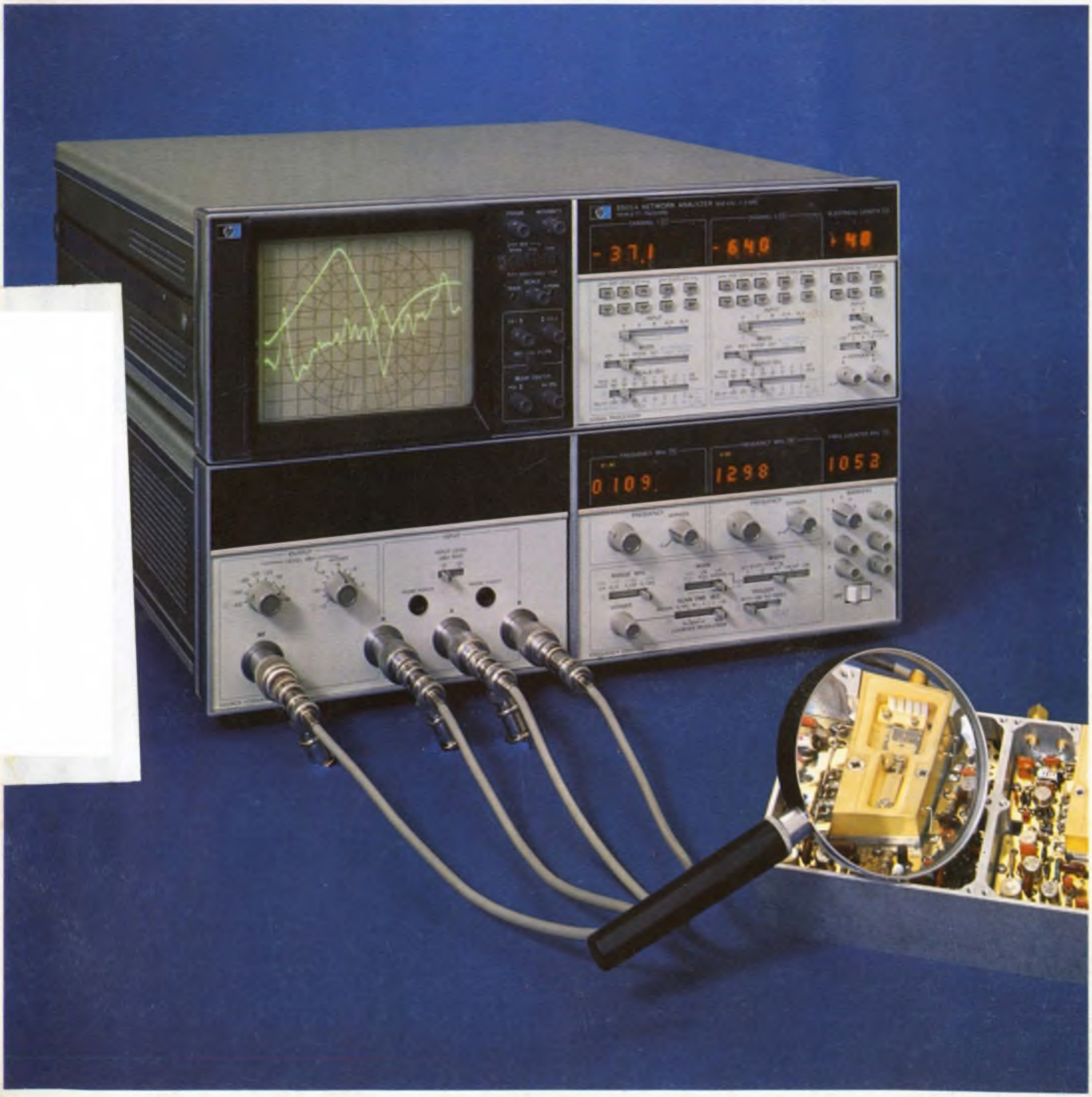
VOL. 23 NO.

Electronic Design® 23

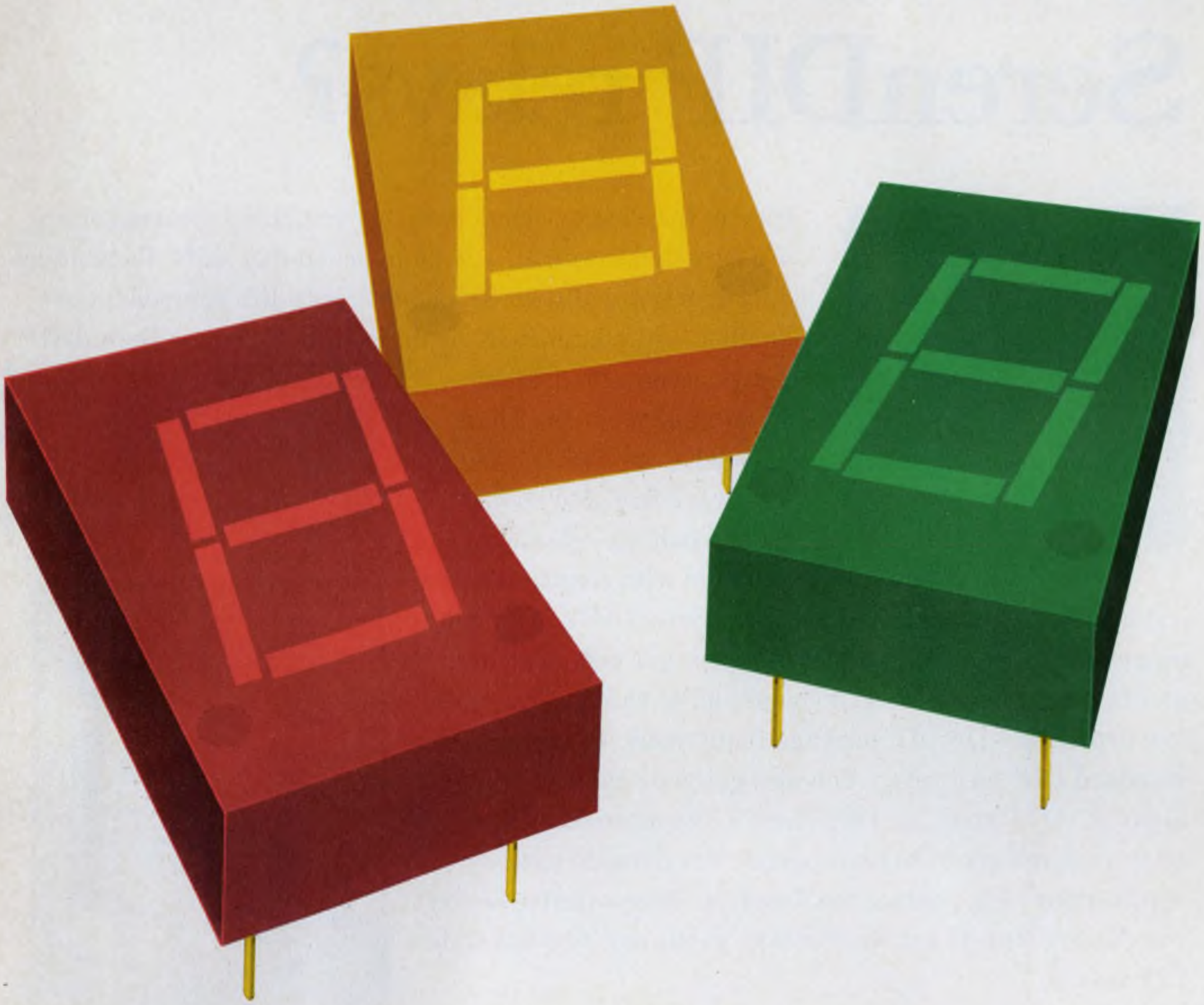
FOR ENGINEERS AND ENGINEERING MANAGERS

NOV. 8, 1975

See network behavior in more detail. A powerful new analyzer boosts frequency range: up to 1.3 GHz and down to 0.5 MHz — the widest yet attained. And the displayed dynamic range of 100 dB is the best around. You also get direct counting to 1.3 GHz, digital display of magnitude and phase and group delay. P. 113.



SURPRISE!



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At 20mA our new High-Efficiency red display is 5 times brighter than our standard red displays. Just 3mA per segment gives you all the brightness you need and makes it ideal for battery powered applications. These large .43" displays are offered in High Efficiency Red, Yellow, or Green and are readable up to 20 feet. The 5082-7650 (High-Efficiency Red), -7660 (Yellow), -7670 (Green) are available in standard DIP packages with left-hand d.p. and common anode configuration. Just $3.95* each in quantities of 100. Contact Hall-Mark, Schweber, Wilshire or the Wyle Distribution Group (Liberty/Elmar) for immediate delivery, or write us for more information and our new application note on contrast enhancement.

01503 *Domestic USA price only.

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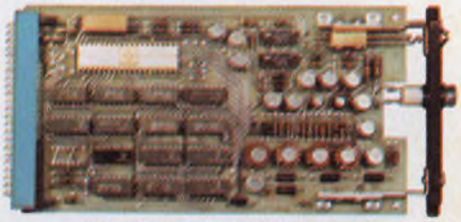
INFORMATION RETRIEVAL NUMBER 2

Did you get the message about our solid state SerenDIP relays?

International telex communication switching systems often are expected to run on a 24-hour, seven-day shift. Continuous duty like that calls for dependable, long-life component reliability — the kind RCA requires from Teledyne SerenDIP® relays used in their trunk terminator modules. These all-solid-state DIP relays provide wear-free and bounce-free switching — features you don't get with electro-mechanical or reed relays. What's more, our SerenDIP's offer high input/output isolation, low level logic input compatibility, and fast response time. And you get all of this in a low cost, low-profile TO-116 DIP package ready-made to replace any standard DIP reed relay. You also get your choice of output: bi-polar, AC (triac), or DC. There's lots more to a SerenDIP relay that you ought to know about. For detailed specs or applications help, contact the Teledyne Relays people nearest you. You're sure to get the message about our all-solid-state DIP relays.



RCA Trunk Terminator Module

RCA CCT-3 Series
Telex Switching System
(Courtesy of RCA/Camden, N.J.)

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INFORMATION RETRIEVAL NUMBER 3

Electronic Design 23

VOL. 23 NO.

FOR ENGINEERS AND ENGINEERING MANAGERS

NOV. 8, 1975

NEWS

TECHNOLOGY

PRODUCTS

Departments

Cover: Photo by Russell Illig, courtesy of Hewlett-Packard, Santa Rosa, CA.

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BME™ "J" DIELECTRIC (COG)	BME-Chip™	BME-Axial™	BME-Radial™
1 thru 100 pF, 5%, 50WVDC	5.1¢	6.8¢	7.5¢
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.01 μF, 20%, 50WVDC	3.5¢	5.8¢	5.8¢
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1.0 μF, 20%, 25WVDC	52¢	––	73¢
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.1 μF, +80 –20%, 25WVDC	5.7¢	8.8¢	8.8¢
.47 μF, +80 –20%, 25WVDC	13¢	16.5¢	16.5¢
1.0 μF, +80 –20%, 25WVDC	19¢	27¢	25¢
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Elimination of precious metal material costs have permitted us to stockpile chips. We now have five to ten million units in over 40 popular values ready for two-week delivery in chip style or four-week delivery in leaded configurations.

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INFORMATION RETRIEVAL NUMBER 4

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Across the Desk

Chicken about progress

In this age of super small components and sophisticated electronics, one industry is still relying on old-fashioned electromechanical gadgetry.

Most of those fried chickens you purchase at the hundreds of fast-food chicken outlets around the country are so crisp and brown and thoroughly delicious because of an old-fashioned synchronous motor driven reset timer manufactured by Gulf & Western's Eagle Signal Div., Davenport, Iowa. The frying is done under pressure in large quantities and as fast as possible, says Joseph A. Carlin, marketing manager for industrial controls. "A half a minute or even several seconds can make the difference between a good batch and a ruined batch," he notes. To duplicate the timing control, electronically, Carlin says, would, of course, be possible—but at two to three times the price of the electromechanical units. And then it wouldn't necessarily be an improvement.

Power Hybrids sets the record straight

We appreciate the coverage given to Power Hybrids, Inc., in the Sept. 1 issue and thought the survey was complete and informative ("Rf and Microwave Semis Rising in Power and Declining in Noise," ED No. 23, p. 34). For the record:

The photo of the TAC-250 circuit was supplied courtesy of Elliot Ressler of the Naval Air Development Center, Warminster, PA.

In addition we detected an error in the caption under the photo. The frequency range should have been 960 to 1215 MHz instead of 960 to 121.5 MHz, but I'm sure the readers instinctively knew the correct range.

Wayne E. Schaub
Vice President Marketing
Power Hybrids Inc.
1742 Crenshaw Blvd.
Torrence, CA 90501

Exact's generator costs less than it seems

We were very happy to see the notice of the Exact Model 7059 Pulse/Sweep/Function Generator on p. 93 of the Aug. 16 issue. May we point out, however, that in your copy you indicated a price of $1895 for this instrument. This is $1000 higher than the actual price of the Model 7059.

Joe Foster
U.S. Sales Manager
Exact Electronics Inc.
455 S.E. Second Ave.
Hillsboro, OR 97123

Misplaced captions

"The focus circuit needs a bit of work."

Sorry. That's Diego Velasquez' "The Toilet of Venus," which hangs in The National Gallery in London.

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.

DELCO'S NEW FAS
HIGH-GAIN TRANSIS

MAJOR PARAMETER LIMITS

TYPE	h_{FE} @ 10A	V_{CBO}	$V_{CEO\,(sus)}$	$V_{CE\,(sat)}$ @ 7A	tf (typical @ 5A)
DTS 515	3.5	300V	250V	5.0V	0.25 μsec
DTS 516	4	400V	250V	1.9V	0.25 μsec
DTS 517	5	500V	250V	1.6V	0.25 μsec
DTS 518	5	600V	275V	1.4V	0.25 μsec
DTS 519	5	700V	300V	1.4V	0.25 μsec
2N6573	5	500V	250V	1.6V	0.25 μsec
2N6574	5	600V	275V	1.4V	0.25 μsec
2N6575	5	700V	300V	1.4V	0.25 μsec

NPN triple diffused silicon transistors. Packaged in solid copper cases conforming to JEDEC TO-3 (TO-204MA) outline dimensions.

Our newest high-energy silicon power transistors have increased capabilities over our earlier types in current ratings, gain and switching speeds. These improvements were achieved without sacrificing the useful peak power handling capacity that is characteristic of Delco's transistors.

Fall time of these transistors is typically 0.25 microseconds. Their biggest advantage, however, is their high current gain as shown on the accompanying beta curves.

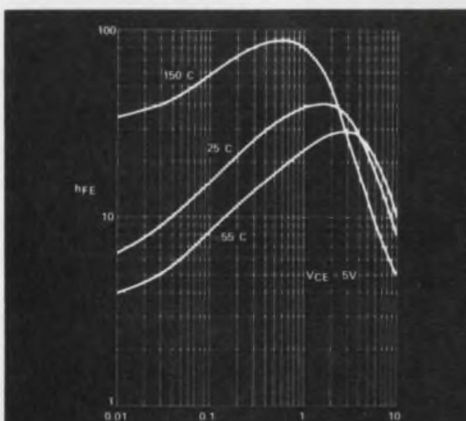
A new characterization feature offered with the DTS-515 series is a graph of capabilities for reverse bias clamped inductive switching. Parameter variables, dealt with in the graph, are voltage, collector current, temperature, and forward and reverse base current. As can be seen in the "V_{BE}(reverse) ≥ 5V" notation, emitter diode avalanche is recommended under certain conditions.

And, of course, these high-energy silicon power transistors come in Delco's solid copper TO-3 packages to ensure low thermal resistance.

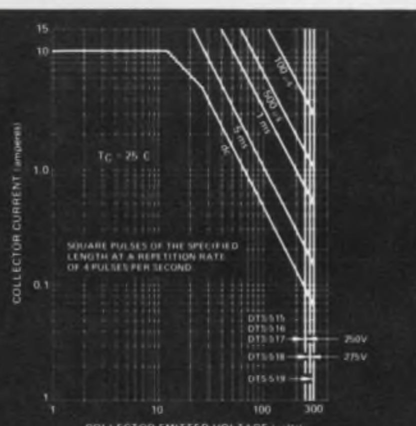
The accompanying curves, charts and circuits tell part of the story. Prices, applications literature and electrical data from your nearest Delco sales office or Delco distributor can supply another part.

But the most important part of the story is how well these new transistors function in your applications.

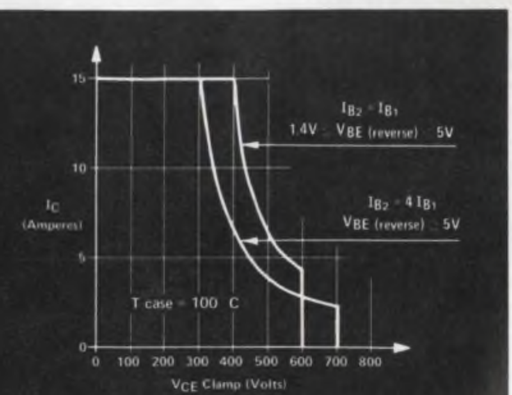
You can order them today; they're in stock at your Delco distributor's.



h_{FE} VS I_C CHARACTERISTICS



SAFE OPERATING CURVES



INDUCTIVE SWITCHING CAPABILITY OF THE DTS519 TRANSISTOR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INFORMATION RETRIEVAL NUMBER 8

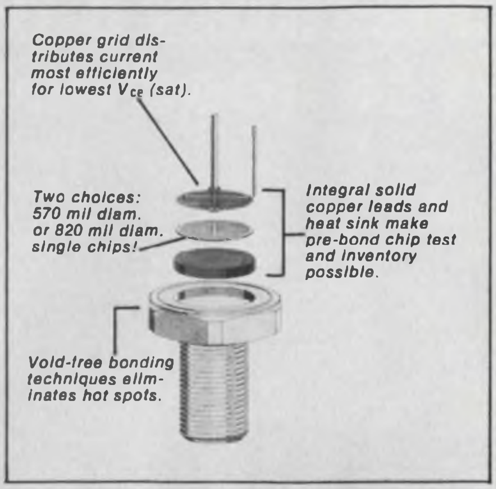
Save Space. Save Weight. Increase Reliability.

