Inkless writing for HP strip chart recorders



New thermal writing option produces a crisp, uniform trace.

For the first time, thermal writing is available for a series of Hewlett-Packard strip-chart recorders. Models 7130A and 7131A, one and two-pen, 10-inch OEM recorders can be equipped with thermal writing pens and event markers for long-term, unattended operation. Models 7132A and 7133A, laboratory versions, can be similarly equipped.

Each thermal tip contains a temperature sensing element used to maintain a constant tip temperature. The tip temperature is therefore independent of ambient temperature, paper speed, etc.

Designated Option 054, the inkless system includes beryllium-tipped pens designed to last the lifetime of the instrument. Recordings are of high contrast and are easy to read.

For more details, check K on the HP Reply Card.

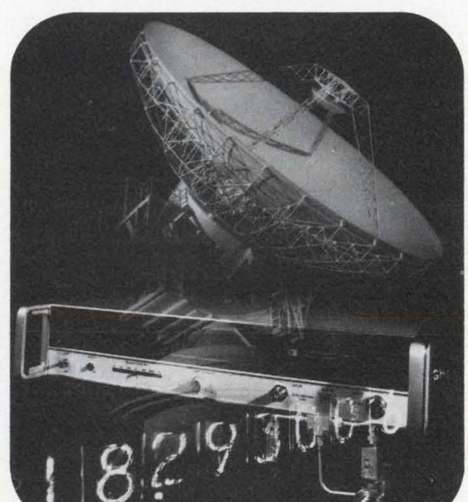
New Application Note helps match microwave frequency counters to measurement requirements

At one time there weren't many microwave frequency counters from which to choose. Now, there are a variety of these counters available with varying degrees of sophistication in design and measurement capability. The new Hewlett-Packard Application Note 144, "Understanding Microwave Frequency Measurement" discusses tradeoffs between microwave frequency counter designs which merit consideration when choosing a counter for a particular application.

The Application Note discusses in detail considerations of measurement speed, accuracy, dynamic range, and tolerance to modulations and unwanted noise on the signal for each of the three common down-conversion techniques: prescale, heterodyne, and transfer oscillator. It also suggests other useful considerations such as input characteristics, sensitivity, and input/output structure.

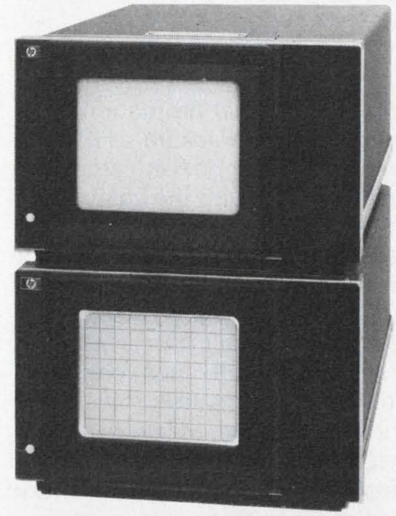
The booklet should prove useful to the microwave engineer in selecting a frequency counter to meet his needs.

For your free copy of this Application Note, check N on the HP Reply Card.

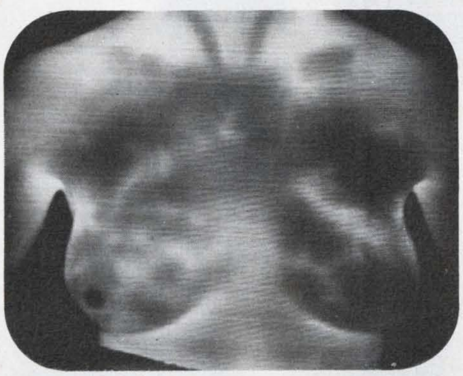


The successful 5340A Frequency Counter represents one of several designs described in the new AN 144, "Understanding Microwave Frequency Measurement".

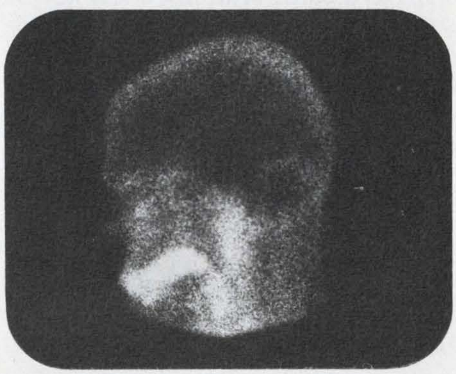
HP high resolution CRT displays for OEM applications

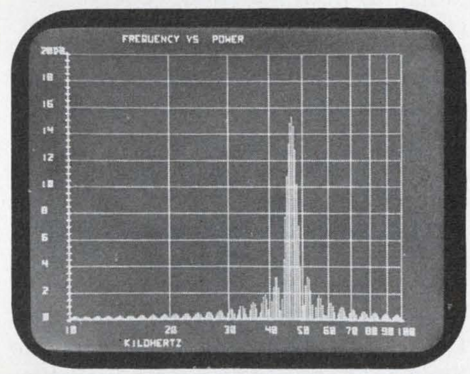
The CRTs in these displays have a totally new design, optimized exclusively for information display and to reproduce fine image detail with superior contrast and uniformity.



Stable light output for long scan periods permits time exposure photograph to paint a picture of body temperature versus location in a medical thermography application.



The 1333A CRT is optimized for photographic image quality with a wide range of gray shades, contrast, and uniformity as shown in this high resolution gamma camera brain scan.



Fine image detail and a well-focused spot at all intensity levels make the 1335A ideal for use in Spectrum, Fourier, Network, and Chemical analysis as well as automatic test systems.

Hewlett-Packard's Models 1332A, 1333A, and 1335A CRT displays are designed to provide excellent images in all types of OEM systems. Applications for these displays include spectrum, network and chemical analyzers, nuclear medicine, medical thermographic ultrasound, and automatic test systems, among others.

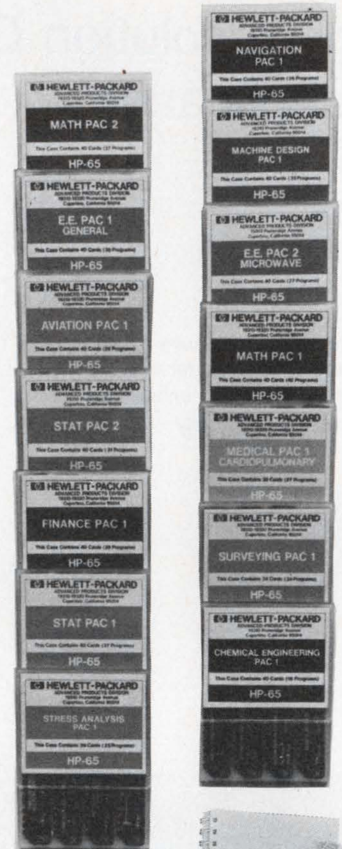
Model 1332A is designed for the OEM that has both visual and some photographic requirements. CRT display parameters are optimized for such a combined application including large 9.6×11.9 cm viewing area. Display brightness is such that it can be viewed in high ambient light conditions while maintaining resolution and gray shades for photographic work.

Model 1333A is designed specifically for applications in which photographic recording of displays is the major factor. The small spot size of 0.20 mm offers exceptional image quality that makes evaluation of photographs easier and more accurate. A specified light output uniformity assures that the display information is an accurate representation of the input signals. The high resolution CRT display qualities make the 1333A ideal for recording rapid sequence dynamic studies in nuclear medicine and for capturing transient displays in ultrasound work. The 8×10 cm screen can be reproduced on Polaroid® film with very little optic reduction which allows the use of almost 1:1 optics and minimizes design difficulties encountered when using enlarging or reducing optics.

For applications requiring variable persistence and storage, the 1335A offers exceptional uniformity needed in OEM medical and instrumentation systems. The variable persistence mode can be used to eliminate flicker on some presentations with the ability to increase persistence to match the refresh rate. In the storage mode, resolution is over 20 lines per cm (50 lines per in.) permitting the retention of sharp details. For maximum flexibility, any operating mode—erase, store, write, conventional, or variable persistence—can be selected with manual front panel controls, remote program inputs, or a combination of both.

For detailed specifications on these CRT displays, Check C on the HP Reply Card.

Buy the HP-65 now* and get $195 worth of proven software FREE



During this special promotion, purchasers of Hewlett-Packard's HP-65 fully programmable pocket calculator will receive FREE with the calculator, a $195 coupon for the delivery of 4 Application Pacs and 5 Users' Library Programs of their choice. The promotion runs through April 30, 1976.

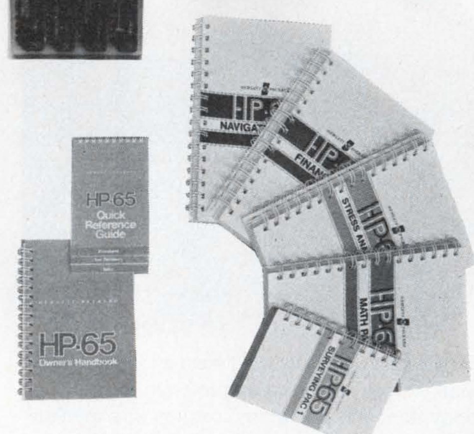
There are 14 Application Pacs currently available in electrical engineering, finance, mathematics, statistics, medicine, navigation, aviation, surveying, machine design, stress analysis and chemical engineering. You may choose any four of these Pacs, each containing up to 40 pre-recorded programs from that particular discipline.

In addition, each purchaser will be able to choose five of 15 popular programs from the HP-65 Users' Library of contributed programs. Each of these programs includes a complete keystroke listing, user instructions and supporting documentation. The entire library listing, available to HP-65 owners, contains more than 4000 contributed programs.

Software is the difference that sets our HP-65 Fully Programmable apart from all other calculators. This hardware/software combination permits the HP-65 to remain the most versatile hand-held computing system available. Like a computer, the HP-65 memorizes programs of any size that are fed into it on tiny magnetic cards, 100 program steps to a card. With just a few keystrokes by the user, it executes the program and gives the answer to complex problems with an accuracy of up to 10 digits. Five User Definable keys plus 51 preprogrammed functions and operations plus a superior editing capability add up to "a great deal".

Call, toll-free, 800-538-7922 (in Calif. 800-662-9862) for an HP dealer near you so that you can take advantage of this special $195 software offer before April 30, 1976.

For descriptive literature only, check A on the HP Reply Card.



*Offer valid until April 30, 1976 in continental U.S.A., Alaska and Hawaii.

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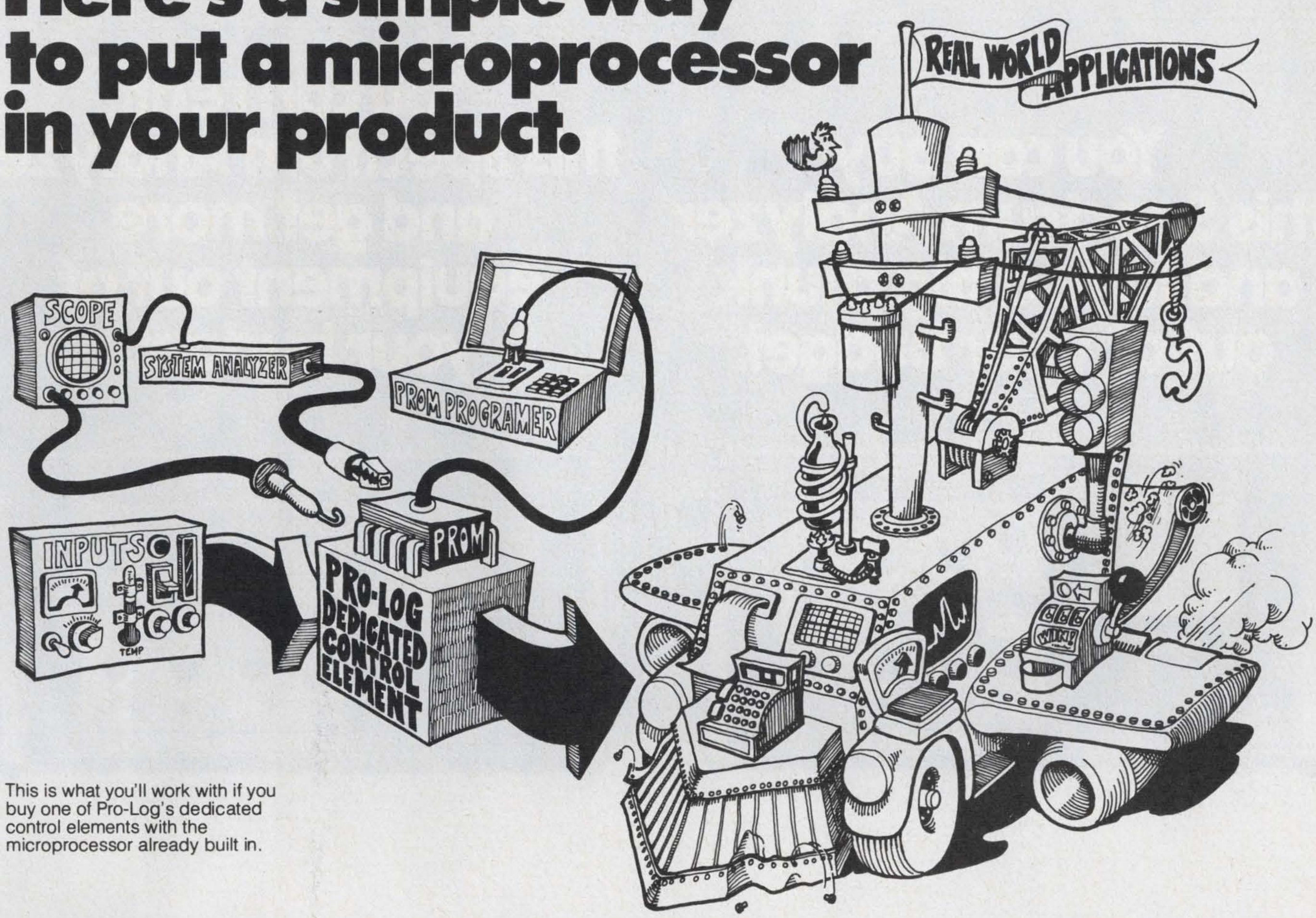
Here's a simple way to put a microprocessor in your product.



This is what you'll work with if you buy one of Pro-Log's dedicated control elements with the microprocessor already built in.

Buy a dedicated control element, for all practical purposes a black box, with a microprocessor already built in.

We've developed subsystems using microprocessors. They come in modular configurations readily expandable to meet your product requirements. You hardwire them directly to relay contacts, switches, push buttons, displays or other real-world devices. They give you all the capabilities of a microprocessor with none of the headaches. And we deliver them in a matter of weeks.

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And system design stays with the design engineer.

Plus, we give you something more, a free set of plans and a second source.

Order 250 subsystems and we'll throw in free non-exclusive manufacturing rights and a complete set of manufacturing and assembly plans allowing you to build your own hardware, relying on us as an established and dependable second source.

We make everything you need to design with microprocessors.

Our starter sets include a microprocessor subsystem, a Series 90 PROM programer, a microprocessor system analyzer, plus all associated hardware. 4-bit sets cost around $3,000, 8-bit sets around $3,500, a substantial savings over what you'd pay if you purchased all these items separately.

We have education too.

Our half-day introductory seminar takes a hard look at the function of microprocessors in real-world applications.

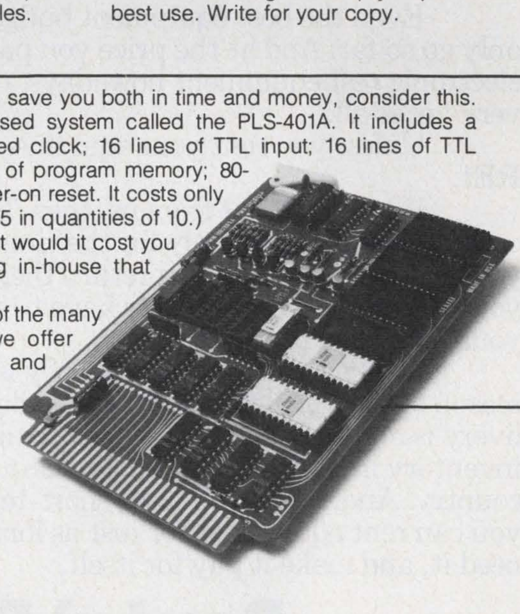
Our three-day hands-on design course teaches engineers how to formulate, program and use microprocessor modules.

Our free booklet, "The Microprocessor User's Guide" answers all your questions.

It explains what a microprocessor is, what it's capable of doing, what criteria you need to evaluate the ones on the market and how Pro-Log can help you put them to best use. Write for your copy.

To show how much Pro-Log can save you both in time and money, consider this. We've got a one-card 4004-based system called the PLS-401A. It includes a microprocessor; crystal controlled clock; 16 lines of TTL input; 16 lines of TTL output; sockets for 1024 words of program memory; 80-character RAM and built-in power-on reset. It costs only $99 in quantities above 500 ($175 in quantities of 10.) How long would it take, and what would it cost you to design and build something in-house that could do the same job?

And this is just one example of the many microprocessor subsystems we offer using 4004, 4040, 8008, 8080, and 6800 microprocessors.



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CIRCLE NUMBER 7

Data General's μP-based mini extends its Nova line

A downward-compatible minicomputer system based on a 16-bit microprocessor has been announced by Data General. Known as the microNova family, the system is available as a full minicomputer, a single central-processing-unit board with 4-k words of memory or as individual CPU, memory and support chips.

"An original-equipment manufacturer can start out with a fully packaged microNova minicomputer, then integrate downward into microNova boards or chips as his development time or product volume allow, without having to redesign hardware or software," says Engineering Vice President Carl Carman.

Since the microNova is completely software-compatible with the company's line of Nova minicomputers an extensive library of software already exists to support the new family.

Included among major competitors who have introduced their own compatible families of μCs through full minicomputers are Digital Equipment Corp., with the LSI-11; Texas Instruments with the 990 Series. Of course, there are several suppliers of monolithic 16-bit MOS chips—notably General Instrument and National Semiconductor.

"In a way, each of these products can satisfy a part of the market," says Data General's Herb Richman, "but in other ways they fall short because they're lacking in product-line breadth, software or other forms of support."

All of the microNova chips are produced by Data General at its plant in Sunnyvale, CA. The CPU has common address and data pins and is designed for use with the company's 20-pin dynamic RAMs. Separate refresh circuitry is not required by the CPU because it has an integral refresh cycle.

The microNova family consists of chip set, board computer and fully packaged minicomputer.

There are two separate serial I/O lines on the chip and a real-time clock. Other chips available to complete the system are an I/O controller to decode a 16-Mb/s data stream for communication with peripheral devices, address-buffer elements, data-line buffers and memory-sense amplifier/buffer chips.

The microNova minicomputer is available fully packaged with a separate calculator-like control panel attached to the main unit by a long flexible cable. Nine-slot and 18-slot versions, each slot having 32-k memory capacity, allow plenty of program storage.

In a complete system including the microNova minicomputer, diskette and ASCII terminal, development software is available at no extra cost.

Software such as a disc operating system, text editor, Fortran IV compiler, assembler, relocatable loader and symbolic debugger provide complete support for developing anything from a fully customized system to a dedicated system using the chip set.

The CPU chip mN601 sells for \$225 (single quantities) and \$95 (500 quantities); the microNova CPU/4k single-board minicomputer with 4-k words of memory costs \$950 (single quantities).

CIRCLE NO. 319

Listen to the sound: the part is corroding

It used to be that listening to corrosion was like watching grass grow. A sensitive electronic listening device can now tune in on corrosion and catch it red-handed. The computer controlled instrument can locate and measure corrosion deep within the bowels of a piece of machinery, inside the wing of an aircraft or even inside an integrated circuit package.

"We look at it as an acoustic previewing of failures," says Allen Green, general manager of Acoustic Emission Technology Corp. in Sacramento, CA. Corrosion is a chemical reaction that usually gives off a minute amount of hydrogen gas. The gas bubbles off like boiling water. The bubbling action gives off a very small level of sound that can be detected in the 100-kHz to 2-MHz window in the ultrasonic spectrum. By listening with an extremely sensitive receiver to the acoustic energy in that portion of the spectrum, corrosion can be detected in a nondestructive way before a failure occurs.

A single piezoelectric sensor is first placed on the item of interest. The signal from the sensor is connected to a preamplifier with an rms noise threshold of about 800 nV, then filtered so specific octave-wide bands of frequencies are looked at individually.

When a sound is detected, additional sensors are placed on the item of interest and readings are taken by each. An LSI-2 computer from Computer Automation, Irvine, CA, analyzes the data from the sensors and, by triangulation, calculates the exact position of the corrosion.

If the signal is too small for an accurate reading, the part can be heated. Green notes that a 10 to 18-F increase in temperature doubles the reaction rate of the corrosion and, therefore, also doubles the level of the sound given off.

When multiple sensors are used the propagation of the reaction can be plotted by the computer as a function of time.

Lockheed-California Co. in Burbank, CA, is using the equipment for structural analysis of aircraft.

The equipment can detect micrograms of loose material inside integrated circuit packages, Green says. He notes that the technique has been used to find the cause of failures where X-rays and other methods failed.

An improved Schottky diode tests for ozone

Chemical elements that are believed to be responsible for depleting the earth's atmospheric ozone layer can now be detected more precisely using an improved Schottky-barrier diode.

These chemicals in the stratosphere signal their presence by emitting electromagnetic radiation of very precisely defined frequencies (in the 115-to-118-GHz and 183-to-184-GHz ranges).

The improved, low-noise diode developed by Dr. Robert Mattauch, Associate Professor of Electrical Engineering at the University of Virginia, Charlottesville, VA, is used as a millimeter-wave mixer in a sensitive receiver to detect these frequencies.

Tests to measure trace gases like N_20 and ozone have already been conducted by sensitive receivers in aircraft using these new diodes up to 40,000 ft. More tests are scheduled for June.

The diodes, measuring only 10^{-4} in. in diameter, are formed on a single gallium arsenide chip 5 × 10 mils in area and 5 mils thick. The small size of the diodes allows a large number of them to be placed on a single chip, although only one of them is actually used as the mixer.

Color-TV picture tube is better and cheaper

A color-TV picture tube that can be manufactured by a fully automated facility has been developed by Zenith Radio and Corning Glass. The tube will cost 20% less to produce and have improved performance.

The tube is built with a deflection angle of 100°, which "provides a desirable combination of styling, power consumption and picture quality advantages," according to Joseph P. Fiore, Zenith's vice president of manufacturing and co-inventor of the Chromacolor picture tube.

The depth of the tube was reduced 2-1/2 in. Resolution was improved by using a smaller electron-beam spot size. And power consumption was held down because the 100° tube uses the same deflection-drive power components used in a 90° unit.

The tube is built with a striped, negative-guard-band phosphor screen. A slot-aperture mask assembly designed by Zenith engineers reduces mask weight by over 2 lb and eliminates the glass skirt around the edge of the faceplate. The aperture mask is held rigid by studs in the four corners of the faceplate panel.

Multistage mask-forming dies are used to accomplish a stable, self-supporting mask that eliminates the conventional frame.

Mask-mounting studs may be precision-located and cemented to the inside face of the tube by an automated process said to be simpler than the stud-mounting and alignment system currently used.

The same mounting studs may be used for automatic precision alignment of the faceplate to the funnel. That eliminates the requirement for precision alignment fixtures now used during the tube-sealing operation. The technique is said to increase alignment accuracy and improve production yields.

The mask is built with an integral electron shield to protect the screen from stray or overscanned electrons. This eliminates the need for a separate shield.

"One of the most important features of the design," Fiore adds, "is the ease of mask insertion and removal. Automation of these operations is now possible using simple equipment."

Zenith is banking on the new picture tube to remain competitive with foreign set makers, which have doubled their share of the market in the past four years.

The company plans to manufacture about 200,000 of the tubes this year.

Army opens $40-million missile flight simulator

A complex of simulators that can recreate virtually any man-made or natural phenomena that a missile might encounter in flight has been opened at the Army's Redstone Arsenal, Huntsville, AL. The $40-million facility will be used by all branches of the military and their contractors in the design, development and evaluation of missile systems. It will also provide a tool for analyzing foreign weapons.

The three-story, 75,000 ft^2 Advanced Simulation Center consists of three environmental simulation systems (infrared, electro-optical and radio frequency) and a hybrid computer complex to tie them together.

The center enables a designer to test sensors, guidance-and-control components and flight hardware. Simulations are performed across a wide frequency spectrum, from near ultraviolet through microwave, with expansion capabilities inherent in the design.

One simulator accommodates missiles with sensor systems operating in both the 0.2 to 0.4 and 1.0 to 5.0-micron bands. The sensors are controlled by a hybrid computer in six degrees-of-freedom while the target is being acquired.

The gimballed flight table provides pitch, yaw and roll movements to the sensor airframe. A target generator simulates a variety of target background combinations, including tailpipes, plumes, flares and fuselages in single or multiple displays against clear, clouded, overcast or sunlit skies.

These combinations are then displayed in azimuth, elevation, range and aspect by the target projection subsystem through a folded optical network, a display arm and a display mirror. Simulation capability ranges from open-loop component evaluation to closed-loop total-system simulation.

"Millions of dollars each year will be saved in research and development and actual flight tests," according to an Army spokesman. The center will also reduce significantly the time and manpower required to develop a missile system.

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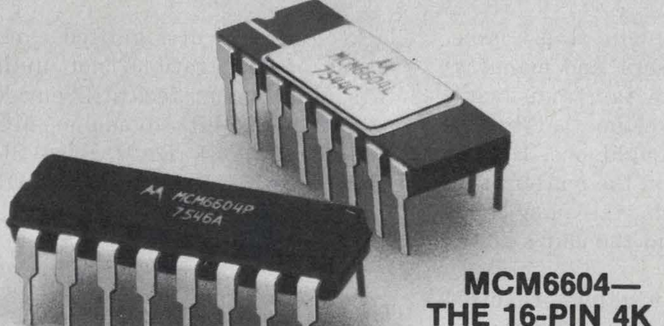
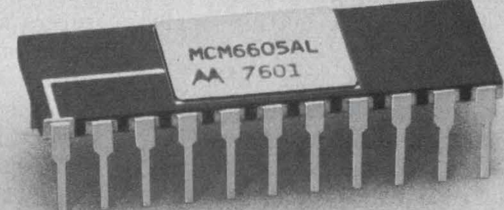
CIRCLE NUMBER 10

Motorola Turns On 4K RAM Availability

We keep hearing of 4K RAM delivery problems, particularly with popular 16-pin types. Well, forget that. With Motorola's totally turned-on 4K RAM production at the Austin, Texas facility, availability is the word for 4Ks. Availability of the 16-pin MCM6604 *and* the 22-pin MCM6605A. Let Motorola eliminate the 4K RAM hassle for you, today . . . and with inflation beating low prices, at that.





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AT THE INTERNATIONAL SOLID-STATE CIRCUITS CONFERENCE

Dynamic RAMs reach 16-k density —and touch off a memory battle

"Users are being dragged kicking and screaming into the 16-k race without first getting really good 4-ks."

That statement was voiced by one participant in the 1976 International Solid-State Circuits Conference in Philadelphia. It was echoed repeatedly by memory-system designers and even by some memory manufacturers.

The occasion was the unveiling of the first 16,384-bit dynamic MOS RAM, an Intel development soon to reach the market (see product feature in this issue, p. 101). But users and manufacturers alike were far from unanimous on Intel's claim that its approach was the right one. Dissent came especially on the matter of an output-data latch, the number of refresh cycles and the chip's power dissipation.

Edward A. Torrero
Associate Editor

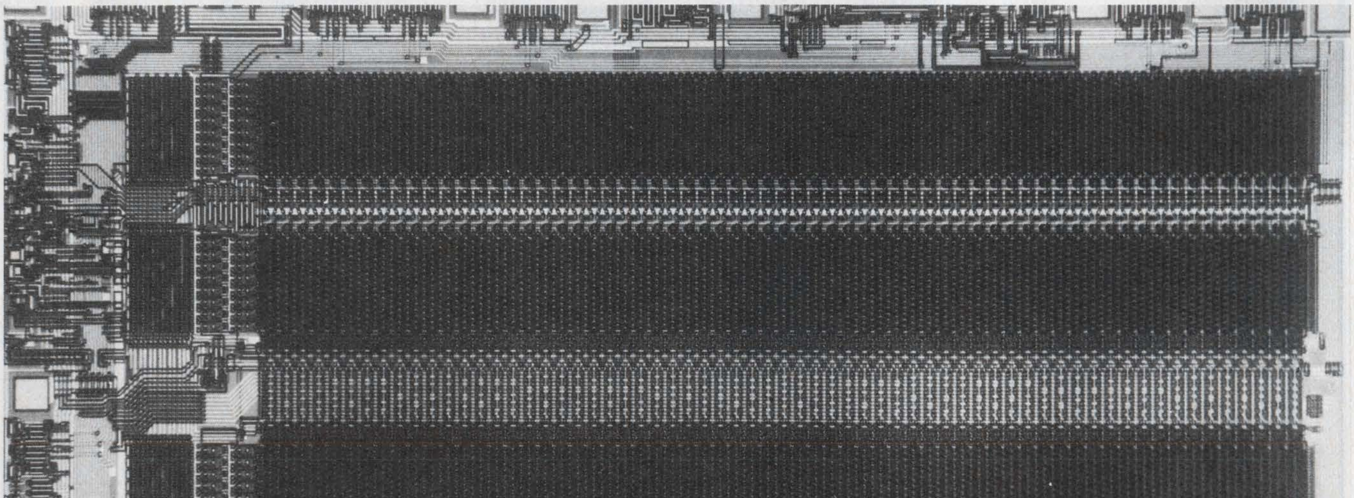
In a private meeting organized by J. Reese Brown, a Burroughs senior staff engineer, users and vendors clashed over the relative merits of Intel's new n-channel memory. Also contested were other approaches to be used by other memory makers, most of whom plan a 16-k entry by year's end.

For memory users, the ominous lack of agreement signified a new round of frustrations not unlike those that many feel still envelop present 4096-bit dynamic MOS RAMs (see "4-k RAM Race Still Wide Open as Designers Try Different Paths," ED No. 6, Mar. 15, 1975, p. 26).

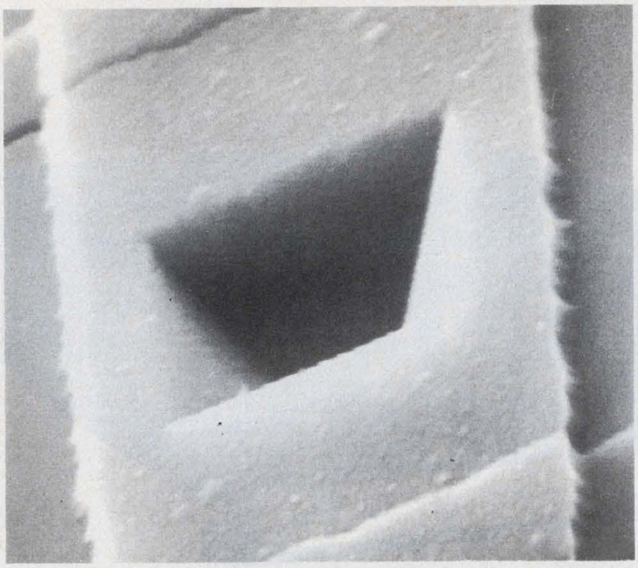
The 16-k bit RAM battle

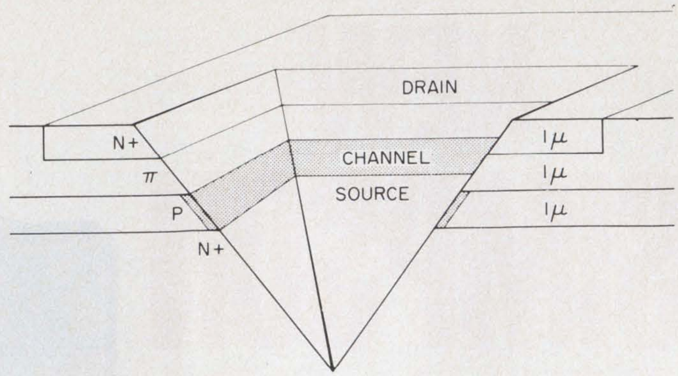
At the heart of the 16-k-RAM debate is the extent to which different manufacturers seek to duplicate some of the features of current 4-k RAMs housed in 16-pin DIPs.

This kind of package for 16-k RAMs is one of the few areas of



A 16,384 × 1-bit n-channel MOS dynamic RAM employs single-transistor cells and two-layer polysilicon technology. Intel's 2116 replaces the Chip Select of 16-pin 4-k RAMs with a seventh address pin.





VMOS transistors—vertical n-channel MOS devices formed on the face of a V-groove—form the basis of a developmental 16-k bit ROM from American Microsystems. The 5-V VMOS ROM has a worst-case access of 200 ns, compared with over 500 ns for equivalent ROMs that use conventional techniques.

agreement: it is used by Intel for its 16-k RAM, the 2116. However, companies like Nippon and Hitachi (which presented a late paper on its developmental 16-k RAM) and possibly Texas Instruments (which didn't participate in the general discussions) are among those thought to be planning an 18 or 22-pin package.

The acknowledged model for the 16-pin package is Mostek's. The company pioneered the 16-pin package for 4-k RAMs. Sockets designed for that package can readily accommodate the similarly packaged, though higher-density, 16-k memory. This is done by abolishing Chip Select (CS) in favor of an extra address line (A_6) supporting two address bits —as in Intel's 2116.

However, the 2116 also incorporates a special output latch like that found on early Mostek 4-k RAMs. That simple latch represents one of the major points of dispute. Unlike a standard latch, the Mostek version maintains data in a Valid state right into a succeeding memory cycle.

"For a chip designer," said Richard Foss, president of Mosaid in Canada, "that latch violates one of the golden rules, that each cycle should be considered a separate entity. If in the next cycle, you have to worry about what happened in the last cycle, you can't restandardize. It's a no-no for testing."

Moreover, the use of Chip Select was one way to clear the output latch in the 4-k RAM. But Chip Select isn't available on 16-k RAMs going into 16-pin packages. Device selection is now an additional function of either the column-address strobe ($\overline{CAS}$) signal, which determines the vertical cells to be accessed, or the row-address strobe ($\overline{RAS}$), which pinpoints horizontal cells.

Refresh woes

The absence of Chip Select can be a particularly acute problem for existing 4-k-RAM-based systems that refresh the dynamic memories with hidden, or "transparent," techniques. The techniques make use of the fact that not all memory elements are accessed at the same time, and are ideal for large memory systems, such as those employed by Honeywell.

While some of the elements are activated by row and column-address signals, other elements have their column-address signals cut off, and are refreshed by $\overline{RAS}$. The so-called $\overline{RAS}$-only refresh isn't possible with a memory chip that contains the output latch.

"With a data-out latch, you have to provide $\overline{CAS}$ to all chips whether you want to or not in order to turn off the data-out from a previously accessed chip," said Paul Schroeder, Mostek's senior design engineer in charge of 16-k RAM development.

"All of the things you need to do to get around this are extremely unpleasant. They're not the kind of things a system designer really wants to do."

For Intel, a strong argument for the latch is that it exists on current 4-k RAMS. Company spokesmen make much of the fact that they can replace the 4-ks in a customer's board with 16-k-RAM samples. The board then works just as if the memories had not been replaced.

Although the 16-k RAMs function as 4-ks—only one quadrant is used—the customer can perform most of his testing. He can check pattern sensitivities, access times and power dissipation. And with an extra address line, he can multiply storage capacity by four.

"I think the customer has been done a disservice by this debate," said David House, Intel's component applications manager. The decision of some manufacturers to drop the latch on their 16-ks, according to House, was a poor business decision, rather than an obvious engineering decision.

"It's definitely not clear that the output latch should not be there."

For the great bulk of applications, an output latch on the 16-k RAM presents no problem, observes House. In fact most memory systems can be readily designed to accommodate both a memory chip with the latch and a memory chip without one.

Such a system must be able to sample data when the clocks are in a Valid state, so that the latchless part works, and must not depend on the output being in a high-impedance state—so that the memory with the latch, like Intel's 2116,

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Most manufacturers declined to detail how they would design their 16-k RAM chip, although American Microsystems indicated it would follow Intel's lead in building a 16-k version of Mostek's early 4-k RAM.

Mostek, however, was adamant in its opposition to the kind of latch it originally inflicted on the industry. The Mostek 16-k RAM, which could be announced as early as midyear, will have a data latch, but one that can be cleared at the end of a memory cycle, when $\overline{CAS}$ goes high.

The benefits are many. Now a $\overline{CAS}$ signal can be used as a separate Chip Select and to simplify the expansion of speed-enhancing page-mode systems. Multiple 16-ks are accessed with a $\overline{RAS}$ pulse, and a $\overline{CAS}$ is applied only to those chips from which outputs are needed. Further, the memory chip can be used in systems that call for transparent refresh.

Another point of controversy is the number of refresh cycles. If compatibility with 4-k RAMs were the sole consideration, the number of refresh cycles would be 64 every 2 ms.

The Intel 16-k RAM allows either 64 or 128 cycles in the 2-ms refresh interval. The memory naturally takes 128 cycles, because of its 128 × 128-element layout. However, internal logic can reduce the refresh requirement to 64 when signalled to do so by a special overlapping of $\overline{CAS}$ and $\overline{RAS}$.

For system designers, 64 cycles would seem to be better than 128. The reduced refresh requirement leads to a somewhat simpler design and to lessened "dead" time.

Critics argue, though, that with a 64-cycle refresh, twice as many sense amps are active than there would be with 128 cycles. The additional amps increase power dissipation.

"Chip temperature could rise by 10 C," said Foss. "If it does, never mind the data sheets, you may have to refresh twice as often, because the chip is that much hotter."

Further, the 2116 has a total of 64 cells on each sense amp, and a total of 256 space-consuming sense amps on the 145 × 235-mil die—close to the maximum size that will sit in a 16-pin DIP, "without using a shoehorn," as one expert put it.

When the refresh requirement is solely 128 cycles, a smaller chip can be built with just 128 cells on each sense amp and a total of 128 sense amps—the approach planned by Mostek.

The result, according to Mostek's Schroeder, will be a chip measuring about 28,000 square mils, compared with 34,000 for the 2116. And the Mostek version will spec its slowest access at 250 ns—which is the top speed for the 2116.

"I expect the highest speed to be 200 ns early in the game," Schroeder said, "and faster units will appear later."

Dissipating power

The 2116's power dissipation was another point of concern. Although the memory was said to consume substantially less power/bit than a 4-k RAM did, the 2116's over-all dissipation was about the same—officially under 3/4 W. For some, the value was too high.

"The arithmetic I've gone through," Schroeder said, "makes me expect that parts having dissipations over 1/2 W tend to have a high junction temperature. If it rises by no more than 10 C, I would be surprised."

That rise could spell trouble for the refresh interval. Published specs don't always take into account the rise in junction temperature. One way to make the spec more meaningful, according to Schroeder, is for manufacturers to test refresh interval with internal junction temperatures at 100 C or higher, and to provide curves of ambient temperature and air flow as functions of cycle rate. ■■

Lack of standards slows progress of analog interfacing for μP systems

Despite impressive advances in the design of monolithic analog-to-digital converters, widespread use of microprocessors in analog systems may be stymied, an expert warned, unless the industry acts immediately to standardize converter hardware.