Paralleling transistors doesn't pay —not when an inherently rugged single device can do the job far more reliably, using much less space, weight, and at lower total system cost. That's why PowerTech's unique single-chip NPN silicon high-power transistor is the *one* way to go.

Used alone, our space-saving single-chip device eliminates multiple failure sources while reducing the environmental testing costs inherent in parallel arrays. Because of their simplicity they're available off-the-shelf–pre-rated, pre-tested and inventoried to meet virtually any hi-rel JAN and JAN-TX hi-current requirements without custom prices and long custom waits. For information, application assistance, and free design guide call Sales Engineering, PowerTech, Inc., 9 Baker Court, Clifton, N.J. 07011; (201) 478-6205.

Type #	(pk.) I_c	V_{ceo}	(h_{fe} = 10) V_{ce} (sat) @ I_c
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.
"BIG IDEAS IN BIG POWER"

INFORMATION RETRIEVAL NUMBER 9

A new low for on-board programing.

AMP introduced the DIP switch to solid-state electronics. Now we've gone still further. AMP's new *low-profile* DIP switches are as low as you can get. You can use them to program ICS right-on-the-board without remote wiring. And sandwich boards in less space, to cut packaging costs.

With our new, low-profile DIP switches, cleaning boards is easier than ever. Simply place our protective covers or pieces of tape on the switches and you can clean complete boards without damage.

We're the people who developed and perfected DIP switches —a whole family of them—including our innovative, pluggable Hexadecimal Rotary Switch. Our experience is broader and deeper than anyone's. At AMP we'll have the right answers for your applications.

Bright new lights.

Unique LED DIP switches are available in SPST "on" or "off" as well as momentary-contact types. They permit rapid, visual circuit test, fault indication and programing verification. Plus, for the first time, they permit DIP packaging of LEDS.

Rockers are detented to avoid accidental actuation. Switch leads and LED leads are terminated independently for circuit connection versatility.

There's nothing quite like new AMP LED DIP switches. For more details on them, or the new AMP low-profile DIP switches, call (717) 564-0100. Or write AMP Incorporated, Harrisburg, PA 17105.

AMP
INCORPORATED

INFORMATION RETRIEVAL NUMBER 12

go for 4K RAMs.

inputs are fully TTL compatible.

Overall system advantages of the 2104 are detailed in a new application brief, "Which Way for 4K... 16, 18, or 22 Pin?" It explains why the 16-pin 2104 is best for very compact systems such as minicomputers, microcomputers, terminals, business equipment, scientific calculators and anywhere high density is needed.

Moreover, we show how the 16-pin standard is compatible with the next generation of even higher density memories. The application brief also tells why the 2107B's simple, straightforward 22-pin design has become an industry standard for computer main memories and many other applications.

Now the industry has two standard configurations—16 pins with multiplexed addresses and 22 pins with parallel addresses. Whichever way you go, you'll find Intel ready to support both in volume production. For delivery of the 2104 or 2107B contact our franchised distributors: Almac/Stroum, Component Specialties, Cramer, Elmar, Hamilton/Avnet, Industrial Components, Liberty, Pioneer, Sheridan or L.A. Varah.

For your copy of "Which Way for 4K..." or data sheets on any of our 4K RAMs write: Intel Corporation, 3065 Bowers Avenue, Santa Clara, California 95051.

intel® delivers.

INFORMATION RETRIEVAL NUMBER 13

NOVEMBER 8, 1975

Microcomputers giving rise to new medical instruments

A new class of mass-producible, intelligent medical diagnostic instrumentation incorporating microcomputers will be developed at the Massachusetts Institute of Technology to overcome the limitations of computer-based medical research systems now used.

Expected advantages of the new approach include the following:

- Substantially lower cost.
- Much smaller instrument sizes, suitable for use in a clinical setting rather than only in a research laboratory.
- Simplified operation, with the microprocessor taking over the monitoring of medical diagnostic tests and routines.
- Data processing in real time and with simplified presentation, so that highly skilled medical researchers or computer personnel are not needed to interpret the results.

The work at MIT will be performed in the Core Microprocessor Engineering Laboratory as part of a new program administered by the Biomedical Engineering Center for Clinical Instrumentation. The center is being established by the joint Harvard-MIT Program in Health Sciences and Technology with the help of a Federal grant of $1,016,439.

The center's first research projects will be the design, development and testing of four basic types of instruments: (1) A computerized monitor for detection of irregular heartbeats; (2) Equipment and techniques for the diagnosis of causes of dizziness and disequilibrium; (3) Instrumentation for collecting and processing respiratory-function data for the study of dynamic events found in asthma victims; and (4) A probe for the measurement of blood flow through tissues to monitor patients during surgery.

The center will be under the direction of Roger G. Mark, M.D., Ph.D., associate professor of electrical engineering in the MIT Dept. of Electrical Engineering and Computer Science. He also is assistant professor of medicine at the Harvard Medical School and director of the Biomedical Engineering Dept. at Beth Israel Hospital in Boston.

Dr. Mark will direct the work of developing a wearable, computerized device that can monitor, identify and evaluate heartbeat irregularities in ambulatory patients. If the beat indicates failure, the device will give a warning.

Dr. Laurence R. Young, professor of aeronautics and astronautics at MIT, heads the project on instrumentation for diagnosing dizziness and vestibular instability. He sums up his approach, which is representative of the over-all program this way:

"The problem is that current methods of diagnosis are clumsy, difficult for the doctor, uncomfortable for the patient, and require specialized equipment that is usually not available in a clinic.

"Our objective is to take a number of test conditions that are used to evaluate dizziness—this requires measurement and analysis of nystagmus, which is an arhythmic movement of the eyes when a subject is rotated or if his balance is upset—and put the instrumentation into a single, usable package for the clinician.

"The next step will be to take computer programs for analysis of this nystagmus and reduce them to the level of hard-wired programs on a microprocessor."

The advantages of reducing this system to a μP-based instrument are lower cost and smaller size. In addition, Young says, you'll have a dedicated machine that a medical technician can use and that does not require a knowledge of software and programming.

Hand-held control unit to monitor artillery

A new hand-held control system that will automatically monitor artillery and ultimately provide correction data for a target is under development at the Army's Picatinny Arsenal in Dover, NJ.

The new device, still in the development stage, will look like a hand-held calculator and will contain a radio to receive firing data transmitted by transducers on a piece of artillery.

According to Dan Ramer, an engineer at the arsenal, the prototype is being built with a MOS Technology two-chip calculator set. The final product, however, will probably use a CMOS microprocessor, he says. The unit, Ramer explains, will use Schottky logic to provide a 100-MHz capability, while all the rest of the circuitry will be CMOS.

To achieve maximum battery life, circuitry that is not in use is automatically disconnected. The unit contains a ROM that holds 256 program steps. This eliminates the need for any sort of programming by the user. Specific calculated data as to shell velocity and acceleration, recoil velocity of the artillery and orientation with respect to gravity are read out on a digital display when the appropriate button is pressed.

The initial unit will only read out these individual parameters, but Ramer says there is no reason why a little extra programming can't be done to have the device read out corrected coordinates for a target.

The transducers for this system, Ramer reports, will be mounted in a removable collar that can be quickly attached to any piece of artillery. The telemetry equipment will be self-powered.

Ramer notes that either the heat, pressure or physical movement of the weapon when fired will be used to generate electricity to power the transducers and transmitter. Final units should go into production in about a year, he says.

Laser-TV bomb sight likely to raise accuracy

Day and night bombing accuracy by Marine Corps aircraft is expected to improve significantly with a new angular-rate bombing system being built at Hughes Aircraft, Canoga Park, CA. Unlike most current bombing systems, neither measurement of range to the target nor inertial quality platform inputs are required.

The bombing unit uses a combination laser and TV system that automatically acquires the ground target and immediately begins to track on the aircraft's first pass over the target.

According to Richard Furtaw, program manager at Hughes: "The unit is basically a simple angular-rate system. The tracker, after locking on a target, provides the aircraft-to-target line-of-sight angle and angle rate to the weapon-delivery computer. This information, combined with the true airspeed and altitude, is processed by the computer yielding the weapon delivery solution."

Target position, weapon release and azimuth-steering information are displayed to the pilot on a head-up display.

Furtaw notes that the dual-mode laser-TV tracker is the heart of the system. A television tracker shares a common optical system with a laser spot tracker. A dichroic filter behind the optics separates the laser energy from the visible light for sensing by a four-quadrant laser detector.

A portable radar set to survey battlefields

A hand-held battlefield surveillance radar being developed for the Marine Corps to detect both personnel and vehicles is so light (10 pounds) and inexpensive (a tenth the cost of existing units) that it's also being considered for other military and civilian applications.

Under development for about four years by the Naval Electronics Laboratory Center, San Diego, the X-band, solid-state transceiver was developed by Rockwell International's Autonetics Div. and the antenna by the company's Missile Systems Div. both in Anaheim.

The reason for the cost reduction, the Navy says, is that it does not require the diode or ferrite phase shifter for each array element that existing radars do.

The unit is designed to use an electronic scan antenna with 26 elements and two ferrite analog circuits to provide ±45-degree coverage. The antenna provides a six-by-six degree beamwidth at 9 GHz, with sidelobes down to 18 to 20 dB. It will weigh about two pounds and will have a beam control power of about 0.5 W.

The X-band transmitter signal is derived from an S-band source, quadrupled and biphase-coded. The resulting signal is applied to an Impatt diode.

The main purpose of using this technique, Navy Laboratory engineers say, is to achieve a more efficient power source and to increase the power output. They predict a transmitter efficiency of 8%—an increase of an order of magnitude over present battlefield surveillance radars. The average power, they estimate, will be 2.5 W, which represents a 20-dB gain over that of conventional units.

The primary advantages of using fiber optics for remote control capability are low weight, RFI/EMI immunity, and wide bandwidth capability. The predicted weight for 50 m of a four-channel fiber optics cable is about one pound.

Hitachi cites advance in optical IC work

Continuous-wave, room-temperature operation of a new distributed feedback semiconductor laser—reported by Hitachi in Japan—promises to bring a practical optical IC system a step closer.

Room-temperature operation eliminates the need for cooling and simplifies substantially the interface between the distributed feedback gallium-arsenide-phosphide devices and OIC elements. Also, it is possible to integrate several of these distributed feedback lasers—each with a different wavelength—in one element. As a result, a number of independently modulated laser beams can be easily generated and sent through a single optical fiber.

With the distributed feedback device, the optical resonation necessary for lasing action is obtained by use of an internal grating structure instead of the mirror surfaces found in regular semiconductor lasers.

This grating structure, according to M. Nakamura, K. Aiki and J. Umeda, researchers at Hitachi's Central Research Laboratory in Tokyo, produces radiation of substantially purer spectral quality and better modal control than that of the conventional lasers.

Data General builds its own MOS chip

Overshadowing Data General's recent introduction of its Nova 3 OEM minicomputer family was the announcement that the machine's memory module would contain a dynamic n-channel, 4096-bit MOS RAM chip manufactured by Data General in Sunnyvale, CA.

It's believed to be the first time a small computer firm has extended in-house manufacture of computer parts down to the level of complex MOS devices.

"The use of in-house manufactured chips," says Donald McDougall, Nova 3 marketing manager, "allowed the chip to be designed with close interaction between our semiconductor specialists and Nova 3 system engineers. This resulted in the best over-all RAM/memory design that could be developed for these computers."

An alternate memory board will be available using MOS parts supplied by Texas Instruments.

The four-slot Nova 3/4 and 12-slot Nova 3/12 are available with core memory in 8-k and 16-k-word increments, or MOS semiconductor memory in 4-k, 8-k or 16-k-word increments.

The new computers feature main memory expansion up to 128-k words, an extended data channel and 16-level priority interrupt structure.

Memory cycle speeds are 700 ns for MOS memory, 800 ns for 8-k word core and 1000 ns for 16-k core.

McDougall notes that at the low end of the OEM market, the Nova 3 challenges microcomputers in a number of applications.

INFORMATION RETRIEVAL NUMBER 15

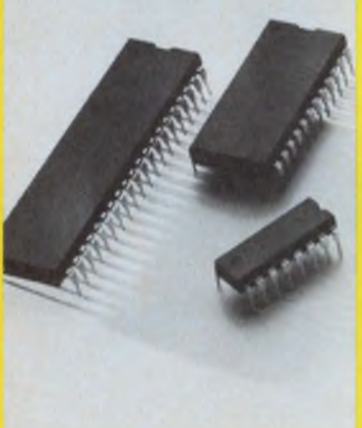
Good news from Hughes for circuit designers bogged down in SSI/MSI:

Now you can get these popular high-density CMOS/LSI circuits off the shelf.

4-Decade Counters

Three CMOS units to choose from:

- 2 MHz, up/down, BCD outputs (HCTR4010)
- 1 MHz, BCD outputs, 16-pin package (HCTR6010)
- 5 MHz, presettable, 7-segment outputs (HCTR0154)

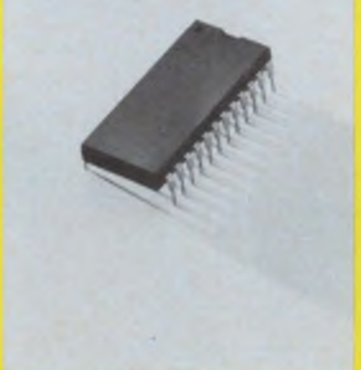


Reader Service No. 271

CMOS Decade Counter/ Latch/Decoder/Driver

(HCTR0200)

- Up/down, 2 MHz, 5V operation
- 7-segment output compatible with LED and LCD
- Units may be cascaded



Reader Service No. 272

CMOS Programmable Logic Array

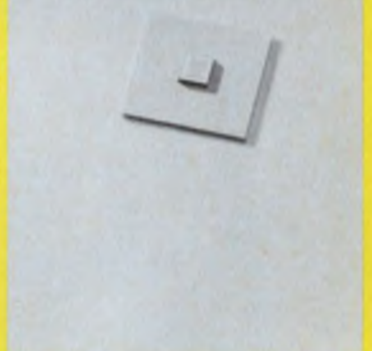
(HPLA0174)

- 1 MHz with 5V supply
- 19 inputs, 16 outputs
- 12 on-chip DFFs,
- 70 product terms

Reader Service No. 273

CMOS LED/LCD Watch Chips

- 32 KHz crystal oscillator
- Hours, minutes, seconds, date
- Low power, AM indicator
- De-bounced set inputs



Reader Service No. 274

Our business is making advanced MOS/LSI devices. Mostly they're custom circuits, but we also produce designs that have widespread application as standard parts.

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Look over these proved-and-packaged circuits and let us know which ones fit your particular needs. We'll send you specs, prices and delivery information.

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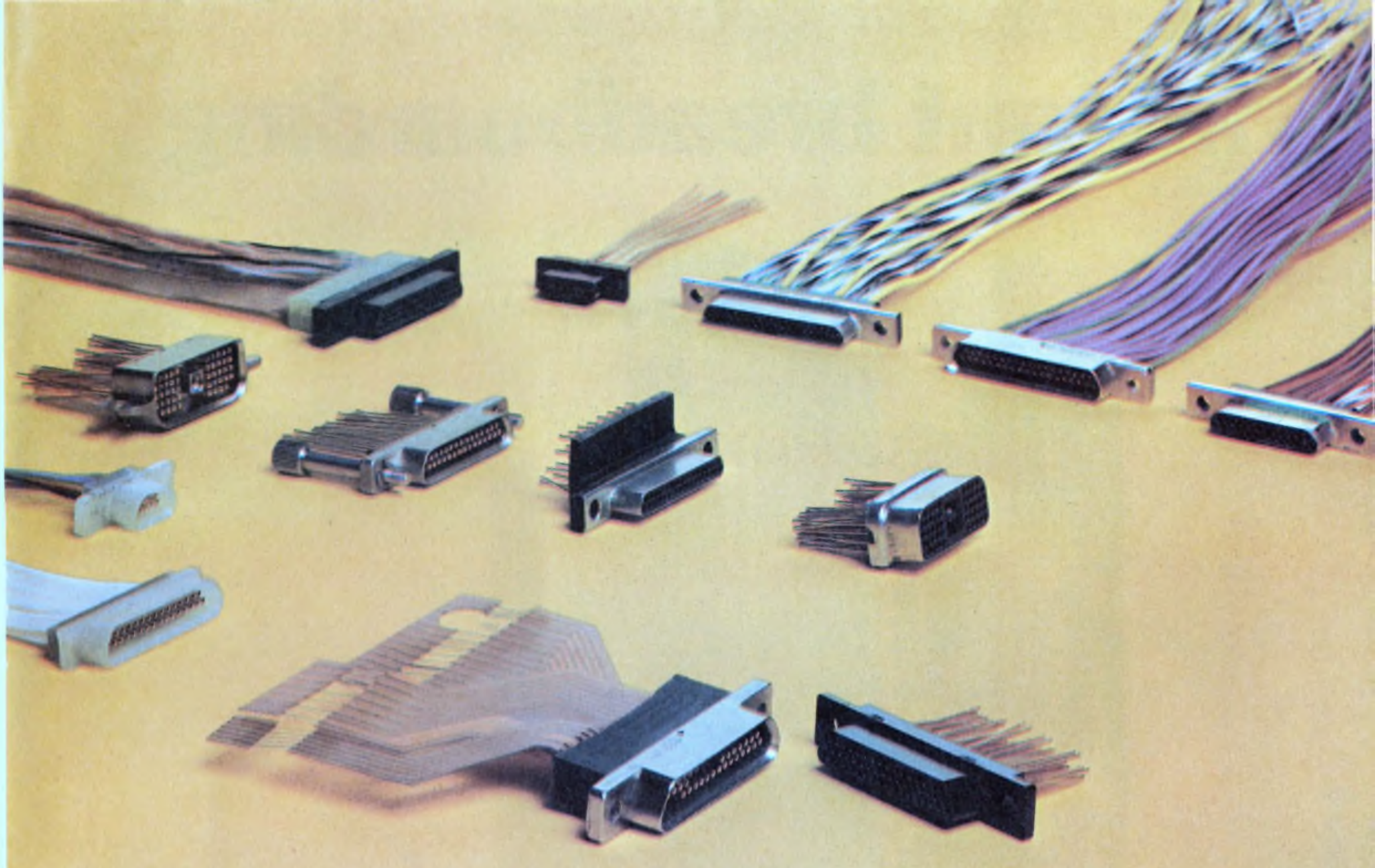

Malco Rectangulars...
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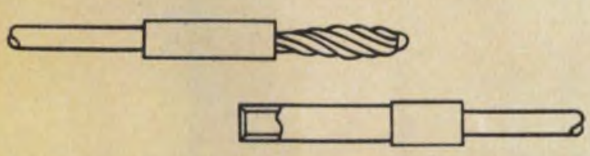

Twist/Con™—22/24 pins and sockets. In the Twist/Con system, the male contact is constructed of seven strands of spring copper alloy wire wound helically around an inner core of three copper alloy strands. This creates a breathing helical spring so that contact is made at many points around the periphery of the pin bundle instead of a few discrete points as in conventional design.

- Material: Copper Alloy
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- Contact Resistance: .008 ohms max.

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INFORMATION RETRIEVAL NUMBER 17

Instant breadboarding

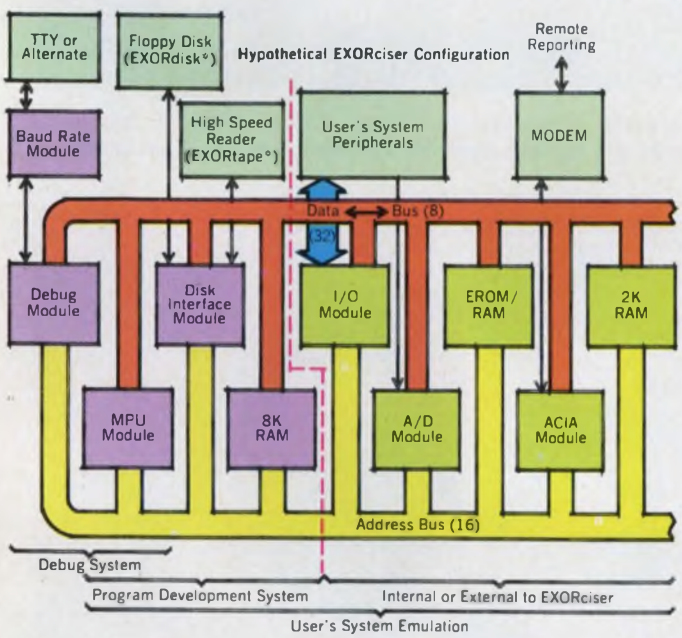
Takes the tedium from microcomputer systems design

"Donkey Work" in microcomputer systems development seems endless. It doesn't have to be! With Motorola's M6800 Family and an EXORciser*, that wasteful tedium is no longer necessary.

EXORciser configuration as a prototype of a unique M6800 system is fast and simple using standard production board options. That's instant breadboarding. It's in the M6800 tradition of simplifying and accelerating the design job. But, instant breadboarding is only one of the key functions of this triple-threat design development tool.

The EXORciser also is used to edit and assemble source programs, and its very name is derived from the functions of debugging, exorcising, and evaluating M6800 system designs in real-time.

It's both the complete system emulation tool and the debug system, too. Two systems in one. Emulation of the user system within the EXORciser chassis is achieved with the use of optional memory and I/O modules. With an external system, connect its bus as



an extension of the EXORciser bus, and timeshare the EXORciser's MPU.

The basic machine consists of MPU, Debug and Baud Rate Modules, with chassis and power supply. Flexibility is enhanced by options for altering memory and I/O, the 2K Static RAM, 8K Dynamic RAM, Input/Output and ACIA modules. EXORciser options also include extender and wirewrap modules, flat ribbon interconnect cable, and battery backup.

There's a full range of M6800 support software and hardware

Support Software. M6800 software meets nearly any need. It's available on commercial timesharing from G.E.,

U.C.S. and Motorola Time-sharing. Custom and host computer software are available, and so is a full complement of M6800 Resident Software.

Evaluation Modules. Certainly the EXORciser is the ultimate M6800 system development tool, but many designers may prefer to first evaluate the operating characteristics of the various M6800 Family devices with one of several evaluation module options. These include a bare board, a completely assembled and tested module, and the same version with an 8K Dynamic RAM module plus resident software.

Support Peripherals. Other systems development tools supplement EXORciser capabilities. The EXORdisk* floppy disk unit and EXORtape* high speed tape reader are available. More items are being added.

For complete story on Motorola's M6800 support hardware and software, use the reader service number or write to Motorola Semiconductor Products Inc., P.O. Box 20912, Phoenix, AZ 85036. Any Motorola sales office or authorized Motorola distributor can handle your questions and your order.

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MOTOROLA M6800

Benchmark family for microcomputer systems.

INFORMATION RETRIEVAL NUMBER 18

News

Smaller, cheaper passive chips spurring hybrid-circuit advances

As hybrid circuit manufacturers reach for more complexity in their designs, impressive advances in individual chip components are turning their ideas into reality.

Capacitors, inductors and resistors are getting smaller and smaller. Component costs also are dropping. And—how lucky can you get?—ranges are being extended.

Chip capacitors are now available with values from 1 pF to well over 200 μF in chip sizes from 30 mils square by 5 mils thick to 250 mils square by 100 mils thick.

Inductors are being offered with values from 1 nH to over 10 mH in both fixed and variable types, while sizes start at 50 × 80 × 25 mils and increase to over 250 × 250 × 200 mils.

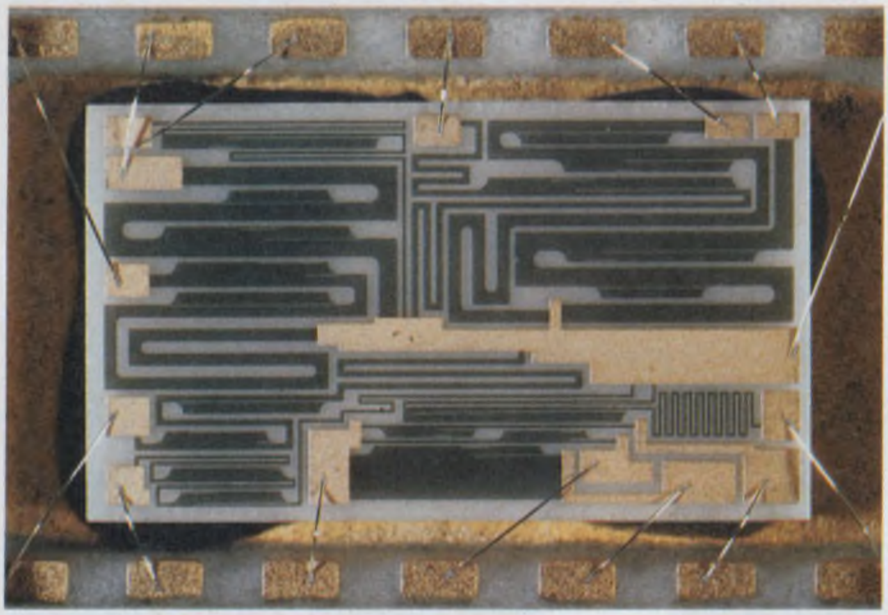
Chip resistors and resistor networks come with values from 1 Ω to 10^{12} Ω, while tracking capabilities are to within 1 ppm/°C.

There are now three major families of chip capacitors: monolithic ceramic, tantalum and MOS. Inductors can be broken down into two families: deposited and wound. And for resistors, there are thin-film and thick-film types.

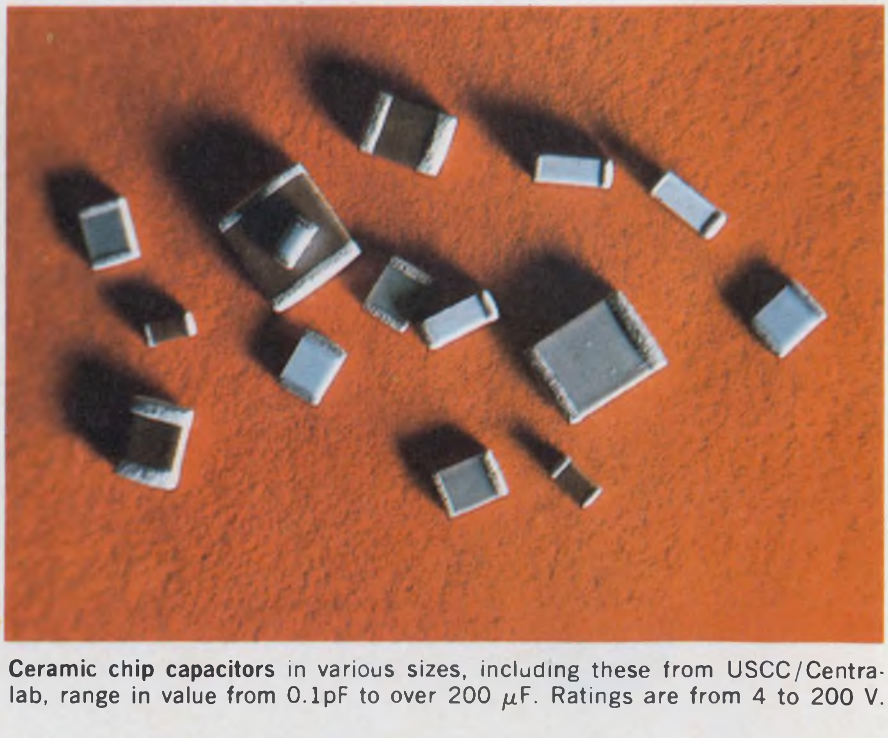
Within each of these areas, manufacturers are developing new ways to lower costs, extend the value range and shrink the size. For instance:

- New materials and processes for monolithic ceramics promise to cut costs up to 50% by eliminating the use of precious metals and replacing them with base metals.
- Thinner dielectrics will permit a fourfold increase of capacitance per unit volume.

Dave Bursky
Associate Editor



Thin-film resistor networks, deposited on either silicon chips or ceramics, made by Analog Devices are coming down in cost when used in high volumes.



Ceramic chip capacitors in various sizes, including these from USCC/Centralab, range in value from 0.1pF to over 200 μF. Ratings are from 4 to 200 V.

■ Better packages for tantalum capacitors promise to eliminate reliability problems of the T-bar construction.

■ New mounting methods are permitting low-cost thermal compression bonding instead of reflow soldering or conductive epoxy.

■ More use of machine operations is expected to cut the cost of chip inductors by up to 75%.

■ Increasing use of laser trimming in thin-film networks is making possible tight-tolerance applications.

■ Automated processing is expected to cut the cost of thin films by over 50% in the next few years.

Base-metal cuts ceramic costs

Ceramic chip manufacturers have had problems with the rising cost of precious metals. USCC/Centralab, though, has done something about it. The company has developed monolithic ceramic capacitors that use a base metal compound for the electrodes. This makes them 30 to 50% cheaper than ceramic types that use precious metals. In 5000-piece lots for a 0.1-μF capacitor, the new capacitors sell for less than 10 cents each.

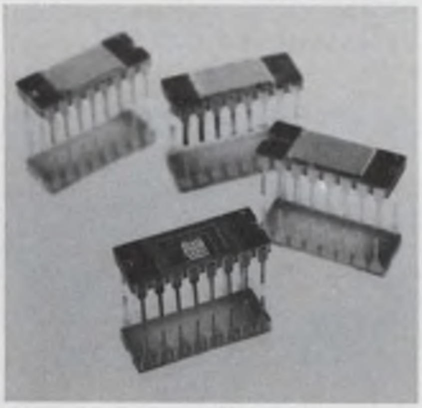
USCC/Centralab, Union Carbide, AVX, Sprague, Centre Engineering and other companies predict that new and thinner dielectric materials will permit higher capacitance per unit volume. More capacitance without an increase in package size will be a reality within the next year.

Ceramic chip manufacturers offer various termination styles designed for reflow soldering or conductive epoxy attach techniques. However, AVX claims to have found a better way with its Planar series of foil-tab leaded chips, intended for low-cost thermal compression bonding. Prices start at \$3 to \$10 in single quantities, and the values range from 1 pF to 1 μF. Four different dielectrics are available, along with 12 chip sizes.

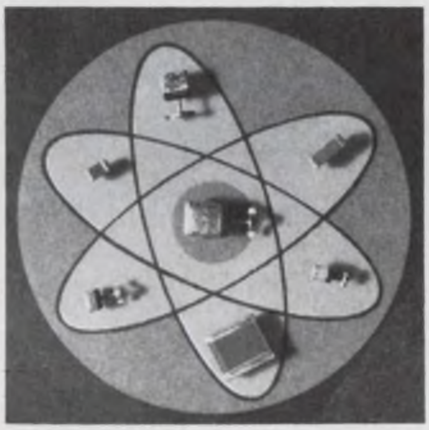
Monolithic ceramic capacitors are the most widely used chip family, but within the family many different dielectric types are available. Three of the most common are the NPO, X7R and Z5U. The temperature characteristics and prices of monolithic capacitors with these materials differ widely.

The NPOs are ideal for high-stability circuits, have tempcos of about ±30 ppm/°C and are typically available with values from 5 pF to 0.02 μF. X7Rs are good for bypassing applications, have tempcos of about 50 ppm/°C and can range in value up to about 0.1 μF. The Z5Us offer the widest range of applications, have tempcos of about 100 ppm/°C and are available with values of over 2 μF.

The lower-cost chips are the NPOs and X7Rs; prices are down around 15 to 20 cents each in 5000-piece lots. The Z5Us cost between 25 and 40 cents for similar lots.



Thin-film resistor networks are often housed in DIPs for easy use. Shown is one from Hybrid Systems.



Tantalum capacitors use T-shaped terminations for mounting onto ceramic substrates. These are from Union Carbide.

Chip sizes start at about 50 mils square by 20 mils thick and range to about 250 mils square by 100 mils thick.

Capacitors that use a material with a high dielectric constant, K—such as the Z5U—have properties that are similar to those of tantalum capacitors, although the values are limited to about 2 or 3 μF when the K is more than 1000.

Medium-K dielectrics, such as the X7R formulations (K between 100 and 1000) can equal the performance of Mylar and polycarbonate types. The low-K types, like NPOs (K less than 100), have characteristics similar to those of mica and polystyrene capacitors.

You need a scorecard

Telling different valued chips apart can be troublesome, since many values are available in the same package size. Marking the values on the tiny chips is an art. Some companies have even resorted to laser marking to get the values ingrained permanently. Coding is done either by letters, dots, numbers or combinations thereof.

If you don't know the value you need, several companies offer adjustable chip capacitors that let you add or subtract capacitance within a limited range. Vitramon has its Vee-Cal series of chip capacitors with an NPO dielectric that permits up to 12 incremental adjustments. Base values start at 10 pF and go up to 680 pF in 24 models. Adjustment increments vary from 1 pF for the small-value units to 20 pF for the larger values.

Each of the Vitramon chips has adjustment contacts on two sides—one set for the coarse adjustment and the other for the fine. A maximum of six adjustments can be made on each side. All that's needed to adjust the value is a lead pencil and an eraser. The chip sizes are all identical—0.18 × 0.05 × 0.05 in.

Semtech offers a different method with its SC6000 series. The company will sell you slabs of monolithic capacitors made from barium titanate ceramic. The slabs are about 1.8 × 1.8 in., which you can then cut to the value you need with a diamond saw. Result: instant custom capacitors.

The Semtech slabs have capacitance values up to 23,000 pF and are available in voltage ratings of 2 to 20 kV. Slabs are also available with custom voltage ratings of up to 70 kV. Prices start at 66 cents and rise to $10 a slab in 1 to 10 quantities.

Tantalums pack it in

To get even more capacitance in a small space, users now have tantalum-based capacitors. These can have values from about 0.1 μF to over 200 μF, while taking up no more room than the large ceramic chips. Typical sizes range from 50 $\times$ 100 $\times$ 50 mils up to 150 $\times$ 285 $\times$ 110 mils.

There are, though, several different termination variations for the chips. For instance, National Components Industries offers end-terminated Blue-Chips, with wide area mounting terminals that are similar to those on ceramic chips. Other companies, like Union Carbide and Corning, have the T-bar structure, which uses the chip itself for one terminal and a lead shaped like a T for the other.

The T-bar has a tendency to break, however, if the chips are not handled with extreme care, says Robert Gress, tantalum capacitor product manager for Corning.

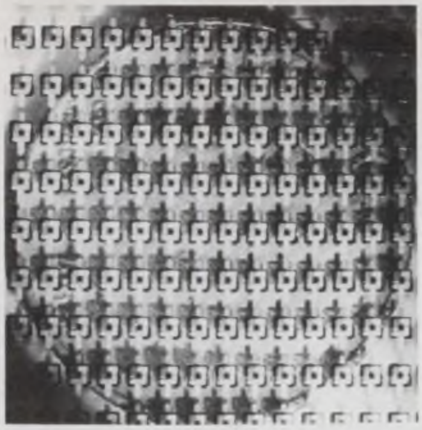
Prices for the tantalum capacitors start at about 20 cents for a low value and increase to about $2 and more for larger values or higher voltage ratings. Ray Irion, marketing manager for Union Carbide, says that tantalum chips cost less than ceramics with the same value. And they provide the user with a more stable temperature characteristic, he notes.

Capacitors get transistorized

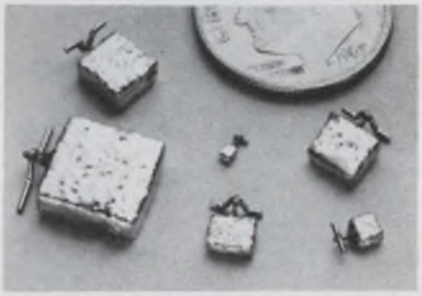
Metal-oxide semiconductor technology is being used for capacitors of low value. But so far only a handful of companies—Texas Instruments, Dionics and Micro Networks, among them—are offering MOS chip capacitors. The values range from fractions of a picofarad to about 150 pF.

The advantages of these chips include their low height from the circuit substrate—typical thicknesses are only 5 mils against the 20-to-50-mil thicknesses of ceramic types.