The call for action came from Hermann Schmid, a consultant for General Electric. Schmid summed up the problem during a panel discussion on "Problems of Analog Interface in Microprocessor-Based Systems" at the ISSCC.

Michael Elphick
Managing Editor

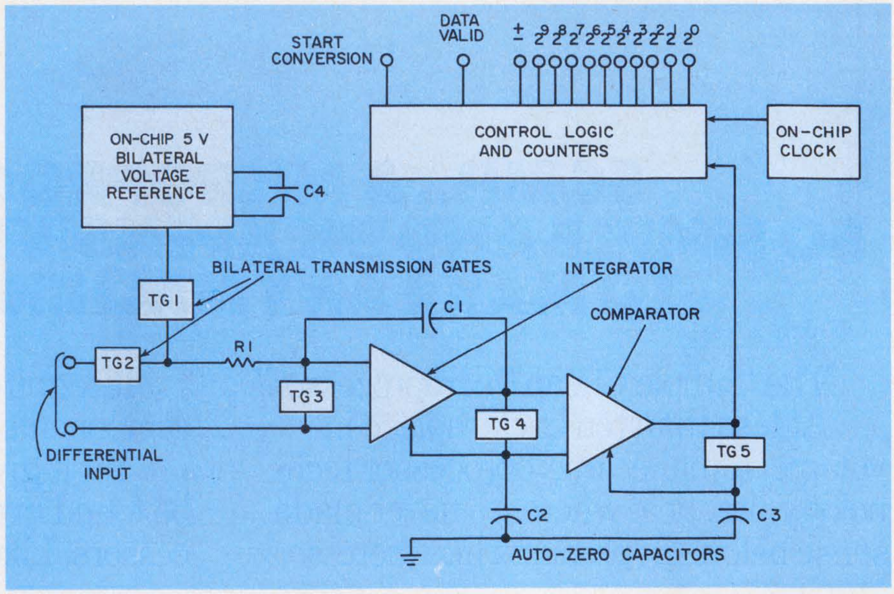
"There must be hundreds of a/d and d/a converters on the market," he said, "but have you ever tried to find a second source for one of them?"

Few circuits are pin-compatible, Schmid added, and they come in all sorts of shapes and sizes and with various voltage requirements. And when you try to interface them with μPs you run into still further problems.

To be useful, the analog interface device should be address selectable, have on-board latches, and have three-state digital outputs for direct connection to the μP's bus, Schmid said.

"Standardization is difficult and we shouldn't underestimate the magnitude of the task," warned Schmid. "But, it must be done. The IEEE interface-bus standard for instruments is an excellent example of what is possible."

Most panelists agreed there was an urgent need for standards. Tom Harper of National Semiconductor said system designers he's worked with seem to be using μPs primarily to reduce their parts count.



Dual-slope integration is the conversion technique used in a monolithic CMOS a/d converter designed by RCA. The 11-bit circuit includes a clock oscillator and a reference source. It operates from a single-ended supply of 4.5 to 15 V.

When substantial hardware is needed for analog interfacing it defeats the purpose of using a μP.

Microprocessor manufacturers may start to include analog-interface circuitry on the μP chips, and system designers may start to replace external hardware with software algorithms, he warned, unless converter manufacturers act quickly to supply compact standardized hardware at low cost.

"Converter manufacturers aren't merely competing with each other," explained Harper. "The real competition is software."

Panelists also agreed that the standardization task would be Herculean. Since it would be practically impossible to standardize the software aspects of analog interfacing without standards for the μPs themselves, Schmid urged the industry to begin with hardware standardization and resolve software problems later.

Even in the hardware area, though, prospects for standardization appeared bleak. While most panelists agreed on the need for addressing capability and three-state TTL digital signals, the panel was sharply divided on the basic question of whether digital data should be handled serially or in parallel.

The hardware's getting better

Although standardization remains elusive, papers presented at the conference showed that IC manufacturers have licked several other problems that tended to restrict use of μPs in analog systems. A/d and d/a converters no longer need to be expensive, slow, inaccurate and bulky.

IC designers proved at this year's conference that most of the traditional constraints have been overcome. It's now possible to build single-chip a/d converters using just about any popular circuit configuration.

Among the developmental a/d converters described at the conference were circuits using CMOS, PMOS and bipolar-LSI processing. Circuit techniques used included dual-slope integration, successive approximation and high-speed parallel conversion.

Perhaps the most impressive a/d converter described at the conference was a successive-approximation circuit, from TRW Systems, that combines speed with accuracy. The 10-bit bipolar-LSI circuit achieves a sampling rate of 5 MHz while consuming only 2.7 W.

Linearity of the basic circuit is 0.4 LSB, but can be improved to less than 0.2 LSB by laser trimming of the chip's thin-film resistors. The only external circuitry needed is a reference source and a clock oscillator. (For a block diagram and more complete description of this circuit, see "Fastest Monolithic 10-bit A/d Device Has 200-ns Conversion Time," ED 5, March 1, 1976, p. 20.)

Although the Systems Group of TRW traditionally doesn't sell components, the company may market the converter circuit later in the year, according to David Breuer, who presented the paper.

Even higher conversion speeds are achieved in a bipolar a/d converter described by Robert Nordstrom of Tektronix. This circuit uses a parallel-conversion technique to achieve a conversion rate of 100 MHz, and the 4-bit chip has sufficient accuracy for use in an 8-bit converter.

The circuit consists essentially of 16 high-speed comparators and a 4-bit binary encoder, integrated on a single chip. A separate resistor network was used for the prototype, which was built primarily to demonstrate the feasibility of integrating the comparators.

Other manufacturers have demonstrated that it's possible to deposit and trim thin-film resistors on a silicon chip, so it should be possible to build a complete monolithic converter based on this design. Each comparator cell consists of only 15 transistors, and standard high-frequency IC processing is used to achieve an f_T of 3 GHz for the transistors. The bit lines deliver ECL levels, but dissipation is only 32 mW for each comparator cell.

MOS shows progress, too

Bipolar circuits won the speed race at ISSCC, but some solid gains were also made in MOS. Of course, for a/d converters, MOS offers the advantages of low cost, high circuit density and low power dissipation. But until recently designers found it difficult to achieve the required performance in the analog portion of a/d converters that employed MOS throughout.

Most designers compromised on a two-chip arrangement, using MOS for the digital portion and bipolar circuitry for the analog section. Now, however, the analog design problems seem to be licked. Three companies announced single-chip MOS converters at the conference—two use CMOS, while one uses PMOS.

One of the CMOS circuits was

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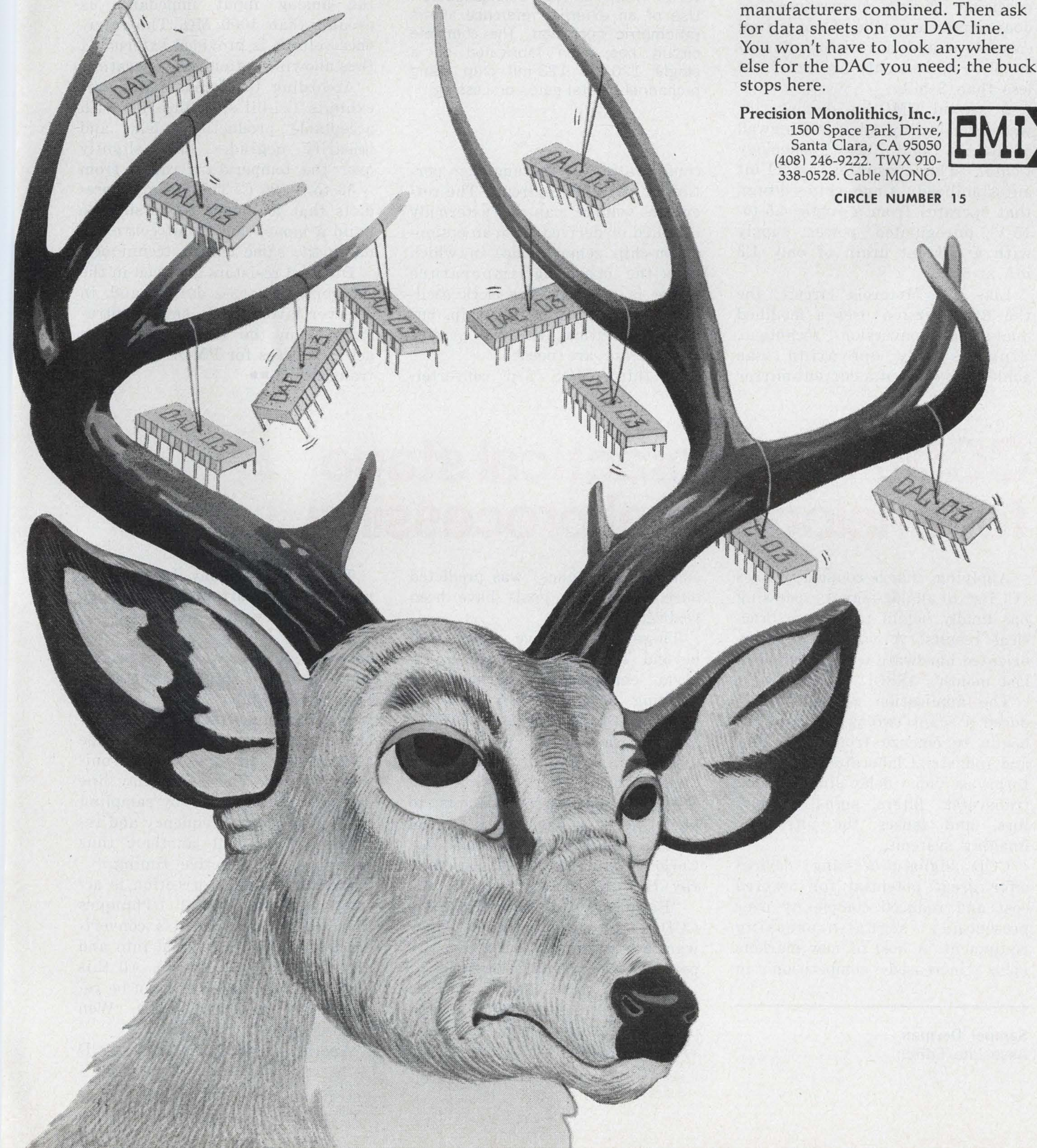


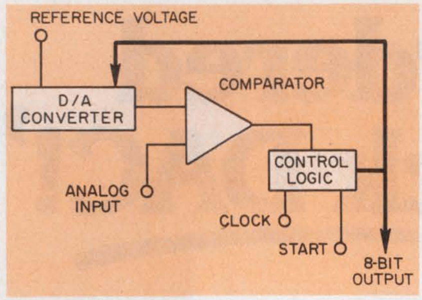
described by Robert Huntington of Motorola Semiconductor Products. His 3-1/2-digit a/d converter provides autopolarity and automatic-zero functions.

Also, it compensates itself for op-amp offsets and the comparator threshold. As a result, the modified dual-slope circuit holds its 0.05% full-scale accuracy over a temperature range of −50 to +75 C and eliminates the need for manual adjustments.

The single-chip circuit needs no precision off-chip components, but does require a couple of noncritical capacitors and a resistor. Power-supply requirements are ±5 V at less than 2 mA.

A second CMOS a/d converter was described by Andrew Dingwall of RCA's Solid State Technology Center. The circuit is an 11-bit autostabilized single-chip design that operates from a single 4.5-to-15-V unregulated power supply with a current drain of only 1.2 mA at 5 V.

Like the Motorola circuit, the the RCA version uses a modified dual-slope conversion technique. Single-supply operation was achieved by use of a current-mirror configuration in the amplifier portion of the CMOS circuit. The reference voltage can be externally supplied or derived from an optional on-chip zener diode—in which case the operating-temperature range is reduced. The clock oscillator is included on the chip, but some noncritical, external passive components are needed.



Successive approximation provides a typical conversion time of 20 μs in an 8-bit PMOS monolithic a/d converter from National Semiconductor. Use of an external reference allows ratiometric operation. The complete circuit has been fabricated on a single 120 × 123-mil chip using p-channel, metal-gate, processing.

A third MOS a/d converter, using p-channel, metal-gate processing, was described by Adib Hamadé. He now works in Iraq, but designed the single-chip 8-bit converter while working for National Semiconductor in the U.S.

The circuit employs a successive-approximation conversion technique to yield a typical conversion time of 20 μs. The 120 × 123-mil PMOS chip includes a d/a converter, a comparator, control logic and three-state output buffers. Because MOS is used for the comparator, the analog input impedance is greater than 1000 MΩ. The reference voltage is provided externally, thus allowing ratiometric operation.

According to Hamadé, the unit exhibits 1/4-bit step linearity with acceptable production yield, and linearity degrades only slightly over the temperature range from −55 to +125 C. The designer predicts that it should be possible to build a monolithic 10-bit converter using the same circuit techniques.

Diffused resistors are used in the inherently low-cost design, and, in a clever layout trick, small protrusions from the resistor diffusion act as sources for PMOS switching transistors. ■■

CCDs reach practical stage for analog signal processing

Applying charge-coupled devices (CCDs) to analog-signal processing has finally begun to achieve practical results. A variety of user-oriented hardware was described at last month's ISSCC.

The application concept—introduced a scant two years ago—has begun to emerge from university and industrial laboratories in such forms as video delay lines, analog transversal filters, signal correlators, and lenses for ultrasonic imaging systems.

CCD signal-processing devices offer great potential for lowered cost and reduced complexity over present-day signal-processing equipment. A host of new markets (plus increased competition in some existing ones) was predicted once these cost goals have been realized.

Samuel Derman
Associate Editor

These devices have passed well beyond the feasibility stage, experts emphasized. As evidence, working specifications for CCD-based hardware were given for such characteristics as linearity, distortion, dynamic range and bandwidth.

"What the engineer wants to know now is whether it's good enough for his application," said Carlo Sequin of Bell Labs, Murray Hill, NJ.

"Engineers don't just think of a CCD as an isolated device. They want a working black box that can perform a particular function."

David Wen of Fairchild, Palo Alto, CA, introduced one of several of these CCD-implemented units, a video-delay line.

The Fairchild delay line serves a number of important needs of the video industry, Wen explained.

One use is for television time-base correction, which is needed when the TV signal is obtained from a video tape or disc. Any existing irregularities in the mechanism that drives the disc or tape reels results in timing-synchronization errors. The CCD delay line can correct the errors by sampling the signal at one frequency and retransmitting it at another, thus changing the effective timing.

Currently, such correction is accomplished by digital techniques that require a/d and d/a converters to transfer the signal into and out of the digital domain. All this very elaborate hardware can be replaced by just one CCD, Wen pointed out.

Another application for the CCD

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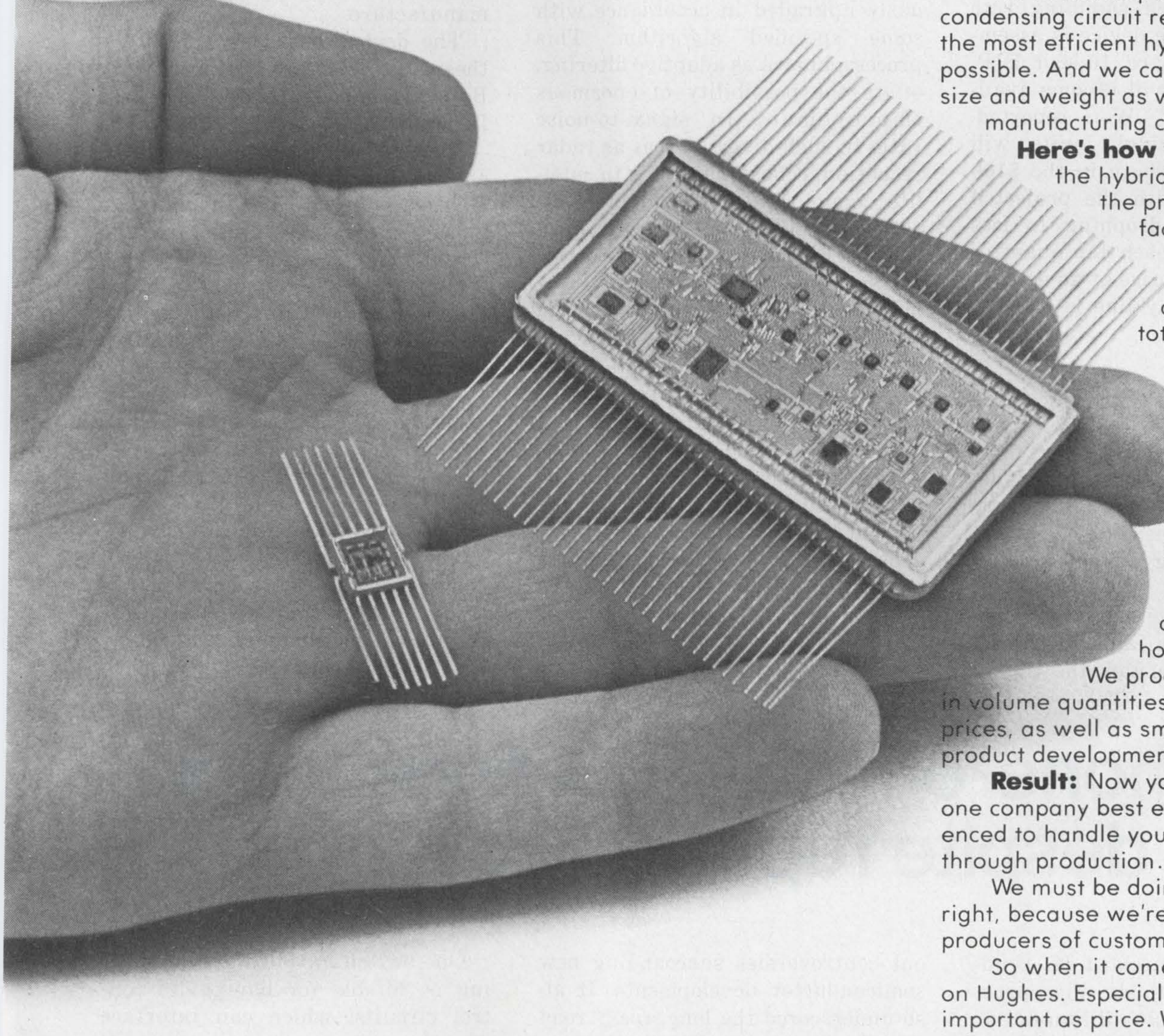

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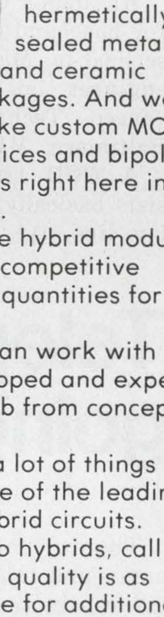


CIRCLE NUMBER 16

delay line is in separating color from black and white in a composite TV signal.

The Fairchild CCD delay line consists of two independent 455-element buried-channel CCD shift registers, complete with transport clocks and input and output terminals, all on a die measuring 79 × 84 mils. The unit has a bandwidth of 4 to 5 MHz, a dynamic range of about 55 dB and nonlinearity of 3 percent or less. Only two external clocks are required.

The output signal of one register can be directly connected to the input terminal of the other to obtain a 910-element delay capable of storing a complete horizontal line of standard television transmission (63.55 μs) with a sampling rate of 14.32 MHz. The device is assembled into a standard 16-lead DIP.

The delay line will become available "very soon," Wen reported. The price for single units will initially be somewhere in the $100 to $200 range, with the projected price eventually dropping to less than five dollars each for quantity lots. The current price of an equivalent standard delay line is $700 to $800.

CCDs filter baseband data

An analog CCD transversal filter for baseband data filtering was described by Marvin White, advisory engineer at Westinghouse Advanced Technology Laboratories, Baltimore, MD.

A CCD transversal filter consists basically of a tapped CCD delay line. At each tap the signal leaves the delay line and passes through a separate variable resistance. Finally, the delayed signals, from each tap, are summed.

Since each resistance can be varied independently, the result is a summation of weighted signals. Any desired filter characteristic can be synthesized by this means. This is a powerful design tool, White explained, because it allows the designer to control a filter's amplitude and phase characteristics independently. In conventional passive filters the amplitude and phase are unavoidably related.

Even more important, said White, the individual resistances can be varied electrically, and the weighting factors can be continuously upgraded in accordance with some specified algorithm. This process, known as adaptive filtering, offers the possibility of enormous improvement in signal-to-noise ratio in such diverse areas as radar reception, echo suppression in satellite communications, and biomedical electronics. For example, it can remove 60 Hz noise from electrocardiogram signals, or separate the heartbeats of fetus and mother.

White provided the following figures for the filter: total harmonic distortion of 0.3 percent for a 1.5-V p-p 1-kHz input signal and a sampling frequency of 16.7 kHz.

White explained that a unique design feature of this device is the use of a floating-clock electrode sensor that provides nondestructive readout (at each tap point) of the CCD delay-line signal. The unit combines both bipolar and MOS technology with the CCD delay line—the first time such a combination has been realized on a single chip.

Completion of the entire system must await the integration of the adaptive-filter algorithm on the chip, White said.

CCDs convolute analog inputs

Patrick Bosshart, an electrical-engineering graduate student at MIT, described an integrated-circuit analog correlator that uses CCDs. An analog correlator performs the convolution of two arbitrary analog input functions and can replace some complex digital systems that do the same job. The CCD correlator, however, uses fewer components and costs less to manufacture.

The device, based on a master's thesis project, was designed by Bosshart and fabricated at Texas Instruments.

The level of performance is high enough to allow the correlator to be used in applications in audio and video-signal processing and in adaptive filtering Bosshart reported.

Potential improvements in ultrasound technology for both medical and industrial applications using a cascade CCD were described by John Short of Stanford University, Stanford, CA.

This device uses CCD delay lines to equalize the total (electronic plus acoustic) propagation time for a set of ultrasonic transducers.

The CCD "lens" has been built and tested and has been shown to produce a resolution near the theoretical maximum for an array of 1.5-MHz transducers. ■■

Telephone-oriented LSI finds tough going despite reported advances

The role of standard IC products—and particularly microprocessors—in the multi-billion-dollar telephone industry appears cloudy.

Despite LSI-circuit innovations described at the 1976 ISSCC, a panel discussion on the future impact of such circuits brought out controversies surrounding new semiconductor developments. It also underscored the long, rocky road ICs must travel before finding acceptance in telephone equipment.

Papers described at the conference covered three major areas in telephony: coder/decoders (codecs), compressor/expandors (compandors) and crosspoint switches.

One switch unveiled at the meeting is notable for having its control circuits, which can interface directly with a microprocessor, integrated on the same chip as the crosspoint array.

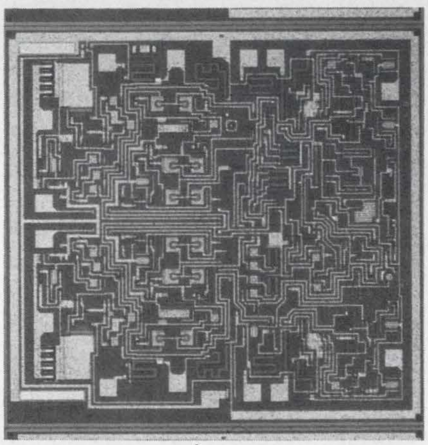
Microprocessor control may indeed be an attractive feature. But the question is, can the microprocessor, or any of the other communications circuits described at

Stanley Runyon
Associate Editor

the conference, find a prominent niche in an industry famous for its caution. If some of the panelists and audience at the informal discussion have their way, the answer is "no."

Although John C. McDonald, vice president of research and engineering for the Vidar Div. of TRW, Mountain View, CA, projected a $3 billion market for LSI/MSI circuits in telephone networks by 1990, others took a different view:

John Rhodes, organizer and moderator of the session, and a technical member of the board of Pye-TMC, a supplier of phone equipment in Wilts, England, stated flatly that "processing and microprocessors are not for telephony." Rhodes apparently meant off-the-shelf silicon products, not custom LSI, of which he proclaimed himself a proponent. Asked to define "custom LSI" Rhodes replied: "It's an IC designed by an engineer who knows the telephone business."



An 88 × 92-mil analog compandor uses ion implantation and matched components to achieve low drift, high accuracy.

Winners and losers

McDonald, on the other hand, told of considerable success with standard ICs, and of disasters with custom circuits. His formula for success: 100 to 500 FITs (failures in 10^9 hours), availability for 20 years or more, and, of course, low price.

Attendees and panelists immediately polarized, lining up on either the custom or standard-product side. While this appeared to be the key issue of the session, the debate actually surfaced as a clash between two giant but antithetical industries—the slow moving telephone establishment and the quick-turnover semiconductor houses.

Just how quickly semiconductor technology can respond to a specific job is demonstrated by the advances outlined at the conference.

In a paper on an all-MOS, companded PCM voice encoder, John P. Tsividis of the University of California, Berkeley, CA, described a partially integrated MOS chip that meets Bell System specifications for signal-to-distortion ratio, gain tracking, single-frequency distortion and idle-channel noise.

Tsividis explained that the chip, fabricated as metal-gate, n-channel MOS, satisfies a commonly used companding algorithm (μ-255) that uses a 15-segment approximation of the nonlinear curve. Thus the s/n ratio is optimized for digital voice transmission.

Analog is king in telephony

Most existing telephone equipment, however, still operates in the analog domain. To improve the s/n ratio of analog transmission, companding remains the traditional technique. Here, a 2-dB change in input level is compressed into a 1-dB variation for transmission, and an expandor restores the 2-dB excursion at the receiving end.

A monolithic compandor was described by Craig Todd of Signetics. As he pointed out, discrete compandors require many components, and so often suffer from excessive temperature drift. The bipolar IC, however, uses ion-implanted resistors and matched IC components, so that the required low-level tracking, distortion and temperature stability are realized without costly external trimming.

The untrimmed distortion of the IC compandor, Todd stated, is 0.5 percent, and the gain change from −40 to 70 C is only ±0.2 dB. Another benefit: low power consumption—just 4 mA are drawn at a V_{cc} ranging from 6 to 18 V.

In the third important application area—that of switching—two ICs that were described met the challenge of low distortion, low loss and low crosstalk. Though electromechanical relays aptly fulfill these requirements, solid-state crosspoints are potentially more reliable, switch much faster than relays and need far less power.

The first IC—outlined by Willy Sansen of Catholic University, Heverlee, Belgium, is an active, bipolar 4 × 4 crosspoint with a low r_{on}-area product (1.7 to 2.5 Ω-mm^2), with low sensitivity to line spikes, and needing no coupling transformers or capacitors.

In operation, the pass transistor of the switch is biased in its active region—instead of the linear region—and the device gain is arranged in a feedback loop to reduce the ON resistance and cut losses. Insertion loss of the switch is as low as 0.1 dB, and ON dissipation is fairly high—80 mW—compared with that of other solid-state methods.

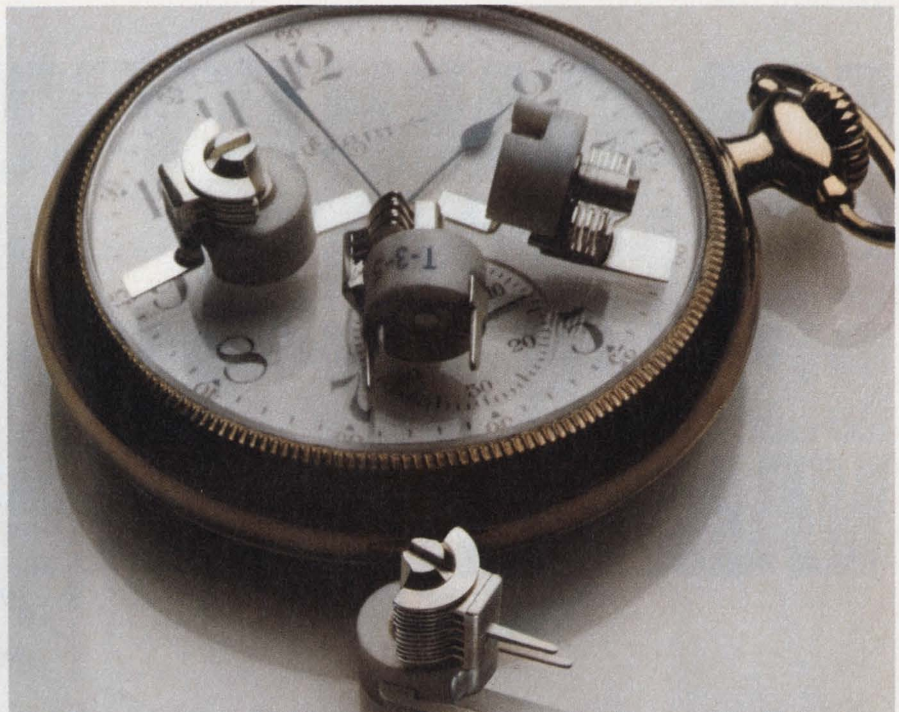
Switching plus digital control

In another approach, Thomas Cauge of Signetics told of a DMOS crosspoint array in which control circuitry was integrated on the same chip. Configured as an 8 × 2 unbalanced network, the switch ON resistance is cut by a factor of three to five over that of conventional MOS that uses the same area.

Cauge listed both the typical crosstalk and OFF isolation of the DMOS switch as −105 dB, and typical ON resistance as 12 Ω at a V_{cc} of 15 V. He noted that the TTL/CMOS compatibility of the chip and the single 15-V supply needed are features designed expressly for microprocessor interfacing. ■■

Papers, anyone?

A complete digest of the papers presented at the International Solid-State Circuits Conference is available at $20 for IEEE members and $30 for nonmembers. Write to: International Solid-State Circuits Conference, Philadelphia Section IEEE Office, Moore School of Electrical Engineering, University of Pennsylvania, Philadelphia, PA 19174.



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Carbon film resistors are calibrated to value during manufacture and offered in ±2 and ±5% tolerances, while carbon comps are culled to provide tolerances of ±5, ±10 and ±20%. There's less drift, greater precision with carbon film resistors, and you'll require less critical characteristics in other circuit parts.

The decision is clear. Mepco/Electra carbon film resistors can give you the high stability, high reliability performance at low cost that carbon comp resistors can't deliver at any cost. If anyone tells you otherwise, it's only a half-baked theory!

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CIRCLE NUMBER 20

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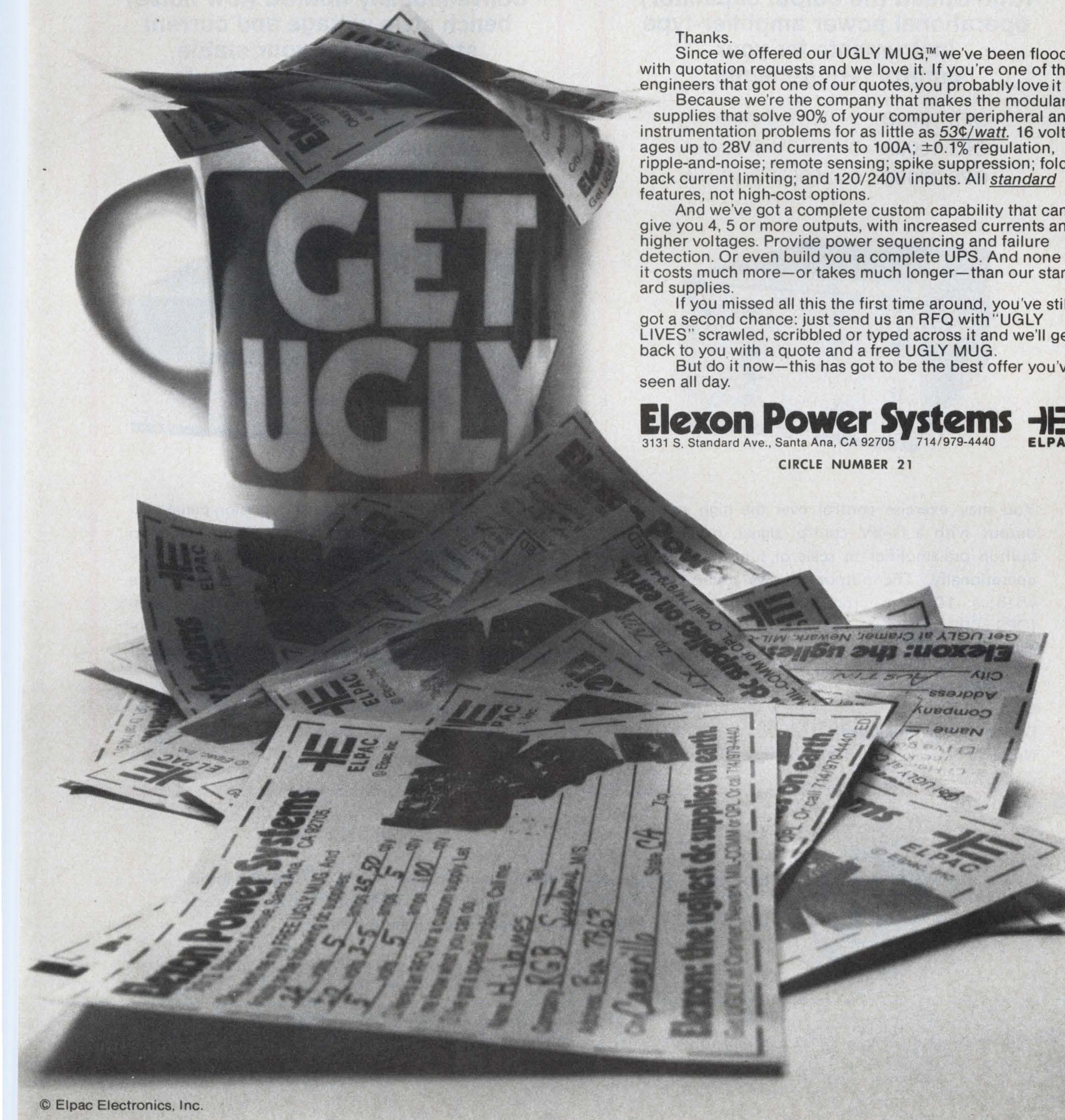

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CIRCLE NUMBER 21

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OPS 500B: 0–500V @ 40 mA
OPS 1000B: 0–1000V @ 20 mA
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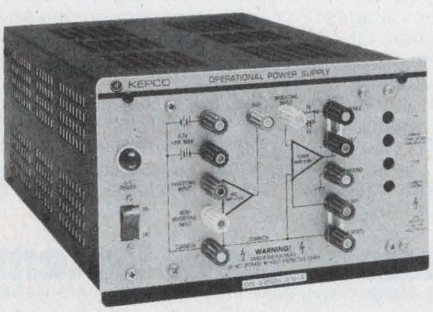

You may exercise control over the high voltage output with a 0–5V control signal, or use the built-in pre-amplifier to scale or sum your inputs operationally. The output follows input signals with a 100 μsec programming time constant (OPS 500B). Current limit is both adjustable and electrically programmable.

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Gain . . . . 10^6 V/V
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CIRCLE NUMBER 22

NASA to develop hand-carried satellite ground terminals

The National Aeronautics and Space Administration is developing a technology base to support a new family of communication satellites for the 1980s. Trends indicate that both fixed and mobile terminals will be smaller and cheaper, and that many will be hand-carried.

The new services would aid in search and rescue and in disaster warning, would collect environmental data from thousands of floating or fixed unattended platforms throughout the world and would offer such capabilities as two-way video and voice transmissions.

NASA will continue research in high-power transmitters and in sensitive receivers. Another component of interest is an antenna that has commandable, adaptive beam contouring for confining transmissions to selected geographic areas.

Because of the growing demand for frequency allocations and the steadily aggravated spectrum crowding on lower frequencies, NASA will maintain current efforts to alleviate overcrowding, while also pursuing a long-range interest in opening up higher frequencies in the spectrum, which are still unused.

Lasers gain status in energy program

The Energy Research and Development Administration has realigned its laser and electron-beam fusion programs and its laser-isotope separation program in recognition of the increasing importance of lasers in the energy field.

Both were formerly under ERDA's Division of Military Applications. Now laser and electron-beam fusion programs will come under a newly created Division of Laser Fusion. Laser isotope separation programs move over to the Division of Nuclear Research and Application as part of ERDA's long-range plan for nuclear fuel enrichment.

ERDA has received proposals for four enrichment projects from private industry, both for building the conventional gaseous-diffusion plants, and for building plants that would use the newer centrifuge approach. But the agency has announced interest in an enrichment approach—laser isotope separation—that might have an even lower cost. Its goal is construction of a laser-enrichment plant by late 1980s.

Patent system may be overhauled

Inventors shouldn't get their hopes up too soon, but reform of the nation's patent system is on the way. Patents in the future may cost less to gain, less to maintain, be less susceptible to challenge because they'll be better validated, and have a better image around the world.

These are some of the heralded benefits of S. 2255, "The Patent Act of 1975," which sailed through the Senate so quickly on Feb. 26 that opponents were caught flatfooted. The bill was passed by a voice vote, without any debate, and sent to the House. Angry protests are expected from such groups as the organized patent bar and the furor will likely produce intensive hearings in the House.

Basically, the reform measure doesn't change any of the substantive portions of the 1836 law. While the patent system was codified in 1952, there have not been significant changes in 140 years, notes Sen. Philip Hart (D-MI), a prime sponsor.

He says the bill will update the present antiquated administrative setup, provide for a more rigorous examination by the Patent and Trademark Office of patent requests, and require greater disclosure of prior art to that office by the applicant. Included in the measure are provisions for lowering and deferring fees to private inventors and small businesses.

Government's contracting procedures to be streamlined

The powerful Senate Operations Committee is now considering landmark legislation that would overhaul the Federal government's $70 billion a year contracting activities.

Introduced by Sen. Lawton Chiles (D-FL), S. 3005, "Federal Acquisition Act of 1976," is designed to legislate changes recommended by the Commission on Government Procurement that couldn't be made administratively.

The bill "directly seeks to substitute effective competition for regulation" and is aimed at relieving a wide range of government surveillance, "but only where effective competition is at work," Chiles says.

A key provision requires the Office of Federal Procurement Policy to establish a single, simplified set of regulations to cover all agencies of the Federal government by meshing regulations generated by the Armed Services Act and the Federal Property Act.

Other titles in the bill define the proper circumstances for agency use of acquisition procedures by competitive sealed bids, competitive negotiations (with an exception for single-source procurements) and acquisition by competitive small-purchase procedures.

Capital Capsules:

NASA's Nimbus 6 meteorological research satellite gets a new task this summer—tracking a Model-T Ford in the American Bicentennial Around-the-World Auto Race, an enactment of the Great Race of 1908. A 30-pound electronic package will be carried by a 1914 Model T to transmit the ground speed of the moving car to the Random Access Measurement System carried by the pole-to-pole orbiting satellite. . . . The Air Force has issued requests for proposals to 31 small business firms for a **dual-bank radar beacon transponder set (AN/TPN-28).** The self-contained, portable 30-pound units are for forward air controllers. Contract award is set for midyear. The Air Force will buy 12 preproduction and 800 operational sets with the Marine Corps slated to get 340 of them. . . . The Navy has awarded Norden Div. of United Technology a development contract for a **lightweight, high-frequency transceiver for shipboard use.** The millimeter-wave communicator weighs 5 lb and offers voice, video or data transmissions over distances of up to 20 miles. Its narrow beamwidth minimizes interception.

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Need: A new computer-grade switch at a price you can afford.

LOW COST • COMPUTER GRADE QUALITY • DESIGN FLEXIBILITY • GOLD OR SILVER CONTACTS • CHOICE OF TERMINALS • MOMENTARY OR ALTERNATE SWITCHING ACTIONS • SPDT, DPDT • DESIGNED TO MEET UL SPECIFICATIONS • UNIFORM FRONT PANEL APPEARANCE AND REAR PROJECTION • MATCHING INDICATOR LIGHT • FRONT MOUNTING SNAP-IN BEZELS—4 SIZES/SHAPES TO CHOOSE FROM • REAR MOUNTING SWITCH WITH ANTI-ROTATION FEATURE • CHOICE OF OVER 200 CAP SHAPES, SIZES AND COLORS • CHOICE OF ENGRAVED, HOT STAMPED OR REPLACEABLE LEGENDS.

Dialight's low cost 554 series switches are available in a wide selection of rear panel and front bezel mounting types. Switches are available with silver or gold contacts for wide range of applications; operating life is 250,000 operations.

Fingertip grips permit easy cap removal . . . lamp replacement is from front of panel . . . no special tools needed.

Caps are available with or without underlying color filter in ⅝" and ¾" square, ⅝" x ¾" and ¾" x 1" rectangles. At Dialight it's your choice because we see your need.

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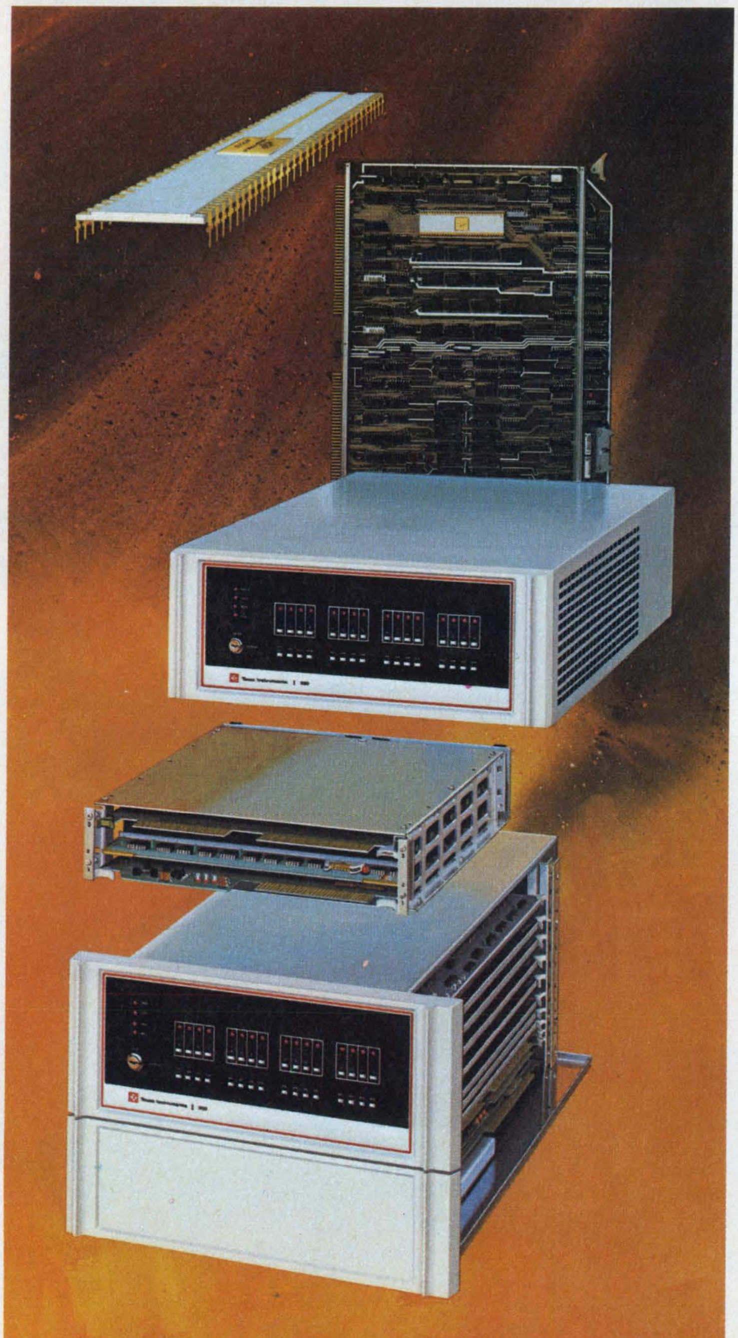

UMENTS HAS RE AND HARDWARE.

ble for application software.

The 990/10 Disc System Software accents the mass-storage, random-access features of the disc with extensive file management and the multi-tasking features of the DX10 Operating System. The system software package includes a multi-pass 990 assembler, link editor, interactive source editor, and numerous other utilities that support easy implementation of application programs.

Flexible Packaged Systems

TI offers two packaged program development systems and a prototyping system for the user who needs his own stand-alone system for software and firmware development of application programs.

These packaged systems provide a flexible method of implementing early project development. These include the low-priced 990/4 Program Development System and the powerful 990/10 Program Development System. The 990/10 system combines the power of the 990/10 minicomputer with the disc-based DX10 operating system and an extensive set of software development tools. The standard package includes the 990/10 minicomputer with 64K bytes of error-correcting memory, ROM loader and diagnostics, 3.1-million byte removable disc kit with accompanying peripherals, and a complete software development package. And, at $24,500, this system costs at least 20% less than comparable equipment from other manufacturers.

For developing firmware modules, there is a $5950 prototyping system which includes a 990/4 computer with 16K bytes of memory and programmer's front panel, and a "Silent 700*" twin-cassette ASR data terminal. Also, an optional PROM programming kit is available for developing read-only memory.

In addition, we provide a wide variety of program development utilities for the 990 family. There is communications software that supports either synchronous or asynchronous data transmission, and can operate with the TX990 or the DX10.

Support from the start

We offer complete training and applications assistance, plus a nationwide service network backed by TI-CARE†, our remote diagnostic, service dispatching and real-time field service management information system.

For more information, call your nearest TI office or write Texas Instruments Incorporated, P.O. Box 1444, M/S 784, Houston, Texas 77001. Or, phone Computer Equipment Marketing at (512) 258-5121.

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CIRCLE NUMBER 24

How to Win at the Microprocessor Game

Today everyone wants to get into the game. But the stakes are high and the rules just aren't very clear.

Now the M-8 Educator tips the odds in your favor by providing in one versatile package everything you need to write and evaluate programs for the F-8 microprocessor. Or use it as a stand-alone control system or operate it as a data terminal. No matter what your application you win with the M-8 Educator.

Software Development. The M-8 Educator's highly flexibly resident monitor contains user callable subroutines for I/O, memory interrogation, and program development. Standard memory is 4K bytes static RAM expandable to 16K bytes per board (system expandable to 64K bytes). An optional E-PROM card contains a CRA (Conversational Resident Assembler) with space for an additional 5K bytes of user-definable memory.

The program is entered on the ASCII-encoded, Hall-effect keyboard in easily-learned F-8 assembly language and the high-resolution, 12 inch diagonal, CRT gives a 64 character by 31 line display. For the hard copy a 110 baud, 20ma. loop, TTY I/O is provided.

Industrial/Process Control. The M-8 Educator's Bus Extension Module provides a powerful interface capability for a wide variety of user applications. Available at the 86-line card edge connector are power, address lines, data bus, all important system control lines, and four, 8-bit parallel, TTL-compatible I/O ports. From plastics manufacturing to medical instrumentation the M-8 Educator holds a winning hand.

Data Communications. Matrix Mode operation (selected via rear-panel switch) disables the self-addressed write operation of the CRT display module. Display refresh memory is then assigned a 2K byte address block on the F-8 system bus. This capability allows the user to treat the CRT as a matrix of "display cells", each with a unique address, providing virtually total freedom in display format and control response, all in software.

The ante? That's the best part. Only $1895 complete with hardware and programming manuals. Delivery is stock to 3 weeks ARO. So whatever your application game call and raise Don Cartner at 913/492-7350. He'll be happy to deal you in. Technical Communications, Inc., P.O. Box 306, Olathe, Ks. 66061.

TECH-COM

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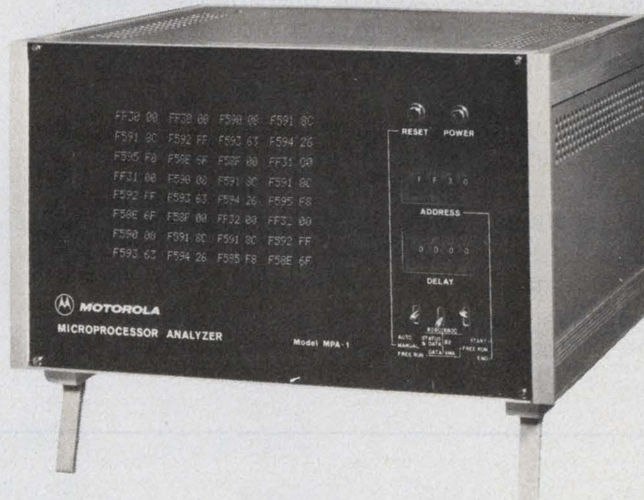
Diagnostic instrument simplifies μP-system testing and debugging

The first diagnostic instrument to combine the features of both logic analyzers and μC-development systems can be used to simplify 8-bit μP-system testing and debugging. Called the MPA-1 Microprocessor Analyzer, it is produced by Motorola Data Products (455 E. North Ave., Carol Stream, IL 60187. 312-690-1400).

The MPA-1 cabinet and display typically works in conjunction with a 40-pin IC test clip that clamps over the μP DIP package to lift address and data signals directly from the DIP mounting pins. The analyzer captures 32-word segments of program execution and displays the information on a 9-in. CRT screen.

Words are shown directly in hexadecimal form, which allows direct comparison with written program instructions, without the need for manual binary-to-hexadecimal translation. Each hex word consists of four characters of address, plus two characters of associated data-bus information.

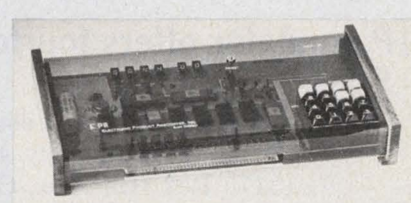
By using individual probe buffers, the instrument can interface directly with the



following: the 8080 from Intel, Advanced Micro Devices, Texas Instruments and NEC; the PPS-4 from Rockwell; the 6800 from Motorola and American Microsystems; the 6500 from MOS Technology and Synertek; and Motorola's

(continued on page 50)

Full microcomputer comes complete with power supply



A ready-to-use, μP-based microcomputer, the Micro 68, comes complete with its own integral power supply and 16-button keyboard. A 6-digit LED display and 128 words of RAM are also included. The Micro 68 is built around the Motorola/AMI 6800 μP, costs $430 and was developed by Electronic Product Associates (1157 Vega St., San Diego, CA 92110. 714-276-8911).

In addition, the 512 John Bug PROM that's included contains all the software necessary to load programs easily, inspect and edit them as necessary, insert break points for debugging, and to execute them. Memory expansion to 64 k and full 16-bit I/O can be accomplished through edge connectors.

The Micro 68 comes in a hardwood cabinet with a transparent smoked-plexiglass lid and measures 9 × 16 × 2 in. Delivery is from stock.

CIRCLE NO. 552

(continued from page 49)

Exerciser system.

The MPA-1 has three basic operating modes. In the Start Display mode, the instrument monitors program execution starting with the trigger-word address and adding the next 31 words in their order of execution. This allows the tracing of program flow, algorithms, interrupt-handling and I/O routines.

In the End Display mode, the MPA-1 can work backwards from illegal operations to track down the source of hardware and software errors. And in the Free Run mode, continuous address and data information are displayed to locate hardware faults and program hang-ups. The instrument can be stopped in this mode; program execution can then be retraced to the source of a mistake.

Other features include Start Delayed Triggering, in which the 32-word display can be delayed digitally up to 65-k clock pulses. This feature allows examination of the inner workings of loops, the results of subroutine calls and other uses in which desired data does not immediately follow the trigger word.

End Delayed triggering, with a delay of 16 clock cycles, provides a before-and-after display in which the trigger word appears in the center of the 32-word block, allowing simultaneous examination of both preceding and following μP activity.

Besides the IC test clip, the instrument is furnished with a standard 40-pin connector and a 40-connector cable. Also, at the rear of the MPA-1 cabinet, two plugs allow access to address-recognition and buffered-clock signals for external counter or oscilloscope triggering.

The MPA-1 package, complete with all three probe connectors plus a choice of one of the available probe buffers, is priced at $2985. Additional probe buffers cost $100 each. The MPA-1 cabinet measures 8 × 13 × 12 in. and weighs 24 lb.

CIRCLE NO. 551

Low-cost cross-assembler runs on IBM 360/370

A cross-assembler for the 8080 μP, designed to run on an IBM 360/370, is claimed to provide a low-cost alternative to the Intel MAC80 assembler available through time-sharing vendors. The MASM80 program is written in Fortran/BAL and executes its operations in under 100 k of memory.

Well Test Data (P.O. Box 7081, Kansas City, MO 64113. 816-444-5519) is offering a source deck and documentation set for $55. Extra features of the MASM80 include direct punching of BNPF decks for PROM programming, object code listing in both octal and hex, and ASCII constant generation with the parity bit either set or reset.

CIRCLE NO. 553

μP emulator offers fourfold increase in throughput

A microprocessor emulator that has from two to four times the throughput of the 8080 μP but is completely software-compatible has been designed by Technology Marketing Inc. (3170 Red Hill Ave., Costa Mesa, CA 92626. 714-979-1100).

Called the TMI 8080E, the emulator consists of 79 multiple-sourced ICs and occupies less than 80 in.^{2} of circuit board area. It requires just 180 ns for a machine cycle and is not as rigidly limited as the 8080 μP, in regard to memory timing.

A substantial advantage of the TMI 8080E, according to the firm, is that the 8080E can drive 10 TTL loads instead of the single-TTL load that can be driven by the 8080. In a system, this improvement in drive capability means that a large 64-k × 8-bit memory can be built into the system along with eight I/O modules, without additional buffering.

(continued on page 52)

Announcing a giant reduction in the Nova line.

You're looking at a whole new family of NOVA® computers. microNOVA. A microprocessor chip, a microcomputer board and a complete MOS minicomputer. All based on the little thing on the tip of the finger.

mN601. The microNOVA CPU.

It's a full-blown, 16-bit NOVA computer. Manufactured by Data General. And fully supported by NOVA software.

And it's not a NOVA computer in name only. This chip has all the NOVA registers, internal data paths and computational elements. The NOVA multifunction instruction set. The NOVA multiple addressing modes. And the NOVA 3 hardware stacking. Plus things that used to be NOVA options: multiply/divide, real-time clock and power fail/auto restart. All standard at no additional cost.

The difference is, all that NOVA has been reduced to a single chip that measures only 225 mils by 244 mils.

Which was no small accomplishment.

For those who need more than a chip, there's the microNOVA computer-on-a-board. A complete, fully-buffered microcomputer that comes with 2K or 4K words of RAM on a single 7½" by 9½" board. You can add on more RAM in either 4K or 8K increments, or PROM boards with up to 4K words. Plus terminal interfaces, general purpose interfacing boards, card frame, power supply and PROM burner.

And for those who need more than a board, there's a fully-packaged 4K word MOS microNOVA mini. It comes with power supply and turnkey console. In 9 and 18 slot versions. Into which you can place as much as 32K words of RAM or PROM. And still have plenty of room left over for I/O.

There's even a microNOVA system specifically for program development. A complete system, with dual diskette drive, terminal and our RDOS-compatible Disc Operating System. Or you can use a Nova 3 system with RDOS. The best development software you can get.

And no matter which microNOVA product you get, you get to use NOVA software like FORTRAN IV. Software that's in use in over 20,000 installations all over the world. So you know it's going to work right the day you get it.

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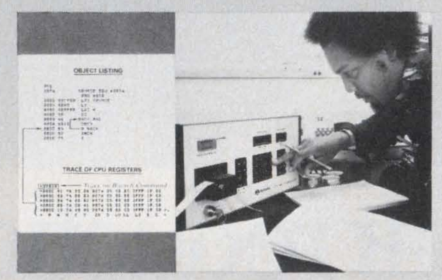
(continued from page 50)

The emulator can cut system size when clock, bus driver, memory and input/output modules are added to the basic 8080 IC. The TMI 8080E single-board processor replaces the 8080 μP, the 8228 controller and bus driver, the 8224 clock generator, the 8216 bus drivers, and the associated circuitry.

The price of the emulator starts at $1200 for a single-unit purchase, and prices drop to $200 in production quantities. Delivery time is 6 to 8 weeks.

CIRCLE NO. 554

System development tool works with PPS-8 μPs



The Assemulator, a system-development tool, can help debug and develop 8-bit PPS (parallel-processing system) microcomputers. The new design aid permits real-time software check-out of systems with peripherals, and makes possible generation of ROM mask codes and encoding of PROMs and EAROMs for the field testing of prototypes.

Designated the PPS-8MP, the instrument comes complete with software and comprehensive programming and operating manuals. It costs $3450 and was developed by Rockwell (3310 Miraloma Ave., P.O. Box 3669, Anaheim, CA 92803. 714-632-1650).

PPS-8MP software consists of a ROM-resident supervisory program that provides utility and debugging functions, and RAM-resident assembly and text-editing programs.

The assembly and text-editing software is supplied on tape and is loaded into the machine's RAM with a TTY, a TI 733 ASR tape reader, or an optional high-speed reader. Memory can be expanded in 2-k-byte increments to a total of 16-k bytes by internally adding RAM or EAROM modules. Even more memory can be added by using an optional bus extender or 8-k byte RAM module.

CIRCLE NO. 555

8080-compatible microcomputer uses bipolar logic for speed

Up to four times the speed of typical 8080 μP-based systems is offered by a new bipolar-based microcomputer, the System 80. It is fully compatible with the 8080 μP, can be purchased with either core or semiconductor memory and has an extended addressing capability of up to 1 megabyte of memory. The μC is made by Electronic Memories and Magnetics (12621 Chadron Ave., Hawthorne, CA 90250. 213-664-9881).

Inside the System 80 is an asynchronous, MSI central processor, a minimum of 16-k, 8-bit words of read/write memory, a direct-memory-access (DMA) capability, a ROM bootstrap loader, an RS-232-C2 interface, an operator's panel and a five-slot chassis that measures 5.25-in. high and has an integral power supply.

Three basic speed/memory configurations are available: the first is a core memory with a 650-ns cycle time; the second is an NMOS semiconductor memory with a 450-ns cycle time; and the third version is a high-speed NMOS unit with a 180-ns cycle time. Memory capacities range from 16 to 64-k bytes on a single board. This approach allows the user to set up a complete 256-k byte system in a 7-in. chassis.

Basic system prices begin at $4150 for 16-k bytes of core memory or $4500 for 32-k bytes of semiconductor memory. Other semiconductor based systems offer 64-k bytes for $5650, 256-k bytes for $14,000 and 1-M byte for $44,000. System 80s are available from stock.

CIRCLE NO. 556

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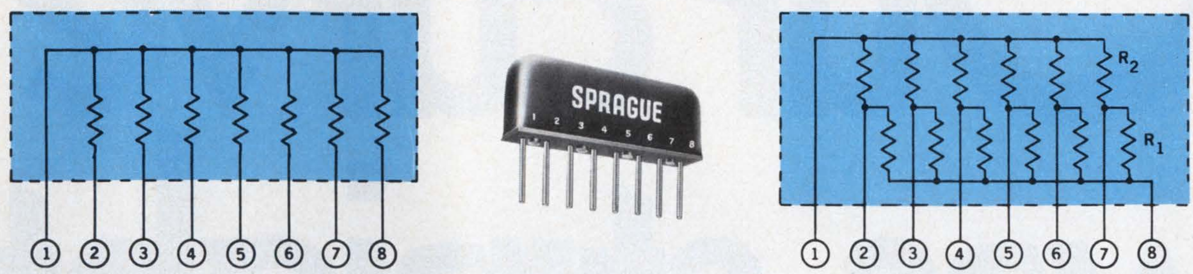

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Low Cost and **High Density Configuration** are only two of the features of Sprague Type 216C Metanet® Resistor Networks. Now, you can also enjoy the benefits of improved power dissipation, better temperature coefficient of resistance, and closer standard resistance tolerance.

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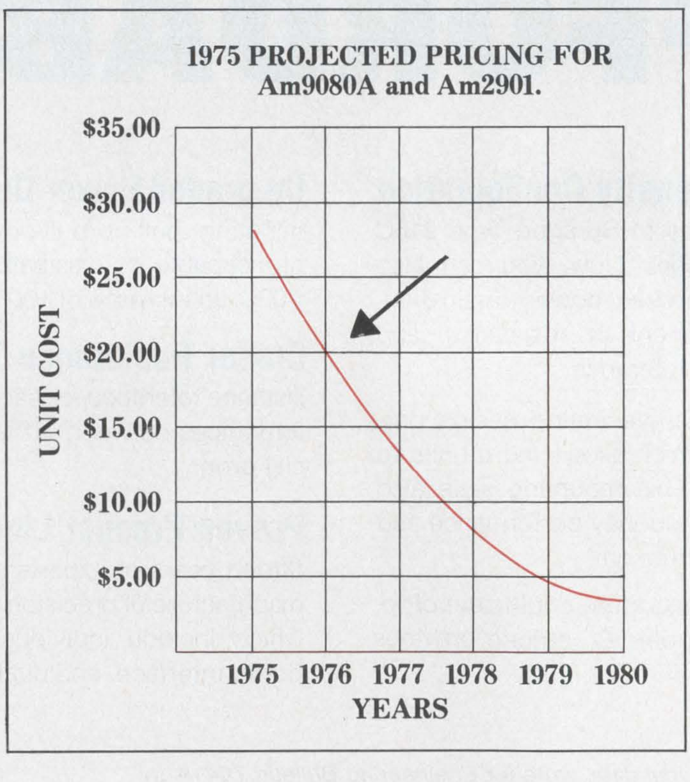
CIRCLE NUMBER 27

Our curve was straight.

Advanced Micro Devices announces the 100-piece price for the Am9080A and Am2901: $21.00. Just like we said.



Last year, we predicted the price would be just over $20.00. We even drew a curve. Now it's happened. And that's only the beginning. Look:

Am9080A. It's built with an advanced ion-implanted, n-channel, silicon-gate process that permits versions with speeds to 250 nanoseconds cycle time (one microsecond instruction time). Our low power (800mW maximum) gives you cooler running systems, less power drain and better reliability. The superior output drive (3.2mA @ 0.4V) gives increased design flexibility and improved margins.

Am2901. It's bipolar, for systems that rely on high speed. It can do a 16-bit register-to-register add in just 145 nanoseconds. It has 16 working registers in a cycle-saving, two-address architecture, and is controlled by nine instruction lines that permit it to do almost anything you can think of.

Another thing. Advanced Micro Devices offers a full line of support circuits for either unit—support circuits that optimize your system, not compromise it.

Whether you can best use the MOS Am9080A or the bipolar Am2901, you can now do it for less. $21.00 in 100-piece quantities.

Just like the curve said.

Am9080A System Circuits

AMD Part Number	Description	Availability
	CPU	
Am9080A/−2/−1/−4	Speeds to 250 nsec 0 to 70°C	In Dist. Stock
Am9080A/−2	Speeds to 380 nsec −55 to +125°C	In Dist. Stock
	Static Read/Write Random Access Memories	
Am9101A/B/C/D	256x4 Speeds to 250 nsec	In Dist. Stock
Am91L01A/B/C	256x4 Speeds to 300 nsec	In Dist. Stock
Am9102A/B/C/D	1Kx1 Speeds to 250 nsec	In Dist. Stock
Am91L02A/B/C	1Kx1 Speeds to 300 nsec	In Dist. Stock
Am9111A/B/C/D	256x4 Speeds to 250 nsec	In Dist. Stock
Am91L11A/B/C	256x4 Speeds to 300 nsec	In Dist. Stock
Am9112A/B/C/D	256x4 Speeds to 250 nsec	In Dist. Stock
Am91L12A/B/C	256x4 Speeds to 300 nsec	In Dist. Stock
Am9130A/B/C/E	1024x4 Speeds to 200 nsec	In Dist. Stock
Am9140A/B/C/E	4096x1 Speeds to 200 nsec	In Dist. Stock
	Dynamic Read/Write Random Access Memories	
Am9050C/D/E	4Kx1 Speeds to 200 nsec	In Dist. Stock
Am9060C/D/E	4Kx1 Speeds to 200 nsec	In Dist. Stock
	Mask Programmable Read-Only Memories	
Am9208/B/C/D	1Kx8 Speeds to 250 nsec	Available Now
Am9214	512x8 mask programmed Speeds to 500 nsec	Available Now
Am9216B/C	2Kx8 mask programmed Speeds to 300 nsec	Available Now
	Erasable Read-Only Memories	
Am9702	256x8 Speeds to 1.0 μsec	In Dist. Stock
Am1702A	256x8 Speeds to 1.0 μsec	In Dist. Stock
Am2708	1024x8 Speeds to 450 μsec	2nd Q. 1976

AMD Part Number	Description	Availability
	Processor System Support Circuits	
Am8212	8-bit I/O Port	In Dist. Stock
Am8224	Clock Generator	In Dist. Stock
Am8228	System Controller	2nd Q. 1976
Am8216/26	Bus Transceiver	2nd Q. 1976
Am25LS138	1 of 8 Decoder	In Dist. Stock
Am9555	Programmable Peripheral Interface	2nd Q. 1976
Am9551	Serial Communications Interface	2nd Q. 1976

CPU: 9080A=480 nsec −2=380 nsec −1=320 nsec −4=250 nsec
Mem: A=500 nsec B=400 nsec C=300 nsec D=250 nsec E=200 nsec

Am2900 System Circuits

AMD Part Number	Description	Availability
Am2901	4-Bit Microprocessor Slice	In Dist. Stock
Am2902	Carry Lookahead Chip	In Dist. Stock
Am2905	4-Bit Transceiver For Open Collector Bus	In Dist. Stock
Am2906	4-Bit Transceiver For Open Collector Bus With Parity Generator/Checker	In Dist. Stock
Am2907	4-Bit Transceiver For Open Collector Bus With Single Data Input	In Dist. Stock
Am2909	Microprogram Sequencer	In Dist. Stock
Am2911	Minimicroprogram Sequencer	2nd Q 1976
Am2914	8-Level Priority Interrupt	3rd Q 1976
Am2915	4-Bit Transceiver For Three-State Bus	2nd Q 1976
Am2916	4-Bit Transceiver For Three-State Bus With Parity Generator/Checker	2nd Q 1976
Am2917	4-Bit Transceiver For Three-State Bus With Single Data Input	2nd Q 1976
Am2918	1 By 2 Port Register	In Dist. Stock
Am2919	Priority Interrupt Expander	2nd Q 1976
Am2950/51	256-Bit RAM, Open Collector Or Three-State	In Dist. Stock
Am2952	1024-Bit RAM, Open Collector	2nd Q 1976
Am2954/55	16-Word By 4-Bit Two Address Register Stack, Open Collector or Three-State	2nd Q 1976
Am2970/71	256 By 4 PROM's With Open Collector or Three-State Outputs	In Dist. Stock

Advanced Microprocessors

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CIRCLE NUMBER 28

Editorial

If I don't know it, it ain't so

A friend of mine had intermittent claudication—a blood-vessel constriction that afflicts many heavy smokers and often leads to amputation. He took massive doses of vitamins and was cured. Another fellow's kidney stones were eliminated by vitamins. And vitamins helped other friends with ailments like high blood pressure, high cholesterol, low energy, headaches, colds, bleeding gums and bursitis.

The average doctor, or the American Medical Association, or the Food and Drug Administration will likely tell you that beyond the nutrition you get in a reasonably balanced diet, vitamins don't really help. Their attitude seems to be that vitamin-deficiency diseases have been licked; nobody gets scurvy or beri-beri anymore; a massive vitamin deficiency can hurt you, but a less-than-massive deficiency has no effect.

If you ask about people who've been helped by vitamins, you get a stock answer; they probably would have gotten better anyway. But what they really mean is probably this: The authorities don't support it, so it can't be so.

And that attitude is too common. Most of us too quickly say, "That can't work. I never heard of it." Even in a profession where we take pride in our creativity, we remain conservative. We shy away from the untried—from material we didn't learn in school or books, and from ideas that don't carry the seal of authority.

It's unfortunate that a powerful precedent for this attitude is set by doctors—whose wisdom and infallibility many of us regard with awe. Doctors, when they don't kill their mistakes, often forget them. For many years they ridiculed the idea that thalidomide could be dangerous. Then overwhelming evidence showed that it mangled unborn babies. And for years the Food and Drug Administration insisted that Red No. 2, which appears innocuously on labels as "artificial coloring," is harmless. The FDA finally conceded that the stuff—widely used in foods, drugs and cosmetics—can cause cancer.

If prestigious authorities like medical doctors and the FDA scoff at ideas that differ from the accepted "wisdom," shouldn't we? Should we cling always to what's safe? Or should we sometimes break away and accept the scorn of authorities?

George Rostky

GEORGE ROSTKY
Editor-in-Chief

FOCUS on Microprocessors

While diversity usually makes a designer's life easier, with microprocessors it can make comparison—not to mention selection—more difficult than ever.

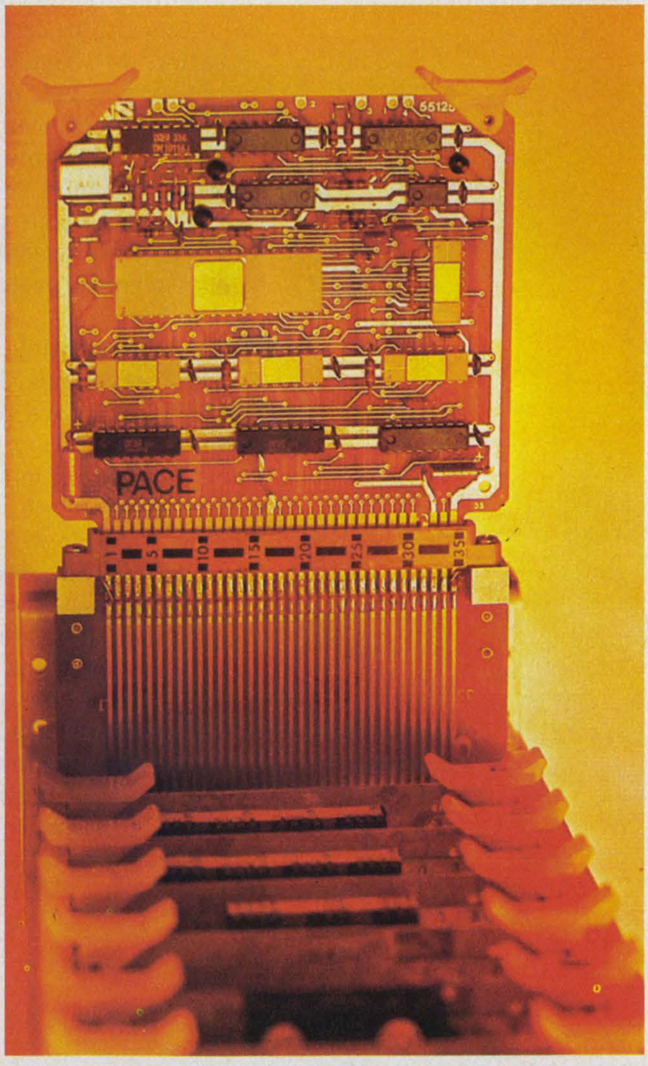
A wide diversity of architectures, support circuits and design aids from available μPs should make it a whole lot easier to pick the right micro. But because microprocessor-based systems must be programmed like conventional computers, you must think of software as well as hardware. Grappling with the intricacies of either could keep you working evenings and weekends, especially since the use of different micros entails different tradeoffs between hardware and software.

Further, the problems of selection may not be helped much by the burgeoning application literature offered with "computers on a chip." You could end up with documentation up to your eyeballs only to discover that key specifications have been inflated or even omitted or that some important characteristics—like operating speed—can't be extrapolated from the mountain of data. Adding to the problems, manufacturers' promotional material may elevate a selling point into an unwarranted selection factor. The prices of microprocessor, or CPU (central processing unit), chips are a case in point.

Manufacturers note that the high-flying 8080 μP, for example, can be purchased now for about $20 in production quantities—quite a drop from its initial price of several hundred dollars. For very high quantities, you can get the price under $10.

But a CPU chip itself is about as useful as a pet rock. For a complete, operating μC (microcomputer), you must add peripheral and interface circuits, as well as memory. A simple μC-

Edward A. Torrero
Associate Editor



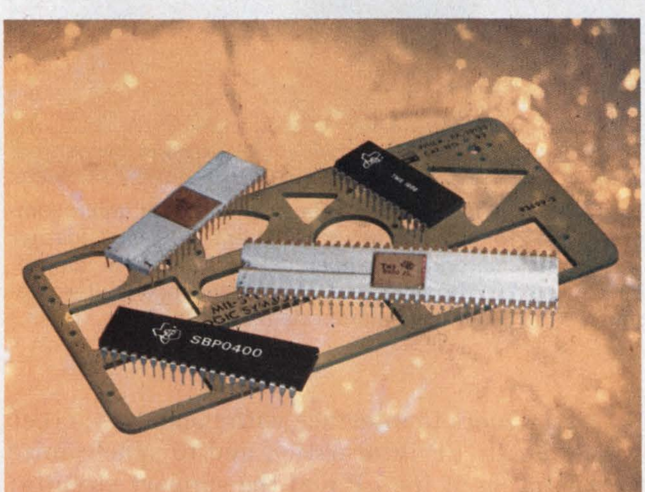
A data-processing controller resides on a PC board measuring only 4-1/2 × 4-1/2 in. The board combines National Semiconductor's Pace (the first single-chip 16-bit μP) with sense amplifiers, hex buffers, a crystal oscillator and clock drivers.

based controller could require at least 25 extra chips surrounding the processor. The cost of the additional components exceeds the price of the CPU by a wide margin. Moreover, a package of system components having an attractively priced CPU may have an over-all cost that's higher than one that doesn't.

Whatever the system hardware's cost, it is likely to be dwarfed by the soaring cost of μC software, which can range from hundreds of dollars to thousands for the finished system. For a $30 μP, such software has been known to cost more than $65,000.

Of course, your software development is a "one shot" expense that can be amortized over the life of the product—assuming it is a successful one. But should you decide to switch micros, you won't be able to transfer a design using the first μP's software to the second. The experience gained from one μP can't be applied to another. Different micros come with different software capabilities, hardware requirements and design aids. That first costly system may have to be scrapped completely.

The most advanced development system for micros, Intel's MDS (microcomputer development system), features in-circuit emulation. The capability permits early fault and error isolation in system prototypes. MDS includes floppy-disc storage and a CRT terminal, and allows the setting of breakpoints symbolically.



A single-chip 16-bit μP is the latest offering from Texas Instruments' growing line of microprocessor products. The new TMS 9900 μP is upward compatible in software with other members of the 990 processor family, which includes a minicomputer.

μP products and technologies: a mixed bag

Microprocessors and related circuits can be obtained in a variety of technologies and product forms. Older micros employ p-channel MOS (PMOS) and offer 4, 8 and 16-bit word lengths. The bulk of present MOS micros uses speed-enhancing n-channel MOS (NMOS) for 8-bit units and specifies a basic cycle time of about 2 μs. More recently, NMOS has been applied to 16-bit μPs and power-saving complementary-MOS (CMOS) has been used to build 8 and 12-bit μPs.

Product forms encompass just about anything you'd care to ask for, from a sack of parts to a μP-based minicomputer. At the simplest level, you can purchase a set of chips that include the CPU, special interface ICs and, generally, special memories. If you don't want to be bothered testing, mounting and interconnecting the chips, you can purchase a logic board instead. The μP-based board comes fully wired and ready to run, although at the very least you generally have to provide system-test equipment and a power supply.

At the high end of the price ladder are complete μP-based development systems, such as Intel's MDS (microcomputer development system), Motorola's Exorciser and National Semiconductor's IMP-16. These units constitute sophisticated hardware/software design aids that offer the conveniences and peripherals associated with minicomputers—at prices to match. A basic system starts at about $5000 and rapidly escalates to about $10,000 if you decide to use such system peripherals as a floppy-disc operating system, video terminal and PROM programmer.

Currently the most popular product form for microprocessors is the do-it-yourself kit. Priced at $500 or less, the μP kit offers designers—especially the growing number of newcomers—an inexpensive and fairly painless way to get a μP system up and running.

However, like the microprocessors they are built around, kits may not live up to all the claims made for them. Ideally a kit should be easy to use and allow some system prototyping. But whether the kit actually does these things often reveals what was left out to keep prices low, even better than it reflects what was put in. The old adage, "you get what you pay for," might well be applied here.

One kit may be priced significantly lower than another, though both use the same microprocessor and offer about the same features. Sometimes the difference in price is due to the use of less expensive ICs in the lower-priced model. These ICs exhibit temperature and voltage limitations that aren't necessarily bad for home experiments, but which could prove disastrous in an industrial environment.

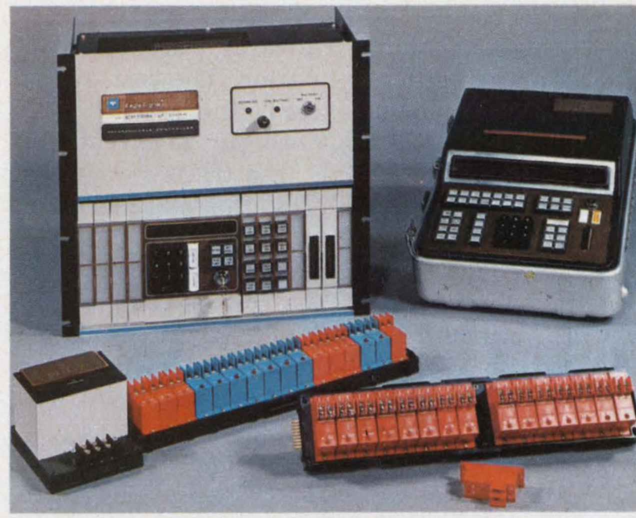
All kits require hand-assembly for program entry. Instructions must be entered one bit at a time, though some units feature hex or octal-code entry, thereby shortening the number of times you have to move a switch or press a button. Manual assembly may not be a problem if your program isn't longer than a few hundred words. But it rapidly becomes unwieldly for a program any longer than that—assuming the kit has sufficient memory to store it.

What you can prototype with a kit depends largely on how much memory comes with it. Capacity ranges from 256 bytes up to 8-k, though most units don't have more than about 1-k of storage. The capacity is sufficient for simple systems.