Larger values than the 150-pF upper limit are possible, note George Seaton, marketing manager for Dionics, and Robert Jay, president of Micro Networks. But

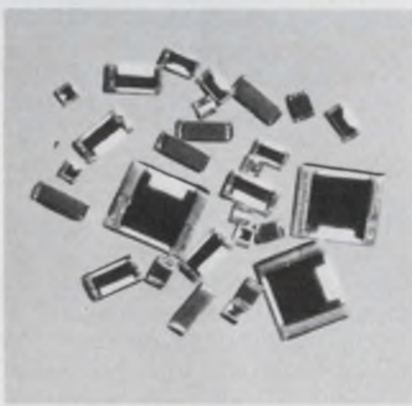


Inductors made by deposits of metal on glass are the specialty of Thinco. Values range up to 120 nH.



Tantalum chip capacitors range in size from 100 to over 250 mils square. A sampling from Corning is displayed.

Monolithic ceramic chip capacitors made by American Technical Ceramics vary in size from 50 to 250 mils square.



Thick-film chip resistors, like these made by KDI Pyrofilm, are available in values from 1 Ω to 10 MΩ.

as low cost becomes the dominant consideration in design, ceramic tends to prevail. However, MOS capacitors can be attached with the same equipment used for semiconductor die mounting and conventional wire bonding.

Typical chip prices in 10,000-piece lots range from 13 cents for low-value units to about 75 cents for high-value. Since the capacitors are deposited on a silicon substrate, many different values can be placed on a single silicon chip.

Dionics, for example, has its Models C-700 and C-1248, which contain capacitors that range from 1 to 39 pF on a 50 $\times$ 35 $\times$ 5-mil chip. The C-700 contains a total of 94 pF, while the C-1248 has a total of 15 pF—but on a chip about half the size.

Chip inductors: Limited choice

Miniature inductors in chip form have been available from only a few manufacturers because they are both hard to make and the very-high-volume demand for them just isn't there. The companies that do offer them have both fixed and variable types, with values from 1 nH all the way up to 10 mH. The variable types are usually available with a tunable range of about half a decade.

"Prices are starting to drop as more of the expensive hand labor needed for wound inductors is eliminated," says Bill Parker, vice president of technical and special components for Airco Speer.

However, the assembly of variable wound inductors is a very delicate operation, and their prices are still in the $3 to $5 range for small quantities—still cheap compared with the $15 to $20 of several years ago.

The cost of fixed units has also continued to decline as production techniques have improved or new methods have been found. Fixed inductors can be bought for as little as 29 cents each in large quantities.

Inductor size is perhaps the most critical factor, after the inductance value. Ultra-small deposited fixed units, such as the L-30 inductors made by Thinco, span a range of 1 to 120 nH and have a chip size of only 50 $\times$ 80 $\times$ 25 mils. These units are made by

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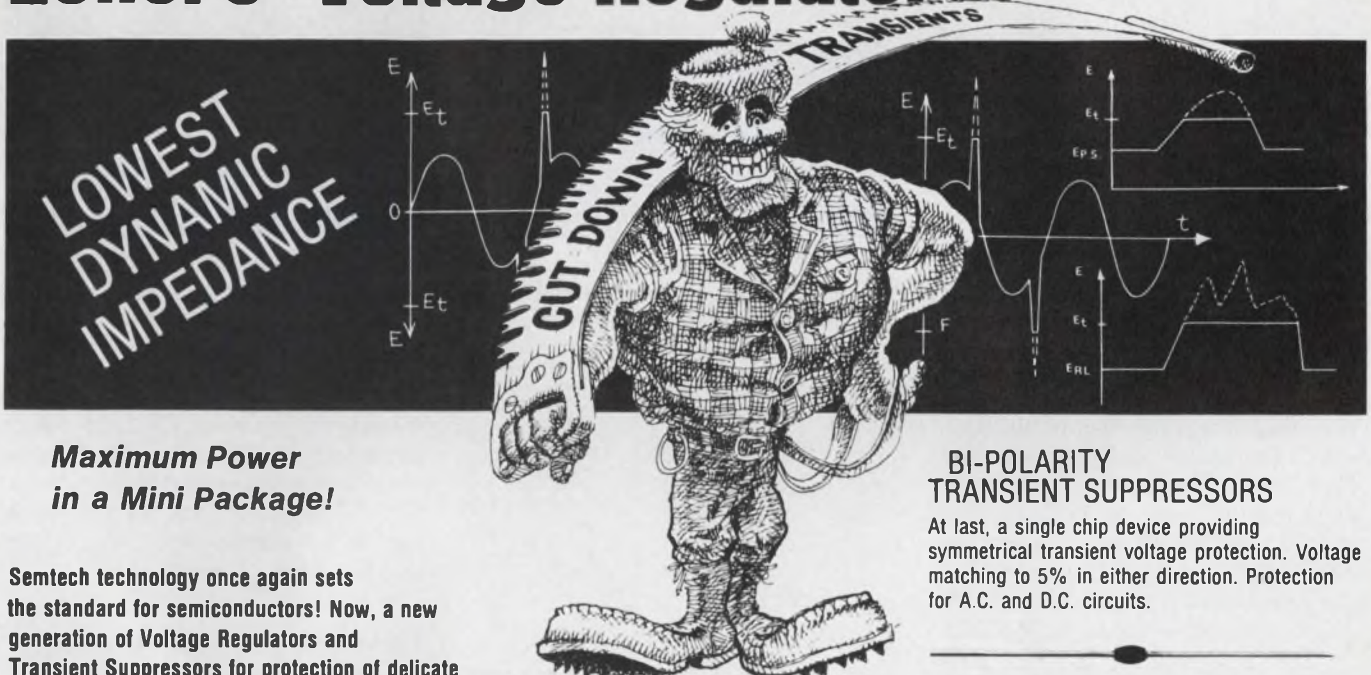

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SX6.8 thru 120
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Low Reverse Leakage
Dimensions (max.): Body .140"D x .165"L
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10 watt

SY6.8 thru 120
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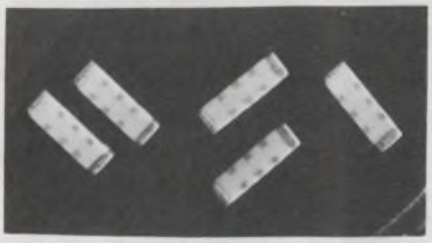


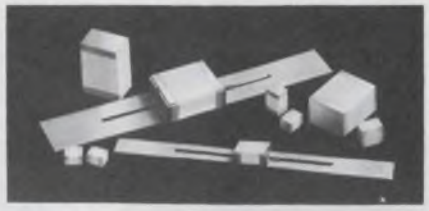
Variable chip capacitors, newcomers to the hybrid scene, are made by Vitramon for easy breadboarding.

Tantalum capacitors in rectangular chip form are the specialty of National Components Industries.

Miniature variable and fixed inductors from Airco Electronics are available with values up to 10 mH.

Pellet resistors by CTS Microelectronics are designed to fit into holes drilled through the substrate.

High-value thick-film resistor chips made by Eltec are so small that stamp perforations dwarf them.



Chip capacitors **designed for microwave ICs** use beam leads. These are from Johanson Monolithics.

vacuum-depositing sequential layers of insulation and metal so they form a square, flat coil. Larger inductor chips, made by Delevan, Nytronics, Vanguard and others, use wound coils of very fine wire that are epoxy-sealed in brick or cylindrical form. They come in sizes up to 250 mils square by 100 mils high.

Inductor manufacturers have had problems in maintaining the coil Q while providing the most inductance in the smallest space. The tradeoff is usually the lower Q, which for these small units is usually under 100, although the L-30 fixed units from Thinco are reported to have Qs as high as 260 at 400 MHz.

Most companies that offer chip inductors also make tuned circuits to custom requirements, since all they have to do is add a tap, or several resistors and a capacitor.

Resistance comes in many forms

Whether you need a high-value resistance or a low one, you have a choice of thick or thin films. Thick films tend to offer the lower cost but lack the temperature stability of thin-films.

Prices for thick-film resistor chips start at about 10 cents each in 10-k lots; thin-film resistors still cost about double that. Manufacturers of thin-film networks, like

Beam-lead capacitors from AVX are designed for thermal compression bonding with foil tabs.

Analog Devices, Hybrid Systems, LRC Microelectronics and National Semiconductor, all feel that as volume applications for thin-film networks increase, prices will drop to compete with those for thick-film circuits.

Thick-film networks are usually not available in chip form; usually they are part of the circuit substrate. Thin films, however, can be built with IC technology, which permits the networks to be treated the same as active chips.

The accuracies of thick-film resistors range from a poor 20% to a fairly tight 1%, with some 0.5% tolerances available on special orders. However, for most applications, trimming thick films to 0.5% is not the answer if tight tolerances are needed. This is because the temperature drift of thick films (depending upon formulation) can be as bad as 200 ppm/°C or as good as 50 ppm/°C.

Thin films have high stability

Thin-film networks, on the other hand, have typical stabilities of 25 ppm/°C and can be formulated down to about 5 ppm/°C. The ratio accuracies of the networks can be trimmed down to 0.001% with computer-controlled laser machines—quite a bit tighter than the accuracies of thick films.

Typical thick-film resistance values range from about 1 Ω to well over 10 MΩ. Mini-Systems offers thick-film chips that range in value up to 1000 MΩ and can handle up to 0.5 W. Their prices start at about 13 cents in 10-k lots, with the chip sizes ranging from 35 × 35 to over 100 × 100 mils.

Other companies—like Airco-Speer, KDI Pyrofilm, Dale, Eltec and CTS Microelectronics—offer chip resistors that are designed for power handling, isolation and special circuit designs.

For instance, CTS manufactures the Ceradot series of cermet pellet resistors. The pellets range in size from 50 mils in diameter and 30 mils thick up to 100 mils diameter and 62 mils thick. Values go from 10 Ω to 1 MΩ. A typical application

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might be to mount the pellets in holes drilled in the circuit substrate and make contact to the top and bottom.

Tolerances for the Ceradots can be as close as 1%, while the temperature drift of the resistance is about 300 ppm/°C. CTS also has rectangular resistor chips that cover a 200-Ω to 350-kΩ range.

If you need high resistance values, try the Eltec. It has thick-film resistor chips with resistances up to 10^{12} Ω. Prices start at about 45 cents each in 10-k lots and accuracies at 30%, narrowing to 5%.

Bulk-Metal for high efficiency

If your circuit needs call for high accuracy and high-stability resistors, thin films are the only way to go. Vishay has just entered the super-precision chip market with its Micro Chip series of 0.01 and 0.001% absolute accuracy Bulk-Metal film chip resistors. Temperature coefficients are down to 5 ppm/°C over a −55 to +150 C operating range. Resistance values at present are limited to 1 Ω to 10 kΩ, but higher values will be available shortly. Prices for these precision chips will be about $3 for 100-piece lots.

Analog Devices offers a thin-film custom service to buyers who fill out a form in the company's catalog. Prices for user-designed networks with 0.1% ratio accuracy typically cost $5 in 1000 quantities.

National Semiconductor has introduced thin-film networks that cost only 35 cents each in 100,000-piece lots. This is for 1% tolerance.

Typical thin-film resistance values range from 10 Ω to about 10 MΩ. Most networks are built on silicon that has a sheet resistivity of about 250 Ω/square. However, Jay of Micro Networks says that materials with sheet resistivities of 1000 Ω/square are "just around the corner." This increased resistivity, he says, is needed to build the low-power circuits required.

Prototype kits—a mixed bag

Did you ever try to calculate the resistance value that you need for a circuit? Or the inductance or capacitance? The law of averages says that you won't have that value available to plug in.

To counteract this breadboard problem, just about every chip company offers a designer's kit of chips. This could range from as few as five chips to several hundred, depending upon what you want to pay and your need. Typical kit prices range from $10 to $700. The kits are usually a great bargain, since they offer a wide selection of component values at a greatly reduced price. ■■

Need more information?

The following companies contributed inputs for this report. The list is far from complete, but it does contain most of the chip component manufacturers. Additional listings can be found in ELECTRONIC DESIGN's GOLD BOOK. The code letters after each company define the various product lines: thick-film resistors (A), thin-film resistors (B), inductors (C), ceramic or porcelain capacitors (D), tantalum capacitors (E), and MOS capacitors (F).

AVX Ceramics, P.O. Box 867, Myrtle Beach, SC 29577. (803) 448-9411. (D) **Circle No. 401**

Airco Electronics, P.O. Box 547, Bradford, PA 16701. (814) 362-5536. (A, B, C) **Circle No. 402**

Alpha Industries, Sylvan Rd., Woburn, MA 01801. (617) 935-5150. (D) **Circle No. 403**

American Technical Ceramics, 1 Norden Lane, Huntington Station, NY 11746. (516) 271-9600. (D) **Circle No. 404**

Analog Devices Inc., P.O. Box 280, Norwood, MA 02062. (617) 329-4700. (B) **Circle No. 405**

Burr-Brown, International Airport Industrial Park, Tucson, AZ 85706. (602) 294-1431. (A, F) **Circle No. 406**

CTS Microelectronics Inc., Box 1278, Lafayette, IN 47902. (317) 463-2565. (A) **Circle No. 407**

Centre Engineering, 307 Benner Pike, State College, PA 16801. (814) 237-0321. (D) **Circle No. 408**

Corning Glass Works, Electronic Products Div., Corning, NY 14830. (607) 974-8237. (D, E) **Circle No. 409**

Dale Electronics, 1376 28 Ave., Columbus, NE 68601. (402) 564-3131. (A) **Circle No. 410**

Delevan Div., American Precision Ind., 271 Quaker Rd., East Aurora, NY 14052. (716) 652-3600. (C) **Circle No. 411**

Dionics Inc., 65 Rushmore St., Westbury, NY 11590. (516) 997-7474. (F) **Circle No. 412**

Eltec Instruments Inc., Central Industrial Park, Daytona Beach, FL 32014. (904) 252-0411. (A) **Circle No. 413**

Emcon Div., Illinois Tool Works Inc., 11620 Sorrento Valley Rd., San Diego, CA 92138. (714) 459-4355. (D) **Circle No. 414**

Gowanda Electronics, 179 Broadway Rd., Gowanda, NY 14070. (716) 532-2236. (C) **Circle No. 415**

Hybrid Systems Corp., 87A 2 Ave., Burlington, MA 01803. (617) 272-1522. (B) **Circle No. 416**

Hy Comp Inc., 146 Main St., Maynard, MA 01754. (617) 897-4578. (B) **Circle No. 417**

Johanson Manufacturing Corp., 400 Rockaway Valley, Boonton, NJ 07005. (201) 334-2676. (D) **Circle No. 418**

Johanson, Monolithic Dielectrics Div., P.O. Box 6456, Burbank, CA 91505. (213) 848-4465. (D) **Circle No. 419**

KDI Pyrofilm Corp., 60 S. Jefferson Rd., Whippany, NJ 07981. (201) 887-8107. (A) **Circle No. 420**

LRC Inc., 101 Digital Dr., Hudson, NH 02051. (603) 883-8001. (B) **Circle No. 421**

Mepco/Electra Inc., Columbia Rd., Morristown, NJ 07960. (201) 539-2000. (D) **Circle No. 422**

Micro Networks Corp., 324 Clark St., Worcester, MA 01606. (617) 852-5400. (B, F) **Circle No. 423**

Mini-Systems Inc., 20 David Rd., North Attleboro, MA 02761. (617) 695-0206. (A) **Circle No. 424**

MuRata Corp. of America, Rockmart, GA 30153. (404) 684-7143. (D) **Circle No. 425**

National Components Ind., Inc., 5902 Australian Ave., West Palm Beach, FL 33407. (305) 842-3201. (E) **Circle No. 426**

National Semiconductor Corp., 2900 Semiconductor Dr., Santa Clara, CA 95051. (408) 732-5000. (B) **Circle No. 427**

Nytronics Components Group Inc., Orange St., Darlington, SC 29532. (803) 393-5421. (C) **Circle No. 428**

Philips Research Press Dept., Eindhoven, the Netherlands. (B) **Circle No. 429**

Piconics Inc., Cummings Rd., Tyngsboro, MA 01879. (617) 649-7501. (C) **Circle No. 430**

Precision Monolithics, 1500 Space Park Dr., Santa Clara, CA 95050. (408) 246-9222. (B) **Circle No. 431**

RCL Electronics Div., AMF Inc., 700 S. 21 St., Irvington, NJ 07111. (201) 374-3311. (B) **Circle No. 432**

Republic Electronics Corp., 176 E. 7 St., Paterson, NJ 07524. (201) 279-0300. (D) **Circle No. 433**

San Fernando Electronic Mfg., 1501 First St., San Fernando, CA 91341. (213) 365-9411. (D) **Circle No. 447**

Semi-Films Div., National Micronetics Inc., Box 188, West Hurley, NY 12491. (914) 338-7714. (B, F) **Circle No. 434**

Semtech Ltd., 652 Mitchell Rd., Newbury Park, CA 91320. (805) 498-2111. (D) **Circle No. 435**

Sprague Electric Co., 645 Marshall St., North Adams, MA 01247. (413) 664-4411. (D, E) **Circle No. 436**

Stackpole Carbon, Carbon Div., Stackpole St., St. Marys, PA 15857. (814) 781-1234. (A) **Circle No. 437**

Tensor Electronics Inc., 11404 Sorrento Valley Rd., Bldg. 120, San Diego, CA 92121. (714) 453-7262. (D) **Circle No. 438**

Texas Instruments, P.O. Box 5012, Mail Station 84, Dallas, TX 75222. (214) 238-3914. (F) **Circle No. 439**

Thinco Inc., Hatboro, PA 19040. (215) 675-5000. (C) **Circle No. 440**

USCC/Centralab, 2151 N. Lincoln St., Burbank, CA 91504. (213) 843-4222. (D) **Circle No. 441**

Union Carbide/Components, Box 5928, Greenville, SC 29606. (803) 963-7421. (D, E) **Circle No. 442**

Vanguard Electronics Co., 930 W. Hyde Park Blvd., Inglewood, CA 90302. (213) 678-7161. (C) **Circle No. 443**

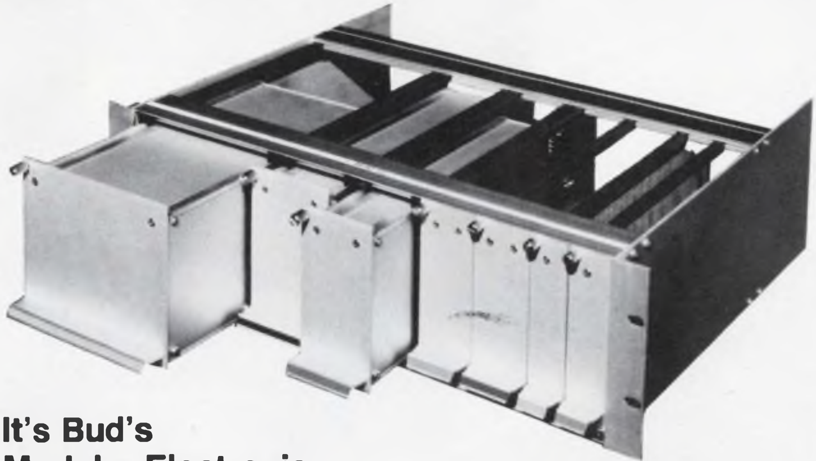
Varadyne, 1547 18 St., Santa Monica, CA 90404. (213) 829-2991. (D) **Circle No. 444**

Vishay Resistive Products, 63 Lincoln Hwy., Malvern, PA 19355. (215) 644-1300. (B) **Circle No. 445**

Vitramon Inc., P.O. Box 544, Bridgeport, CT 06601. (203) 268-6261. (D) **Circle No. 446**

When you've got a new product that excites 1,235 people at Wescon, you've got what they want.