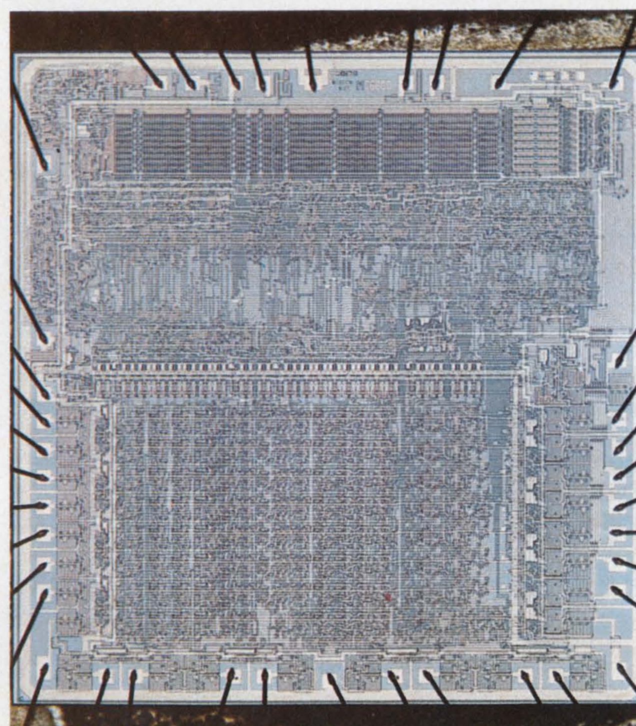
But storage capacity can easily become a problem for applications that need 1000 or more words of code—like a computer-peripheral controller. Moreover, long programs can't be debugged easily. A hand-assembled program that has errors has to be redone completely, unless spaces (No Op instructions) have been left in the program for corrections.

The most serious problem arises when the set of components doesn't come with adequate monitor and debug programs. A monitor program provides the means to drive a control panel or operate the system through a teletypewriter. A debug program lets you single-step the system one instruction at a time, examine memory, and insert breakpoints. Typically, the monitor and debug programs are combined in ROM and offered as firmware.

Without these essential programs, that μP system does little more than talk to itself. Of course, monitor/debug software can be developed. But presumably you bought a kit because you wanted to learn about microprocessors the easy way.



Features often associated with minis combine with the ease-of-use of other programmable controllers in the Eptak industrial-control system from Eagle Signal. The system uses the 8080 μP.



The 6800 μP forms the nucleus of an 8-bit microcomputer chip set that includes a peripheral-interface adapter and an asynchronous-communications interface circuit. Introduced by Motorola, the chips have been alternate-sourced by American Microsystems and Hitachi.

Chip sets reduce package count

Newer μP-chip sets have overcome one of the most serious shortcomings of early μPs—the need for a host of supporting chips to interface with peripheral devices, data-communication lines and even the μP's own memory. The first 8-bit μP and the only one for about two years—Intel's 8008—required 20 or so additional standard-TTL circuits to make it work.

Constrained primarily by the limitations of an 18-pin package, the 8008 needed the following: registers to address memory, either ROM or RAM; decoders to interface with memories; other ICs to handle μP information and to synchronize the operation of the μP and the support circuits; clock circuits; and a number of interface ICs, depending on the application. For example, in a multichannel data-communications application, each channel requires an asynchronous receiver/transmitter and associated interface ICs.

Now improved μPs like Intel's 8080, Motorola's 6800 and Fairchild's F8 have come along. Special LSI peripheral and memory circuits match and enhance the μPs they support. Together with improvements in the CPU chips, the resulting chip sets constitute minimal-chip configurations that can drastically reduce package count while improving performance.

But even new chip sets may not be all they seem. Some manufacturers stress the fact that their μP systems can run from TTL levels of 5 V and ground. However, more than a single supply may be needed if you decide to use such memories as some of the new 4-k dynamic RAMs, or some PROMs. Also, you'll need another supply if you want to hook up a device that spits out ASCII characters, or more simply, if you try to provide the μP's demanding clock requirements with conventional circuitry.

Expansion can present other problems. Since many chip sets employ nonstandard memories, you're limited in the choice of storage elements, even though the manufacturer claims that any memory works well with the μP—including core, though that admission may have to be pulled out of a semiconductor manufacturer. In some cases, you can use the memory of your choice, but only after you've added special memory-interface ICs to your "minimal" chip system. And if the memory is static, you might use a different interface chip than the one for a refresh-hungry dynamic memory.

Further, several chip sets employ mask-programmable ROMs for program storage. These can be found in such MOS μPs as those that employ bit-slice configurations, as well as those that incorporate the control memory within the CPU circuits. In such cases, your system-development time will have to include the manufacturer's turnaround time for ROM mask programming.

An obvious time-saving solution would be to employ PROMs, especially the erasable kind, as a growing number of designers are now doing. But again, these components can entail additional circuitry and power supplies.

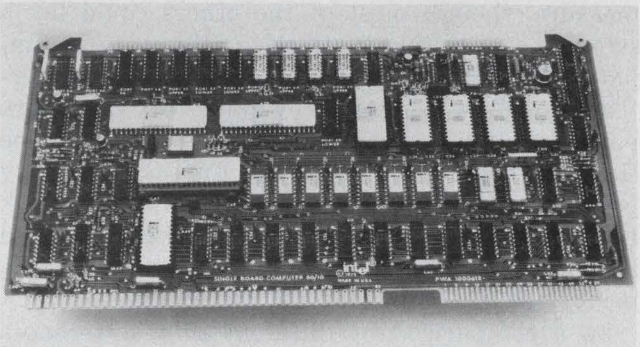
For situations that do entail additional circuits, manufacturers provide an ever expanding line of package-saving MSI (medium-scale-integration) circuits. Unlike key LSI peripherals, though, the MSI units aren't always an economical buy. You do save on, say, a complex data-communications chip or a direct-memory-access controller that replaces 10 or more standard-TTL circuits, but you won't always save with an MSI component that replaces just a few standard packages. The best bet is carefully to select the components you want in a manufacturer's μP family and consider making up the rest with standard TTL.

Shop around, too, for the best price tag on the same component. It wasn't always possible to do so when μPs were virtually sole-source products and typically were offered only as part of complete chip-package orders and only when you purchased the associated memory from the same IC manufacturer. That practice has since died down, mainly because of falling memory prices. But several designers report they still encounter it. If you find this problem, go to an alternate source.

Avoid specification pitfalls

Though microprocessors are far too complex to be characterized by a simple data sheet, specifications for μPs do abound. Ideally one should be able to use the published data to make a selection. However, spec sheets don't always reveal what a μP will do, or how it will react in your application.

A widely omitted spec is noise immunity, even



A single-board microcomputer based on the 8080— Intel's SBC 80/10—features 48 lines of programmable I/O. The board includes 4-k bytes of ROM and 1-k byte of EPROM.

though manufacturers promote their products as ideal for use in industrial equipment. For some μPs, the omission may be intentional. A comparison between input levels for peripheral circuits and the address-output levels of the μP may show little or no protection against unwanted transients.

However high noise immunity specs can be expected from newer microprocessors. For example, CMOS μPs from Harris Semiconductor, Intersil and RCA excel in noise immunity—a forte of the low-power technology.

If you don't have the noise immunity needed, you'll quickly discover the fact when you move from a clean, noise-free bench to a production environment. Of course, the problem can be overcome with simple level shifters and pull-up resistors. These components are cheap, but they do take up valuable board space and drive up power dissipation.

Another spec that's hard to find is the length of time the μP will hold data from a memory after Write signals have dropped. Some memories, especially the most inexpensive, can't work with a μP unless they hold data for, say, 100 ns. Too low a hold time results in data loss. Without the hold-time spec, memories added to the system may have to be selected by trial and error.

Speed specs confuse

Of the specs that are generally published, few are more numerous than the ones offered as a measure of a microprocessor's operating speed. A typical data sheet specifies a basic cycle (or microcycle) time, state time, clock rate, execution time, interrupt time, and time to add two decimal numbers, among other "times." Paradoxically, none of these nor any combination gives either a complete measure of a μP's computing speed, or fully tells how much work the μP can do in a unit of time.

Consider cycle time—possibly the most useless measure, though most of the others could lay a strong claim to that distinction. Many microcomputer operations require several cycles to be performed. This is especially true of the more powerful instructions, which take far more time than the basic cycle indicates. Further, it's very possible for one μP with a seemingly high clock rate to perform a fundamental operation—like register-to-register add—more slowly than it is performed in a unit with a slower clock.

In a comparison of different μPs, differences in architecture and chip design tend to minimize the importance of specs like clock rate and cycle time. Moreover, all of these time specs don't measure such critical times as the over-all time needed to perform important routines. Not accounted for are additional delays, particularly those needed to obtain information from memory.

For example, one spec sheet says that a Call instruction for a subroutine takes about 11 states for execution. Since each state takes about 1/2 μs, the Call instruction should be completed in less than 6 μs. However, memory must be referred to five times before the instruction is completed, and each reference typically adds an additional state time since few memories are sufficiently fast. So a Call can easily take significantly longer than expected.

Often the number of instructions is spotlighted as an indication of the μP's prowess. There are several reasons why this emphasis can lead to fallacious comparisons. A number simply doesn't reveal what instructions are available for data movement and manipulation, for decision and control, or for I/O operations.

Nor does a number tell which instructions are single or multibyte in length. Double-byte instructions take twice the memory of single-byte

One of the first development systems to use the 8080, Process Computer Systems' Micropac 80/A simplifies the design of controllers for industrial equipment.

instructions. And missing instructions can always be made up with additional hardware or with software routines, although the latter sacrifices speed. Further, a μP that features a number of addressing modes allows tighter and more efficient coding than a μP with more limited addressing capabilities.

Sometimes the number of available μP instructions depends on which page of the applications manual you're reading—because the manufacturer has multiplied instructions. The multiplying factor may be the number of addressing modes or the number of registers (in, say, a load-to-register operation), or the number of conditions (for example, those on which a branch may occur). Other multiplying factors may be used, so that one or more parts of the original instruction set might be multiplied several times.

Improved instruction sets do come with longer-word-length μPs and with advanced versions of older units. For example, 16-bit models can handle multiplication or division with a single instruction. In 8-bit μPs, these functions call for either subroutines or special circuitry.

Further, advanced μPs offer the original instruction set of a predecessor, and more powerful instructions, too. However this "software compatibility" doesn't allow routine upgrading of systems by chip replacement. And a pin-compatible higher-speed version of a μP doesn't produce a faster, more efficient system unless there are some design changes first. In general, expect to redesign if you want to employ the new hardware/software tradeoffs efficiently.

Programming ease: a key selection factor

A microprocessor's instruction set and architecture determine one of the most frequently stressed selection factors—programming ease.

Programming can be very time consuming. Various estimates place the number of lines of "shippable" code that a programmer can write in a day at less than 20 because of the time needed to write the program, run it, and then to debug, check and finally document the code.

However, microprocessor-chip designers are constrained by limitations of technology and packaging; their chips must fit into a package no larger than a 40 or 42-pin DIP. As a result, each µP reflects a very different series of compromises and tradeoffs. Though each manufacturer says his µP is easy to program, the programmer is actually both helped and hindered by each µP. The degree of each depends on the specific application involved.

For example, one µP's instruction set may seem to be quite complete. It has a fine complement of test and branch instructions, all the logic instructions you need and all the memory-reference instructions you could possibly require.

But the µP doesn't allow program-relative addressing, though most other addressing modes are available. If you are writing a large program —as more and more microcomputer designers are —you can't easily relocate a ROM-based program from one memory-address space to another. So design changes may require a redoing of the program.

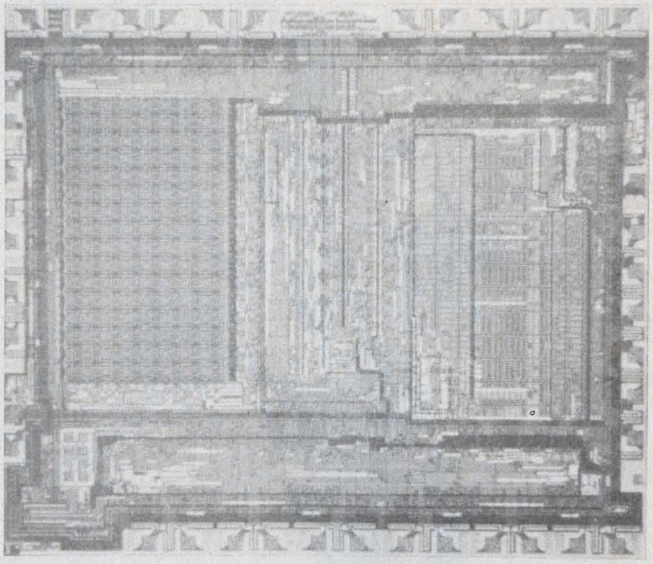
Another µP may allow the memory-addressing mode as well as indirect and indexed addressing, but at the expense of no direct addressing—the most common type. In this case, you'll be able to move programs around, but you won't be able to address all of memory without detouring through the index register.

Benchmarks get mixed reviews

One solution to the problem of comparing chaotically different µPs is the use of benchmarks. In theory, these short test routines show how well different µPs perform critical tasks, like moving data from one part of memory to another. These software tests, adherents argue, provide a quick and easy short-cut to the one obvious but unwieldly solution: writing complete, optimized programs for different µPs and comparing results.

In practice, though, different benchmarks from different µP manufacturers show that each has a better product than anyone else. And a benchmark test that puts one µP on top of the heap can be modified ever so slightly so that the pace-setting µP loses out to others. For example, one manufacturer provides a benchmark test that shows its unit is the best mover of data in a µP's memory. But if that pace-setting micro must also deal with an interrupt during data-move operations, it falls far behind the pack.

Benchmarks designed for one particular architecture can be thoroughly ineffective for another. If you're doing a job that requires 16 bits of precision for the job, then a 16-bit µP will out-distance 8-bit versions. When many different operations need to be performed a multiregister µP will outperform one with fewer available registers. For any model, no software test reveals the hardware side of the story—the required support circuits and necessary power supplies, for example.



The F8 two-chip set consists of a CPU and a program-storage unit. The CPU (above) contains a 64-byte scratchpad, eliminating the need for RAM in many applications. When needed, though, external RAM can be added to an F8 system. Introduced by Fairchild, the F8 is also available from Mostek.

And for a number of applications, benchmark tests may be just plain meaningless. In a host of µP applications, the micro may spend much of its time waiting for some external event, like the closing of a switch or the pressing of a button, that can take milliseconds just for the contact bounce to die down. A test that merely compares sub-millisecond operating speeds has little relevance to this problem.

Still, benchmarking provides meaningful results when used to compare two slightly different versions of the same system. The difference might be the use of a somewhat altered µP, or a modified I/O scheme. In other cases, design the benchmark to the specific application or task at hand. If you're presented with comparative benchmark tests, be sure they are specified completely. ■■

Need more information?

For additional information on specific products, circle the appropriate information retrieval numbers. For data sheets on many microprocessor and related products, consult ELECTRONIC DESIGN's GOLD BOOK.

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Circle No. 501

(continued on page 64)

(continued from page 63)

Adaptive Systems, P.O. Box 1481, Pompano Beach, FL 33061. (305) 942-4000. **Circle No. 502**

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Displays don't trouble 8-bit μPs.

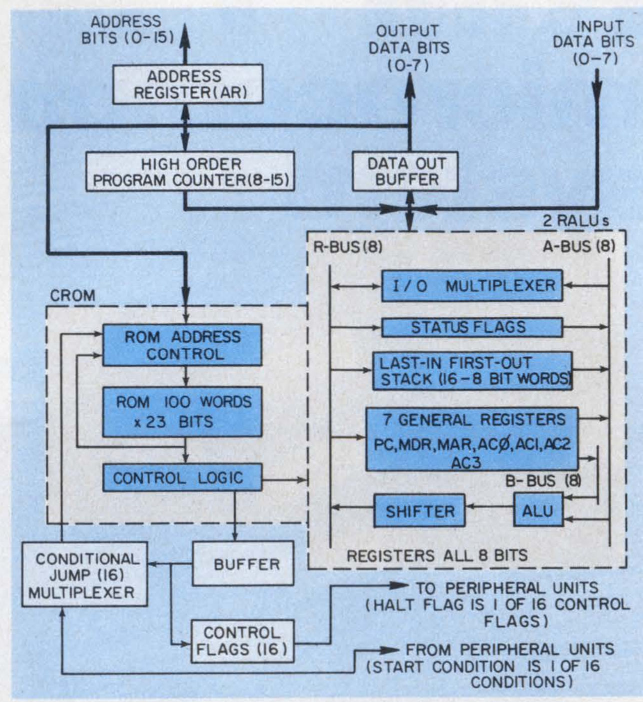
The μPs easily provide information for displays as diverse as simple digital types and data-demanding video terminals.

The data-handling capabilities of 8-bit microprocessors are both versatile and flexible enough to interface with displays that run the gamut from simple seven-segment digital types to complex CRT terminals.

A seven-segment digital display requires only infrequent updating, and when it is updated, very little information actually transfers to the display. A video-display terminal must be updated—or refreshed—very frequently (unless a storage tube is used), and that entails a large amount of data.

Data can be transferred from buffer memory to a display by various methods. The simplest is a software-controlled transfer, which uses minimal peripheral-interface hardware. However, the software approach may turn out to be the slowest one when performed on the usual macroprogram level. Higher data rates can be obtained through microprogramming.

A completely hardwired direct-memory-access (DMA) approach achieves the highest throughputs. A microprocessor like the IMP-8 (Fig. 1) allows these and other data-transfer methods.



1. **The IMP-8, an 8-bit microprogrammable μP,** employs two 4-bit RALUs (register and arithmetic logic units) and one CROM (control read-only memory). The μP's instruction set can be changed by modifying the existing CROM or by adding extra CROMs in parallel.

Treat the display as a standard peripheral device

When you use the 8-bit microprocessor,[1,2] the display should be treated as a standard peripheral unit that attaches to the μP's bus in the same way that memory does. The IMP-8 instruction set contains no instructions specifically intended for peripheral operations. All peripheral transactions with the CPU are performed by standard memory-reference instructions, like Load Accumulator from memory and Store Accumulator in memory.

Two basic software-control methods—loop and in-line—may be employed on the macroprogram level.

The loop method executes a sequence of instructions over and over again (Fig. 2). This method has the advantage that only a few words of code are needed to transfer a large block of data from memory to the peripheral. However, to keep track of the buffer word being processed, the pointers for the last-in, first-out stack must be incremented and tested continually. As a result, the actual rate of transmission is relatively slow.

In Fig. 2, BUF1 represents the starting address of the first buffer. AC3, the third accumulator, functions as the index register and increments once for each data word transferred. When AC3 becomes equal to zero, the loop will be terminated and the transfer of a second buffer can begin. For each pass through the loop, four machine instructions must be executed, requiring 44 machine cycles at 1.4 μs (minimum) per cycle. Hence, one 8-bit word can be transferred every 61.6 μs.

When only a few data words need be trans-

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ferred to a peripheral, the data rate can be increased about 50 percent by using the in-line method (Fig. 3). This method eliminates the control loop and uses instead a separate Load and Store-instruction pair.

In Fig. 3, BUF1 is again the starting address and AC3 serves as the base index register. The short program increments the displacement value for each Load instruction. The method requires only the execution of two machine instructions for each data transfer, and these two instructions require only 26 machine cycles at 1.4 μs per cycle. Hence one 8-bit word can be transferred every 36 μs. However, the in-line method requires more memory to store the control program than does the loop method.

Microprogramming speeds data transfers

Other techniques for data transfer deal directly with the microprogram that controls the execution of each machine instruction. With the IMP-8 μP, you can add or delete portions of the microprogram to achieve an altered instruction set.

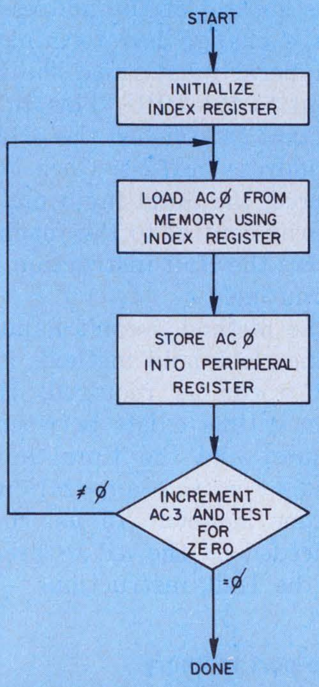
But microprogramming lengthens development time and costs, and it can entail additional CROMs (control and read-only memories). In general, this approach becomes economical only for high-volume applications.

IMP-8 microprogramming structures are identical to the structures of other members of the IMP family.[3] Each microinstruction specifies the exact function of the ALU and any external logic during that microcycle.

For example,

ADD, AC3,, AC2 CIN

specifies an Add operation. The A-bus operand is AC3, and the B-bus operand is undefined—and consequently is interpreted as all zeros. CIN indicates that the result will be incremented. In this example AC2 indicates that the final result (after incrementing) will be stored in that accumulator.




```
       BUF1= X'15Ø         ;Start First Buffer
       BUF2= X'25Ø         ;Start Second Buffer

       LI    3,D(BUF1)     ; Load Index Reg
       LDP   2,BUF1        ; Load Page
Loop:  LD    Ø,(3)         ; Load Data Indexed
       ST@   PERIF         ; Store Indirect
                           ; IN PERIF
       AISZ  3,1           ; INCR and Test Index
       JMP   Loop
       LI    3,D(BUF2)     ; Load Second Index
       LDP    2,BUF2       ; Load Second Page

       And so on ....

PERIF: .DWORD  X'8DØØ
```

2. **The loop method uses only a few words** of machine code to transfer an 8-bit word from memory to a peripheral display. However, each transfer takes a lengthy 62 μs since stack pointers in the RALUs must be continually tested and incremented. A speed-enhancing microprogrammed approach uses the same flow chart.

Several microinstructions are sequenced together to form a general subroutine. Each subroutine is executed as a response to a fetched and decoded macroinstruction from memory.

A microprogram-loop method like that discussed on the macroprogram level offers several advantages. First, the four-machine-instruction loop is replaced by a single machine instruction. And since all data are transferred within the execution of a single machine instruction, the over-all data rate can be reduced dramatically.

The example in Fig. 4 requires only 9.2 machine cycles per pass through the loop. Since each machine cycle requires only 1.4 μs, each word transmitted takes just 12.9 μs. That's about 1/5 the time needed by the macroprogrammed loop.

The in-line method, when applied on the micro-

```
        BUF1 = X'15Ø


        LI       3,D(BUF1)
        LDP      2,BUF1
START:
        LD       Ø,(3)   ;LOAD FIRST WORD
        ST@      PERIF   ;SEND TO PERIPHERAL
        LD       Ø,1(3)
        ST@      PERIF   ;SEND SECOND WORD
        LD       Ø,2(3)
        ST@      PERIF   ;SEND THIRD WORD

        AND SO ON .....

PERIF:.DWORD  X'8DØØ
```

3. **The in-line method increases the data rate** of the loop method by about 50 percent when only a few words need be transferred. The routine reads a memory location's data into accumulator zero and then outputs that data to the peripheral. It then reads the next memory location and transfers its data to the same peripheral. The routine continues to do so for each pair of Load and Store instructions.

program level, doesn't increase speed much over the microprogrammed-loop approach. Only two machine cycles can be saved per word transmitted. Everything else in the example remains the same. Thus, the transmission rate reduces to one word every 10 μs.

Because the total microprogram storage area is rather limited for the IMP-8, the in-line method should be employed only for very limited data transfers, even though a comparison between this method and the macroprogram in-line version shows a 3-to-1 speed advantage. It requires only one machine instruction, as opposed to two for each buffer-word transferred.

Hardware-controlled data transfers

In the clock-hold DMA method—a hardware implementation—the requesting peripheral must generate a clock-hold request whenever it requires data (Fig. 5). The request temporarily stops the CPU clocks for a maximum of 10 μs. During this period, the CPU address buffers are disabled, allowing the requesting peripheral to take control of the address bus.

Data rates are limited to the cycle rate of the memory. For example, with a memory having 1-μs access, up to 10 words of data could be transferred during a 10-μs clock-hold period.

Since no software control is needed, the peripheral's request can be serviced in less than 1 machine cycle, or 1.4 μs. However only a limited number of data words per request can be transferred; the clocks can be held only for a short period of time each machine cycle.

An interrupt-controlled DMA doesn't rely on a stopping of clocks. Instead, the peripheral requiring data requests a CPU interrupt.

The interrupt must be serviced under program control. First the DMA interrupt-service routine executes a Halt instruction, which sets the CPU Halt flag. This flag and its complement then are used as the appropriate address-buffer enable/disable signals. As was the case with the clock-hold method, data can be transferred at the cycle rate of the memory once the requesting peripheral obtains control of the address bus.

When data exchange has terminated, the requesting peripheral must raise the Start jump-condition input to the CPU. This in turn resets the Halt flag that established the original setting of the CPU address buffers. Once the Halt flag has been lowered, the Start input can be lowered, too. This returns control to the machine instruction that follows the Halt instruction in the interrupt-service routine.

Although the method doesn't handle data any faster than the clock-hold method, it can transfer as many words as required. However, an interrupt-latency time exists between the actual interrupt request and the time the first word is transferred. For the application described, the latency time is about 75 μs, corresponding to the time needed by the μP to prepare for its execution of the Halt instruction.

Organize a two-port memory

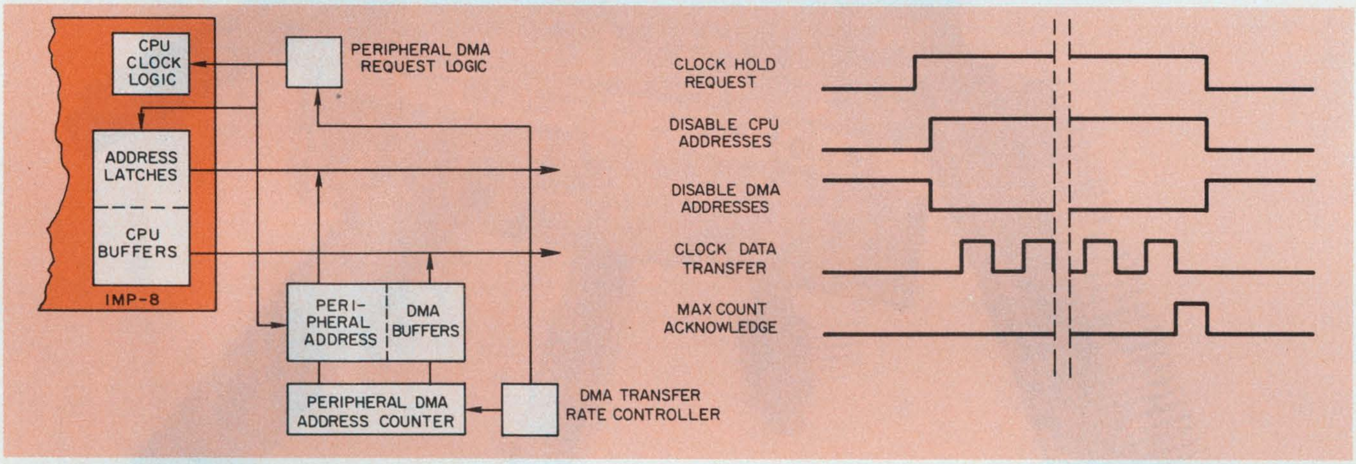
In all of the examples described, the buffer memory was presumed to be part of the main-system memory. But since data are all that are being transferred, there is no reason for the buffer memory to be organized the same way as the instruction memory. In fact, if the buffer is organized as a two-port memory, high data rates can be sustained for any length of time without the need for a μP interrupt. This, in turn, would eliminate the interrupt latency time, and allow transfer of data within one machine cycle or 1.4 μs on the standard IMP-8.

One port performs read-only operations, and is controlled directly by the peripheral. The second port, a write-only, is connected to the main μP I/O bus.

The μP generates data and stores it in the buffer memory, from which the peripheral takes data. However, the buffer memory does not acknowledge the transfer to the IMP-8 μP. After each write operation, the CPU must check the buffer to determine if it is in a DMA mode. Only when the buffer completes a data transfer can the μP write in new data.

```
*        MEMORY ADDRESS REGISTER(MAR) CONTAINS PERIPHERAL
*               PAGE ADDRESS.
*        MEMORY DATA REGISTER(MDR) CONTAINS PERIPHERAL
*               BYTE ADDRESS.
*        ACCUM 3 CONTAINS BUFFER PAGE ADDRESS.
*        ACCUM 2 CONTAINS BUFFER BYTE ADDRESS.
*
*
LOOP     PFLG,HI,MAR,,Ø       Ø          * SEND HIGH ORDER PERIF ADDRESS
         PFLG,LO,MDR,,Ø       Ø          * SEND LOW ORDER PERIF ADDRESS
         PFLG,WRITE,ACØ,,Ø    Ø          * WRITE DATA IN ACØ TO PERIF
         ADD,AC3,,AC3         CIN        * INCR AC3
         B,NREQØ              CONTINUE,FETCH   * TEST, IF BUFFER DONE
                                               * FETCH NEXT MACHINE
                                               * INSTRUCTION
CONTINUE
         PFLG,HI,AC2,,Ø       Ø          * SEND BUFFER PAGE ADDRESS
         PFLG,READ,AC3,,ACØ   DATAIN     * SEND BUFFER BYTE ADDRESS, THEN
                                         * READ NEXT WORD IN BUFFER
                                         * SAVE IN ACØ FOR NEXT TRANSMISSION
         B                    LOOP       * REPEAT LOOP
```

4. **A microprogram-control version of the loop** method increases data rates by a factor of five. The listing, which shows the source code to a microassembler, implements the flow chart shown in Fig. 2. The first several lines essentially are comments that identify the locations of different pieces of information.



5. **A completely hardwired transfer technique**—clock-hold DMA—can service a peripheral's data request in less than one machine cycle, or 1.4 μs. But only a limited number of words can be transferred, because the clocks can be held only for a short period during each machine cycle.

When the peripheral requests data from the buffer, it must wait only until the completion of any previous μP write operation. Since this is always less than one machine cycle, the peripheral requesting data always gains access in less than one machine cycle.

The examples given in this article are by no means the only methods of transferring data from memory to peripherals. In fact, it may be possible to combine these methods to satisfy different application requirements. Also, the examples cover only the case of transferring blocks of data from memory to peripherals. The same concepts hold true, with minor modification, for transferring to the microprocessor's memory data from the peripheral device.

Moreover, the same methods can be used with the IMP-16, a 16-bit version of the IMP-8. In all cases, the rate of transmission will be comparable and the hardware required will be similar. The only significant difference is that 16-bit data words will be transferred where 8-bit words were before. ■■

References

1. *IMP-8 Applications Manual*, Publication #4200032, National Semiconductor, Santa Clara, CA 95051.
2. *IMP-8 Programming Manual*, Publication #4200031, *ibid.*
3. *IMP Microprogramming Manual*, Publication #4200062, *ibid.*

CIRCLE NUMBER 34

CIRCLE NUMBER 35 ►

Unite μP hardware and software the easy way. Design a universal test system that checks, debugs or troubleshoots—from breadboard to field.

When you near the end of a μP-based design and face the problem of joining the nearly completed hardware to the almost finished software, let a universal test system officiate at the final coupling.

Such a test system can be very useful. First, it allows you to communicate with the μP system through a keyboard. Second, the program can be loaded into a RAM memory from tape generated by either time-sharing or a proprietary development system like Motorola's Exorcisor. Then the μP system can be operated from the program as stored in the RAM. Third, selected portions of the program can be exercised, and the program modified to perform special tests or system-hardware adjustments. The RAM memory can be tested to ensure that it is operating properly.

A particular advantage in programs with a short turn-around time is that system development and software debugging can proceed on hardware in the breadboard or prototype stage.

Finally, as the system nears completion, it can be operated entirely on its own, but with the test option available in case problems develop.

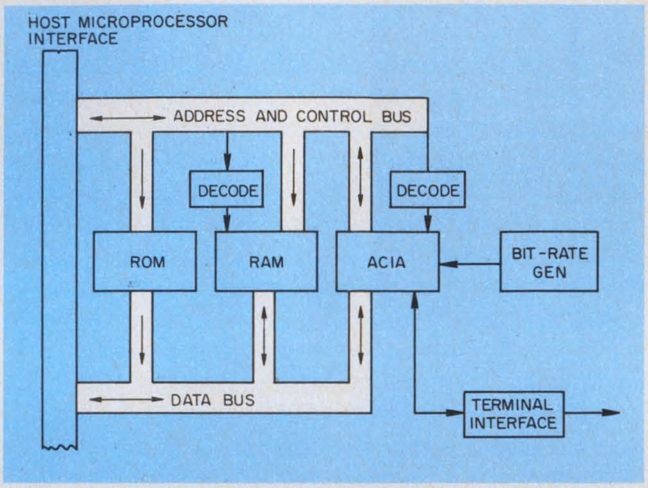
The test system can still be used for production units even after the μP product is finished. And when the products are out in the field the test system can serve as a troubleshooting aid, for both hardware and software.

No need to change standard procedure

In developing a μP system you usually follow a standard sequence of steps: 1. The system requirements are written down in statement form. 2. Algorithms are developed from these statements. 3. Rough code is written and assembled to implement the algorithms. 4. The code is simulated and refined on either a time-sharing system or on a proprietary development system like the Exorcisor or Intellec.

Eventually, you must fit the refined program into the hardware system. This ultimate marriage may not occur until after the system is prototyped. What makes the test system so effective with small μP systems is that it interfaces with existing hardware without significant modification to that hardware.

Jim Barnes, Senior Project Engineer, and **Bert Bergquist,** Design Engineer, Motorola Semiconductor Products, 5005 E. McDowell Rd., Phoenix, AZ 85008.



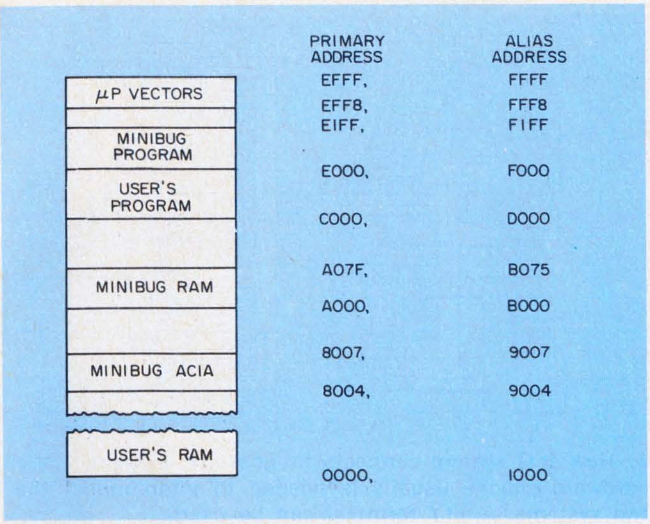
1. **A universal test system consists** of a number of LSI and MSI packages. The ROM holds the test program, the RAM acts as a scratchpad, and the ACIA interfaces the terminal with the test system.

Hardware for the test system consists of three LSI packages, four conventional IC packages, an interface connector to the terminal and additional interface connections to the data, address and control buses of the host μP (Fig. 1).

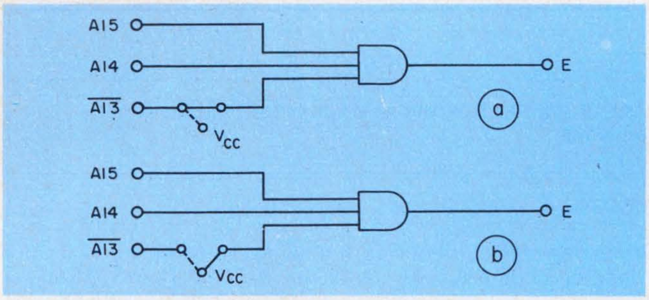
The LSI packages—all components of the M6800 μP family—include the Minibug II firmware ROM (this is the same ROM supplied with Motorola's Evaluation Module II), the M6810 RAM as a scratchpad and the M6850 asynchronous communications interface adapter (ACIA) for connection to the terminal.

MSI packages include the MC14411 bit-rate generator, the MC14025 gate package for ACIA address decoding and the MC1489/MC1488 pair, which provides the RS232 interface. If you use a TTY terminal requiring a 20-mA current loop, then a 4N33 optocoupler can act as the interface.

The ROM provides the program that recognizes both requests to perform standard operations and the routines that actually perform



2. **The memory map shows wired addresses** and those used during system start-up.



3. **Generation of system-enable signal:** in the TEST mode, firmware decodes C to generate an enable signal (a). Without TEST, C or E is decoded (b). Response is to CXXX or FXXX, depending on whether $\overline{A_{13}}$ or V_{cc} is connected.

them. The RAM—in addition to providing dedicated storage areas for stack, target, interrupt and data-enclosing vectors—also contains a small area that can hold limited test routines. Finally, the ACIA provides the serial-to-parallel interface to the terminal.

Connection of the test system is complicated by the μP-controlled start-up sequence. The μP's first action is to put all address lines, except A_0, at the HIGH level (hexadecimal address FFFE) and then look for the high-order byte of the program's starting address. Next, the μP puts A_0 HIGH (hex FFFF) and looks for the low-order starting-address byte.

When a program like the Minibug II is used, μP action must direct a vector to the start of the Minibug II ROM; when the operating system is used alone the same action must point to the start of the system ROM. Similar requirements exist for the interrupt vectors located at FFF8 through FFFD.

Equalizing the addresses

The Minibug ROM is wired to respond to address EXXX, but it must also respond to FXXX at system start-up. To see how this can be accomplished, you must interpret these locations in terms of the actual address lines. Hex E and F are equal to binary 1110 and 1111, respectively. The corresponding address line configurations are A_{15}, A_{14}, A_{13}, $\overline{A_{12}}$ and A_{15}, A_{14}, A_{13}, A_{12} respectively.

To make addresses E and F react equally, you need only make A_{12} an X, or a Don't Care. Then the Minibug II ROM—though wired as EXXX—will respond to FXXX.

As shown in Fig. 2, the Minibug II program also reserves AXXX for its RAM and 8XXX for its ACIA. With A_{12} as a Don't Care, the BXXX and 9XXX are unavailable without additional decoding. Since the low-order addresses usually are reserved for peripherals and program RAMs, the CXXX (or DXXX) 2-k byte area is only recommended for programs in small systems; more than 2-k bytes of program call for additional hardware decoding.

When you compare hex F (binary 1111) and hex C (binary 1100), and realize that you have already made A_{12} a Don't Care, you see that F and C differ only in A_{13}. Take advantage of this situation: Hook-up a single-pole, double-throw switch to determine whether the system is in the Minibug II or system-ROM program. Figure 3 shows how to generate the system-enable signal, E. The signal responds to CXXX when $\overline{A_{13}}$ is connected and to either CXXX or FXXX when V_{CC} is connected.

In operation, the system calls those functions that accomplish the desired end. These functions include:

- Read a memory location to a printer.
- Write into any memory location from an external keyboard.
- Write into memory from tape.
- Print a designated section of memory on either printer or tape (with computed checksum).
- Vector to a target program.
- Memory test (five patterns and a walking-bit test).
- Punch and load binary tape.

The memory-test function allows exhaustive testing of any block of memory the designer may designate by use of the M function. The tests are as follows:

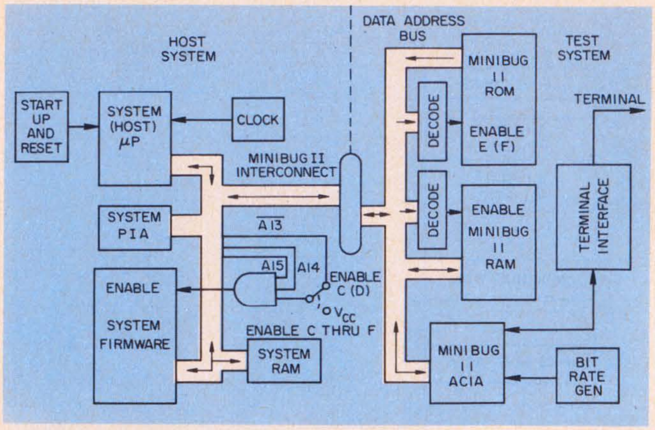
- A Walking address.
- B Write FF into all locations and verify.
- C Write AA into all locations and verify.
- D Write 55 into all locations and verify.
- E Write 00 into all locations and verify.
- W Write a single walking bit through the entire memory.

As each test is completed, the corresponding letter is typed—if a test fails, the user knows immediately which one.

The function, "Punch binary tape," allows punching the exact contents of memory on tape

Table 1. Memory examine-and-change sequences

ENTER (Command)	RESPONSE
M	Space
XXXX (4 Hex digit memory loc.)	Space XX (2 Hex digit of memory contents.)
XX (2 Hex digit of new data.)	
C.R. or L.F. or ↑	1) C.R. stores data and responds with* 2) L.F. stores data, increments address and opens that location. 3) ↑ stores data, decrements address and opens that location.



4. **How test system connects to host μP** system. Little hardware change usually is needed to interconnect the two systems. A TTY terminal can be used.

Table 2. Test system response and command

ENTER (Command)	RESPONSE	ENTER	RESPONSE
G	Space	XXXX (4 Hex digit users starting address)	Goes to user's program and executes instruction sequence.
DISPLAY REGISTERS			
R			Prints register contents as follows: condition code XX, ACCB XX, ACCA XX, INDEX XXXX, P COUNTER XXXX, STACK XXXX
MEMORY TEST FUNCTION			
W	Space		A B C D E W, carriage returns, prints*.
PUNCH BINARY TAPE			
Y			Tape is punched, carriage returns and prints*.
READ BINARY TAPE			
Z			Memory is read to printer, carriage returns, prints*.

—no ASCII II conversion is made, as is when talking with a printer. A tape header is generated that includes the word count and starting address. Record length is 256 words. If the record is longer, another header is inserted after each 256-word sector.

The "Read binary tape" function is exactly the inverse of the punch binary tape function—the record is written into memory at the starting address contained in the tape header.

Note that, with the test system, the memory-examine-and-change sequence should be learned first, because this sequence sets up portions of other commands (Table 1).

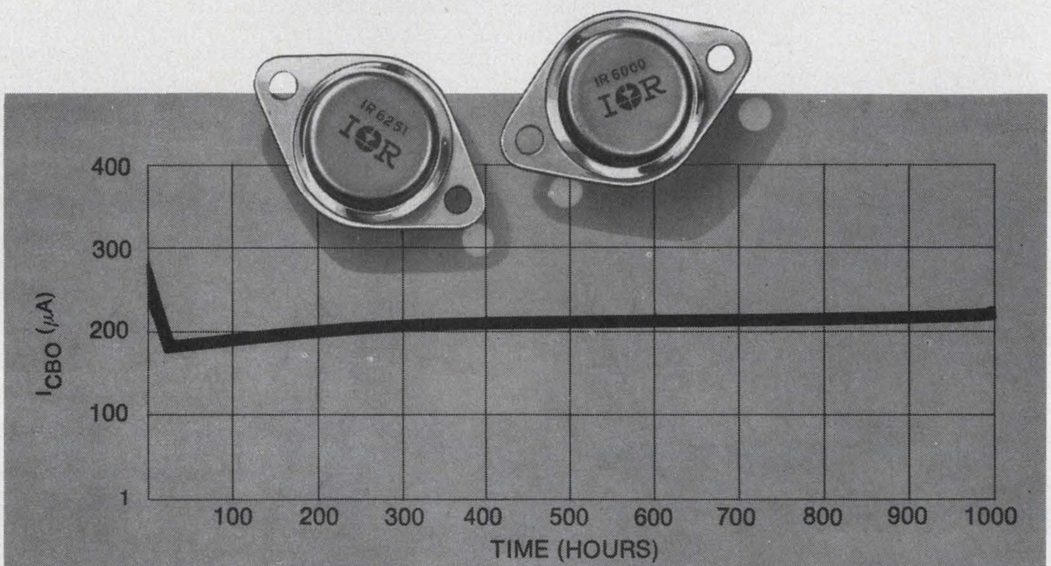
With the test system and a terminal both properly connected to your system (Fig. 4), and with the power on, a press of the system reset or restart button causes the terminal to respond with a carriage return, line feed and a printed asterisk. The system is now ready to accept commands from the terminal.

To load tape into memory, first load a formatted tape into the terminal and set the tape reader to Auto. Then just enter the command "L" following the asterisk, and the tape is loaded. To print out the memory contents or punch a formatted tape, first enter the high and low-order starting-print address into memory locations A002 and A003. Then enter into locations A004 and A005 the high and low-order END print address. After the asterisk appears, enter the command "P." The response is printout or recording of the formatted data.

To use the program-interrupt sequences, enter the assigned addresses into the test system as follows: at memory locations A001 and A002, the high and low-order hardware-interrupt vector; at A006 and A007, the nonmaskable interrupt; and at A00C and A00D, the software-interrupt vector.

The various commands associated with the user's program are given in Table II. ■■

Darlingtons that last.



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Whether you use Darlingtons or discretes, without high-temperature stability, you're dead. Failure may be a boon to the aftermarket, but for OEM's it can start something big... and bad.

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It's due to our hard-glass passivation techniques, plus 28 years' experience building high reliability power semiconductor devices.

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IR6060	25A	3.90μs	300-400V

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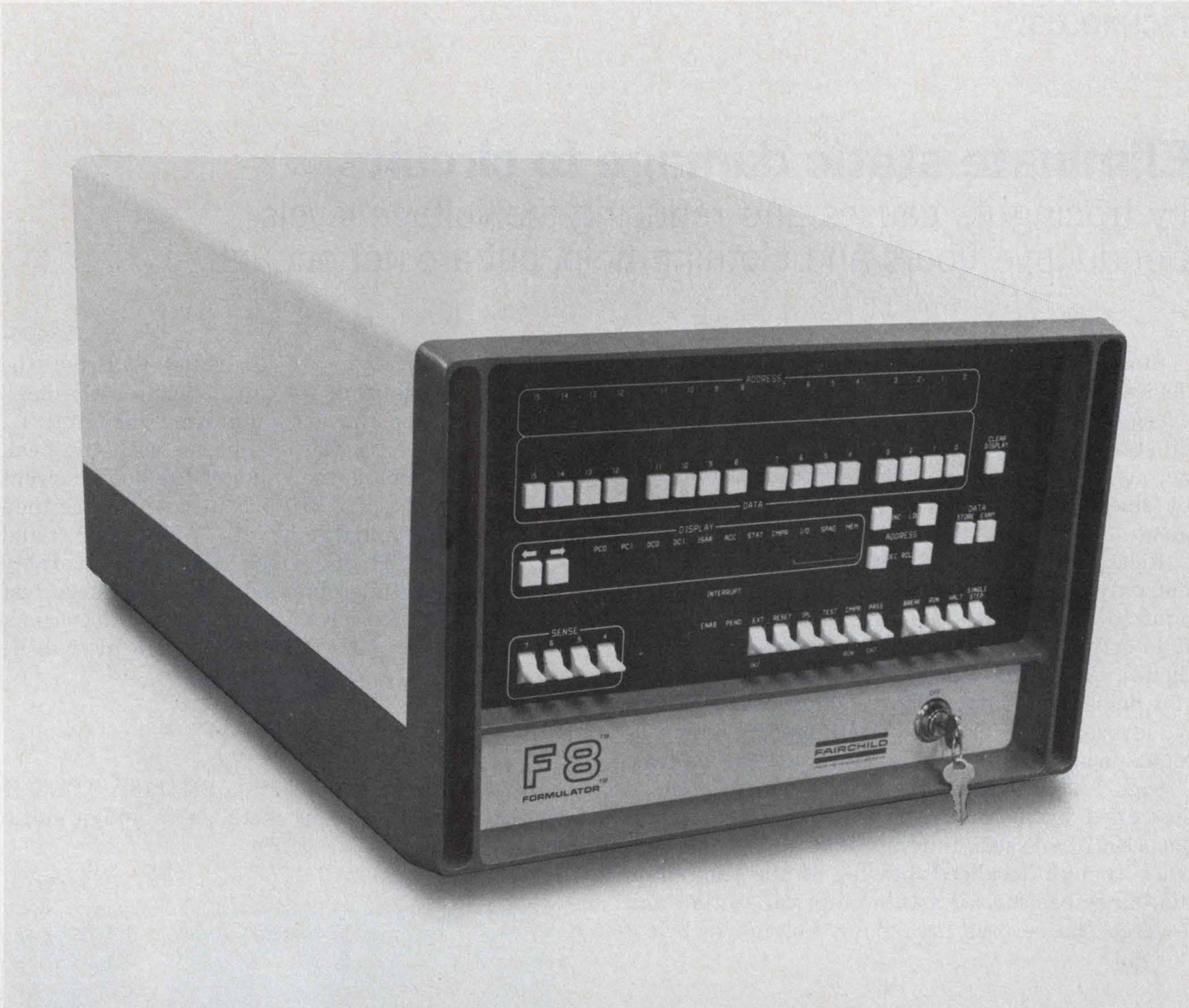
CIRCLE NUMBER 37



Fairchild's F8 Formulator: It gets you from μp design to hands-on prototype in half the time.

The Formulator is a powerful new microprocessor development tool that offers you all the design assistance you'll need to develop a microprocessor-based system or product. It saves time by:

1. Eliminating the need for an external system breadboard.
2. Putting your design energy where you need it: On the non-microprocessor circuits and on the operating features of your total product.
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8. Providing self-test at the push of a button.

The Formulator can be interfaced with either an HP2644 terminal or an ASR33. Fairchild offers a fully integrated software package including an operating system complete with monitor, text editor, assembler and debug package.

The Formulator was designed by systems people with reliability and maintainability as a design criteria. Each Formulator is burned in for 120 hours at 120°F prior to shipment. The Formulator can be delivered immediately–lease or rental plans are available.

Write for more information to: Fairchild Microsystems Division of Fairchild Camera & Instrument Corporation, 1725 Technology Drive, San Jose, California 95110. Phone (408) 998-0123

FAIRCHILD
MICRO SYSTEMS

CIRCLE NUMBER 38

Eliminate static damage to circuits

by tracing its causes and reducing the voltage levels. Conductive floors and clothing help, but are not enough.

Static discharges can damage many solid-state devices, but you can prevent this by using an energy-storage model to help minimize the causes of static buildup. Many of the potentially dangerous electrostatic voltage levels are generated by operator movement or assembly-line movement.

Relatively low static-voltage levels can damage not only MOS devices, which are commonly recognized to be static-sensitive, but also junction field-effect transistors, some bipolar devices, diodes, thick-film resistors and other small junction devices. The potential for damage is especially severe in the low-relative-humidity environments usually found in assembly and design areas.

Fig. 1 shows typical static-discharge damage sustained by a 2N3112 JFET. In some circuits the JFET will still function and appear normal, even though localized heating from the static discharge has melted a thin elliptical section and lowered the reverse breakdown voltage to below normal.

Use an energy-storage model

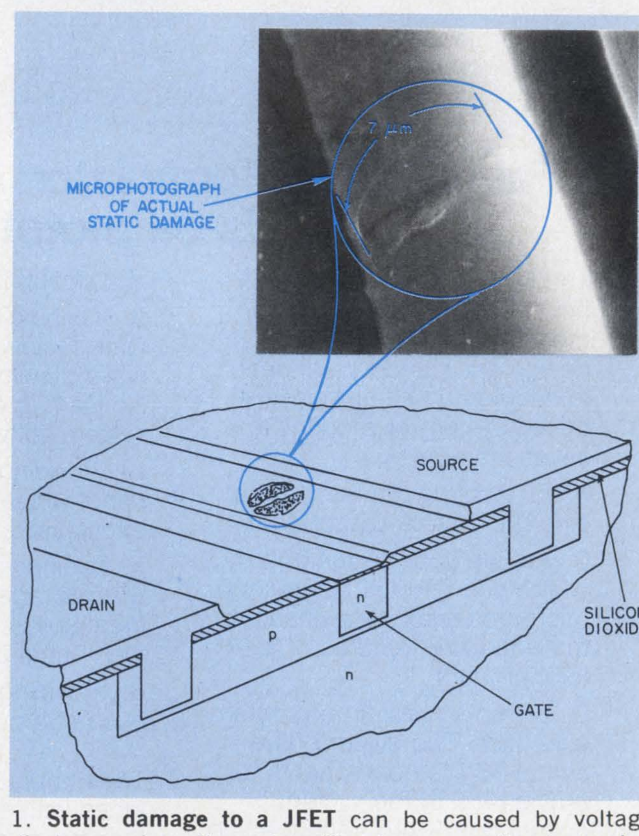
To study the effects of operator-generated static-energy discharge on semiconductor devices, use an energy-storage model of the body (Fig. 2a). The body acts as one plate of a capacitor, C_H, which is in series with the skin and body resistance, R_H. The other plate of the capacitor is formed by the ground.

Published values for C_H range from 100 to 10,000 pF and from 0 to 18 kΩ for R_H, depending upon the measuring method selected.[1-16] To arrive at realistic values for use in this article, the measurement circuit of Fig. 2b was used to compute R_H and C_H from charge and discharge waveforms observed on an oscilloscope.

The test subject was connected to a mercury relay through a wrist strap that had a surface area of 40 sq. cm. First, the subject was charged to a dc potential between 200 and 2000 V, then discharged through a 1-kΩ resistor. From the discharge waveform, we can determine the peak current, I_p, and the discharge time constant, T_C. The value of I_p is then compared with the peak current I_O, which is the value of the body current if $R_H = 0$ and $C_H = 270$ pF. R_H and C_H are then calculated and found to be: $R_H = 87$ to 190 Ω and $C_H = 132$ to 190 pF, which compares favorably with earlier results obtained under discharge test conditions.[8,15] So, for the rest of this discussion, the values $R_H = 100$ Ω and $C_H = 218$ pF will be used.

Determine device sensitivity

Let's see what happens to a 2N4118A JFET if we use these three test methods to judge static discharge damage (Fig. 3):



1. **Static damage to a JFET** can be caused by voltage discharges into the gate without necessarily destroying the JFET. However, the JFET fails more readily if stressed near its voltage limit.

Whitson J. Kirk Jr., Lane S. Carter and **Max L. Waddell,** Staff Engineers, Electronic Products Dept., Bendix Corp., P.O. Box 1159, Kansas City, MO 64141.

1. A human-body model charged with a dc power source.

2. A human body charged with static voltage generated by movement.

3. A human body charged with a dc power source.

In each test, C_H was charged to a known voltage and then discharged through the gate-source junction of the JFET. A change in the junction reverse-breakdown voltage at a junction current breakdown voltage, with no significant change in transconductance or pinch-off voltage. These devices would perform normally for a time in many applications. However, the effects in Fig. 1 resemble the melt transition that results from the second breakdown of a pn junction.[17] And increased current density in the melt region can reduce operating life and power-dissipation capability.[18,19]

■ The resistance in series with the JFET gate

Table 1. Observed effects of JFET test

Test Conditions[1]	Device-Failure Voltage Levels[2]										
	70	85	100	120	140	160	190	230	270	320	380
Human-Body Electric Model											
Direct-Current Charge											
$R_H = 0$, $C_H = 97$						D			D	D	
$R_H = 0$, $C_H = 218$					CCD				CC		
$R_H = 0$, $C_H = 425$			C		C	C	D				
$R_H = 100$, $C_H = 218$							D	CCCD	CDDD	CCDD	CC
Actual Human Body											
Movement-Generated Charge					C	D					D
Direct-Current Charge					DD	C		C			

Notes:

1. R_H values in ohms, C_H values in picofarads.

2. Each JFET receives one discharge pulse at each test voltage until failure occurs. The letter C indicates catastrophic failure when the reverse breakdown voltage drops to less than 3 V. The letter D indicates degradation when the 5-μA gate-source reverse breakdown voltage decreases by 50%.

of 5 μA provides a sensitive indicator of degradation. The results of this experiment are summarized in Table 1. Degradation did not vary appreciably with different discharge sources.

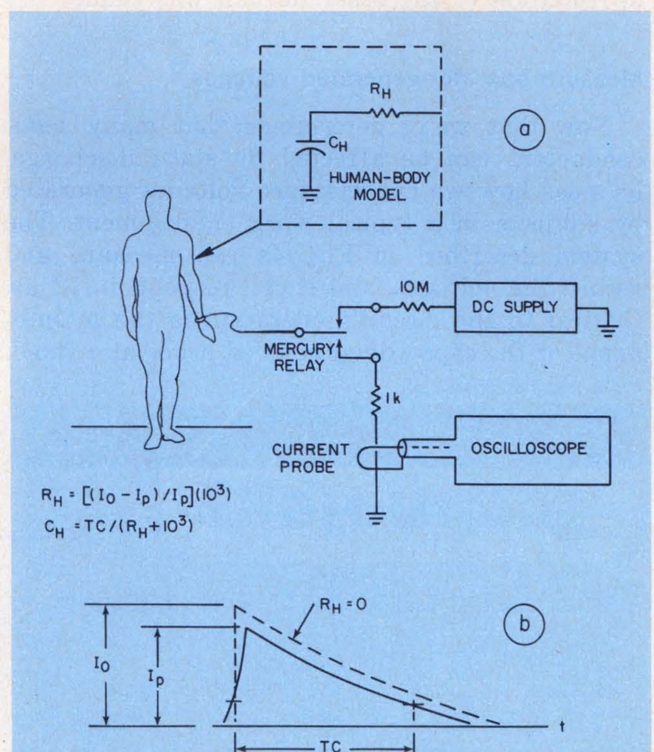
Other results from this experiment include these:

■ The discharge levels at which the failure occurred were lower with reverse-breakdown polarity (100 to 380 V) than with forward-conduction polarity (600 to 765 V) on the gate-source junction.

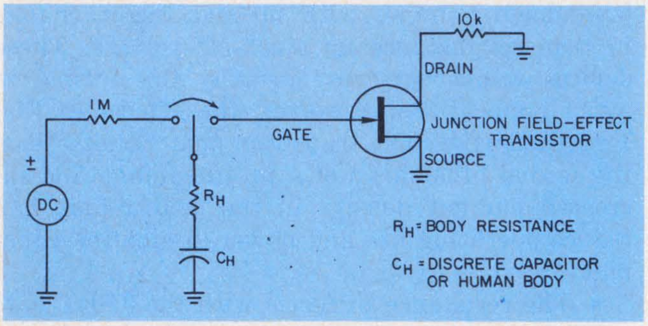
■ The capacitance value or energy level influenced, to some extent, the voltage required to degrade the transistor. CMOS circuits with diode protection were also found to be energy-sensitive. Unprotected MOS proved to be voltage-sensitive rather than energy-sensitive.

■ Repeated discharge pulses at voltages below the degradation level didn't significantly degrade the device. This indicates that progressive degradation from repeated pulses is minimal. The mean degradation voltage for a 15-sample group that received a single pulse at each voltage was 282 V. Another group of five devices was given 10 pulses at each voltage; these ended up with a mean of 230 V. There was no statistical difference between the two groups.

■ Half of the JFETs showed a decrease in



2. **A model of the human body** starts the analysis of how voltages build up (a). By measuring the rise and decay times we can calculate the time constant and thus the values of R_H and C_H (b).



3. **The charge-discharge model for the human body** indicates how energy is stored from a dc source and then discharged through the small-signal device under test.

limits the current arising from discharging voltages, thereby providing some protection to JFET and CMOS devices. Normal body resistance doesn't sufficiently isolate the device. Series resistances well above 1 MΩ are required for protection against voltages as high as 4 kV.

In another study, several bipolar transistors, some diodes and some FETs were tested with the circuit of Fig. 3. The results are tabulated in Table 2. Initial pulses for MOS devices were 16 V; for all other devices, they were 70 V. If the pulse resulted in no change in the reverse breakdown voltage, the pulse voltage was increased by 20% and the test repeated; the maximum voltage applied was 3 kV. Although FETs proved to be the most sensitive to static discharge, some degradation of the other devices was found.

Measure operator-generated voltages

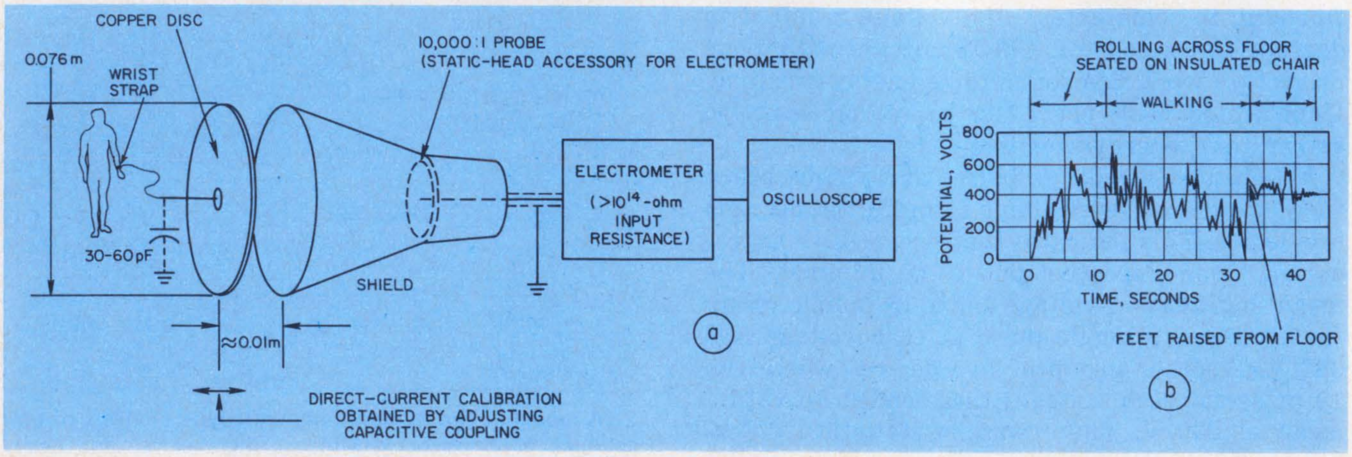
Now that we've determined that many semiconductors can be affected by static discharge, let's see how we can measure voltages generated by subjects in a typical work environment. The system described in Fig. 4a can measure and record the voltages, and it can respond in 12 μs. Critical to the circuit's operation is the maintenance of the capacitively coupled probe at a fixed, calibrated distance from the conductive disc connected to the operator.[20] A typical voltage output generated by the subject intermittently gliding on an insulated chair and walking across a conductive floor is shown in Fig. 4b.

The floor was of conductive vinyl tile, which has a resistance of 0.95 MΩ.[21] The chair was insulated with rubber rollers, and the subject was wearing composition-soled street shoes. The relative humidity was 4%. Under these conditions, spikes of 700 V were generated; these can degrade small-junction devices. Although portable static meters and electrostatic voltmeters can measure dc static voltages, they cannot detect rapid transients.[22]

After the subject had been monitored for several conditions, the results were summarized (Table 3) and some conclusions drawn:

- With the exceptions noted in the table, peak generated voltages were observed at points where the feet of the subject partly or totally lost contact with the ground plane. This is typical when a reduction in capacitance increases triboelectric voltage.
- Conductive-soled shoes or conductive shoe covers limit voltage generation on a conductive floor to 50 V or so, as long as the shoes remain in contact with the conductive surface.
- When the relative humidity is 45%, a subject's street clothing does not provide a conductive path between the skin and the conductive seat of a chair. (Typical resistance through street clothing was found to be about 10 GΩ).
- Neither conductive shoes on an insulated floor nor insulated street shoes on a conductive floor provide static protection.

The time it takes for a movement-generated charge to dissipate is also important. The graph in Fig. 5 shows how voltage dissipates from a 500-V starting level for a variety of environmental conditions. With conductive shoes, on a conductive floor, the charge on a subject can dissipate in less than 1 ms, which means there



4. **To monitor the generated electrostatic** voltage, a test set can be built with an electrometer amplifier (a). The voltage peaks generated by the moving subject can be measured on an oscilloscope (b).

is a good probability that any charges will dissipate before contact is made with a static-sensitive device. The three rates observed with leather street shoes on a conductive floor vary so markedly that this combination cannot be considered reliable. All other conditions studied have even slower discharge rates, though, which makes them even more dangerous.

As seen on the graph, an increase in relative humidity decreases the discharge time for composition-soled shoes on a conductive floor. However, to ensure adequate protection, a relative humidity much higher than 45% would be required, but then the working conditions might become uncomfortable or undesirable for sensitive circuits.

The effect of subject-to-ground shunt resistance on the peak voltage generated is shown in Fig. 6. For the shoe and floor materials tested, any combination of conductive devices that *always* ensures a resistance of less than 10 MΩ between body and ground provides good static protection for MOS devices and an R of less than 100 MΩ for junction devices. Other materials, such as rubber-soled shoes or waxed floors, could produce higher peak voltages, which would then require lower shunt resistances.

Minimize the static hazard

By modifying facilities and process procedures, you can minimize the hazard of static-discharge damage to solid-state devices without requiring an operator to think about being grounded before handling components or assemblies. A wrist strap offers poor grounding protection, at best.

Minimum design requirements for a static-discharge-protected facility include:

- A conductive floor with a resistance in the 25-to-300-kΩ range, tested in accordance with National Fire Protection Association codes. The 1-MΩ upper limit in the codes is marginal; an upper limit of 300 kΩ indicates a more uniform distribution of conductive path and thus lowers peak voltages.
- Conductive shoes with a maximum resistance of 500 kΩ, tested under the same guidelines as the floor.
- Conductive chairs with a maximum resistance of 1 MΩ between the seat and a metal plate under the chair. If a foot rest or rollers are provided, they also must be conductive. (Although the conductivity through an operator's clothing may be low, the presence of the grounded seat reduces voltage amplification when the feet of the operator are lifted from a grounding plane.)
- Conductive foot rests under the table.

To validate reliability, at periodic intervals resistance measurements should be made on each operator at his work station. The operator-to-ground resistance is voltage-dependent and cannot safely exceed the limiting protection resistance implied in Fig. 6. A system check like this accounts for the random distribution of conductive particles on both floor and shoes, and should be used to supplement standard floor and shoe-resistance measurements. And don't forget conventional precautionary equipment, such as conductive tabletops, conductive foam packaging and soldering irons with grounded tips.

The spray cleaning of electronic assemblies with

Table 2. Typical device degradation threshold

Device	Threshold,[1] volts	Test Results: Degradation criteria[2]
Diodes		50% drop in V_R at I_R = 5 μA
1N459	>3000	
1N916	3000	
TI551	450	
1N4151	>3000	
Zener Diodes		50% drop in V_R at I_R = 5 μA
LVA356	>3000	
Transistors		50% drop in $V_{(BR)CBO}$ at I_B = 5 μA
2N2222	1000	
2N2369A	460	
2N2432A	620	
2N2540	1450	
2N2907	1200	
2N3117	1000	
2N3570	380	
2N4251	460	
2N4872	1200	
2N5154	>3000	
Junction Field-Effect Transistors		50% drop in $V_{(BR)GSS}$ at I_G = 5 μA
2N2608	320	
2N3112	530	
2N3971	160	
2N4118A	140	
Metal-Oxide-Semiconductor Transistors		I_G >5 μA at V_{GS} = 22 V
GI MEM 520c (chip)	58	
Complementary Metal-Oxide-Semiconductor Integrated Circuits		> 0.5 μA input at 10 V or > 10% decrease in output voltage across 100-kΩ load
RCA CD4001	250	
Silicon-Controlled Rectifiers		50% increase in I_{CGO}
2N886A	680	
2N3030	1000	

Notes:

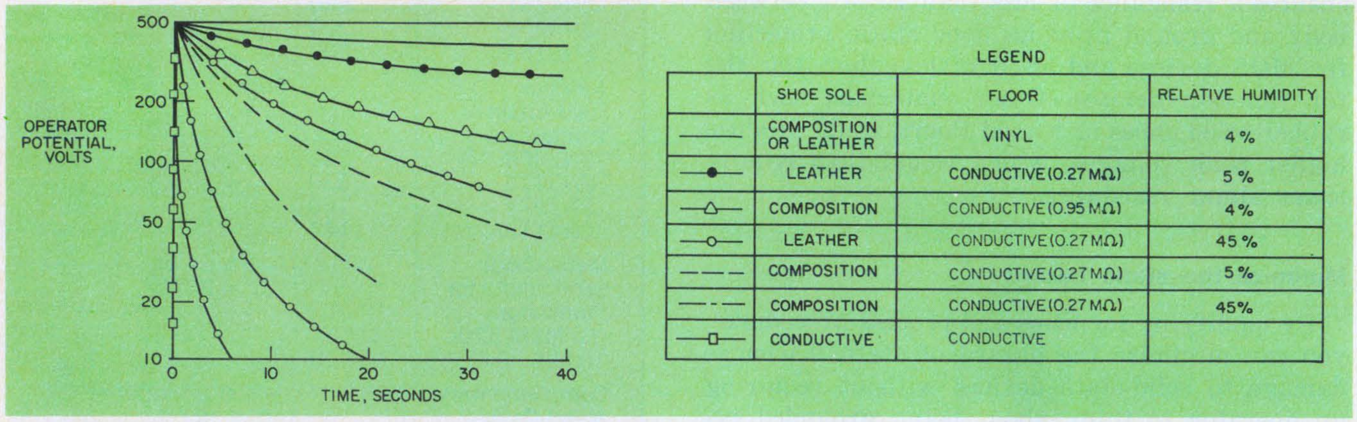
1. Reverse-breakdown polarity.
2. Where V_R is the reverse voltage, I_R the reverse current, $V_{(BR)CBO}$ the collector/base breakdown voltage, I_B the base current, $V_{(BR)GSS}$ the gate/source breakdown, I_G the gate current, V_{GS} the gate/source voltage and I_{CGO} the gate leakage current.

Table 3. Typical generated voltages

Shoe/Chair Combination	Peak Voltage Generated[1]		
	Conductive Floor I[2]	Conductive Floor II[3]	Insulated Floor[4]
Conductive-Soled Shoes			
Conductive Chair	20	100	700
Insulated Chair		500	
Leather-Soled Shoes			
Conductive Chair	340	370	600
Insulated Chair	1200	900	800
Composition-Soled Shoes (man-made)			
Conductive Chair	500[5]	1100[5]	1050[5]
Insulated Chair	500[5]	1100[5]	1550

Notes:

1. For an operator walking to chair, sitting down and lifting feet.
2. A conductive tile floor with 0.27-MΩ resistance, relative humidity of 45%, R_g of 0.5 MΩ from operator through conductive shoes and floor to ground, with 1 μA measuring current.
3. A conductive tile floor with 0.95-MΩ resistance, relative humidity of 4% and R_g of 11 MΩ.
4. Insulated vinyl tile floor and relative humidity of 4%.
5. Peak voltage observed during walking phase of operation.



5. **Electrostatically generated voltages** decay at a rate that depends upon the relative humidity and the materials in the floor and clothing. Decay times can take several minutes to reach safe levels.

solvent after soldering operations can also generate potentially dangerous electrostatic charges.[23] The polarity and magnitude of the charges is a function of the resistivity of the solvent, the spray rate and the triboelectric voltages or contact potential of the solvent and assembly materials. Assemblies that get this precharge can be damaged if the gate of a JFET is accidentally grounded. The charge, however, must have the proper polarity to impose an excessive reverse-breakdown potential on the gate.

To study the effects of various solvent systems, several solvents that produce positive and negative charges were used to neutralize the voltage on a printed-circuit board.

The PC laminate selected was epoxy glass (Type GH per MIL-P-13949), the spray pressure was 234 kilopascals (34 psig), and the relative humidity was 4%. Table 4 shows some of the compositions studied, and the test results are plotted on the graph of Fig. 7. Mixing a low-resistivity solvent with the normal cleaning solvent results in improved control of charge generation.

The upper limit on solvent volume resistivity for adequate protection under the test conditions was 50 kΩ-m. Although ethanol was used in the controlled experiments, other low-resistivity polar solvents are equally suitable. ■■

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Table 4. Cleaning solvent mixtures

Solvent System	Compositions Studied					
	Component	Concentration, percent by volume				
A	trichloroethylene	100.0	90.0	80.0	72.5	50.0
	trichlorotrifluoroethane	0.0	6.5	13.0	17.9	32.5
	ethanol	0.0	3.2	6.3	8.6	15.7
	methanol	0.0	0.3	0.7	1.0	1.8
B	tetrachloroethylene	80.0	66.4	60.0	53.6	40.0
	2-ethoxyethanol	20.0	16.6	15.0	13.4	10.0
	trichlorotrifluoroethane	0.0	11.0	16.3	21.5	32.5
	ethanol	0.0	5.4	7.8	10.3	15.7
	methanol	0.0	0.6	0.9	1.2	1.8
C	trichloroethylene	59.6	azeotrope			
	ethanol (200-proof)	40.4				

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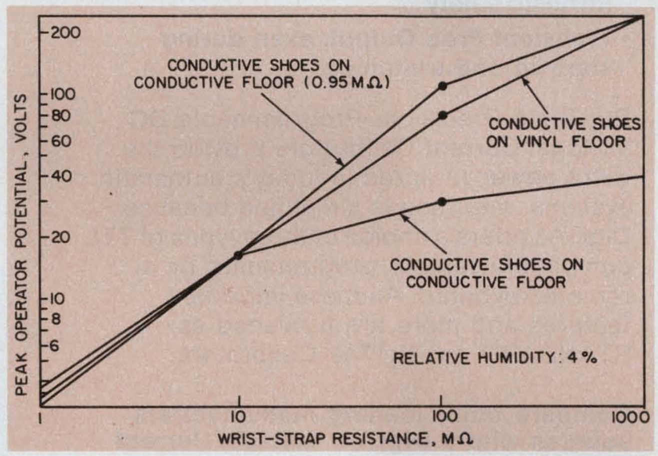

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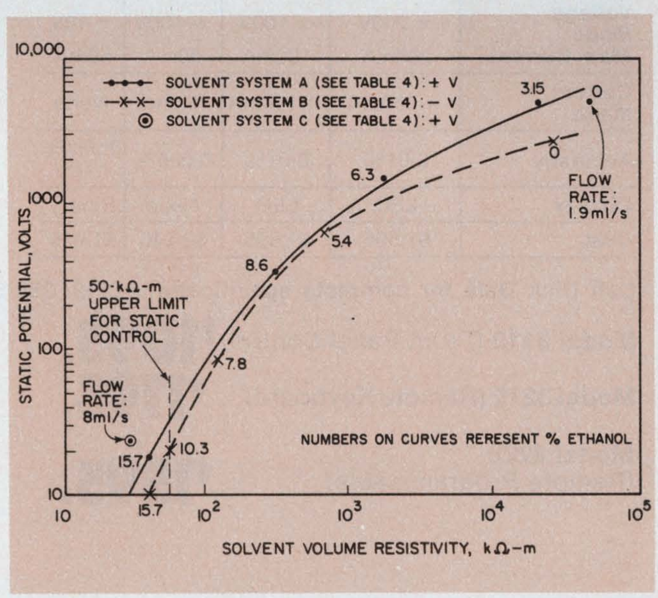

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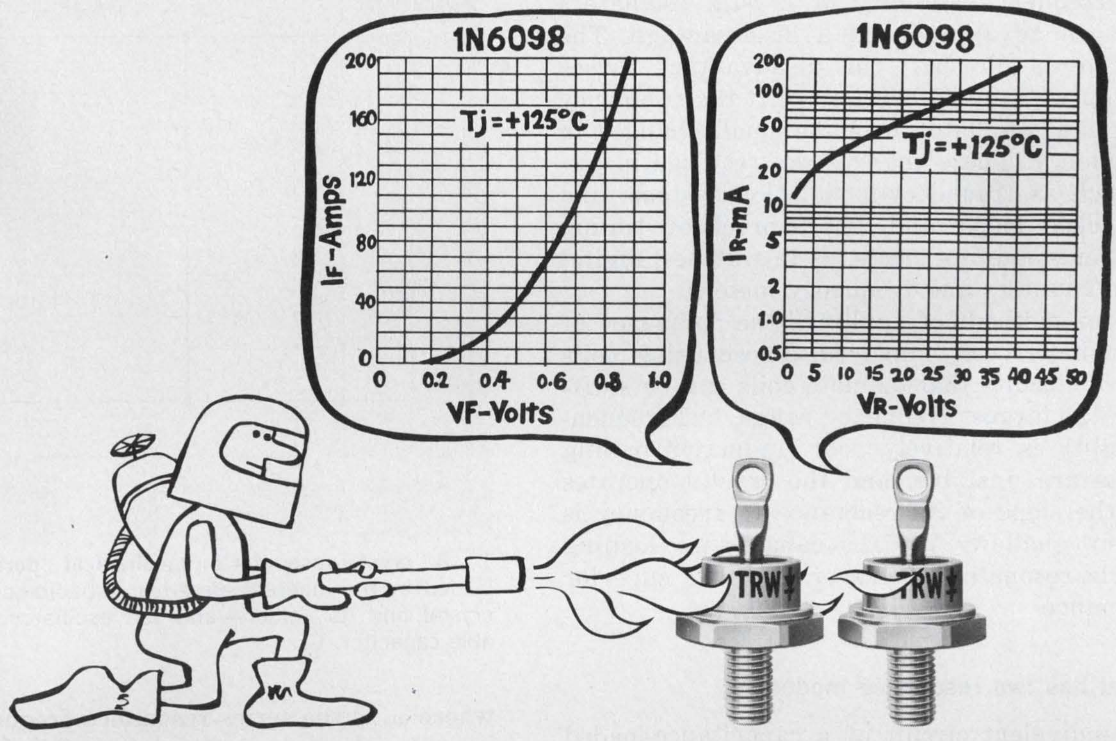

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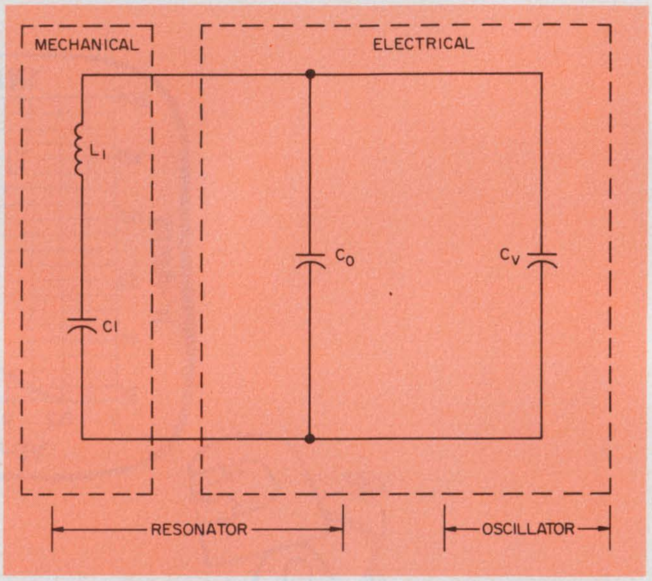
The frequency stability of crystal oscillators is both an advantage and a disadvantage. The advantage is obvious; the disadvantage arises when you wish to deliberately shift the frequency of a crystal oscillator to make small changes in its frequency. These changes are required in circuits such as frequency-modulation systems and phase-locked loops, and where precision timing adjustments must be made, as in watches, digital interval counters and frequency meters.