Bud has it!



It's Bud's Modular Electronic Packaging System.

And 1,235 people were stopped in their tracks at the Bud booth during the Wescon show to see it, talk about it. Here's what they saw. Talked about.

Accurate alignment.

Highly stable, one-piece, full length guides provide accurate alignment of circuit boards and edge connectors. The edge connectors are mounted directly to the end of the guides, thereby eliminating the need for separate mounting rails and spacers. Glass-loaded polycarbonate guides rest on the horizontal cross rails of the sub-racks. Since guides do not carry the weight of boards or sub-units, there is no guide distortion.

Variable guide spacing.

Plug-in guides can be spaced instantly on any pitch that is a multiple of 0.200". Basic pitch of 0.200" with a normal card pitch of 0.600" provides 0.200" on the wiring side and 0.400" on the component side of the circuit board. When guides are plugged in at an 0.400" pitch, 42 circuit boards can be housed.

Easy insertion.

Guides are flush with the front of the sub-rack. Circuit boards and sub-units can, therefore, be inserted into the sub-rack even when the sub-rack is located above or below eye level.

No profiling of boards.

A specially designed connector end foot provides lead-in for each board and, also, allows the edge connector to be the full height of the board. Board profiling is eliminated.

Simple and rugged construction.

The system has been uniquely designed with a minimum number of components to assemble. Rugged aluminum extrusions and heavy gauge aluminum panels provide extreme rigidity. The front panels are brush finished and anodized while all other aluminum parts are etched and anodized.

And it's flexible.

One of the major advantages of the Bud System is that the componentry comes in a range of sizes. In sum, the System adapts to your application. Sub-rack frames are available in standard 19" width, four E.I.A. panel heights and two depths. Eight sub-racks, 30 sub-units, six printed board units come in individual easily assembled kits. Eight standard circuit boards and 16 standard edge connectors are also available. Special Connector Mounting Rails can be ordered to accommodate other types and sizes of connectors.

See it. Talk about it.

Your Bud Representative has complete data on the new Modular Electronic Packaging System. He also has a demonstration model. See it. Work with it. Then you'll realize here's a highly functional system that adapts to your ideas, your imagination, your system.

BUD

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4605 East 355 Street Dept. 11A
Willoughby, Ohio 44094

INFORMATION RETRIEVAL NUMBER 101

Phone your nearest Bud Representative.

JACK BERMAN CO., INC.
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504-279-4598
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801-534-1500

LUND & COMPANY INC.
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Dallas, Tex.
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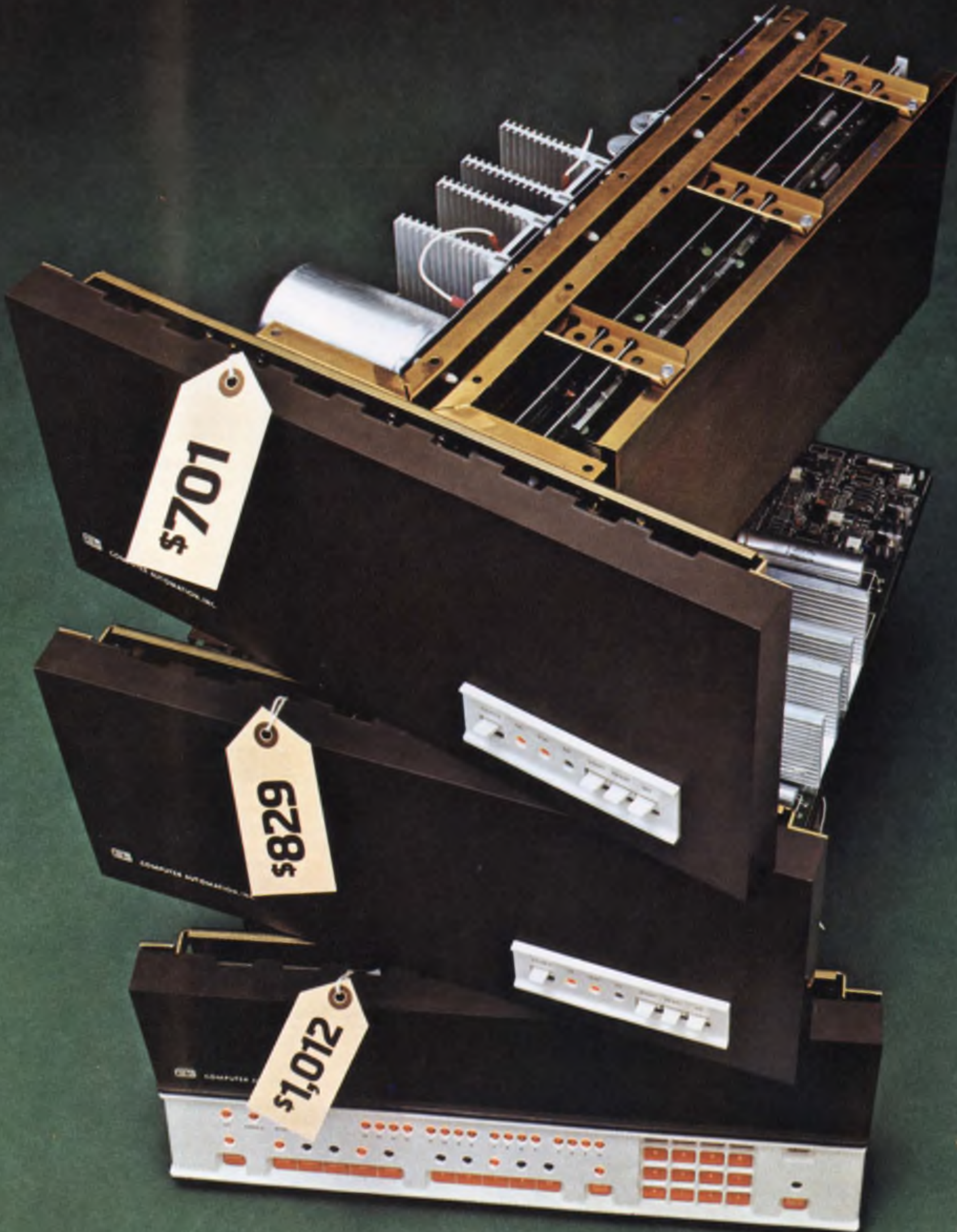
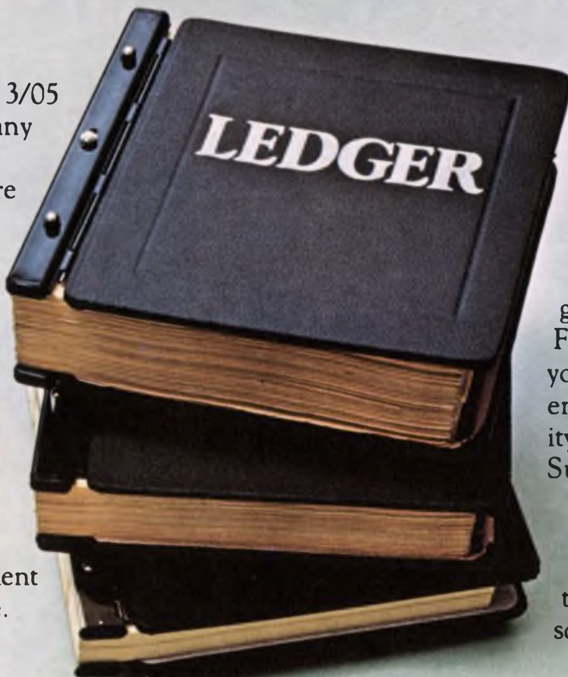
What our bottom-of-the-line



The New ALPHA™ LSI-3/05

Introducing the lowest priced, 16-bit, full-scale, fully compatible, packaged computers in the world.

can do for your bottom line.



Stack the new ALPHA LSI-3/05 millicomputer up against any other low-end computer.

Preferably while you're sitting down, because on price alone, you're bound to be astounded.

Ready? $701 total packaged price. And that's complete with 256 words of MOS RAM, and a CPU that offers a really powerful instruction set, Power Fail Restart, Real-Time Clock and Autoload capability.

Try to buy an equivalent computer at twice the price.

Have it your way.

You also get the capability to configure your computer pretty well the way you want it. A choice of packaging, of course, that includes either the Operator's or the Programmer's Console, power supplies and so on.

A choice of two standard I/O options.

And a choice of optional memory configurations that include RAM/ROM, RAM/EPROM and RAM-only in sizes from 256 words all the way up to 32K words. Totally addressable.

Maxi-Bus compatible ALPHA LSI-3/05 achieves unprecedented cost-effectiveness with ComputerAutomation's new Distributed I/O System.

Family connections save you still more money.

So far, what we've been talking about could easily add another five or six figures to the bottom line of your ledger.

But there's more. Really big savings on off-the-shelf software, peripheral controllers and I/O interfaces.

The reason is that the ALPHA LSI-3/05 millicomputer is a full-fledged member of ComputerAutomation's LSI Family... Maxi-Bus compatibility and the whole works. So, every piece of Family hardware we've ever developed will work like it was made for the ALPHA LSI-3/05. Including ComputerAutomation's exclusive new Distributed I/O System... just like you see it in the picture.

With this versatile interface system, you can interface virtually any kind or combination of peripherals. Parallel or serial. Just by plugging them in.

Your cost? Probably less than $200 per interface.

The pros know.

Computer-wise OEM's will tell you that product requirements sooner or later get ahead of the hardware. For instance, the computer you buy today may not have enough I/O or memory capacity for tomorrow's Mark II Super Widget.

Then you'll have to scrap all your software and your interface designs, because they're not about to work on some other machine.

You lose.

Of course, with our LSI Family of compatible computers you don't.

You can switch to a different CPU or a different memory anytime. Faster, slower, bigger, smaller. The electrical interface will still be the same; the original programming will still work.

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From the people who brought you the NAKED MINI®.

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And now the ALPHA LSI-3/05 millicomputer.

One cost breakthrough after another. Breakthroughs that didn't just happen... a lot of profits got plowed back into R&D.

But then, that's the price of leadership.

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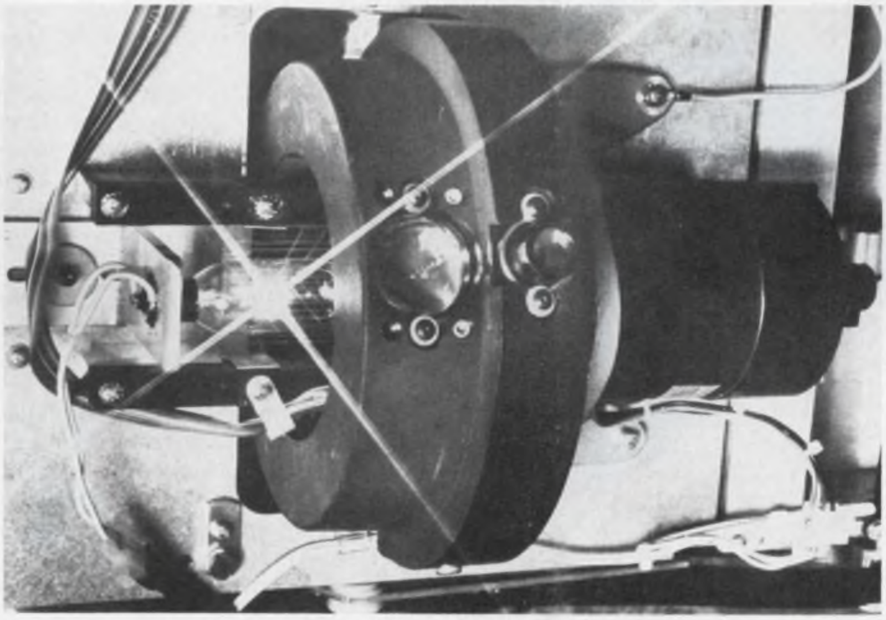
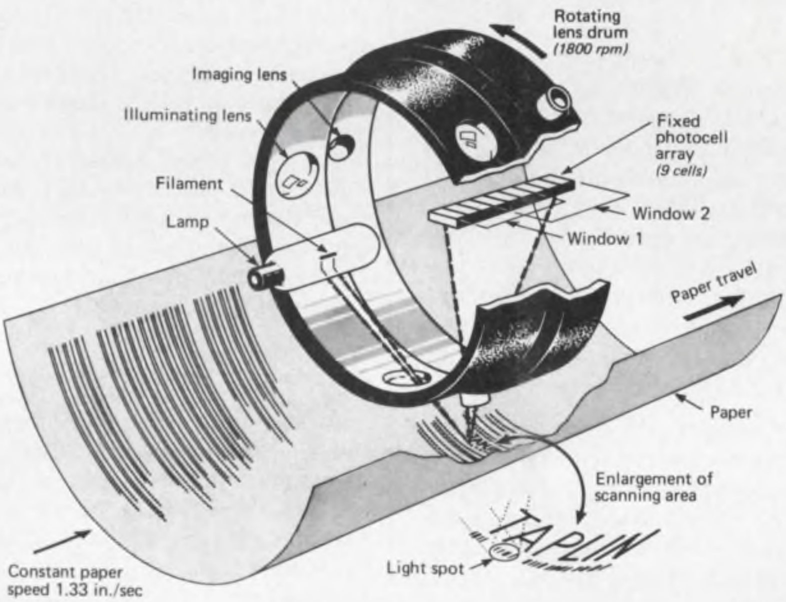
All prices shown are for lots of 100 (U.S.A. only).

Optical reader scans coded copy at 400 characters per second





The optical drum is the only moving part in the Model 101 reading mechanism. The drum rotates at 1800 rpm, scanning the typed line at 1000 inches per sec.

A new low-cost optical page reader scans typewritten copy with a throughput rate equivalent to that of 20 to 30 computer keyboard operators.

The reader, which uses special typewritten copy that contains a bar code under each character, can scan a densely typewritten page in 10 seconds—400 characters per second—according to Gordon Baty, president of Taplin Business Machines, Burlington, MA, the system developer. The company recently changed its name to Context Corp.

The machine reads out data in an 8-bit ASCII format and also in the RS232C serial code at 4800 or 9600 baud. With modifications, other codes can be used.

Called the Model 101, the machine was developed for use as a minicomputer peripheral, Baty says. Typists use a special $30 ball for an IBM Selectric or Remington SE-100 typewriter.

The key to the system is a continuously rotating three-lens barrel that scans the copy and focuses the 0.024-in.-high code bars onto a fixed linear array of nine photocells. These cells are electronically gated to give an effective array of six four-bar cells. The electronics controlling this selection, according to Baty, provide the following advantages:

- The typewriter letters are rejected and only the bar codes are read.
- The proprietary bar code, which consists of four narrow or wide vertical bars and three narrow or wide spaces between the bars, reduces errors. It has a built-in parity check that prevents the reading of spots of dust or dirt.
- If error-free typewritten copy is used, the accuracy of the reader is better than 1 character in 25,000.
- The machine can read "free form" typing—numerical data, lines and corrections typed anywhere on the page—so long as the lines are within the system's skew

Jim McDermott
Eastern Editor

tolerance of ±0.070-in.

The Model 101 code, says Leland J. Hanchett, manager of advanced product development for Context, was chosen over previous codes for several reasons. The code corresponds to four bars and three spaces. Both the bars and the spaces are wide for a digital ONE, Hanchett explains, or narrow for a digital ZERO.

The basic code provides a seven-element array with 128 possibilities, but because the typewriter prints only 88 characters, the most easily recognized sets of 88 bars were chosen.

Use of the four-bar code aids in holding down reading errors, Hanchett notes. In contrast with other optical bar codes, he says, dust specks and other sources of optical noise, instead of making the system believe it is exposed to a false character, tend to make the bar code unreadable. The machine then provides an indication of unreadability.

For example, Hanchett explains, the dust speck is more likely to obscure the space between bars, producing three bars instead of four. The dirt may add another bar, making a total of five. The system electronics rejects such false readings.

Further, Hanchett points out, if the bar and space widths fall substantially outside the specified dimensions, it will be diagnosed as a "can't read."

On the other hand, Hanchett notes, with bar codes that follow the Teletype or ASCII format, the addition of a speck of dirt can add the equivalent of a bar and cause an error.

No timing errors

In the electronics for interpreting the bar codes, the Model 101 detection system starts a clock count at the beginning of every bar and every space, and it stops counting at the end of every bar and space.

In this way, Hanchett says, the system is free from the cumulative timing errors of ASCII coding methods. ASCII-coded systems use the timing circuits to generate a strobe, which samples whether a bar is present at predetermined intervals.

Another limitation of the ASCII

Special type ball imprints bar codes for character recognition beneath each of the typewritten characters.

method, Hanchett asserts, is that samples of the horizontal bars in the typed letters can be misconstrued as a code bar. For this reason, ASCII bar readers require that the first typed line coincide with a preprinted marker and that the paper be stepped in precise line increments. As a result, free-form typing cannot generally be used.

In the new reader a sheet is inserted, and it progresses beneath the rotating optical head at a uniform rate of 1.33 in/s. This head design was chosen, Hanchett says, to eliminate the drawbacks of scanning with mirrors, as well as those of mechanical systems that scan back and forth across the page.