Various methods of "pulling" the frequency of crystals have been employed. Those using coils or active circuits that emulate coils can be shifted over the largest frequency range, but frequency stability is relatively poor. Inductive pulling elements are unstable, and the crystal operates where the slope of its reactance vs frequency is relatively shallow. Variable-capacitance loading of quartz resonators, however, provides superior performance.



1. A crystal-resonator's mechanical parameters are loaded by the inherent electrical capacitance of C_o—the crystal and its holder—and the oscillator's input variable capacitor, C_v.

A crystal has two resonance modes

The equivalent circuit of a capacitance-loaded lossless quartz crystal is shown in Fig. 1. The crystal's mechanical inertia is represented by L_1 and its mechanical compliance by C_1. The electrical capacitance of the crystal and its holder is represented by C_o and the capacitance of the oscillator's input circuit by C_v.

A crystal can resonate in two modes: a series, and a parallel, or antiresonant, mode. The parallel-mode resonance frequency is slightly higher than the series mode; thus in the parallel mode, the mechanical element of the crystal behaves effectively as an inductive reactance that resonates with the capacitive reactance of C_o and C_v in parallel.

The reactance of the mechanical element is

$$X_m = \omega L_1 - \frac{1}{\omega C_1}. \quad (1)$$

Since

$$C_1 = \frac{1}{\omega^2_0 L_1} \quad (2)$$

where ω_0 is the series-resonance frequency of the crystal, substituting Eq. 2 into Eq. 1 yields

$$X_m = L_1 \frac{[\omega^2 - \omega^2_0]}{\omega}. \quad (3)$$

If we let $\omega = \omega_0 + \Delta\omega$, (4)

so that $\omega^2 \simeq \omega^2_0 + 2\omega_0 (\Delta\omega)$, (5)

and substitute Eq. 5 into Eq. 3, then

$$X_m \simeq 2 L_1 (\Delta\omega), \quad (6)$$

because $\omega \simeq \omega_0$.

At parallel resonance, the reactance of the mechanical branch, X_m, equals the reactance of C_o and C_v in parallel. Thus from Eq. 6,

$$(\Delta\omega) = \frac{1}{2 \omega_0 L_1 (C_o + C_v)} \quad (7)$$

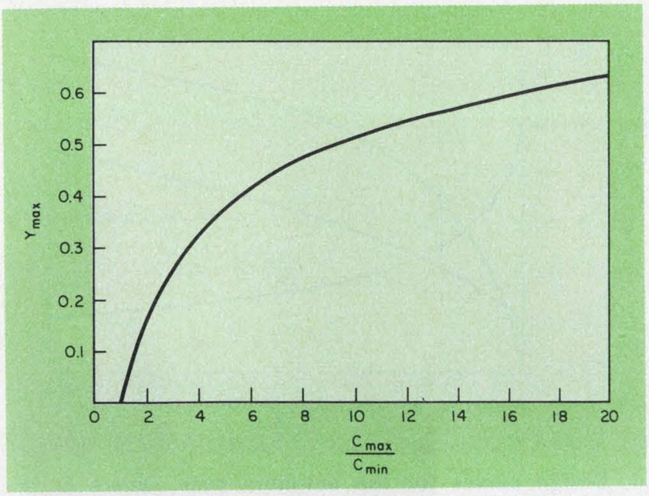
Substitute Eq. 2 into Eq. 7 and rearrange to get

$$\frac{(\Delta\omega)}{\omega_0} = \frac{(\Delta f)}{f_0} = \frac{\frac{C_1}{C_o}}{2\left[1 + \frac{C_v}{C_o}\right]} \quad (8)$$

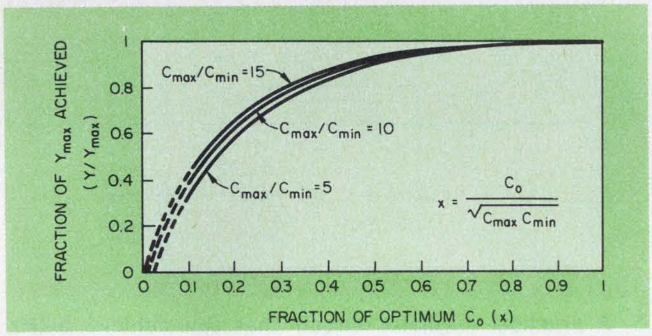
An electromechanical coupling factor, r_o, determined by the crystal cut and method of mounting can be defined as

$$r_o = \frac{C_o}{C_1}. \quad (9)$$

Frank W. Noble, Electronics Engineer, Laboratory of Technical Development, National Heart and Lung Institute, Dept. of HEW, Bethesda, MD 20014.



2. **The maximum possible value of the frequency deviation factor,** y, is a function of the ratio C_{max}/C_{min} of capacitor C_v and is obtained when $C_o = \sqrt{C_{max}\,C_{min}}$.



3. **The fraction of y_{max} that is attainable** when the crystal capacitance, C_o, is not the optimum value is not strongly affected by the C_{max}/C_{min} ratio, as shown by varying the ratio over a range of 3:1.

Eq. 8, expressed in kHz/MHz for convenience, can now be written as

$$\frac{(\Delta f)}{f_o} = \frac{500}{r_o\left[1+\frac{C_v}{C_o}\right]}\ \text{kHz/MHz}, \qquad (10)$$

or

$$(\Delta f)_{max} = \frac{500\,f_o}{r_o\left[1+\frac{C_{min}}{C_o}\right]} \qquad (11)$$

and

$$(\Delta f)_{min} = \frac{500\,f_o}{r_o\left[1+\frac{C_{max}}{C_o}\right]}. \qquad (12)$$

Let's define the pulling range, B, as

$$B \equiv (\Delta f)_{max} - (\Delta f)_{min}, \qquad (13)$$

then

$$\frac{B}{f_o} = \frac{500}{r_o}\left[\frac{1}{1+\frac{C_{min}}{C_o}} - \frac{1}{1+\frac{C_{max}}{C_o}}\right]. \qquad (14)$$

Maximizing the pulling range

To maximize the pulling range, we let the function within the brackets of Eq. 14 equal y and then differentiate to get

$$\frac{\partial y}{\partial C_o} = \frac{C_{min}}{[C_o + C_{min}]^2} - \frac{C_{max}}{[C_o + C_{max}]^2}. \qquad (15)$$

Setting Eq. 15 to zero and solving, yields the conditions for the maximum pulling range,

$$C_o = \sqrt{C_{max}\,C_{min}}, \qquad (16)$$

when C_o is the geometric mean of the C_v extremes. Then

$$y_{max} = \left[\frac{1}{1+\sqrt{\frac{C_{min}}{C_{max}}}} - \frac{1}{1+\sqrt{\frac{C_{max}}{C_{min}}}}\right]. \qquad (17)$$

A plot of Eq. 17 is shown in Fig. 2. However, practical circuits generally yield a smaller pulling range than allowed by Eq. 17, because the C_o for standard crystals is usually too small to satisfy Eq. 16, even when care is taken in the oscillator design.

Calculations show that the value of C_{max}/C_{min} does not strongly affect the percentage of y_{max} that is achievable as C_o is varied below its optimum value as given by Eq. 16.

A practical example

To gain a quantitative "feel" of magnitudes we are dealing with, let

$$C_{max} = z\,C_{min}; \qquad (18)$$

thus the optimum value of C_o from Eq. 16 becomes

$$C_o = C_{min}\sqrt{z} \qquad (19)$$

and $C_o = C_{max}/\sqrt{z}$ (20)

Fig. 4 contains a replot of Fig. 2 along with C_{min}/C_o and C_{max}/C_o.

Now we can solve a practical problem: How to achieve 5-kHz deviation from an AT-cut 7-MHz crystal that has $r_o = 250$, $C_o = 5$ pF and $C_{min} = 7$ pF.

First assume that $C_o = \sqrt{C_{max}\,C_{min}}$ can be achieved. Then from Eqs. 14 and 17,

$$\frac{B}{f_o} = 2y_{max} = \frac{5}{7} \qquad (21)$$

and

$$y_{max} = 0.357$$

From Fig. 4, scale C we get,

$$\frac{C_{max}}{C_{min}} = 4.45;$$

from scale A,

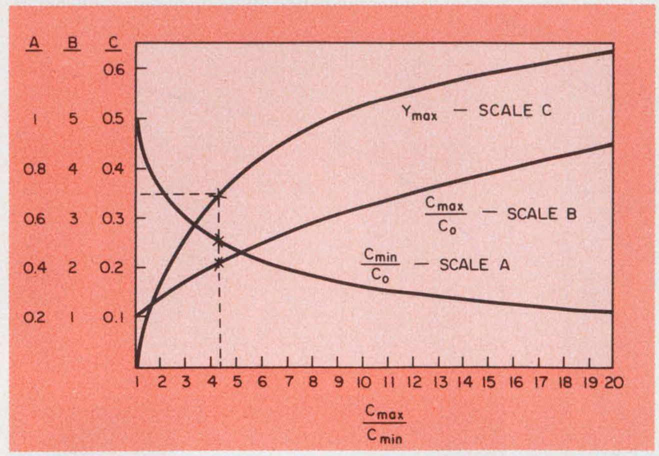
$$\frac{C_{min}}{C_o} = 0.475, \text{ or } C_{min} = 2.37\text{ pF};$$

and from scale B,

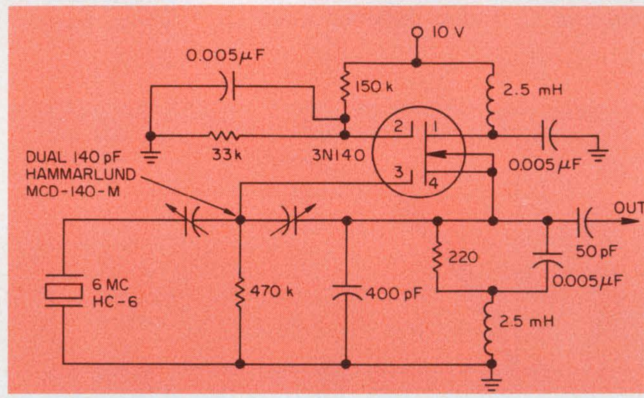
$$\frac{C_{max}}{C_o} = 2.12, \text{ or } C_{max} = 10.6\text{ pF}.$$

An oscillator with a C_{min} as small as 2.37 pF is difficult to achieve; practically, C_{min} tends to be about 7 pF, even with very careful design. Of course, the optimum condition, $C_o = \sqrt{C_{max}\,C_{min}}$, is therefore not achieved.

Nevertheless, with a C_{max}/C_{min} larger than the



4. **Design curves for the optimum case,** where $C_o = \sqrt{C_{max} C_{min}}$, can be used to solve practical problems.



5. **A practical oscillator circuit** that can achieve 5-kHz deviation from a standard 6-MHz, AT-cut, HC-6 crystal resonator uses a dual-air-variable capacitor.

theoretical value 4.45, the deviation range can still be achieved.

Assume that a C_{max}/C_{min} of 10 can be obtained readily; thus $C_{max} = 70$ pF. Then the corresponding y_{max} from Fig. 2 is 0.520 and $B/f_o = 1.04$, from which the deviation for the 7-MHz crystal results in 7.28 kHz.

Since we need $y = 0.357$, the value of y/y_{max} is 0.686—considerably removed from the optimum condition. With $C_{max} = 70$ pF, the optimum value of C_o for this oscillator becomes 22.1 pF.

Generally, to achieve optimum conditions for pulling, you should use special crystals that have plated areas larger than twice the diameter for standard crystals.

A practical oscillator circuit is shown in Fig. 5. In the interests of achieving a small minimum value for C_v, the circuit uses a dual-air-variable capacitor with its sections in series.

This configuration reduces the minimum value of C_v by more than half that of a single-capacitor arrangement. Maximum capacitance is also less than half the maximum capacitance of a single capacitor, but this is not important because an adequate C_{max}/C_{min} ratio can readily be achieved with standard components. ■■

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A versatile CMOS circuit changes mode when bias and load are changed

The CMOS circuit of Fig. 1 can perform many electronic functions, depending only on the circuit's applied bias and load. The circuit can be used as an amplifier inverter, amplifier follower, frequency doubler, oscillator, or a multivibrator. Though over 20 such versatile circuits have been developed,[1] the circuit in Fig. 1 is particularly practical, simple and easy to apply. The circuit can also be designed in IC form.

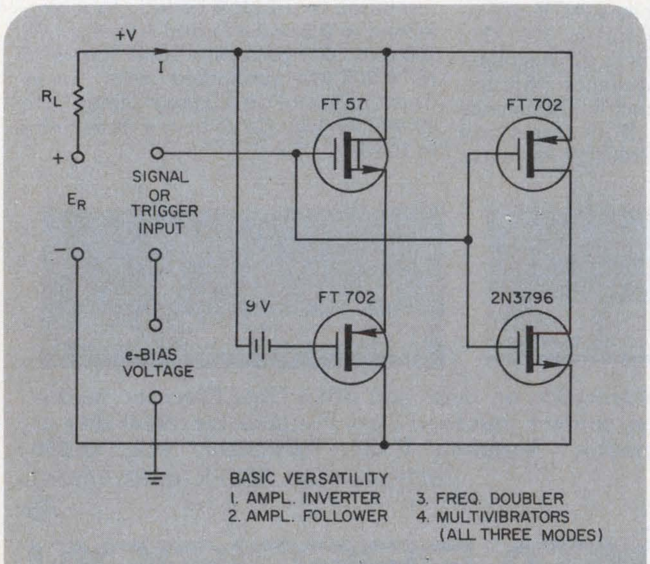
The circuit's functional versatility is made possible by its special I-V characteristics, with analytic properties that satisfy conditions for several electronic functions on the same portion of the I-V plane.

For example, in the I-V plot of Fig. 2, the point $I = 3$ mA, $V = 11.2$ V can be obtained when the bias, e, is either 3 or 1 V. At this point, the transconductance, $\partial I/\partial e$, is positive or negative, depending on whether e is 3 or 1 V, respectively. For $\partial I/\partial e > 0$, the circuit can work as an amplifier follower, and for $\partial I/\partial e < 0$, as an inverter.

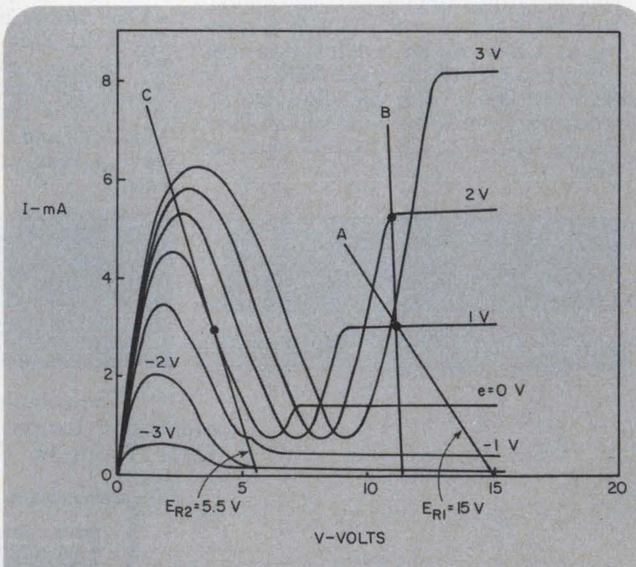
The circuit is a three-terminal combination of two n-channel and two p-channel MOSTs. The particular choices of depletion-type n-channel devices, FT 57 and 2N3796, and the 9-V threshold battery for the p-channel FT702 unit determine the curvature of the characteristic curves and the location of the zero-bias curve on the I-V plane (Fig. 2). Further modification of the curves can be obtained by the insertion of another battery in series with the gate of the other FT702.

The circuit operates as a follower amplifier when it is biased at $e = 3$ V, $E_R = 15$ V and load resistor, R_L, equals 1.2 kΩ. With the same R_L and E_R, but with $e = 1$ V, the circuit operates as an amplifier inverter. With the load line, where $R_L = 76.2$ Ω, $E_R = 10.4$ V and $e = 2$ V, the circuit is a frequency doubler. But with the same load line and $e = 1$ V, the circuit is again an inverter, and with $e = 3$ V, a follower.

With load line C, $R_L = 567$ Ω, $E_R = 5.5$ V, and with an appropriate inductor in series with R_L, the circuit behaves as an astable multivibrator when $e = 0$. With an LC circuit connected, the circuit works as a quasi sine-wave oscillator. And when $e = 2$, 3 or -4 V, the circuit works as a monostable multivibrator. The circuit's signal input terminals can be used for trigger pulses.



1. **A circuit made with four CMOS devices becomes a versatile circuit** whose properties depend only on the load and bias values.



2. **The characteristic curves of the CMOS circuit** provide properties for amplification, inversion and multivibrator operation, all on a single I-V plane.

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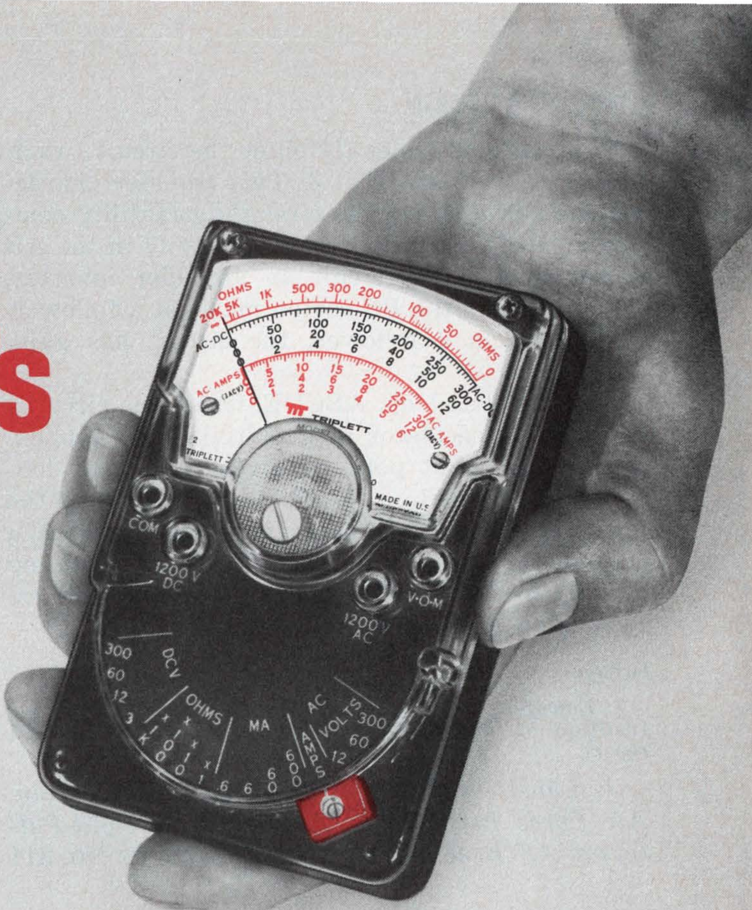

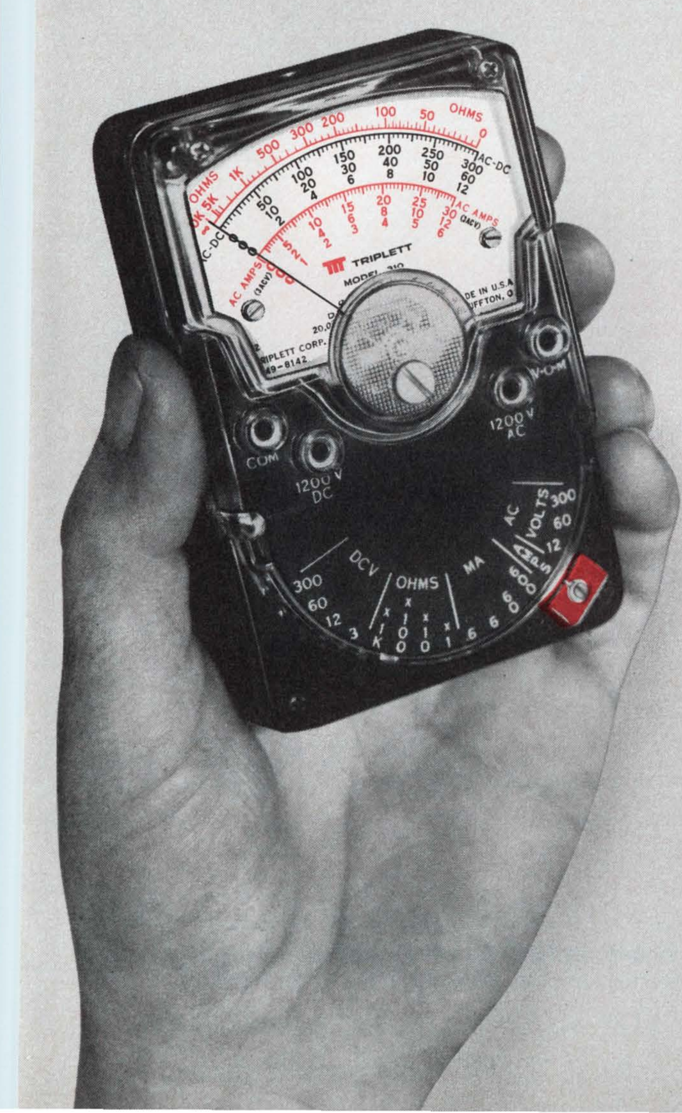

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It is perhaps easier to follow the circuit's various functions with Fig. 3. This transfer characteristic curve shows the circuit's versatility comprehensively. With $R_L = 5\ k\Omega$, biasing in the AB region makes the circuit an amplifier inverter, and biasing in the BC region makes it a follower. Note that as a follower, the circuit has gain, $\partial V/\partial e > 2$.

The complete loop, ABCDE, traces the circuit's behavior in oscillator and multivibrator applications. Biasing at point B gives frequency doubling, but with $R_L = 5\ k\Omega$, the ABC part of the curve is not symmetrical and would provide a distorted output. To optimize frequency-doubling action, the curve can be made more symmetrical by changes in R_L and the threshold voltage.

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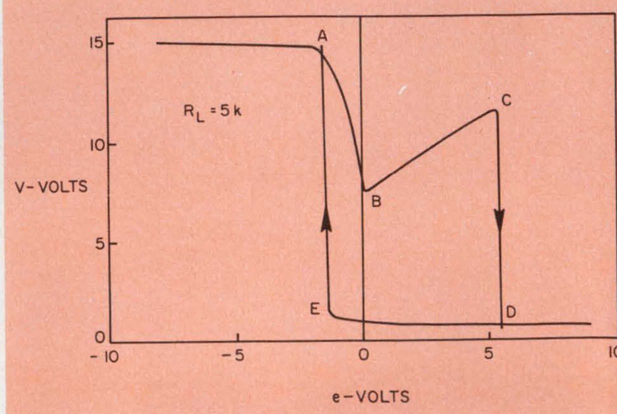
J. Lubelfeld, Dept. of Electrical Engineering, Air Force Institute of Technology, Wright-Patterson AF Base, OH 45433. CIRCLE No. 311



3. **A transfer characteristics curve** for $R_L = 5\ k\Omega$ clearly shows how the different bias voltages, e, provide the different functions and modes.

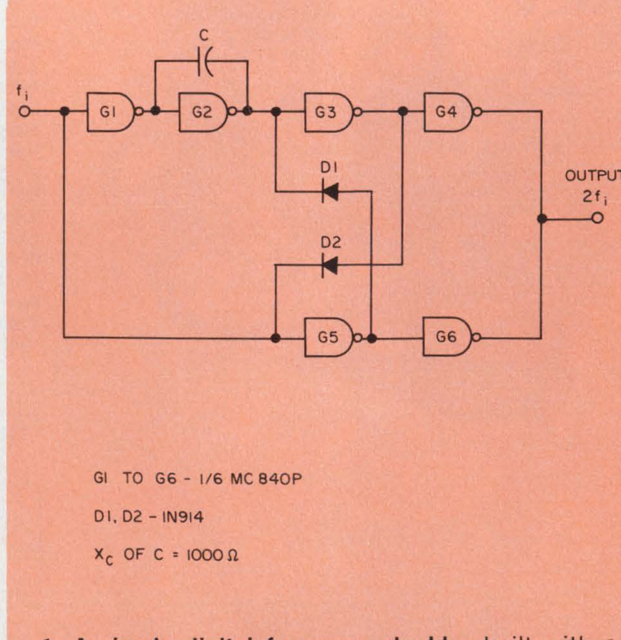
Digital frequency doubler works to 100 kHz

A digital frequency doubler that works from 1 Hz to 100 kHz can be built with only one hex-inverter chip, two diodes and a capacitor (Fig. 1). The circuit requires a square-wave input. To produce an approximately symmetrical output, the capacitor, C, should have a reactance of 1000 Ω at the input frequency. If symmetry is important, the capacitor may be padded with a series or parallel resistor to provide almost perfect symmetry at the frequency used.

The output circuit includes inverters G_3, G_4, G_5 and G_6 that are cross-coupled by diodes D_1 and D_2. The input signal is split into two components that are phase-shifted 90-degrees from each other with the help of inverters G_1 and G_2 and capacitor C. The two shifted signals are combined to provide a doubled-frequency output.

The circuit is very stable and several stages can be cascaded to a frequency limit of about 100 kHz.

Gerald L. Vano, Systems Engineer, Alden Research Foundation, 117 N. Main St., Brockton, MA 02403. CIRCLE No. 312



1. **A simple digital frequency doubler** built with a hex-inverter can operate from 1 Hz to 100 kHz.

High-frequency zero-crossing detector operates beyond 50 MHz

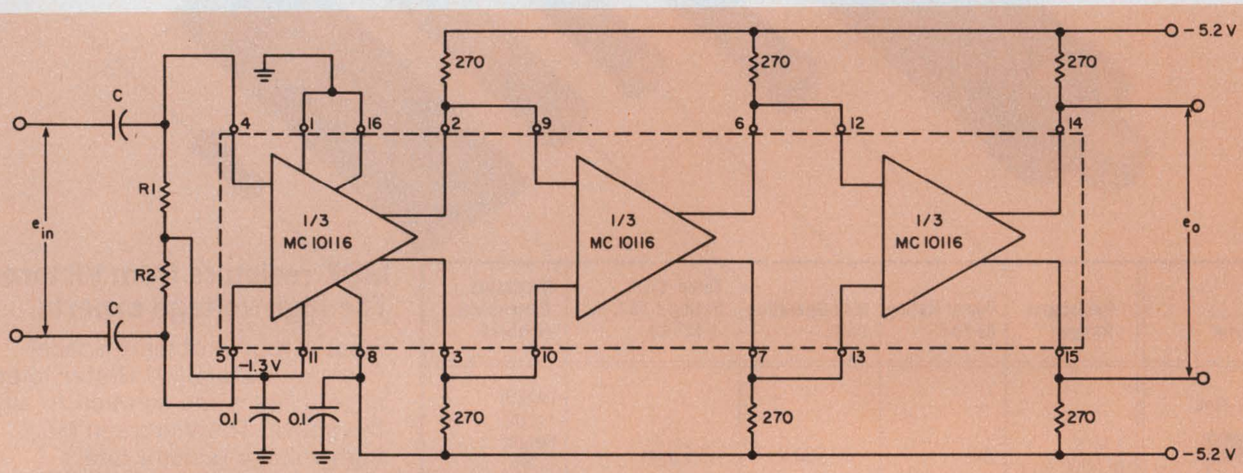
The three sections of an MC10116 ECL receiver when connected in tandem make a sensitive zero-crossing voltage detector that is capable of operation beyond 50 MHz (Fig. 1). Input voltages of this detector may range from 30 mV to 5 V, peak to peak. The zero-cross point does not change by more than 2 ns over this large input range.

The MC10116 chip contains three differential amplifiers, each with a gain of approximately eight; thus the over-all gain of all three stages in tandem is 512. Input biasing is derived from the negative 1.3-V reference-voltage delivered at pin 11 of the chip. This voltage centers the dc of the input amplifier for class-A amplification and maximizes its common-mode-rejection capability.

For input signals less than 100 mV the first amplifier stage operates in a class-A mode. Larger signals force all stages into a fully switched mode. Propagation time through one stage is about 2 ns in the switched mode, and less in class A. Since only the first stage ever operates in class A, the propagation time difference between the smallest signal, 30 mV, and the largest signal, 5 V, will vary only by the difference between the class-A and switched-mode delays—much less than 2 ns.

The value of input resistors R_1 and R_2 can be chosen to match the line impedance. And the values of the coupling capacitors, C, should be selected in conjunction with R_1 and R_2 to provide the required low-frequency response.

William A. Palm, Principal Engineer, Magnetic Peripherals Inc., 7801 Computer Ave., Minneapolis, MN 55435. CIRCLE NO. 313



A high-frequency zero-crossing detector operates over a wide range of inputs—from 30 mV to 5 V, peak to peak. The circuit triggers at the crossing point within 2 ns over the total input range.

IFD Winner of November 22, 1975

Douglas Thom, Development Engineer, Novus Div., National Semiconductor Corp., 1177 Kern Ave., Sunnyvale, CA 94086. His idea, "Capacitor Drops Voltage with Little Heat for Low-Cost, Low-Voltage Power Supply" has been voted the Most Valuable of Issue Award.

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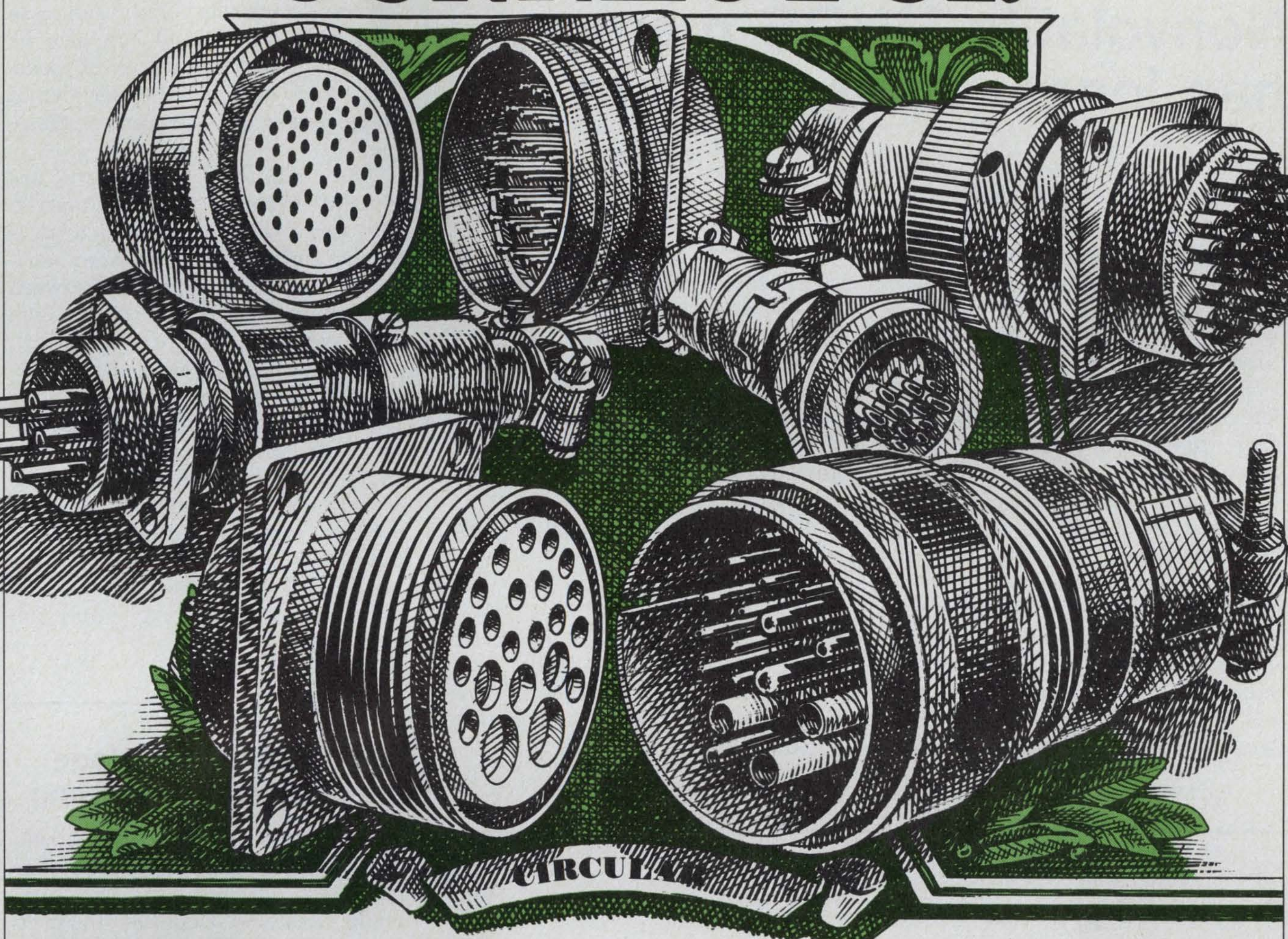

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CIRCLE NUMBER 45

Nonvolatile MNOS memory has longer operating life

A nonvolatile semiconductor memory that overcomes the short life of the conventional MNOS (metal-nitride-oxide semiconductor) transistor has been revealed by the Tokyo Shibaura Electric Co. in Japan. Because the characteristics of the MNOS transistor deteriorate after each write operation, the lifetime is usually well below 10^6 cycles.

Standard MOS memory cells are combined in the Toshiba memory with MNOS transistors, and in normal operation the MNOS transistors are not used. Data are written into the MNOS transistors only when nonvolatility is essential, such as to protect against data loss in the event of a power failure. Because the MNOS transistors undergo a minimum number of write cycles their lifetime is increased.

The major drawbacks at present are that ten transistors are required for each memory bit and costs are likely to be higher than if a CMOS RAM with back-up power supply were used. Current work is aimed at improving yield and increasing the level of integration.

A 64 × 4-bit array is feasible now but Toshiba hopes to achieve a 1 k-capacity in the next year. The 64 × 4 RAM can retain data without power for at least one year, has a read access time of less than 500 ns, a write-cycle time of less than 1 μs and a power consumption of 600 mW.

Green LED process boosts light output

A new process for producing green light-emitting diodes with luminous intensities of 30 millicandelas at an operating current of 10 mA has been developed by Siemens AG, Erlangen, West Germany. The diodes can operate with up to 60 mA, and at the higher currents the light output is sufficient to illuminate the surroundings.

The first stage in the production of the devices is the direct synthesis of polycrystalline gallium phosphide from pure gallium and phosphorous. This is then converted to monocrystalline GaP on which an n-type GaP layer is grown, at 900 to 1100 C, by means of fusion epitaxy. Further doping with zinc produces the pn junction, which is required for light emission.

640 characters displayed on 40 × 50-cm LCD

A large-area liquid-crystal display panel has been jointly developed by Hitachi, Dai Nippon Tokyo and Asahi Glass. The panel, which measures 40 × 50 cm, can display 640 characters (Roman letters, numerals and Japanese kana characters) and can also be used in a computer-graphics mode. The panel, still in an experimental stage, makes use of matrix addressing.

The individual characters are generated from a 9 × 7 dot matrix. The space between vertical lines is 9 mm, and the space between horizontal lines is 3 mm. Between characters, the space is 18 mm (vertical) × 100 mm (horizontal).

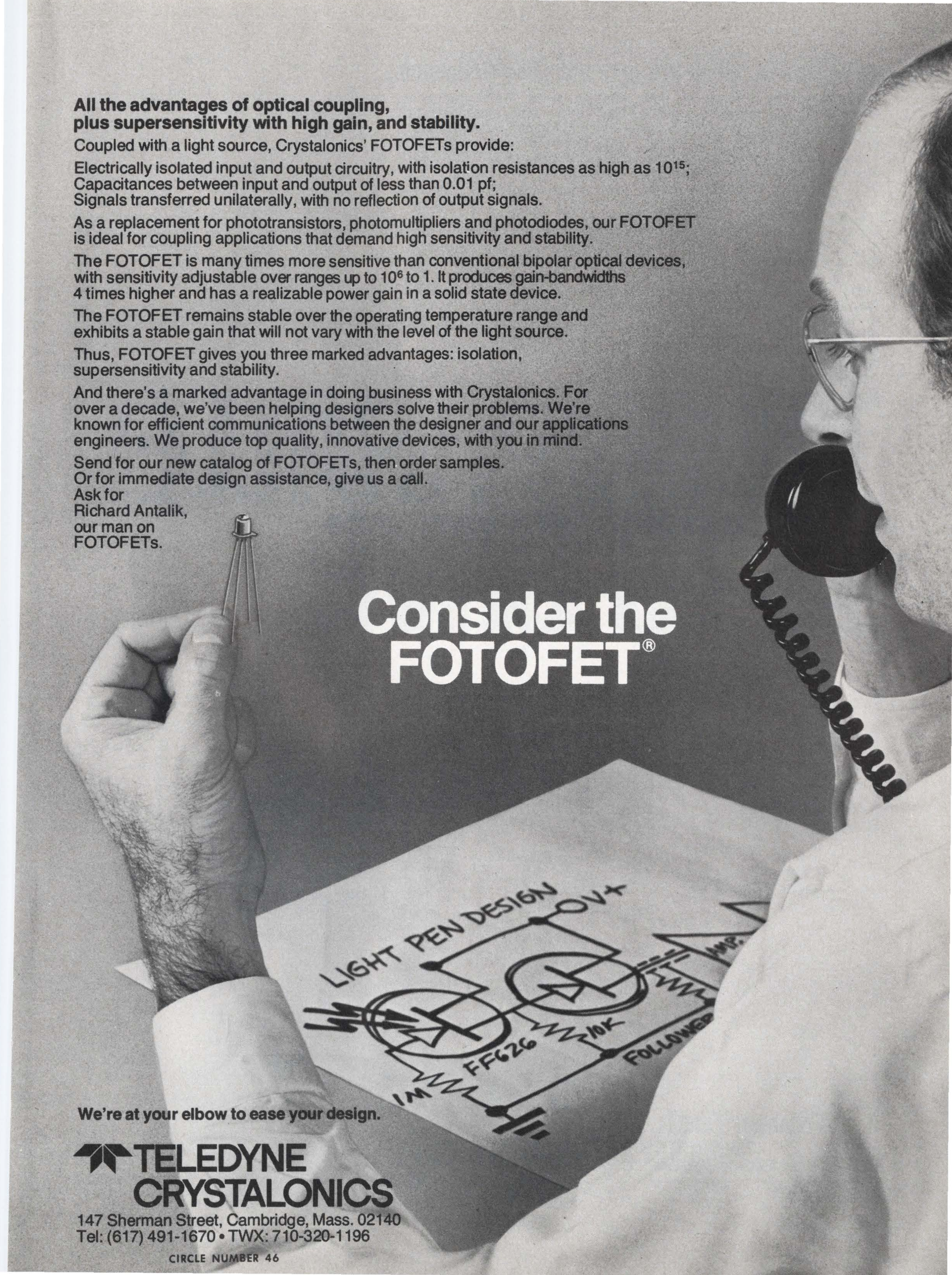
The liquid-crystal material developed for the panel contains four ionic additives and has an operating temperature range of −10 C to 74 C, a threshold voltage of 6.9 V rms and a cut-off frequency of 3.4 kHz. Contrast ratios up to 25:1 have been obtained for the complete panel operating with a maximum rise time of 1.5 s and fall time of 0.8 s.

Helicopter rotor blade used as radar antenna

A unique radar that uses a helicopter rotor blade as the antenna has been developed by the Electronic Systems Dept. of Ferranti in Edinburgh, Scotland. The antenna is built into one blade of the rotor assembly and wholly contained within the aerofoil section.

Because of the large span of the rotor blade a very narrow beam in azimuth—about 1/2 degree—is produced. This sharp beam, together with a 50-ns transmitted pulse and an antenna-rotation speed of 240 rpm, results in a 360-degree plan-view radar picture of high resolution.

The rotor-blade radar, called Rodar, is expected to extend the operational capabilities of helicopters. For example, the high definition of the radar will enable small objects, such as survivors at sea, to be rapidly detected in search and rescue operations.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plus supersensitivity with high gain, and stability.
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Electrically isolated input and output circuitry, with isolation resistances as high as 10¹⁵; Capacitances between input and output of less than 0.01 pf; Signals transferred unilaterally, with no reflection of output signals.
As a replacement for phototransistors, photomultipliers and photodiodes, our FOTOFET is ideal for coupling applications that demand high sensitivity and stability.
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CIRCLE NUMBER 46

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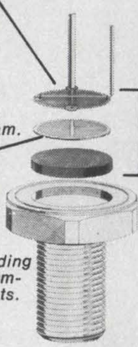
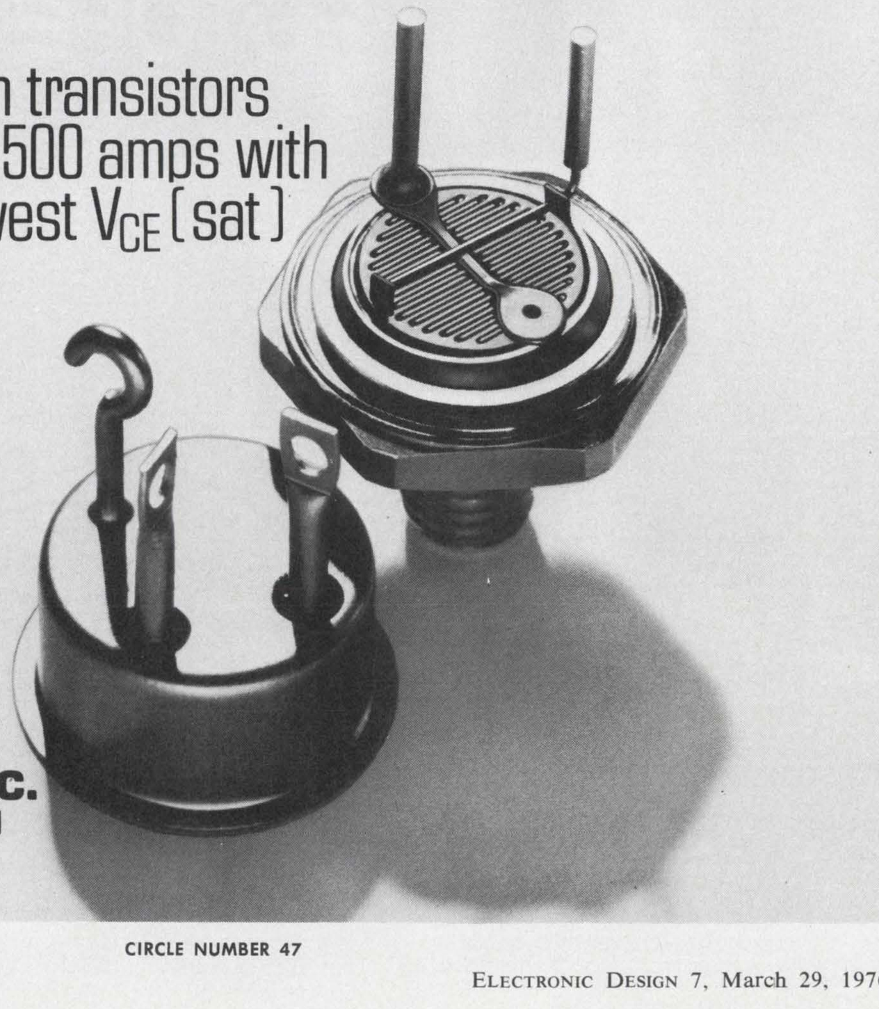
JAN-TX 2N5926	90A	120V	0.6V @ 50A
PT-7511	90A	200V	0.6V @ 50A
JAN-TX 2N5927	120A	120V	0.6V @ 70A
PT-6502	200A	80V	0.7V @ 100A
PT-9502*	500A	80V	0.5V @ 300A

350 Watt Power Rating
*625 Watt Power Rating
Guaranteed SOAR



TO *UN*PARALLEL IS TO SAVE:

Silicon transistors to 500 amps with lowest V_{CE} (sat)



PowerTech, Inc.
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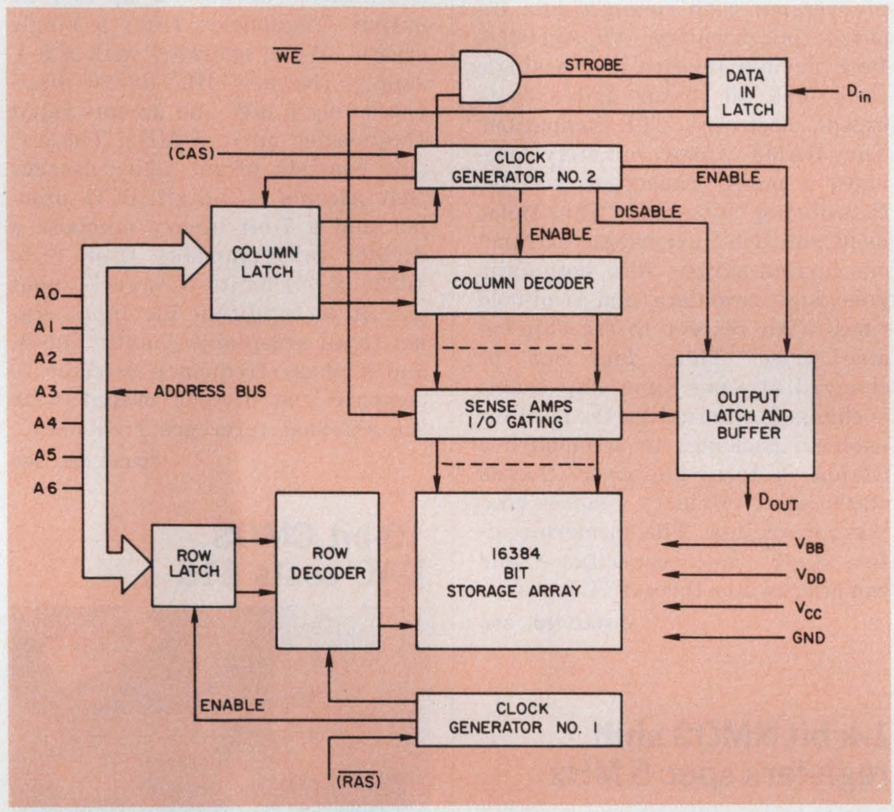
CIRCLE NUMBER 47

16-k bit RAM has the same speed and lower dissipation/bit than 4-k versions



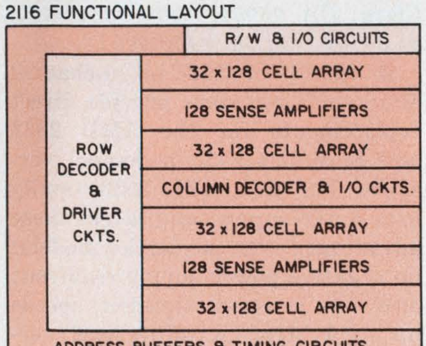
Intel, 3065 Bowers Ave., Santa Clara, CA 95051. (408) 246-7501. P&A: See text.

With the introduction of Intel's 16-k bit NMOS random-access memory—the highest density RAM to date—designers can achieve a 4:1 increase in memory-board density without sacrificing speed and with savings in power.

The new 2116 offers plug compatibility with 4-k dynamic RAMs like the company's 2104. Both units come in 16-pin packages and employ multiplexed addressing. And both specify best access and cycle times of 250 and 375 ns, respectively.

Further, the new semiconductor memory dissipates less than 700 mW in active operation and only 12 mW on standby. Compared with Intel's 4-k RAM, the 2116's power specs represent a reduction in dissipation/bit by a factor of almost four.

2116 FUNCTIONAL LAYOUT



Other features shared by both the 16,384-bit and 4096-bit RAMs include operation from power supplies of 5, −5 and 12 V, similar supply-current requirements, and TTL inputs and outputs. Also, they can both be refreshed in 64 address cycles, and have the same refresh interval requirement of 2 ms.

The pinouts of the two 16-pin RAMs are identical, with one exception: The A_6 address input of the 16-k RAM replaces the chip-select (CS) input of the 4-k RAM. The 2116 has seven address inputs, and the 2104 has six. Other pins are the same: column-address strobe ($\overline{CAS}$), row-address strobe ($\overline{RAS}$), write enable (WE), three-state data output, data input and supplies.

Intel has also developed the Model 3242 address multiplexer and refresh counter for use with the 16-k RAM. It converts a 14-bit-wide address into the 7-wide multiplexed column and row addresses, and controls either 64-cycle or 128-cycle refresh. (The latter is also possible with the 2116). The 3242 comes in a 28-pin DIP.

The 16-k bit memory employs a single-transistor storage cell and uses the company's n-channel silicon-gate MOS technology. The cell design differs from the 2104 in two major respects: two layers of polysilicon are used for interconnections instead of one, and bit-cell lines are diffused, not deposited metal.

The chip-design changes halve cell area to 13 × 35 μm and reduce cell capacitance to 0.03 pF. The resulting chip measures 145 × 235 mils, or about 34,000 square mils—only about twice that of some 4-k RAM chips.

Power dissipation has been kept low by several techniques. For example, half the memory is inactive during operation. Also, sense-amplifier load devices are shut off as soon as the write or restore operation is completed.

Though operating as a 16,384 × 1-bit RAM, the 2116 is divided into

(continued on page 102)

(continued from page 101)

two 8-k RAMs that share a column decoder (see functional layout). Each 8-k RAM has two 32 × 128 cell arrays, which in turn share 128 sense amplifiers.

In normal operation, A_6 selects one of the two 8-k RAMs, and the other 8-k RAM is kept inactive to conserve power. Address lines A_0 to A_5 and the strobe inputs select the bit in the active half. The strobe inputs drive internal TTL-to-MOS level converters and clock generators, which time internal operations. For increased operating voltage margins, address and data inputs as well as the $\overline{CAS}$ and $\overline{RAS}$ inputs, have been augmented with on-chip latches.

A special refresh mode was developed to achieve 64-cycle refresh—the usual amount for a 4-k RAM because of its 64 × 64-cell array. The 2116 is typically a 128 × 128 array, but to require 128 refresh cycles for the 16-k RAM would reduce the availability of memory to the system.

The refresh signal is multiplexed onto the $\overline{CAS}$ input at the $\overline{RAS}$ transition. The output then goes to the high-impedance state. A_6 is ignored, and all cells on the selected word line are refreshed in both 8-k RAMs. Thus, 128 × 2, or 256 bits, are refreshed simultaneously and only 64 cycles are required. For 128-cycle refreshing, read cycles can be used, or alternatively, the $\overline{RAS}$ input can be used to control row-by-row refresh.

Intel plans to produce a family of 16-k RAMs based on the 2116 design. Three versions have been specified to date: The standard 2116 has maximum access time of 350 ns and a maximum read or write cycle time of 500 ns. A dash-2 version provides the top access and cycle times (250 and 375-ns maximum). Finally, a dash-4 version offers maximum times of 300 and 425 ns. All of these times are identical to those of similarly labelled Intel 4-k RAMs.

Production quantities of the 16-k RAM are expected by the middle of the year. Initial prices are $50 for quantities of 50 to 100. Intel says production volumes will reduce 16-k memory costs to 0.1¢/bit by the middle of 1977.

CIRCLE NO. 305

4-k RAMs have 200-ns access

Advanced Micro Devices, 901 Thompson Pl., Sunnyvale, CA 94086. (408) 732-2400. $15.30 to $21.60 (100); stock.

A pair of 4096-bit dynamic RAMs features access times to 200 ns and maximum power dissipation of 750 mW (at 0 C). The RAMs are available in a 22-pin package with separate data input/output circuitry—the Am 9060—or in an 18-pin version with common data input/output circuitry—the Am 9050. Both devices require only a single clock, and all inputs and outputs except clock are TTL compatible. The RAMs' input circuitry provides a purely capacitive load, so that during chip-enable transitions, memories don't experience extraneous current surges. Also, both units guarantee zero-data and read-hold times with respect to the chip-enable pulse. Thus data can be changed at same time chip enable is changed, eliminating the need for external packages to accomplish a timing delay. Moreover clocked static-input circuitry reduces timing constraints. The memories offer 20-pF clock capacitance and can sink two-to-three TTL loads.

CIRCLE NO. 306

1-k bit NMOS shift registers spec 5 MHz

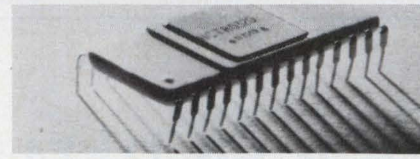
Synertek, 3050 Coronado Dr., Santa Clara, CA 95051. (408) 241-4300. $4.95 to $11.50 (100-999).

A family of 1024-bit n-channel MOS shift registers provide direct replacements for the AMD 2833 and Signetics 2533 p-channel versions. The new SYP 2533 family uses a 5-V supply, and offers these advantages over the earlier models: no negative power supply required; 50% less power dissipation; speeds up to 5 MHz. A militarized version—SYM 2833—operates over the temperature range of −55 to 125 C, and is guaranteed to 2 MHz.

CIRCLE NO. 307

Fellow we know designed a Citizens Band radio for his Volkswagon. He wanted a phone in his bug.

CMOS synthesizer offers 1021 frequencies

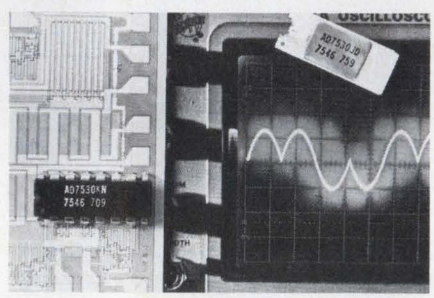


Hughes Microelectronic Products, 500 Superior Ave., Newport Beach, CA 92663. (714) 548-0671. $8.50 (1000).

A CMOS/LSI digital frequency synthesizer can provide up to 1021 output frequencies from a single crystal. When operated with a 5-V supply, the new HCTR0320 dissipates only 5 mW and accepts input frequencies up to 5 MHz. The circuit consists of an adder/decoder that accepts a 3-digit BCD number and a 7-bit binary number; a divider programmable from 3 to 1023; a "Schmitt Trigger" input circuit to condition the input signal to an acceptable counter input, and a phase/frequency detector to compare the divider output with the external reference frequency.

CIRCLE NO. 308

10-bit CMOS DAC costs $15



Analog Devices, Route 1 Industrial Park, P.O. Box 280, Norwood, MA 02062. (617) 329-4700.

A monolithic CMOS multiplying d/a converter features 10-bit accuracy, resolution and linearity, and it costs only $15.00 (in hundreds). The DAC operates from a single 5-to-15-V-dc supply and dissipates only 20 mW, including the ladder network. The unit has a differential nonlinearity tempco of 2 ppm of FSR/°C maximum, gain-error tempco of 10 ppm of FSR/°C maximum and operating temperature range of 0 to 75 C. Output current settles in 500 ns to 0.05% when the DAC switches all digital inputs low to high or high to low with a 10-V reference.

CIRCLE NO. 309

The first true universal LED lamp.

You get constant brightness from 4.5v to 12.5v—or even 16v. And that's not all.

Good-by resistors.
Good-by brightness fluctuation.
Good-by higher loading costs.
Good-by bigger inventories.
Hello universal lamp. That's what it's all about.

The Constant Brightness Lamp (CBL) is a bright new packaging idea from Litronix. The CBL has an IC voltage regulator built into the lamp so the voltage across the lamp doesn't matter so long as it is within a wide range. You can even take the lamp out of one circuit and put it into another. The brightness never varies.

Our CBL's operate over three wide voltage ranges between 4.5 and 16 volts. And they plug into any PC board that accepts a T1 or T1 ¾ package. Even existing boards. What could be more convenient!

Price-wise, they make incredible sense. When you consider you don't have the extra costs for resistors, loading, inventory, and overhead, you can get the convenience of CBL's for about the same installed cost as ordinary lamps.

RLC-200	20 ma @ 4.5-12.5v	T1 ¾ package	37¢ in 1000 pc. quantities
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RLC-210	10 ma @ 4.5-11v	T1 package	40¢ in 1000 pc. quantities

Get turned on. Ask for details on the new Constant Brightness Lamps from Litronix, Inc., 19000 Homestead Road, Cupertino, Calif. 95014. Phone (408) 257-7910. TWX 910-338-0022.

No wonder we're No. 1 in LEDs

litronix

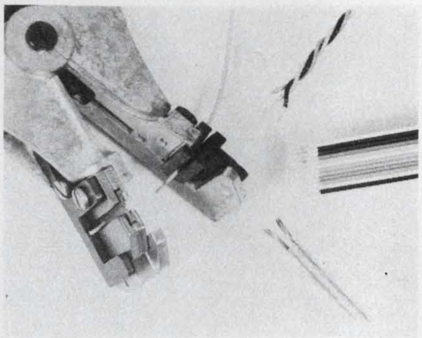
CIRCLE NUMBER 49

Plastic-blade stripper handles multiwire cables

Alpha Wire Corp., 711 Lidgerwood Ave., Elizabeth, NJ 07207. (201) 925-8000. $39.95 with three blade sets (unit qty).

A new concept in wire stripping, the Alpha plastic-blade stripper, uses blades made of a space-age plastic called Stilan. Its cutting edges are harder than wire insulation, but softer than copper. This allows the blades to strip insulation from a wire or cable without damage to the conductors and without the need for careful selection of the proper sized notch as with a conventional stripper blade.

The stripper can remove the insulation from multiwire cables such as twisted pairs, flat cables and twin-lead antenna wire in one action without the need to separate the individual wires, and do it as quickly as from ordinary hook-up wire.



Alpha claims that time studies show the plastic-blade stripper can operate at least 25% faster than models using steel blades. The wires being stripped don't have to be carefully positioned between the stripper blades; a number of different wires can be stripped at the same time; and the stripper requires no adjustment for wire size, type or number of conductors. Even poorly manufactured wire with off-center conductors is protected against nicks; the plastic blades cut through the insulation, but deform around the conductor.

The stripper can handle any size wire from AWG 12 through 28 with almost any type of insulation —PVC cross-linked polyethylene, rubber, neoprene—except Teflon and Kynar.

Stilan is a patented polymer originally developed for aerospace applications. The cutting edges last up to 50,000 strips on simple hook-up wire. Replacement injector blades slide easily into place. No tools are needed for replacement.

CIRCLE NO. 301

Hand-operated tool cuts and crimps leads

Electronic Production Equipment Co., 6 Kane Industrial Dr., Hudson, MA 01749. (617) 562-9123. $9.50; stock.

A hand tool, the Model 975, is designed to flush out and crimp component leads. It is lightweight, weighing only 5 oz., and measures 5 in. long. The return-spring is double-coil steel and plastic handles are shaped to fit the palm of the hand comfortably.

CIRCLE NO. 320

Mini transistor sockets handle EIA size devices

Garry Manufacturing, 1010 Jersey Ave., New Brunswick, NJ 08902. (201) 545-2424. From $0.50; 4 to 6 wks.

Miniature packaging sockets, which will accept standard EIA-size transistors, are available for RO-52, TO-5, TO-18 and in-line transistors, with 3, 4, and 6 pins. Pin circles have either 0.1 or 0.2 in. diameters. The sockets feature closed-entry contacts which resist distortion or damage from misaligned or over-sized leads. Terminal sleeves are brass and the plating is gold over nickel. Socket terminals for most applications are available: printed circuit, turret, solder-pot, and wrapped-wire.

CIRCLE NO. 321

Solvent disintegrates cured epoxy compounds

Hightemp Resins, Inc., 225 Greenwich Ave., Stamford, CT 06902. (203) 325-4124. See text.

Hightemp 5625 can disintegrate cured epoxy compounds. It is nonflammable, noncaustic and nonacidic and will not attack metals. The solvent is available in minimum 10 lb. containers for $0.75/lb. and in 45 lb. lots for $0.69/lb.

CIRCLE NO. 322

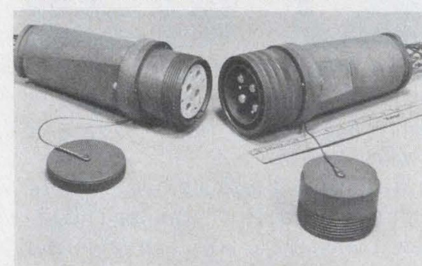
Conductive grease helps make RFI-tight case

Emerson & Cuming, Inc., Canton, MA 02021. (617) 828-3300. $4.70/lb (5 lb and up); stock.

Eccoshield CO is a conductive grease that has a volume resistivity of less than 100 Ω-cm. It can lubricate metal-to-metal sliding contact areas, which require continuous electrical conductive paths. The grease can also ground enclosures, which require lubrication to overcome friction as well as electromagnetic-interference control and rf caulk metal-to-metal joints. Proper shield design and use of Eccoshield CO can produce insertion loss values of 100 dB.

CIRCLE NO. 323

Heavy-duty connectors meet MIL-C-22992E

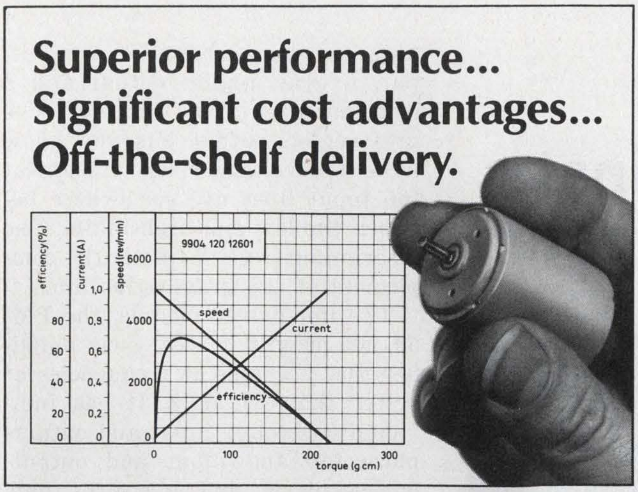


Amphenol Connector, 2801 S. 25th Ave., Broadview, IL 60153. (312) 261-2000. For 100-up quantities: $100 (mated pair); stock.

A line of multicontact, heavy-duty, waterproof plug and receptacle connectors is fully qualified to latest specifications of MIL-C-22992E, Class L. Shell size 28, 32, 44 and 52 connectors, with current ratings of 40, 60, 100, and 200 A, respectively, are initially available. The power distribution connectors offer several significant features: An arc-suppression chamber within the connector protects users from serious shock hazards, an internal multiple-part environmental sealing mechanism completely waterproofs the assemblies, whether mated or unmated, a built-in five key shell polarization prevents mismatings and an integral safety ground is included in compliance with requirements of OSHA and the National Electrical Code for grounding connectors.

CIRCLE NO. 324

Superior performance... Significant cost advantages... Off-the-shelf delivery.



Miniature ironless rotor DC motors. Ideal for cassette drives.

The typical performance graph shown above speaks for itself. Our miniature ironless rotor 12 VDC motors not only have the desired characteristics for cassette drives, they also offer an important price advantage—under $10.00 in 500-piece lots. As low as, if not lower than, any competitive motor. Fast, off-the-shelf deliveries, too!

Motor time constant is 23 MS; rotor torque 50 gcm; starting torque 230 gcm. Plus, low noise levels and smooth cog-free operation. The motor can also be ordered with double shaft for use as a tach motor. 24 VDC models also available.

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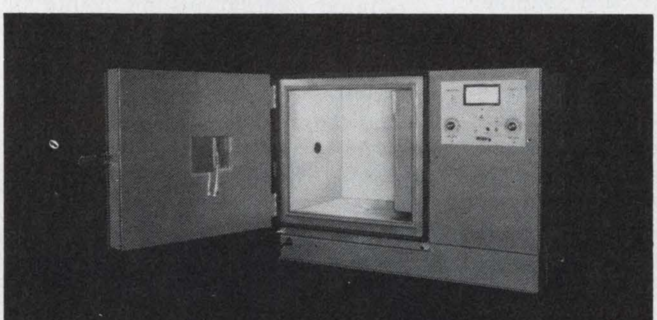
CIRCLE NUMBER 54



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It's extremely versatile, too. Benchmaster offers medium or extreme temperature ranges—with or without humidity.

Benchmaster is available in 4 performance variations:

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Model BTRS: –30°F to 350°F with humidity
Model BTR: –100°F to 350°F with humidity
Model BTC: –100°F to 350°F without humidity

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CIRCLE NUMBER 55

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MICROTEMP is a reliable, accurate, easy to install, "one shot" thermal limiter. Because of its patented design and construction, it won't derate. And, it's unaffected by age or extended use.

Compare this data:

- opening tolerance— ±3° F.
- temperature range— 58 to 242° C. (136 to 468° F.)
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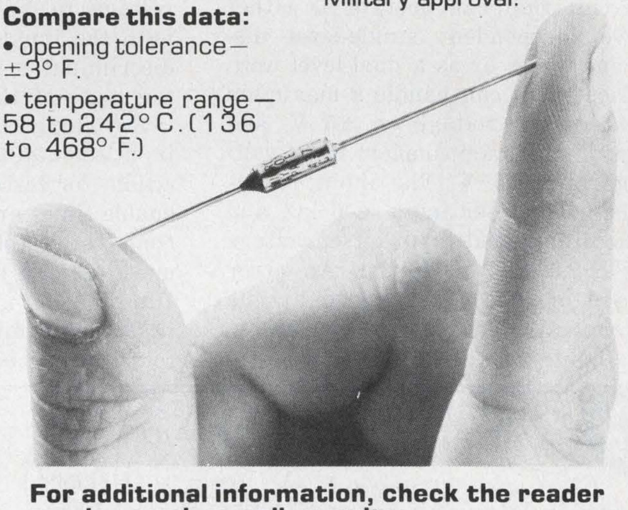
- economical – priced as low as 9¢
- proved reliable in millions of on-the-job applications
- installation ease—assorted terminations, mounting packages and insulations are available

Recognized under the Component Program of Underwriters' Laboratories, Inc. UL File #E40667A. CSA and BSI Certificate #5041 approved. Recognized by MITI and VDE. Military approval.



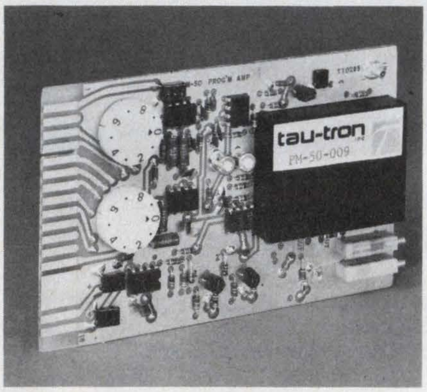
For additional information, check the reader service card, or call or write:

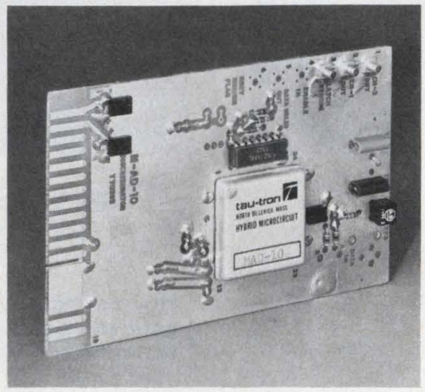
MICRO DEVICES CORP.

1881 Southtown Blvd., Dayton, Ohio 45439
Ph: (513) 294-0581 Telex: 28-8087

CIRCLE NUMBER 56

Drive lines and discriminate pulses at 50-MHz data rates





Tau-Tron, 11 Esquire Rd., North Billerica, MA 01862. (617) 667-3874. P&A: See text.

High-speed comparators and line drivers for automatic test equipment have been introduced by Tau-Tron. These units can operate at frequencies of over 50 MHz and are available in either printed-circuit mountable modules or complete PC-card assemblies.

The analog-comparator module, the M-AD-10, is a 1 × 1-in. hybrid circuit that can operate as either two independent single-level discriminators or as a dual-level unit. Each input can handle a maximum differential voltage of ±5 V, and has a maximum common input voltage of ±3.5 V. The input resistance for either input is 6 kΩ, and the differential input offset voltage is ±2.5 mV at 100 Ω. An error band of ±2 mV is added by the comparator to the input signal.

Inputs of the M-AD-10 are intended for ECL-level signals, as are the outputs. However, the outputs have open-emitter transistors that require external termination.

When operated as two independent comparators, each discriminator has its own threshold adjustment. In the two-level mode, the two data inputs are tied together and the trip points can be set using separate threshold adjusts. Each discriminator also contains a latch that either permits the reference voltage to be compared normally with the input signal, or locks the discriminator output to the existing state of the data.

Switching times are fast—the input-to-output, high-to-low transition, for instance is 10 ns. Latch-enable times are also 10 ns, and the time the strobe line requires to move data to the output is a mere 1 ns.

The discriminator module offers four usable outputs—a channel-1 high output, a channel-2 low output, a gray region output and a discriminator-valid output. The gray-region output lets you know when the voltage levels present at the input lines are somewhere between the low and high limits. The discriminator-valid line is the complement of the gray-region line.

The line-driver module, the PM-50, is a programmable power amplifier that operates at frequencies of better than 50 MHz. It has individual control of input and output-pulse top and input and output-pulse bottom and measures only 1.25 × 2 in. The input is designed for ECL-level signals and is terminated by 50 Ω to −2 V. (50 Ω to ground is available as an option.)

Both the input and output pulse tops and bottoms can be adjusted over a ±2-V range, although ±5-V adjustment ranges are available on the outputs as an option. The amplifier has an input impedance of 10 kΩ and will reproduce the original input signal to within ±20 mV. Rise and fall times for the amplifier are 2 ns, typically, with the total propagation delay reaching only 7 ns.

Signal aberrations on rising or falling edges are guaranteed to be no more than 100 mV pk-pk or 7 percent (whichever is greater) when the module is properly terminated. Output terminations must be specified when the module is ordered, and can be any value between 50 and 100 Ω.

Prices for the modules start at $350 for the M-AD-10 discriminators and reach $450 for the amplifier module. Circuit cards with the modules built in range from $400 to $585. The cards measure 2.5 × 5 in. Modules and cards are available from stock.

CIRCLE NO. 304

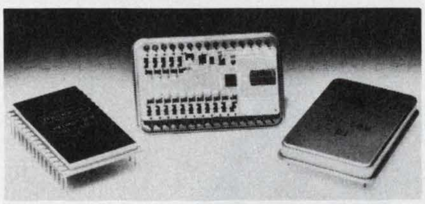
Improved acquisition modules cut costs

Data Translation, 109 Concord St., Framingham, MA 01701. (617) 879-3595. See text; 4 wks.

The DATAX II series of modular data-acquisition systems offers improved specs at lower prices than the company's older DATAX I series. Models DT5720 and DT5740 offer 12-bit resolution and throughput speeds of 50 and 25 kHz at prices of $575 and $475, respectively. The modules have three-state outputs, which permit their use with most microcomputer systems. Linearity of the DATAX II series is ±0.5 LSB over 0 to 70 C and the systems have an accuracy of 0.03% for the full-scale range. All units are housed in 3 × 4.6 × 0.375 in. metal modules.

CIRCLE NO. 325

Multiplying d/a accepts 13-bit input words



Beckman Instruments, Helipot Div., 2500 Harbor Blvd., Fullerton, CA 92634. (714) 871-4848. From $100 (100-up); stock.

The 877-69 series of multiplying d/a converters includes units with resolution of up to 13 bits. They have provisions for external ac or dc references for full four-quadrant operation, can handle ac reference frequencies from dc to 10 kHz, and have an MSB inversion input for TWO's complement or offset binary arithmetic options. The 30-pin, dual in-line metal or ceramic packaged devices are available in two accuracy (linearity and gain) code models. Typical accuracy of Model 877-69M-D1 (metal package) is ±0.012% at 25 C, guaranteed to ±0.025% over −55 to +125 C, or ±0.05% at 25 C guaranteed to 0.1% for Model 877-69M-D2. Typical accuracy of Model 877-69C-C1 (ceramic package) is ±0.012% at 25 C guaranteed to ±0.025% over −25 to +85 C or ±0.05% at 25 C guaranteed to ±0.1% for Model 877-69C-D2.

CIRCLE NO. 326

IT'S FA

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J

Stephen J. Scorza
General Manager
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In July 1975, Nobel assumed U.S. stocking, marketing, and sales operations for Jermyn, an English company. (Jermyn manufactures semiconductor hardware: IC and transistor sockets, mounting pads, transi-pads, insulators, and heat sinks.)

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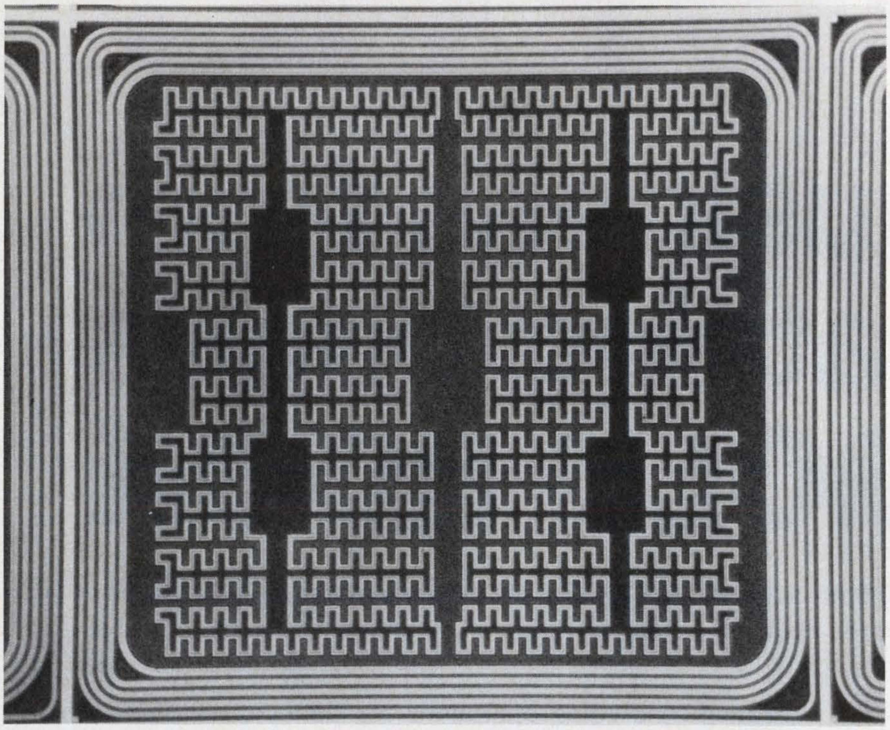
ELECTRONIC DESIGN'S GOLD BOOK IS WORKING ...IT'S WORKING FOR READERS...AND IT'S WORKING FOR ADVERTISERS, TOO.

10 & 15-A transistors switch fast and have high gain



General Semiconductor Industries, 2001 W. Tenth Pl., Tempe, AZ 85281. (602) 968-3101. See text; up to 1000 pieces available from stock.

The first 10 and 15-A power transistors that have total switching times of less than 1 μs are available from General Semiconductor Industries. Their dc-current gains are at least 10—a figure most other manufacturers require Darlington configurations to get, and then only at slower speeds.

Of the discrete transistors already on the market, the one that comes closest is the SVT 400-12 from TRW Power Semiconductors (Lawndale, CA). It is a 12-A, 400-V device with a maximum rise time of 0.5 μs, a maximum storage time of 2 μs, and a maximum fall time of 0.5 μs. Its dc-current gain is at least 10.

In comparison, the XGSR15040 from General Semiconductor is a 15-A, 400-V device that has a maximum rise time of 0.07 μs, a maximum storage time of 0.35 μs and a maximum fall time of 0.2 μs. Minimum dc current gain is also 10. There are also 250, 300 and 350-V versions with the same switching speeds but minimum gains of 20, 15 and 10, respectively.

General Semiconductor's 10-A device has the same gains at 250, 300 and 350-V as the equivalent 15-A versions and are just as fast.

These General Semiconductor transistors all come in a standard TO-3 package. The allowable junction temperature for the transistors ranges from −65 to +175 C. Saturation voltage on all of the General Semiconductor devices is no higher than 0.8 V.

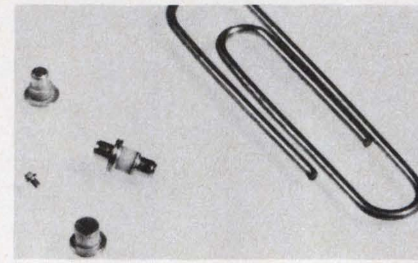
Costs, in 100-999 quantities, for the 15-A transistor start at $14.75 for the 250-V unit and increase to $20 for the 400-V unit. 10-A device pricing ranges from $13 for the 250-V unit to $14.25 for the 350-V unit.

TRW's transistors cost $8 to $9 for 100-piece lots.

General Semiconductor CIRCLE NO. 302

TRW CIRCLE NO. 303

Varactor tuning diodes have Qs of 12,000

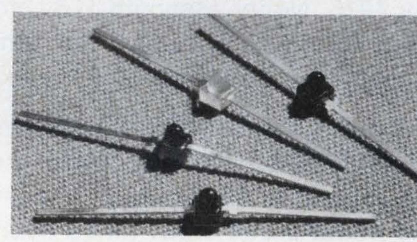


Alpha Industries, 20 Sylvan Rd., Woburn, MA 01801. (617) 935-5150. $75 to $98 (small qty.); 15 days.

The DVE4550 series of gallium arsenide tuning varactors has wide tuning ratios and high values of Q. A choice of five standard ceramic/metal packages is available. All diodes are burned-in prior to final measurement. Some of the diode characteristics (when measured at 25 V and 10 μA) include: capacitance range, 0.4 to 4 pF; Q_{-4} range (at 50 MHz), 4300 to 12,000; Q_{-4} range (at 1 GHz), 215 to 600; and reverse leakage current at 20 V bias, 100 nA.

CIRCLE NO. 327

LED lamps come in many colors



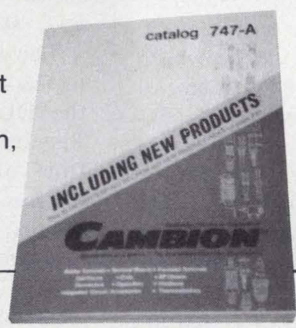
Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, CA 94304. (415) 493-1501. $0.19 to $.65 (100-999).