The role of the rotating lens assembly is to illuminate the characters to be read and to focus the typewritten elements onto the nine-element photocell array.

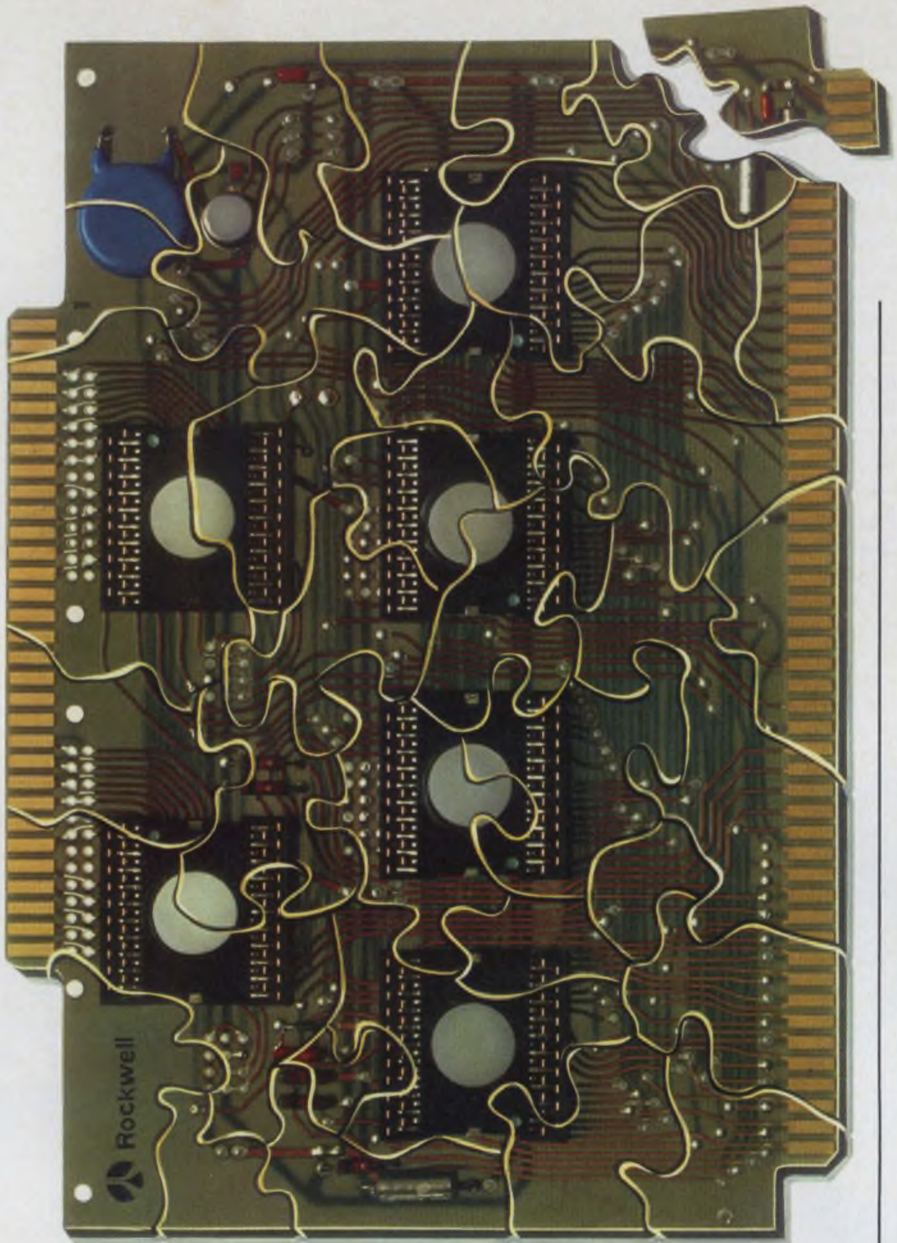
The paper is drawn by a vacuum into a semicylinder shape as it travels under the reading head, Hanchett explains. Thus the lenses view the entire line at constant focal length.

The optical drum rotates at 1800 rev/min or 30 rev/s, sweeping a beam of light across each line of typed characters. At the 30 rev/s drum speed, the light spot travels across the width of the page at about 1000 in/s.

Since the characters are typed at 10 per inch, each character in a line is illuminated for about 100 μs. This provides an instantaneous reading rate for a single lens of 10,000 characters per second.

However, because the rotating drum houses three pairs of illuminating and imaging lenses, the typed line is swept three times by a light spot per revolution. ■■

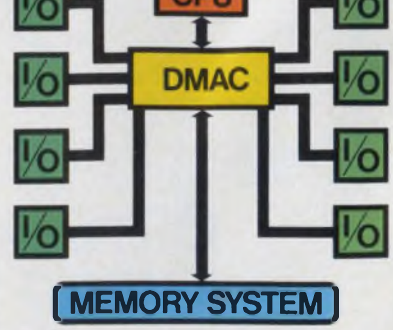
Rockwell a system



DMAC:

Another burden lifted from the CPU.

Our 8 channel Direct Memory Access Control (DMAC) gives priority to data flow between the I/O's and the system's memory. Once again, the CPU is freed from a routine, time-consuming chore.



Intelligent I/O's do the CPU's busywork.

We've identified many common tasks performed by microprocessing systems and designed intelligent LSI I/O's to control them — independent of the CPU. The CPU is thus able to delegate mundane chores such as running the peripherals, while concentrating on the serious thinking it does best.

The spreading of intelligence among the I/O's also reduces the amount and cost of program memory in your system. And because the CPU is no longer responsible for monitoring a multiplicity of functions all over the lot, programming becomes simpler, faster, and more flexible. You simply plug in or remove a chip with minor, not total, software changes to add or subtract functions.

is there with
approach to microprocessing.

PARALLEL PROCESSING:
HIGH SPEED RESULTS FROM LOW COST TECHNOLOGY

With so much independent intelligence spread through our system, many tasks can be executed at virtually the same time. With our parallel processing system (PPS) you can now perform tasks with MOS microprocessing that would otherwise require higher cost technologies.

A THRILLING CASE HISTORY

A fellow designed a new cash register whose I/O's sprawled over three PC boards and cost about $250. He felt there was a better way and went to a large microprocessing house, but one which sold chips, rather than systems. They reduced him to one large and two small PC boards, with a cost of about $160. Finally, he came to Rockwell, where we applied our LSI system approach to his problem. He walked out with his entire system in LSI on one PC board at a cost of about $85.

MILLIONS OF DOLLARS SAY WE'RE SERIOUS ABOUT ALL THIS

We've spent millions of dollars to develop more than 40 LSI microprocessor circuits to offer you LSI options for most of your electronic needs. As well as a worldwide sales and field service organization. Add to that a production capacity of tens of millions of circuits per year and you get the picture: giant Rockwell is very serious about tiny microprocessors. Don't let anyone tell you otherwise.

Help is never more than ten digits away:

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Just call us at any hour and tap into a wealth of Rockwell customer support: detailed literature, software libraries, assembler - simulators and other design aids. Programming and board development assistance. And training programs at our facilities or yours. Some of this help is free; some costs. Take as much or as little as you need. What's important is that it's there. Right now.

Stop trying to solve microprocessor problems by bits and pieces. Instead, see how Rockwell's LSI system approach can help you. Call Bill Roland at (714) 632-3729 or write to:
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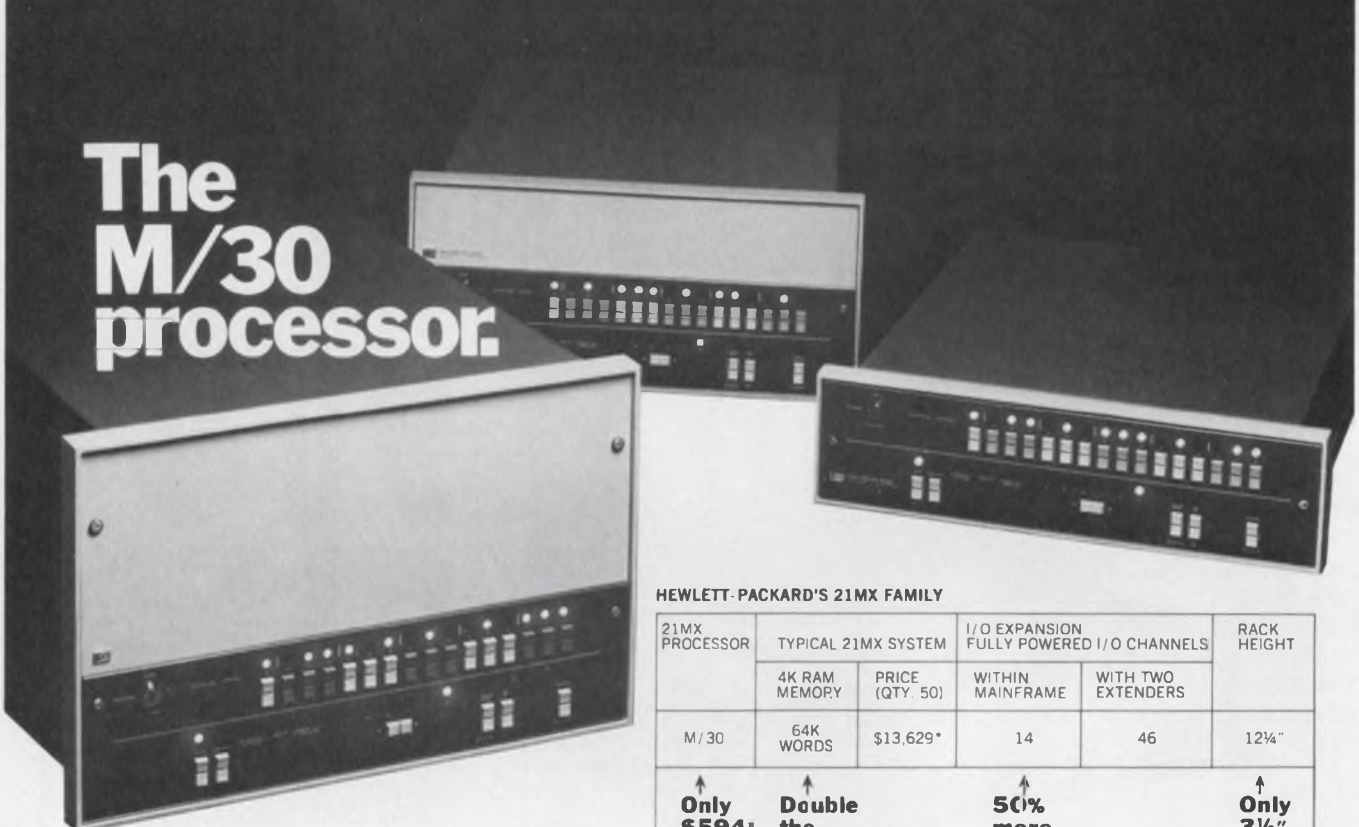
Rockwell International
P.O. Box 3669
Anaheim, California 92803

Rockwell International

...where science gets down to business

INFORMATION RETRIEVAL NUMBER 23

Now, a Hewlett-Packard 21MX for OEM's who think big.



HEWLETT-PACKARD'S 21MX FAMILY

21MX PROCESSOR	TYPICAL 21MX SYSTEM		I/O EXPANSION FULLY POWERED I/O CHANNELS		RACK HEIGHT
	4K RAM MEMORY	PRICE (QTY. 50)	WITHIN MAINFRAME	WITH TWO EXTENDERS	
M/30	64K WORDS	$13,629*	14	46	12¼"
Only $594* more	**Double the memory**		**50% more I/O slots**		**Only 3½" more rack space**
M/20	32K WORDS	$ 7,788*	9	41	8¾"
M/10	16K WORDS	$ 5,049*	4	36	5¼"

***Domestic USA OEM prices quantity 50.**

Now Hewlett-Packard brings 4K RAM semiconductor technology to OEM's with large memory needs. Compatible with all previous 21MX minicomputers, the new M/30 offers the same modularity, the same flexible user microprogrammability.

Not only does 4K RAM technology bring you more reliability, you also benefit from our recent February 30% price reduction on memories. (Send for your free copy of our recent "Engineering Evaluation Report." It proves the 4K RAM based 21MX minicomputer series is 50% more reliable than our previous "core" based machines.)

And take a hard look at what HP offers you in I/O. We give you more: 14 I/O slots in the M/30. But equally important they're all fully powered with vectored interrupts.

Plus Dynamic Mapping with addressability to 1 megawords.

Choose the 21MX that fits your thinking: M/10, M/20 or M/30. Ideal solutions for OEM's from 8K to 256K.

For complete data, write or phone your nearest Hewlett-Packard sales office.

HP Minicomputers. They work for a living.

HEWLETT hp PACKARD

Sales and service from 172 offices in 65 countries.
1501 Page Mill Road, Palo Alto, California 94304

22529

INFORMATION RETRIEVAL NUMBER 24

Straight talk about IC sockets.

Integrated-circuit sockets are becoming such a household item, people are starting to forget something.

They're not all alike. And the differences can have a major impact on the performance and profitability of the products they're used in.

That's why we've decided to go over a few socket basics.

THE REASONS... AND THE RISKS.

All sockets serve basically the same purpose: they allow you to replace ICs without damaging either the IC or the PC board. In so doing, they make both design changes and field service economically feasible for you and your customer.

There's only one problem. When a socket fails, troubleshooting can be a nightmare—to a point where you'd have been better off without sockets in the first place. So it pays to be sure that the sockets you buy are right for your application.

CHOOSING THE RIGHT SOCKET.

Buying the right socket is much more than a matter of profile and price. It's matching the right one to the demands of your application.

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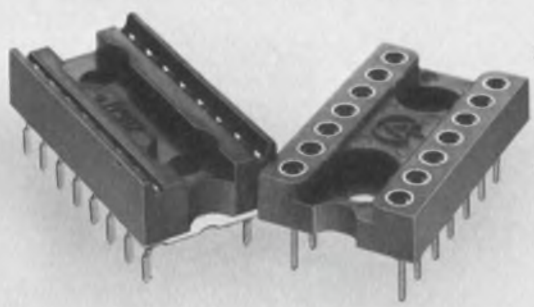

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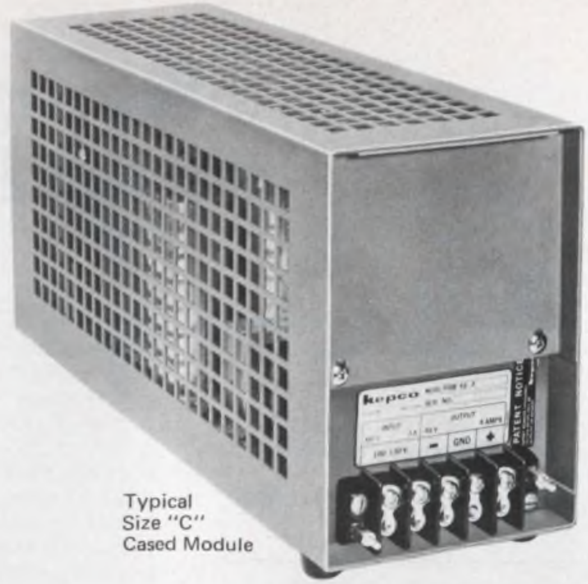

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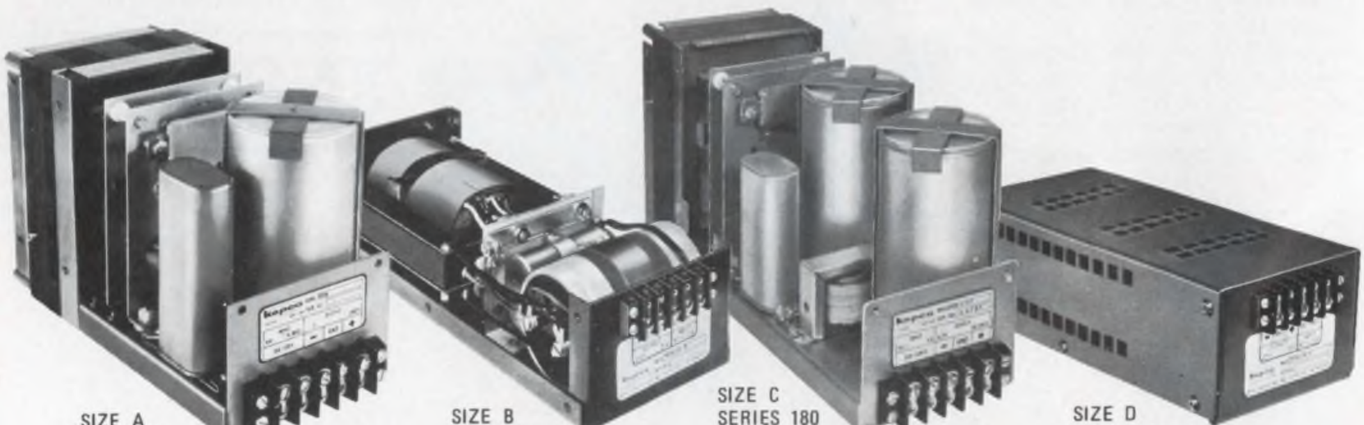

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INFORMATION RETRIEVAL NUMBER 26

Washington Report

An independent FAA sought

The Federal Aviation Administration may regain its old place in government life through a father and son act. Sen. Barry Goldwater (R-AZ) and his son, Rep. Barry Goldwater Jr. (R-CA), have introduced bills in their respective chambers on Capitol Hill that would take the FAA out from under the Dept. of Transportation and once again make it an independent agency.

In 1967 the then independent Federal Aviation Agency ran its own show, but management experts argued—and won—the debate that resulted in all forms of transportation being lumped into one department. By stacking bureaucracies on top of one another Senator Goldwater contends, the Government has introduced some obvious shortcomings—such as adding 18 months or more to the FAA's procurement process. Both father and son argue that independence will permit the agency to act more quickly to update its services and improve air safety.

Better distribution of NSF grants urged

Contending that there is a pattern of administrative abuses and mismanagement in the National Science Foundation, Sen. Jesse A. Helms (R-NC) has introduced a bill to provide a peer review and management system for awarding grants. A similar bill in the House has been introduced by Rep. John B. Conlan (R-AZ). Both bills are aimed at obtaining better nationwide distribution of grants and the blocking of projects of questionable value.