Four new low-cost LEDs in a radial-lead subminiature epoxy package include a red, yellow, green and a high-efficiency red type. They can be mounted in stacked arrays on 2.21-mm centers for high-density applications. A tinted diffused lens for each color provides high on-off contrast with a wide viewing angle. At a forward current of 10 mA, the red HP 5082-4100 has an axial luminous intensity of 0.7 mcd; the red HP 5082-4101, 1 mcd. Forward voltage is 1.6 V. The high efficiency red has an output of 3 mcd at a forward current of 10 mA and forward voltage of 2.2 V.

CIRCLE NO. 328

Behind every good designer is a new Cambion catalog.

Our new giant 747-A general catalog has a 56-page section just on new products introduced since our last big catalog. That's in addition to our familiar products like solder terminals, terminal boards, insulated terminals, coil forms, coils, RF Chokes, connectors, capacitors, IC accessories, hardware and thermoelectrics. You can get one behind you free just by writing: Cambridge Thermionic Corporation, 401 Concord Ave., Cambridge, MA 02138.



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CIRCLE NUMBER 61

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And it does it on a wide 100mm channel and at a remarkable 30Hz. Available in 2, 3 and 4 channel models with all the Gould exclusives, of course.

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CIRCLE NUMBER 62

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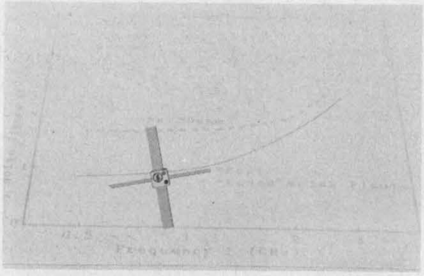
FOR DATA CIRCLE NUMBER 271
FOR DEMONSTRATION CIRCLE NUMBER 272

Microwave transistors have 1.7 dB of noise



Fujitsu Limited, Syuwaonarimon Building, 1-1 Shinbashi, 6-Chome, Minato-ku, Tokyo 105, Japan.

A microwave low-noise transistor, the FJ203, has noise characteristics of 1 dB at 1 GHz and 1.7 dB at 2 GHz. The transistor is passivated with silicon-nitride film and is housed in a metal/ceramic hermetic package. Specifications of the transistors include: a gain-bandwidth product, f_T, of 8 GHz; a maximum available power gain of 13 dB at f = 2 GHz; and a power dissipation of 200 mW, max.

CIRCLE NO. 329

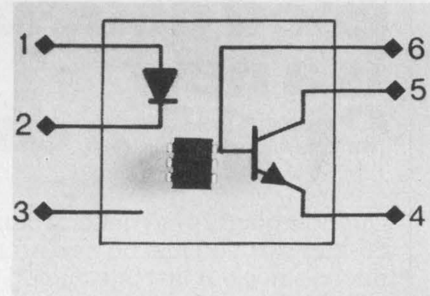
Voltage crowbars handle 3 to 235 A continuous

MCG, 297 Skidmore Rd., Deer Park, NY 11729. (516) 586-5125. From $3 (1000-up); 2 wks.

The Series LVC-1 dc crowbars switch in less than 10 μs from an open to a virtual short circuit. Potentially destructive energy from transients, series regulator faults, misadjustments, etc., can be almost eliminated. The crowbars recover when power is momentarily removed. Trip voltages are available from 4.7 to 600 V dc at current levels ranging from 3 to 235 A dc. Temperature range is −55 to 100 C.

CIRCLE NO. 330

Improved opto-isolator replaces earlier version



Energy Electronic Products, 6060 Manchester Ave., Los Angeles, CA 90045. (213) 670-1275. $0.89 (100-up); stock.

The EL 74 A opto-isolator comes in the same six-pin plastic DIP as the EL 74, which it is replacing. The improved unit has a response time of 2 μs compared with 20 μs for the old; a dark current of 50 nA instead of 500 nA; and a breakdown voltage of 30 V instead of 20 V. Current transfer ratio, isolation voltage and isolation resistance are the same as for the older units (35%, 1500 V, and 100 GΩ, respectively).

CIRCLE NO. 331

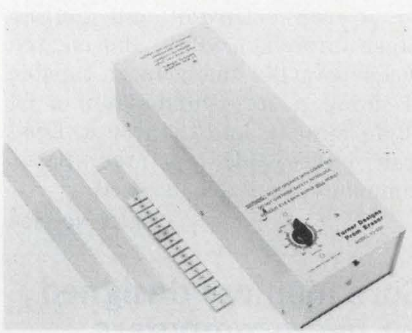
Disc storage multiplexed among four processors

Wang Laboratories, Inc., 836 North St., Tewksbury, MA 01876. (617) 851-4111. $800: first units, $500: each of three additional; 2 wks.

Disc-storage units are one of the most expensive elements of any data-processing system, according to Wang. With its new Model 2230MX-A/B disc multiplexer, a user can cut this cost. The multiplexer allows up to four System 2200 processors to share a single disc drive. Access is on a "daisy-chain" basis, with a master controller polling each processor sequentially on an equal-priority basis. All processors sharing the disc have almost concurrent access at all times, since a single access typically requires from 20 to 80 ms to complete.

CIRCLE NO. 332

PROM eraser delivers calibrated UV dose



Turner Designs, 2247A Old Middlefield Way, Mountain View, CA 94043. (415) 965-9800. $295 (unit qty).

The Model 30-000 PROM eraser can deliver the correct UV wavelength and intensity for MM5203Q, 1702A, 2708 and similar type PROMs, and handle as many as 60 simultaneously. Devices are loaded with removable metal trays, which protect the PROMs against electrostatic damage. Operation is controlled by an adjustable timer, calibrated in increments of 1 min. Exposures can be set from very short durations to more than 1 h. Lamp start is automatic. The operator is protected from UV exposure by a door interlock and from ozone by a specially designed lamp envelope.

CIRCLE NO. 333

CIRCLE NUMBER 65

CIRCLE NUMBER 66

2400 lpm printer sells for $3000

Houston Instrument, One Houston Square, 8500 Cameron Rd., Austin, TX 78753. (512) 837-2820. See text.

A 2400 line/min printer, Model 8210, sells for only $3000. Its output is 80-columns wide on 8-1/2-in. paper. Also a 132-column output, which prints on 14-7/8-in. paper at 1400 lines/min sells for $3785. Their features and performance rival that of $10,000-to-$20,000 printers, according to the manufacturer. The features include a full-print line-buffer memory, automatic top-of-form advance, 400-in/min paper-advance speeds, the ability to use both roll and fanfold paper interchangeably, and enough speed to make the printer capable of doing a core dump from a 64 kbyte mini in less than 30 s. Low-cost electrostatic printer paper commonly available is used.

CIRCLE NO. 334

Core memory designed for microcomputers

Ampex Corp., P.O. Box 33, Marina del Rey, CA 90291. (213) 821-8933. $99.95 (OEM qty).

The MCM-4300 is the second in Ampex' family of microcomputer core memories designed for terminal, peripheral and microprocessor applications. The memory provides a nonvolatile storage of 2048, 1024, 512 or 256 four-bit data words. Applicable to read/modify/write applications, the memory modules provide data access in 450 ns. Only a single uncompensated 5-V power source is required. Each module includes timing and control, data and address registers, decoding and drive circuits and a TTL-negative-true interface. Multiple modules may be combined in parallel for larger capacities.

CIRCLE NO. 335

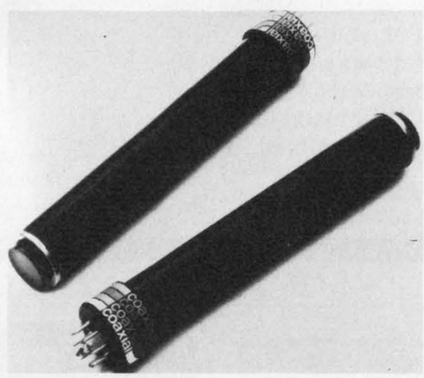
Sensitive relays come in low-profile package

Gould Inc., Allied Control Div., 100 Relay Rd., Plantsville, CT 06479. (203) 628-9654. From $3.15 (1 to 24); stock.

The MPCS relays have a 160 mW sensitivity at pull-in. They are available in either a 1-form-C or 2-form-C contact configuration. Either configuration can switch 2 A. The relays are also low-profile units—only 0.415 in. high × 0.6 wide × 1.1 in. long.

CIRCLE NO. 336

Lead-oxide vidicons offer users many plusses

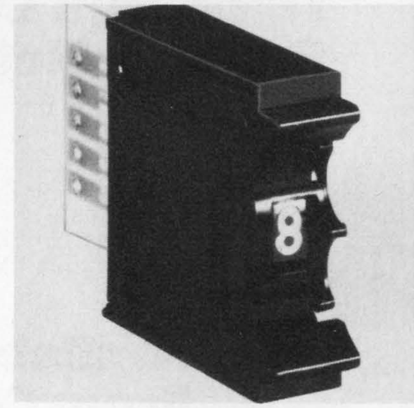


English Electric Valve North America Ltd., 1 America Dr., Cheektowage, NY 14225. (716) 632-5871. $1925 to $2200 ea.; stock.

The P8130 series of Leddicon (lead-oxide vidicon) TV camera tubes has five advantages over typical vidicons. Because of its coaxial construction it offers: separate or integral mesh operation, reduced line-scan pickup, operation at any attitude, self-generated or variable-light bias that results in low lag and good dynamic resolution with uniform dark current, and use in virtually any 30-mm-diameter camera. The tubes fit standard, unmodified, 30-mm sockets (such as type 56021) and require a total current of 300 mA for energizing the cathode heater and internal light bias source. The heater voltage of the tube is 6.3 V ±5%, the ratio of capacitance of the signal electrode to that of all other electrodes is 3 pF to 6 pF and the peak spectral response is approximately 500 nm.

CIRCLE NO. 337

Narrow thumbwheel switches cut panel space

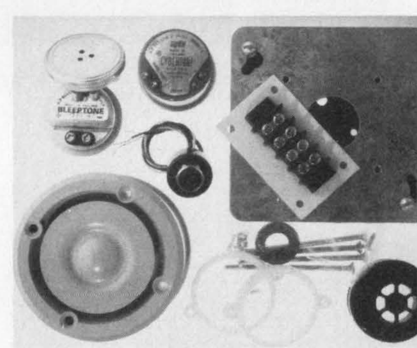


Cherry Electrical Products, 3600 Sunset Ave., Waukegan, IL 60085. (312) 689-7702. $2.15 (2000-up); stock.

A 0.35-in.-wide thumbwheel switch series, the T35, has 0.16-in.-high dial characters. The T35-02A comes in a black-gloss finish and has BCD outputs. The T35 series thumbwheels may be ordered individually or in assemblies of several switches ganged side-by-side. An assembly of 40 switches complete with end caps, uses only 1 × 12 in. of front-panel space.

CIRCLE NO. 338

Bleep to blast with this sound kit

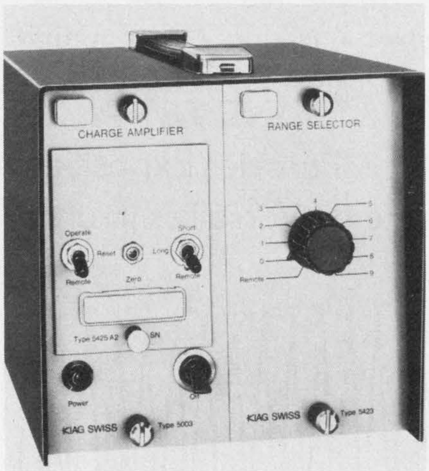


C.A. Briggs, Co., P.O. Box 151, Glenside, PA 19038. (215) 885-2244. $34.95 (unit qty); stock.

The new Cybersonic designer's kit makes it possible for the designer to listen to and demonstrate a bleep to a blast range of sounds. The 14 sounds that can be produced from the devices and accessories included in the kit provide nominal sound-pressure levels of 65 to 90 dBA at distances of 3 to 10 ft. Current drain is in the range of 3 to 30 mA at the nominal-operating voltage of 12 V dc.

CIRCLE NO. 339

Charge amplifier works over wide range



Kristal Instrument, 2475 Grand Island Blvd., Grand Island, NY 14072. (716) 773-4150. From $300 to $975; stock to 2 wks.

Charge amplifier, type 5003, and range selector, type 5423, convert electrical charge signals (100 to 10^6 pC) from piezoelectric transducers into proportional voltages for direct reading on a scope or other indicating instrument. The amplifier comes with three, six or nine ranges, which can be set manually or, optionally, by remote control. Fine adjustment of the individual range is also possible to calibrate the amplifier for a specific transducer.

CIRCLE NO. 340

High-voltage pulser sells for $965

Instrument Research Company, P.O. Box 231, Lincoln, MA 01773. (617) 897-7647. $965; 30 days.

Model 941 power pulse generator is priced below $1000. Featuring an output adjustable to 2 kV at load currents to 1 A, the new unit maintains a clean pulse into an essentially capacitive load. The driver features complementary TTL outputs together with an independent ±30-V offset and amplitude capability—a combination which permits driving all logic families directly. The 941 thereby offers four simultaneous outputs together with five modes of operation—single shot, triggered, gates, delayed and normal PRF.

CIRCLE NO. 341

Analog VOMs, move over! Here's a pocket DVM

Sencore, Inc., 3200 Sencore Dr., Sioux Falls, SD 57107. (605) 339-0100. $124.

Pocket-portable DVM35 takes aim at portable analog VOMs. The unit features three-digit readout, 1% dc voltage accuracy, coupled with 15-MΩ input impedance. Capabilities include 1-A and 10-MΩ measurements plus 2000 V dc with a "times two" button on the probe that doubles all voltage ranges for expanded field use, plus increases the input impedance to 30 MΩ. DVM35 weighs only 1 lb with AA-size batteries. It is said to be "drop-proof" and "burn-out-proof."

CIRCLE NO. 342

Sweep generator carries low price tag

Wavetek Indiana, 66 N. 1st Ave., Beech Grove, IN 46107. (317) 783-3221. $495; 30 days.

Model 1050A sweeper sells for less than $500. The broadband instrument covers a frequency range of 1 to 400 MHz and has a calibrated rf output of from +10 to −60 dBm. Flatness of ±0.25 dB is accomplished with p-i-n diode leveling and both harmonic and nonharmonic spurious signals are 30-dB below the output. Sweep linearity is 2%.

CIRCLE NO. 343

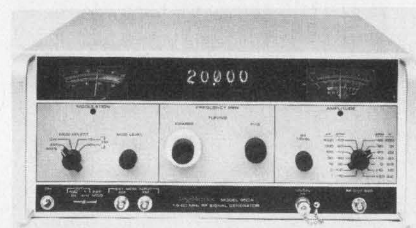
Digital temp meter comes in DIN case

Columbia Research Labs, Woodlyn, PA 19094. (215) 532-9464. $350; 6 wks.

Model DT-103 digital temperature meter is packaged in a DIN-standard case measuring 3.780 × 1.890 × 3.750 in. The instrument displays directly in degrees C or F on a 0.55-in. 3-1/2-digit display. A single platinum resistance probe covers −200 to 500 C. Accuracies range from ±3 C over the full range to ±1 C from −100 to 100 C.

CIRCLE NO. 344

Sig gen tunes from 1.5 to 80 MHz in one band



Logimetrics, 121-03 Dupont St., Plainview, NY 11803. (516) 681-4700. $2275; 60 days.

Model 950A FM-AM signal generator is continuously tunable over the range of 1.5 MHz to 80 MHz. The unit offers direct 5-digit frequency readout and is said to be the lowest priced generator in its class to provide this feature. Calibrated FM deviation of 0 to 10, and 30 kHz is read directly from a meter on the front panel. FM distortion is less than 3%.

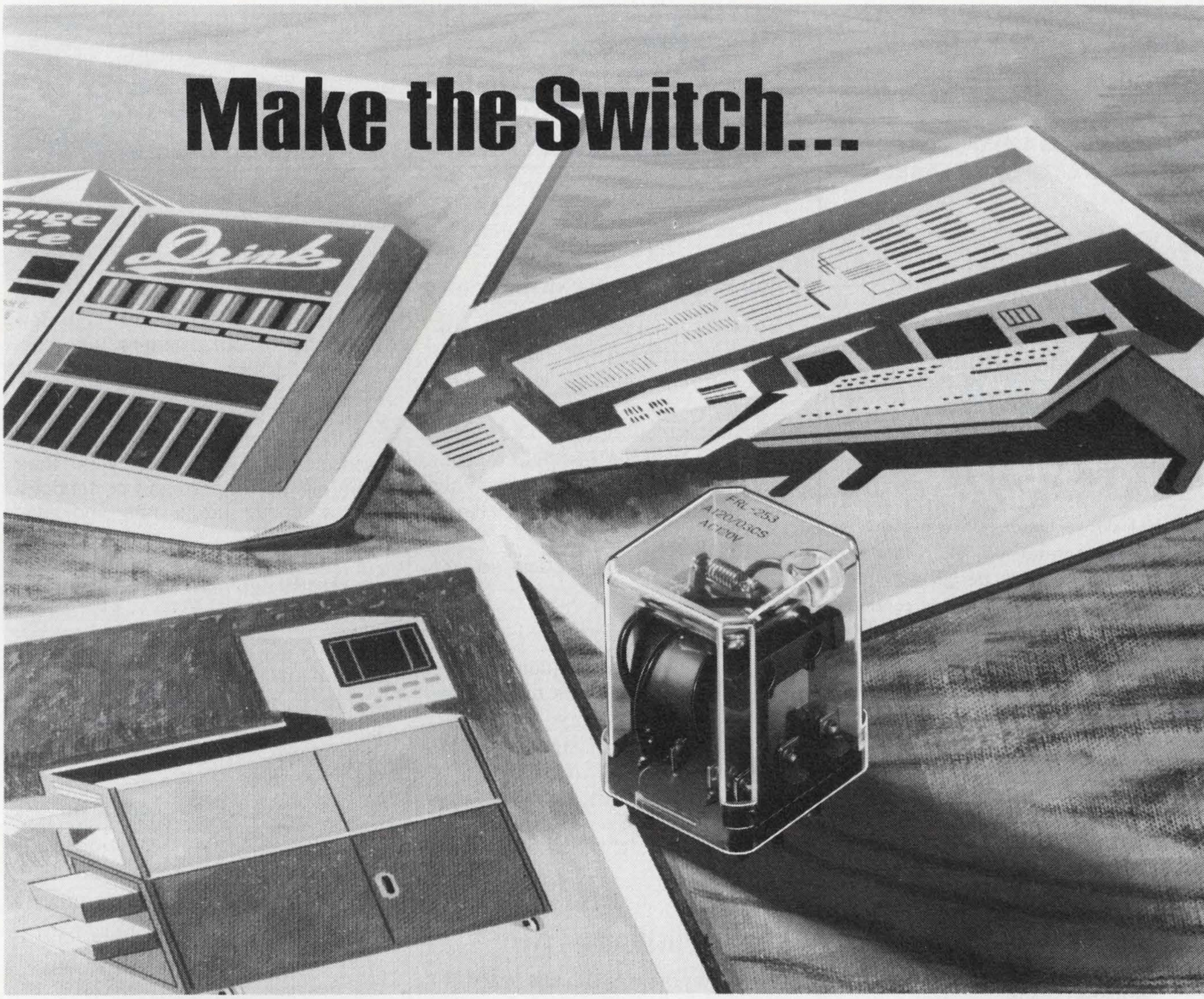
CIRCLE NO. 345

PROM copier features hexadecimal key entry

Technitrol, Inc., 1952 E. Allegheny Ave., Philadelphia, PA 19134. (215) 426-9105. $850.

Model 107K is a new PROM programmer/copier/reader/verifier with hexadecimal keyboard for entry of data and addresses. The unit provides auto-copy between selectable minimum and maximum addresses, programs or lists addresses sequentially or randomly, verifies master to copy while reading or writing, stops on error detect, displays copy data and address in "read," and displays keyboard data and address in "write."

CIRCLE NO. 346



Fujitsu quality miniature power relays

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Are you a maker of vending machines, control equipment, business machines, communications gear, or entertainment products? If so, then chances are you're a large consumer of miniature power relays, especially in the up-to-10-amp range. If you think about it for a minute, you're probably willing to consider an alternate source for your relays, if this maker can match the quality and performance of your present source's products, yet at a price that will spell savings for you. Well, now that you've thought about it, take a look at what Fujitsu has to offer.

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CIRCLE NUMBER 76

Application Notes

Power-supply performance

How to make accurate load regulation measurements by using Kelvin four-terminal connections is covered in a bulletin. Proper metering techniques and line sources as well as thermal environment and difficulties in measuring tempco are discussed. Deltron, North Wales, PA

CIRCLE NO. 347

Audio products

How to use low-frequency wave and spectrum analyzers to measure distortion, frequency response, wow and flutter, signal-to-noise ratio and cross-talk of high-quality audio products are detailed in a 16-page brochure. Hewlett-Packard, Palo Alto, CA

CIRCLE NO. 348

Data-acquisition system

An interfacing scheme used to connect minicomputers to groups of analog transducers and voltage sensors is described in a six-page note. Circuit drawings as well as a full timing diagram for random and sequential channel operation are included. Datel Systems, Canton, MA

CIRCLE NO. 349

Arithmetic subroutine

A comprehensive, powerful new subroutine used to dynamically evaluate arithmetic expressions is described in a 52-page booklet. This subroutine, written using a modern structured programming compiler, is available to the higher order language IBM 370 programmer, enabling him to instantly enhance his system by adding sophisticated arithmetic specification to his user communications. National Institute of Health, Div. of Computer Research and Technology, Bethesda, MD

CIRCLE NO. 350

Vendors Report

Annual and interim reports can provide much more than financial-position information. They often include the first public disclosure of new products, new techniques and new directions of our vendors and customers. Further, they often contain superb analyses of segments of industry that a company serves.

Selected companies with recent reports are listed here with their main electronic products or services. For a copy, circle the indicated number.

Spectra-Strip. Interconnection devices and systems.

CIRCLE NO. 351

Aeronautical Radio (ARINC). Air-ground-air communications service, electronic switching systems and intercity communications.

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S.R.C. Laboratories. Photomultiplier tubes and fluid-flow inducing devices.

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SRI. Basic and applied research.

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Triangle Industries. Electrical products for construction industry, pre-insulated pipe, automatic merchandising machines and music systems, coin-operated phonographs and dollar-bill changers.

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Union Carbide. Chemicals and plastics; gases, metals and carbons, and consumer and related products.

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New Literature

Thumbwheel switches

Photographs, descriptions, specifications, truth tables and mounting instructions of thumbwheel switches are offered in an eight-page catalog. C&K Components, Watertown, MA

CIRCLE NO. 361

IC sample/hold device

Technical specifications for the Model SHM-IC-1, an integrated circuit sample-and-hold device, are given in a four-page brochure. A general description, block diagram and mechanical specifications are included. Datel Systems, Canton, MA

CIRCLE NO. 362

Power supplies

How you can have your own individual power supply by selecting submodular units is illustrated in a brochure. Output voltages, typical output currents and prices are itemized for each model. Power/Mate, Hackensack, NJ

CIRCLE NO. 363

Measurement systems

A 112-page book contains all published data sheets on the HP 9600 measurement and control systems, networks, software and peripherals. Hewlett-Packard, Palo Alto, CA

CIRCLE NO. 364

Rf transistors

A 16-page rf communications transistor catalog contains product information for both 12 and 28 V devices, at specific frequencies, by application from 2 MHz to 1 GHz. Also included is a competitive package cross-reference and an rf transistor cross-reference. Solid State Scientific, Montgomeryville, PA

CIRCLE NO. 365

Proximity switches

Self-contained industrial proximity switches are highlighted in a 16-page brochure. It contains application drawings, product listings, simplified ordering guides, electrical and operating characteristics, drift and sensitivity charts, circuit diagrams, schematics and mounting dimensions. Micro Switch, Freeport, IL

CIRCLE NO. 366

Digital data processor

The CP70A second generation digital data processor is pictured, described and specified in an eight-page brochure. In-depth discussion is devoted to the nature of and uses for the many standard programs available. California Instruments, San Diego, CA

CIRCLE NO. 367

Discrete semiconductors

A 112-page discrete semiconductor guide contains technical specifications and application data on field-effect transistors, dual field-effect transistors and dual bipolar transistors. The guide groups products by application with a comparison table of key parameters for each device. Intersil, Cupertino, CA

CIRCLE NO. 368

Analog IC designs

"101 Analog IC Designs," a 150-page book, contains practical designs for amplifiers, comparators, current sources, flip-flops, gain control circuits, gates, op amps, oscillators, phase detectors, PLLs, Schmitt-triggers, timers and voltage regulators. The book costs $3 prepaid. Interdesign, 1255 Reamwood Ave., Sunnyvale, CA 94086

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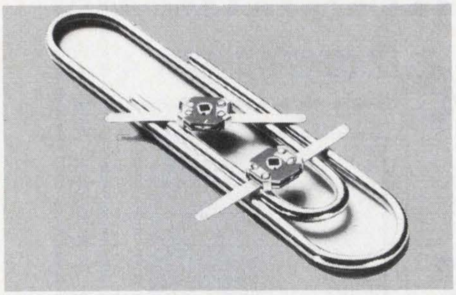

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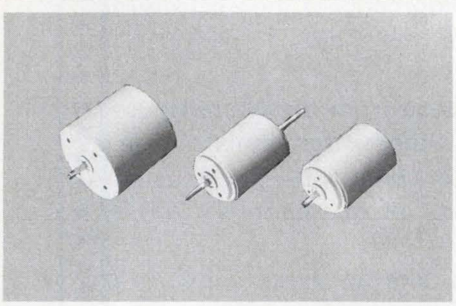
THIN-TRIM CAPACITORS 181



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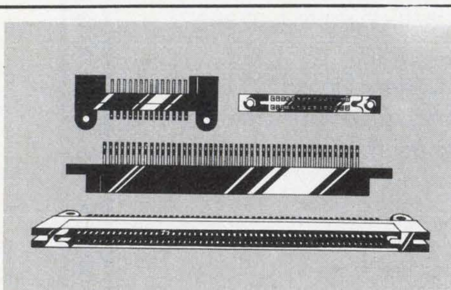

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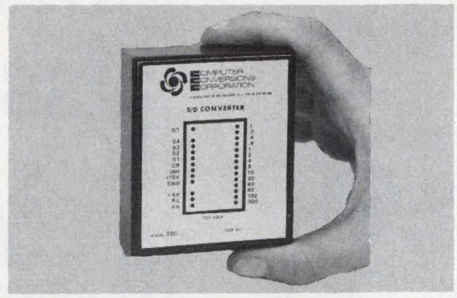

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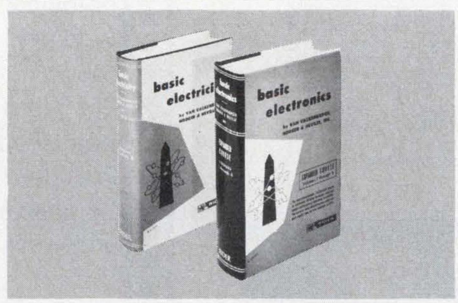

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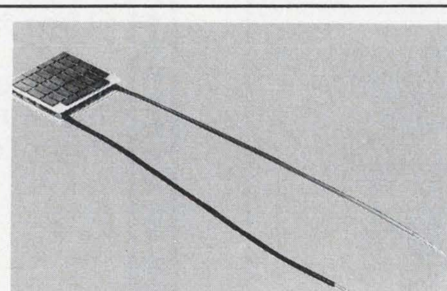

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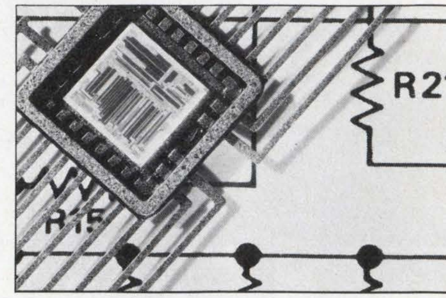

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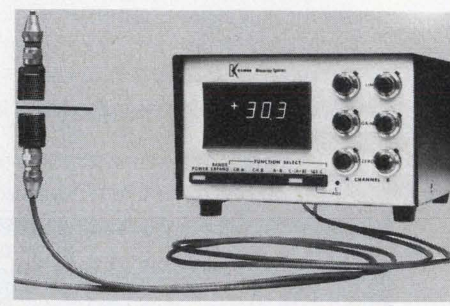

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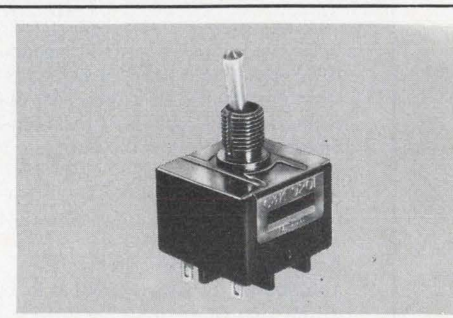

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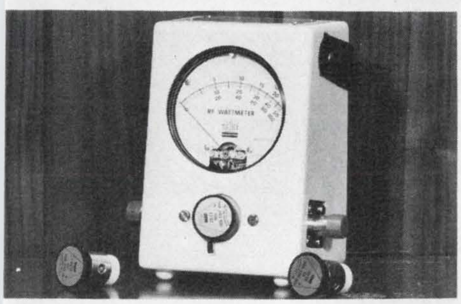

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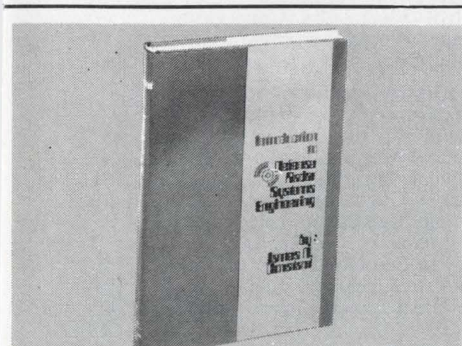

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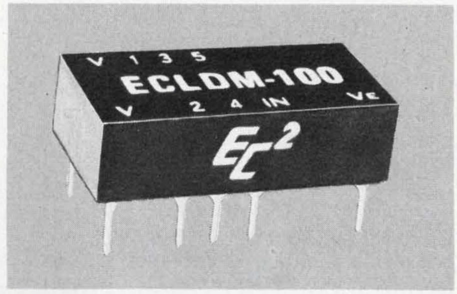

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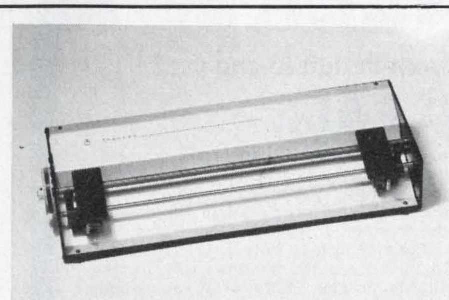

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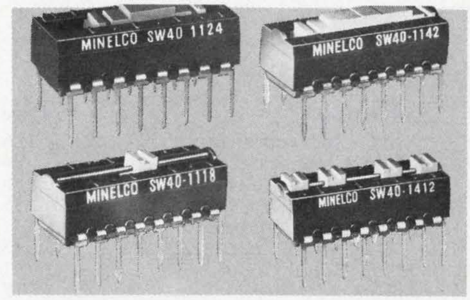

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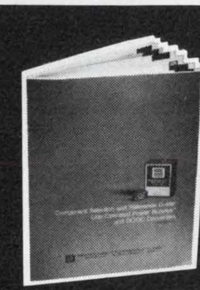

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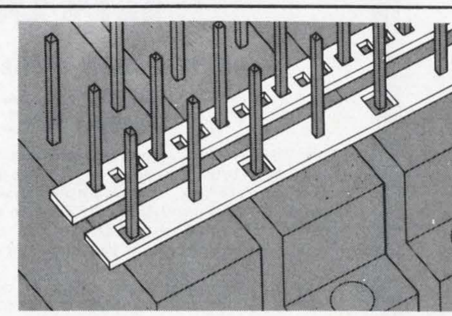

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- O Engineer
- P Consultant
- R Scientist
- S Physicist

2 ☐ **Your principal job function:** *(Insert code)*

1. General and Corporate Management
2. Design and Development Engineering (circuits, components, equipment systems)
3. Engineering Services (evaluation, quality control, reliability, standards, test)
4. Basic Research
5. Manufacturing and Production
6. Engineering Assistants (draftsman, lab assistant, technician)
7. Purchasing and Procurement
8. Marketing including Sales
9. Other Personnel (explain) ______

3 Plant ☐ Your own work ☐ **The primary end product (or service performed) at your plant, and the product (or service) that is your own work.** *(Insert code in each box even if the same)*

Plant	Your own work	
A	A	Large Computers
B	B	Mini-Computers
C	C	Computer Peripheral Equipment
D	D	Data Processing Systems (Systems Integration)
T	T	Office and Business Machines
E	E	Test, Measurement and Instrumentation Equipment
F	F	Communications Systems and Equipment
H	H	Navigation and Guidance Systems and Equipment
J	J	Consumer Entertainment Electronic Equipment
G	G	Consumer Electronic Appliances
N	N	Other Consumr Electronics
K	K	Industrial Controls, Systems and Equipment
L	L	Components and Sub Assemblies
M	M	Materials and Hardware
Q	Q	Aircraft, Missiles, Space and Ground Support Equipment
P	P	Oceanography and Support Equipment
R	R	Medical Electronics
U	U	Industrial Companies within the OEM incorporating Electronic Equipment in their end product, not elsewhere classified
V	V	Independent Research, Test and Design Laboratory and Consultant. (Only if you are not connected with a manufacturing company.)
X	X	Government Agency and Military
2	2	Industrial Companies using and/or incorporating any Electronic products in their manufacturing, research or development activities.
1	1	Commercial Users of Electronic Equipment
3	3	Distributor
4	4	School, University or Library
5	5	Other (explain) ______

4 ☐☐☐ **Your design function:** *(Insert each letter that applies)*

- A I do electronic design or development engineering work
- B I supervise electronic design or development engineering work
- C I set standards for, or evaluate electronic design components, systems and materials

5 ☐ **Your principal responsibility:** *(Insert code)*

1. Management other than Engineering
2. Engineering Management
3. Engineering

6 ☐ **Please estimate:** *(Insert letter)*

The numer of electronic engineers at this address:
(A) 1 **(B)** 2-5 **(C)** 6-19 **(D)** 20-49 **(E)** 50-99
(F) 100-249 **(G)** 250-499 **(H)** 500-999 **(J)** Over 1000

8 **Products you specify or authorize purchase of:** *(Check all codes that apply.)*

- ☐ 1 Resistors and Capacitors
- ☐ 2 Connectors
- ☐ 3 Switches and Relays
- ☐ 4 Function Modules: Op Amps, Converters, etc.
- ☐ 5 Potentiometers
- ☐ 6 Test and Measurement Equipment
- ☐ 7 Computers, Medium and Large
- ☐ 8 Electronic Power Supplies
- ☐ 9 ICs and Semiconductors
- ☐ 10 Microwave Devices
- ☐ 11 Minicomputers
- ☐ 12 Computer Peripherals
- ☐ 13 Computer Components
- ☐ 14 Cabinets and Enclosures
- ☐ 15 Panel Meters, Analog or Digital
- ☐ 16 Readout and Display Devices
- ☐ 17 Rotating Components
- ☐ 18 Cooling Products
- ☐ 19 Printed Circuits
- ☐ 20 Calculators
- ☐ 21 Indicators including LEDs
- ☐ 22 Materials, Potting and Stripping
- ☐ 23 Communications Equipment

7 ☐ **Please write in box total number (other than self) to be served by this subscription at this address and list individuals and their titles below. If no other person is served please indicate "0" in the box at left.**

Name (Please Print)	Title

9 **Do you specify or buy through distributors?** ☐ YES ☐ NO

10 **Minicomputers at this address:**

		Model	Qty.	Model	Qty.
3	Cincinnati Milacron				
C	Computer Automation				
D	Control Data				
E	Data General				
F	Digital Equipment				
I	General Automation				
K	Hewlett Packard				
M	Honeywell				
O	IBM				
N	Interdata				
7	Microdata				
	Modular Computer				
	ROLM				
V	Systems Engineering Labs				
9	Texas Instruments				
x	Varian				
	Other				

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Quad Operational Amplifiers	CA124G, CA224G, CA324G, CA3401G*
Quad Voltage Comparators	CA139AG, CA139G, CA239AG, CA239G, CA339AG, CA339G
1A N-P-N Transistor Arrays	CA3724G, CA3725G

*New types

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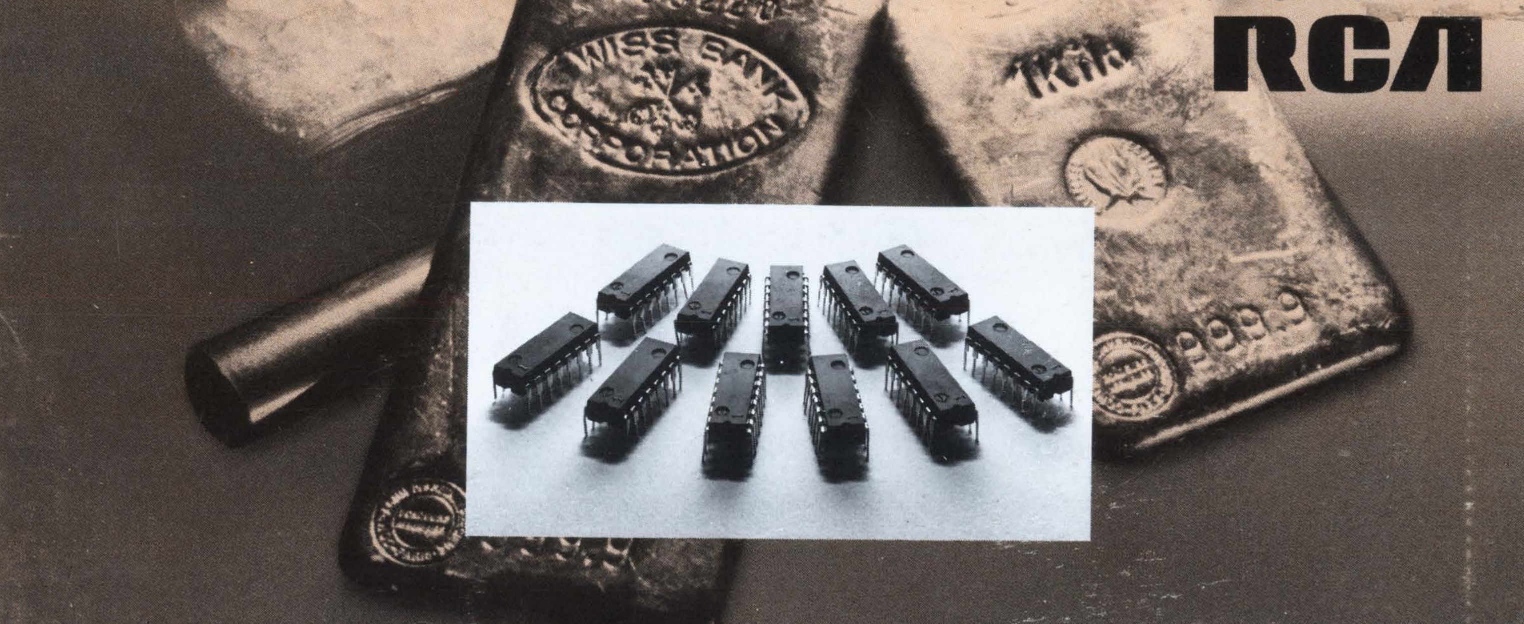

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