At present, there is no single decision process in the foundation. On all but the larger grants, the program officer has formidable power. The bills to amend the National Science Foundation Act of 1950 would, among other things, require a review of applications by a peer group of no less than five qualified individuals in a particular field. The NSF program officer could select half of the group from an approved list, the applicant could name 20% and the remaining 30%, chosen randomly.

Recent statistics, says Rep. Conlan, "show that NSF funding is restricted primarily to a small group of preferred institutions within a few states, with special preference to an elite corps of academic institutions heavily represented on the foundation's advisory committees."

Defense budget backers arm for new battles

The war over the Defense budget goes on with the Senate Armed Services Committee victorious over the Senate Budget Committee and the House of Representatives in the first engagement. But more battles lie ahead.

Just prior to the August recess, the Senate, at the urging of its new Budget Committee, refused to approve the conference report on the authorization bill, which was a stinging defeat for Sen. John Stennis (D-MS), chairman of the Armed Services Committee. Although the more liberal Senators wanted billions sliced from the bill, Senator Stennis and the other conferees reported back with a bill that was further trimmed by only $250-million. The Senate has now passed this version almost placidly, with the defense budget-cutters reserving their next attack for the appropriations bill passed by the House on Oct. 2.

The authorization for the coming 15 months now amounts to $30.9-billion. The conferees cut $60-million for a nuclear strike cruiser. The AWACS program still calls for six aircraft, but $60-million was cut from the program and spares. The Air Force F-15 program was reduced $22.3-million on all spares, in addition to AWACS, $22.7-million. The Navy's patrol frigate program was cut from 10 to nine vessels, saving $85-million.

With the "shopping list" bill out of the way, the Senate began considering a $112-billion appropriation bill, which would cut some $4.5-billion from the sum the Defense Dept. now plans to spend this year. A spirited fight is expected in the Senate, for example, over the AWACS program. The House, which reluctantly agreed to a six-plane program, voted money for only two planes.

According to the Senate Budget Committee, the House appropriation bill exceeds the Senate committee's guidelines by $700-million. A replay of the donnybrook on the authorization bill is assured, because this will be the last chance to cut defense spending during the next 15-month period that began on July 1.

California leads in defense contracts

When it comes to winning the defense dollar, California still reigns supreme, capturing one-sixth of the total procurement in the fiscal year that ended last June. According to the Defense Dept. Comptroller, the total value of military procurement for the year came to $43.3-billion; California contractors got nearly $8-billion of that.

New York State was second with $3.7-billion, followed by Connecticut, $2.3-billion, and Texas, slightly over $2-billion. States with more than $1-billion in contracts were Massachusetts, Washington, Missouri, Virginia, Pennsylvania, Florida and Ohio. Montana, with $5.1 million, received the smallest slice of the pie.

Capital Capsules:

The Air Force has developed a Voice Input Code Identifier that enables a computer to recognize spoken digits and certain command words, say Air Force engineers, who tested it with a variety of regional accents. The identifier will be used with the Automated Speaker verification system for controlling entry to restricted areas. . . . The Army's Safeguard ballistic missile defense system became operational Oct. 1. It will not be deployed, however, due to terms of the U.S.-Soviet detente. . . . **Libya is looking for $30-million worth of air control training equipment**, including air traffic control, search and rescue and computer systems. . . . The Army's selection of the French-German air defense system, Roland II, over an American system is described by the Defense Dept. as **"a major step forward in defense cooperation among NATO allies."**. . . . **The Army is giving a longer reach to chaff dispensers by sending the jamming material via rocket.** The projectile dispensers are powered by 2.75-inch rocket motors.

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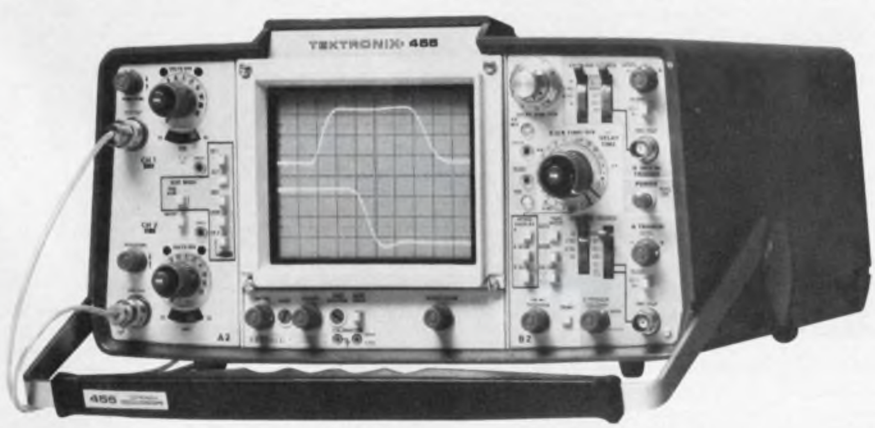
INFORMATION RETRIEVAL NUMBER 27


TEKTRONIX 455
455

HiNIL Interface

Keeping the bugs out of microprocessor systems with high noise immunity logic.

An MOS microprocessor system can be troubled by disastrous bugs unless it is protected against noise transients generated by switches, electromechanical peripherals and other nearby noise sources, such as lamps and machinery. But filters and shielding, the traditional cures, are often difficult to add to a microprocessor because of size and cost constraints.

These problems can be avoided by substituting HiNIL interface devices for conventional I/O logic. HiNIL—Teledyne's bipolar High Noise Immunity Logic—has a guaranteed DC noise immunity about 10 times that of TTL, for example (3.5 vs. 0.4V). Also, HiNIL blocks AC transients large enough to cause TTL malfunctions. Two additional advantages are superior output drive and, in low power systems, protection of CMOS memory and random logic inputs.

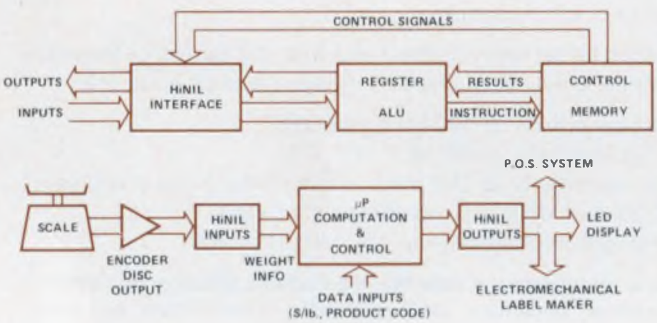


Figure 1. Use of HiNIL interfaces in POS systems with electronic scale. Top diagram shows basic microprocessor configuration.

One manufacturer of microprocessor-controlled electronic scales decided to use the configuration in Figure 1 because he was concerned about the consequences of incorrect weights and prices. The probability of errors resulting from noise transients was high because the scale would be used in a supermarket POS system, where the environment includes refrigerators, fluorescent lamps, meat grinders and electromechanical label makers.

In the system, the microprocessor receives weight codes from an encoder disc in the scale and operates a cash register interface, LED display, and relays of a receipt printer or label maker. The system designers put HiNIL interface logic on the microprocessor board to handle the I/O functions, suppress noise transients picked up along the transmission lines, and drive the peripheral devices. HiNIL output interfaces can drive long lines, relays, displays and lamps without additional components since they sink up to 65 mA and source up to 12 mA. (The new 390 buffer series will sink up to 250 mA.)

Manufacturers of systems requiring random logic are finding that HiNIL and CMOS are an ideal combination. They maximize system noise immunity and assure an excellent system function/power product. HiNIL and 54C/74C CMOS interface directly at V_{CC} voltages from 10 to 16 volts, the power supply range of HiNIL. Moreover, HiNIL protects CMOS inputs from destruction by static electricity and from harmful DC input levels that can exist before CMOS circuits are powered up.

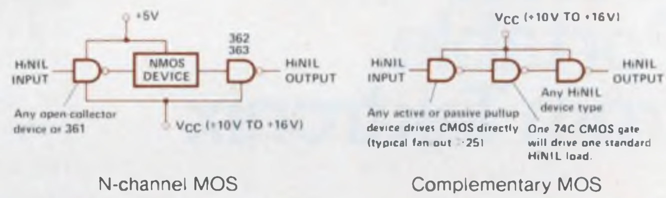


Figure 2. Typical HiNIL/MOS and HiNIL/CMOS interfaces

The rules for using HiNIL with MOS or with CMOS operating at lower voltages are simple. The pullup resistor of an open collector HiNIL device is connected to the desired high logic level voltage (see Figure 2). To use HiNIL with other bipolar logic, just plug in a Teledyne dual or quad interface circuit (see table). HiNIL is also compatible with most analog devices.

Examples of HiNIL Interface Devices

301 Dual 5-Input Power Gate 302 Quad Power NAND Gate (OC)	65mA relay or lamp driver
323 Quad NAND Gate (OC) 332 Hex Inverter (OC) 334 Strobed Hex Inverter (OC)	Input noise protection plus open-collector pullup to other logic levels
350 8-Bit Multiplexer 351 Dual 4-Bit Multiplexer	Drive longer lines than TTL with 10X noise immunity (I_{OH} = 12mA)
361 Dual Input Interface 362 Dual Output Interface 363 Quad Output Interface	361 directly connects HiNIL to DTL/RTL/TTL 362 and 363 connect DTL/RTL/TTL to HiNIL
367 Quad Schmitt Trigger 368 Quad Schmitt Trigger (OC)	Suppress 100V/1μs spikes, protect CMOS decode switches, etc.
380 BCD to Decade Decoder 381 BCD to Decade Decoder (OC) 382 BCD to Decade Decoder 383 BCD to 7-Segment Decoder	Provide decode/drive for lamps, LEDs, gas discharge displays, etc.
390 Interface Buffer Series	250mA HiNIL driver series will be available soon

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INFORMATION RETRIEVAL NUMBER 28

Editorial

Ignorance and apathy

Dan, an old buddy, telephoned the other day to relate a conversation. He was sipping some lemonade at the Wagon Wheel, a local culture center in California's Silicon Gulch, when he overheard two semiconductor executives.

"What's wrong with this industry," Will was philosophizing, "all boils down to two factors—ignorance and apathy." Jerry stirred his drink, steepled his hands, looked at the ceiling, then replied, "I don't know. And I don't give a hoot."

Jerry may have been kidding. But the story, even if apochryphal, is more sad than funny. It's sad on two counts. First, far too many of us don't know and don't care. And second, far too many of us don't know and don't care that we don't know and don't care.

We adjust too readily. When we see our own companies turning out shoddy products or engaging in practices that might be less than admirable, we close our eyes. We see nothing and want to see nothing. Maybe the social and economic setup makes us insecure and fearful. Or maybe we're too comfortable. And maybe our comfort is too easily shaken by our seeing things and giving voice to our consciences. Maybe our blinders help us drug our consciences. Unfortunately, conscience can't be buried. So there's one tragedy.

The second may be a blessing rather than a tragedy. Most of us can't see what we can't see—even when we are shown.

Tell one fellow that there's too much bigotry in the world. And he might agree, if he cares to agree, while denouncing Jews, or blacks, or women, or red-headed men, or Easterners or Westerners, or whomever. Tell a man there's too much conceit in the world and he might agree while hailing his own virtues. Tell an engineer there's too much equipment around that fails too readily and he might agree, while condemning those who don't use his designs with the utmost caution.

Maybe it's fortunate that most of us have a built-in mechanism to protect us from seeing some of our ugliness. But wouldn't it be better if we were secure enough and strong enough to see and care?

George Rostky

GEORGE ROSTKY
Editor-in-Chief

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INFORMATION RETRIEVAL NUMBER 30

Technology

Increase microcomputer efficiency

with interrupt and DMA capabilities. A microprogrammed μP needs only seven extra ICs and six new instructions.

Two common features of large computers—program interrupt and direct memory access (DMA)—can be readily applied to microcomputers. These features give micros a vast increase in processing efficiency.

Program interrupt allows external hardware to initiate program operations without continuous program monitoring. It also makes more time available for program operations by reducing time spent waiting for I/O devices to complete operations (see box).

The DMA feature provides controls for high-speed direct transfer of data between an I/O device and memory. No program intervention is required during the transfer. Data can be transferred at rates up to the maximum speed of the memory—much faster than would be possible under program control. And the DMA feature allows attachment to the microcomputer of high-transfer-rate devices, such as magnetic tape and disc units.

Moreover program interrupt and DMA can be simple to build into a microprocessor. A microprogrammed processor,[1] in particular, requires only seven additional ICs, six new instructions and nine extra control-ROM bits (Fig. 1).

Making decisions

Both interrupt and DMA operations occur between instructions. Thus these operations affect normal instruction fetch and execute sequences. At the end of each instruction the microprocessor must select the next sequence to be performed—execution of an interrupt, one of two DMA operations or the fetch and execution of a normal instruction.

This decision-making begins with the ROM address register (RAR) of Fig. 1. It clears to zero at the end of each instruction, so that ROM-address zero starts the next instruction fetch portion of the microprogram. A memory called the End-Op ROM decodes the status of the following lines: Interrupt Request (INTR), Interrupt Enable Flip-Flop (INTEN), DMA Request (DMAR), and DMA Write (DMAW). The decoding produces an address that is loaded into the RAR at the end of instruction execution.

If no interrupt or DMA requests are present, the ROM emits an address of zero, and RAR sets to the start of the next instruction-fetch sequence. If an Interrupt or DMA request is present—indicated by activation of the INTR and/or the DMAR lines—the RAR loads with the starting address of the appropriate Interrupt, DMA Read or DMA Write sequence. The End-Op ROM is so coded that DMA operations have priority over interrupt operations. Also both INTEN and INTR lines must be active before the interrupt sequence can be selected. A flow chart of these operations appears in Fig. 2.

Once an interrupt request has been received and the execute sequence has been entered, the interrupt request must be disabled. Otherwise the hardware will continue to loop through the interrupt execute sequence. The End-Op ROM, enabled at the end of the interrupt sequence, continues to generate the sequence start address as long as INTR is active.

The INTEN flip-flop overcomes this problem. It disables the interrupt request (INTR). And the INTEN flip-flop clears during the interrupt sequence, and may be set—or cleared—under program control by new instructions.

The INTEN flip-flop is loaded from the I/O bus and by bit 15 (least-significant bit). The circuit is set or cleared when the 6701s emit all ONEs or all ZEROs as data, respectively. Also the flip-flop must be clocked with an additional control-ROM bit.

The right time for requests

Interrupt and DMA requests can come at any time. However any request must be made available before the end of the microstep that enables the End-Op ROM.

Specifically these signals must be stable for one ROM access time plus a counter-load setup

David C. Wyland, Microprocessor Design Manager, Monolithic Memories, 1165 E. Arques Ave., Sunnyvale, CA 94086.

Interrupt and DMA: μP time savers

Both program interrupt and direct-memory access capabilities conserve valuable microprocessor time. They allow a computer to devote most of its time to a long program, while simultaneously providing immediate response for shorter, more urgent functions.

The program-interrupt function provides what its name implies: the ability to suspend a running program to perform a higher-priority one. When the latter program is completed, the original one resumes.

One example of interrupt is printer buffering. Serial printers are often slow—about 10 characters per second. To print a line of characters without interrupt, the CPU transfers a character to the printer, waits 100 ms until that character is printed and then transfers the next character. This procedure repeats until all the characters in the line are printed. However, only a few microseconds are needed to transfer a character. So the microprocessor spends most of its time waiting for the completion of print operations.

The program-interrupt feature eliminates this waiting time. Now the printer causes a program interrupt when it has completed a character. And while the printer is busy, the microprocessor begins or continues the execution of a program.

When the printer interrupts current program operation, the microprocessor is forced to begin execution of a special interrupt-service routine. The interrupt-service program gets the next character to be printed, sends it to the printer and re-enables the interrupt. If the last character has been printed, no commands are sent to the printer. The microprocessor can return to the original program (usually called the background program) and continue operating. Processor time is required only for a few microseconds every 100 ms.

The direct-memory access (DMA) feature allows the high-speed transfer of data directly between the memory and an I/O device. Memory cycles are "stolen" from the processor for use by the I/O device that is transferring data.

Typically the DMA feature is used to transfer blocks of words to a list in memory. The I/O device supplies the memory address and data for each word to be transferred. It also contains the logic to increment the address to the next word on the list, count the number of words transferred and determine when the transfer is complete.

Direct-memory access must be used when data-transfer rates exceed those that are possible with program-controlled transfers. For example, a disc-file unit may require a byte of data every 3.2 μs. This can easily be too short for a program. Within the required interval, the program must do the following: detect the transfer request, get a byte from a list, transfer it to the disc unit, increment the list address counter, decrement the word counter and test the word counter for a zero result. But with DMA, the I/O device usually contains all the logic necessary to perform data transfer in one memory cycle—typically 1 μs.

DMA is also useful for low-speed block transfers, such as in the serial-printer example. And DMA can be used simply to make more processor time available. However, it is particularly useful for medium-speed devices with transfer rates of 1000 to 10,000 bytes per second.

If a device transfers data at 100 μs per byte (10,000 bytes/sec) and the interrupt service program requires 60 μs to run each interrupt, only 40% of the processor's time is available for the background program during the transfer. But if DMA transfer is used, only one 1-μs memory cycle will be "stolen" from the processor every 100 μs. Thus 99% of the microprocessor's time can be applied to the background program.

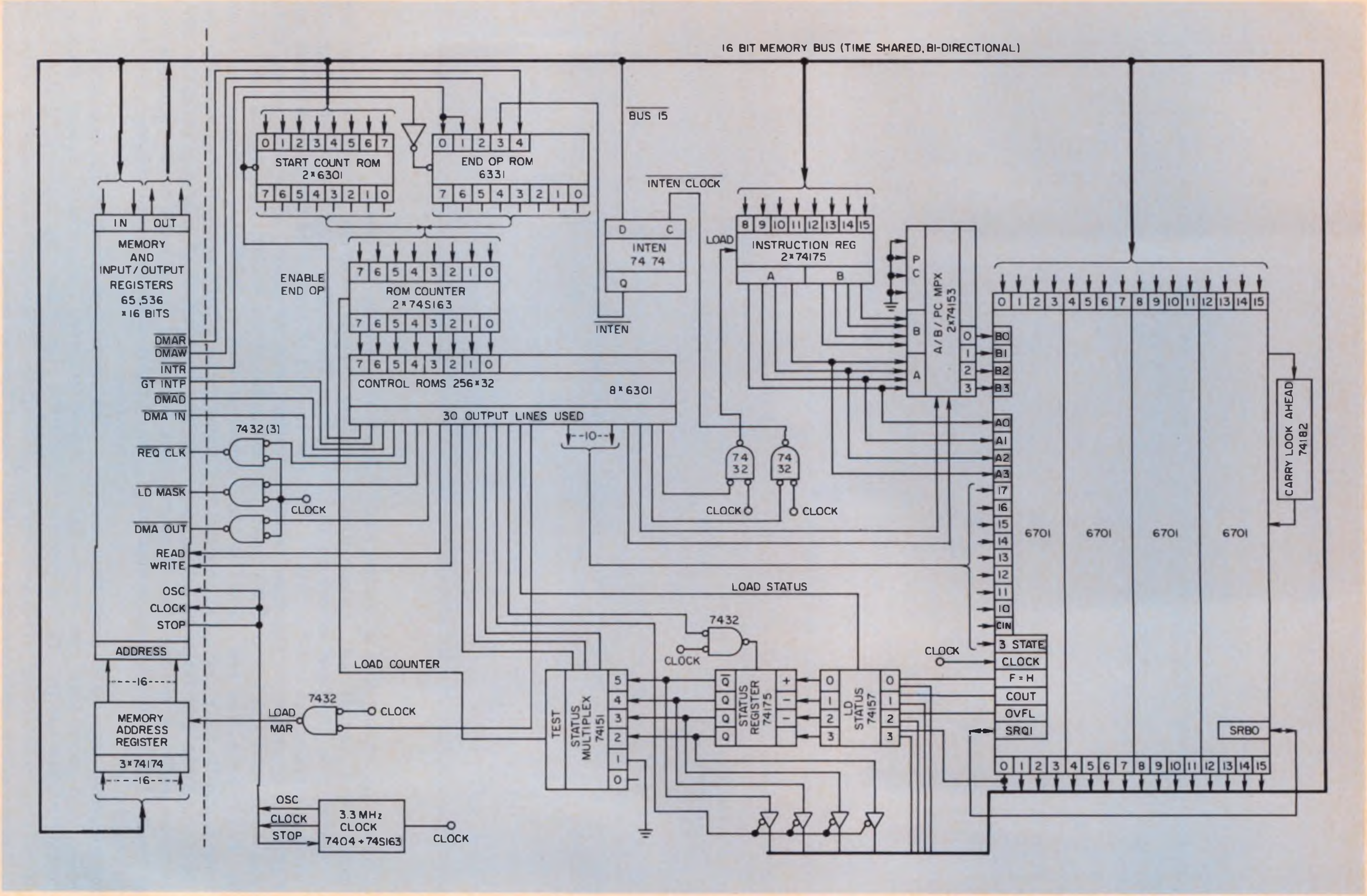
time and before the trailing edge of counter-load RAR clock. These signals are synchronized through clocking into flip-flops earlier in the microprogram, providing the settling time.

In our system a synchronizing flip-flop in each device requests an interrupt and/or DMA operation (Fig. 3). The flip-flops are clocked at the end of State 0, and they are clocked at appropriate points in the DMA and interrupt microprograms to ensure sufficient settling time. Timing diagrams for the DMA and interrupt operations appear in Fig. 4.

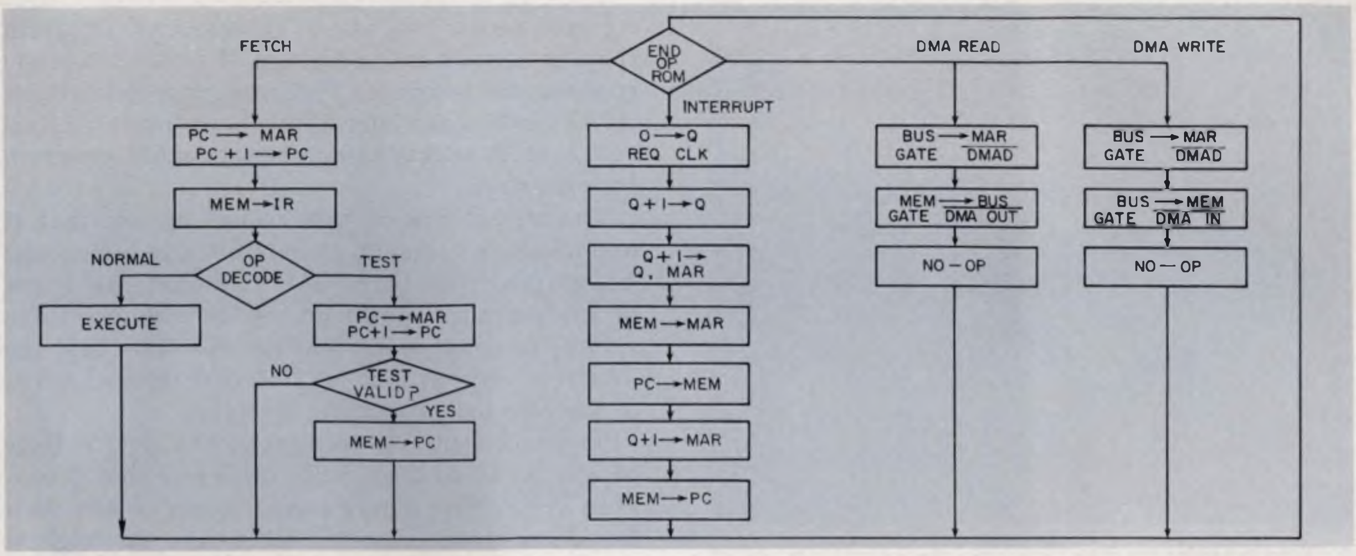
A microcomputer may have more than one DMA device, and more than one device may simultaneously request service. Thus a priority scheme is required to determine which gets serviced first. It also specifies whether a read or write operation is to be performed.

This priority selection is performed by the logic in Fig. 3. The DMA Request flip-flop sets at the end of State 0 of the microprogram, ensuring that at least one microprogram state exists before the End-Op ROM is enabled. It also ensures that at least two microprogram state times minus a ROM access time and counter set-up time exist before all lines must be stable. During this period if any DMA Request flip-flops sets, the $\overline{\text{DMAR}}$ line (an open-collector OR bus) activates.

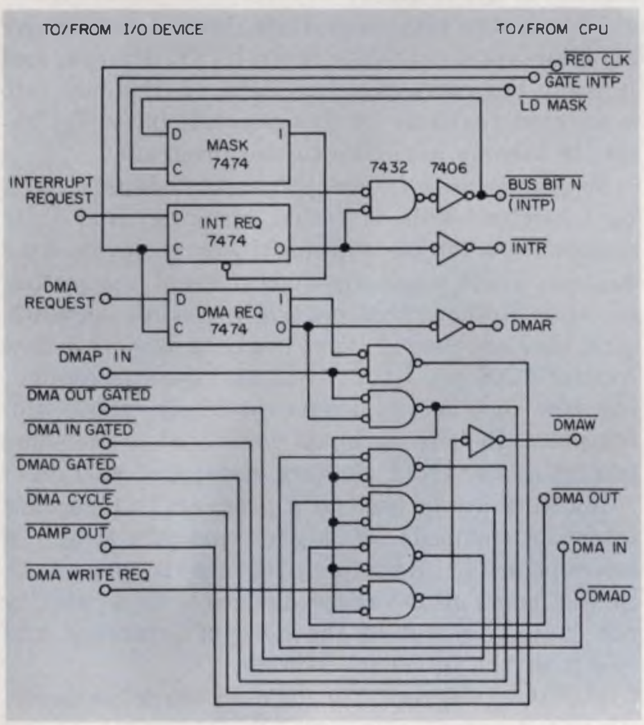
The priority of simultaneous requests is resolved in serial, "daisy chain" fashion: Each set of DMA request logic has a priority enable input, $\overline{\text{DMAP IN}}$. If this input is low and the DMA Request flip-flop is set, I/O device logic is enabled



1. **A microcomputer employing bipolar processor slices** (the 6701s) uses just seven additional ICs, six new instructions and nine extra control-ROM bits to obtain interrupt and direct-memory-access capabilities. This relatively simple implementation is possible because the 6701s are microprogrammable.



2. **Decisions affecting interrupt and DMA requests** focus on the End Op ROM. It determines whether the processor will perform a DMA operation, an interrupt sequence or a normal instruction fetch and execution.

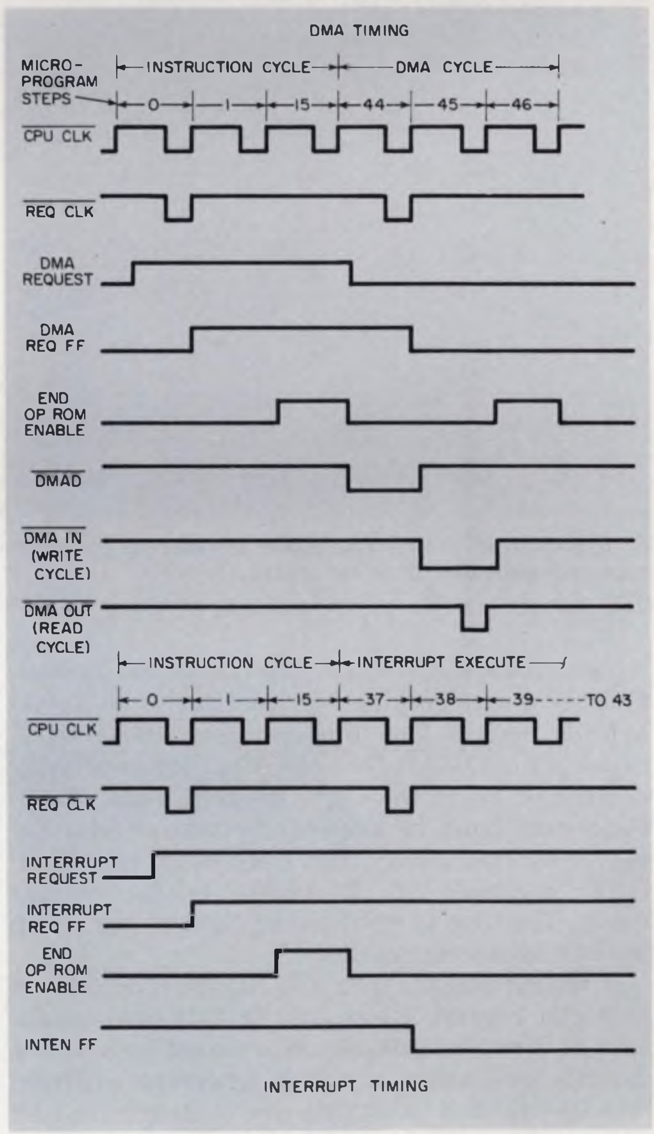


3. **Each I/O device contains all the logic needed** to initiate interrupt and DMA transfers.

to receive the next DMA cycle, and to drive the DMAW line, which controls read/write selection.

The DMAP IN line is permanently enabled, or grounded, for the highest priority device. Each set of logic generates a priority output signal, DMAP OUT, that goes to the DMAP IN input of the next lower priority device. This signal is normally low, unless the DMAP IN line is high or the DMA Request flip-flop is on. Either of these forces DMAP OUT high.

(continued on page 74)



4. **Both interrupt and DMA operations** require special timing. The timing diagrams are segmented by microprogram steps defined in Fig. 6.

NEW INSTRUCTIONS

Op Code	A	B

Instruction Format

Op Code	Instruction	Operation
19	Interrupt Enable	Sets Interrupt Enable flip-flop
20	Interrupt Disable	Clears " " "
21	Load Interrupt Status	Interrupt Status — Register B
22	Set Interrupt Mask	Register B — Mask flip flops
23	Save Status	Status bits — Register B
24	Restore Status	Register B — Status flip-flops

NEW CONTROL-ROM BITS

Name	Function
INTEN CLK	Clock to INTEN flip flop
REQ CLK	Clock to all request flip flops
GATE INTP	Gates device INTP signals to bus
LD MASK	Clock to Mask flip flops
GATE STAT	Gates Status bits to bus
LD STAT	Gates bus to Status flip-flop inputs
DMAD	Gates device DMA address to bus
DMA IN	Gates device DMA data to bus
DMA OUT	Clock to DMA device data register

5. **Data transfer for interrupt and DMA** entails the use of these new instructions and additional control-ROM bits.

ROM ADDRESS	OPERATION	COMMENTS
0	PC → MAR, PC + 1 → PC	INSTRUCTION FETCH
	REQ CLOCK	UPDATE REQ FFs
1	MEM → IR	
	DECODE AND LOAD START COUNT	
5	B + A → B, END	OP = 7, ADD
	GATE END OP ROM	END OF EXECUTE
37	0 → Q	BEGIN INTERRUPT EXECUTE
	REQ CLOCK	UPDATE REQ FFs
	INTEN CLOCK	CLEAR INTEN FF
38	Q + 1 → Q	1 → Q
39	Q + 1 → Q, MAR	2 → Q, MAR
40	MEM → MAR	GET PC STORE ADDRESS
41	PC → MEM	STORE PC
42	Q + 1 → Q, MAR	3 → Q, MAR
43	MEM → PC	GET NEW PC VALUE
	GATE END OP ROM	END OF EXECUTE
44	BUS → MAR	BEGIN DMA READ EXECUTE
	DMAD GATE	DMA ADDRESS → MAR
	REQ CLK	UPDATE REQ FFs
45	MEM → BUS	OUTPUT DMA WORD
	DMA OUT GATE	STROBE DEVICE REG
46	Q → Q (NO OP)	END OF EXECUTE
	GATE END OP ROM	
47	BUS → MAR	BEGIN DMA WRITE EXECUTE
	DMAD GATE	DMA ADDRESS → MAR
	REQ CLK	UPDATE REQ FFs
48	BUS → MEM	DMA DATA → MEMORY
	DMA IN GATE	GATE DMA DATA → BUS
49	Q → Q (NO OP)	END OF EXECUTE
	GATE END OP ROM	
50	NOT USED	
254	NOT USED	
255	0 → PC, END	OP = X, ILLEGAL OP (RESTART @ 0)

6. **A portion of the microprogram** is reserved for interrupt and DMA execution sequences.

Thus the DMA Request flip-flop of the highest-priority device seeking service disables all lower-priority devices. The flip-flop raises DMAP OUT, causing the DMAP IN lines of all lower-priority devices to go to the high, disabled state. Sufficient time must be allowed for this priority decision to ripple from the DMAP IN to DMAP OUT terminals of all devices in the request chain. The time is provided by the two microstep periods mentioned earlier.

A microcomputer may also have several devices that can request interrupts. In this case resolution of simultaneous requests transforms into a priority resolution of which interrupt program will be executed. And this can be determined by another program.

In our system, all interrupting devices activate a common interrupt-request line, INTR. The interrupt-execute sequence causes the program counter to be set to the address of a common interrupt-service program. This program determines which devices are currently requesting an interrupt, and it selects the highest-priority program for execution.

The advantages of this technique are that it minimizes the amount of hardware required and allows priorities to be set and modified under program control. However, the technique requires several program steps between the time that the interrupt request is generated and the beginning of the selected program's execution.

To implement the technique, the device logic of Fig. 3 has an open-collector driver that generates INTP. The driver's connection to the data bus determines priority; bit 0 has the highest priority, while bit 15 has the lowest. The driver is activated by a new control-ROM bit, GATE INTP (Fig. 5). The ROM bit, in turn, activates during execution of a new instruction, Load Interrupt Status (LIS).

This instruction causes all devices requesting an interrupt to activate their INTP drivers, and it loads the corresponding data on the bus into a selected register. In this way all interrupt requests become available to the program.

In some cases interrupt-request signals must be inhibited. This is called masking, and it is done with a simple flip-flop in each device (see Fig. 3). These mask flip-flops prevent the setting of other flip-flops that control interrupt requests. And they are loaded from the data bus by a new control-ROM bit, LD MASK, and the corresponding new instruction, Interrupt Mask. Mask flip-flops have their data inputs connected to the same bus bit as the INTP drivers mentioned earlier.

Masking can be used by a program to recognize interrupt requests of higher priority while a lower-priority interrupt program is processed. Simply mask all interrupt devices with a priority not exceeding that of the current interrupt and re-enable the interrupt system.

For the interrupt function to work properly, it must be possible to save all previous data and to restore it after the interrupt has been serviced. This is easily done for CPU registers and the program counter. However, we also must be able to save and restore the status indicators.

Two new Control ROM bits are required: GATE STAT, to place the status bits on the data bus for save operations, and LD STAT, to load the status bits from the bus for restore operations. Two new instructions—Save Status and Restore Status—are also required.

Three other control-ROM bits are required for DMA: DMAD, which causes the requesting DMA device to gate its address onto the data bus; DMAIN, which causes the DMA device to gate data onto the bus for write operations; and

Interrupt

METHOD: SINGLE HARDWARE INTERRUPT
SOFTWARE PRIORITY DETERMINATION
HARDWARE FOR INTERRUPT STATUS SENSE
INTERRUPT LATENCY: 2.4 μs (8 MICROCYCLES)
MASKABLE INTERRUPT 16

DMA

METHOD: SYNCHRONIZED REQUESTS
HARDWARE PRIORITY DETERMINATION—DAISY CHAIN
DMA LATENCY: 1.5 μs (5 MICROCYCLES)
DMA TRANSFER RATE: 1.11 MEGAWORDS/SEC (3 MICROCYCLE LOOP)

7. **A performance summary** reveals latencies of only 2.4 μs for interrupts and 1.5 μs for DMA.

$\overline{\text{DMAOUT}}$, which strobes DMA memory data.

The execution sequences for interrupt and DMA operations appear in Fig. 6. The interrupt sequence causes the old program counter to be stored at the memory location defined by the contents of location 2. The program counter is then loaded with the contents of location 3—the location of the interrupt-service routine. The DMA execute sequences have an extra, dummy step that ensures a minimum of two steps between the request clock and the enable of the End-Op ROM.

Interrupt and DMA performance is measured by the maximum delay—or latency—between the submission of a request and the start of the corresponding execution sequence. Other important specs are the transfer rate for continuous DMA requests and the number of different maskable interrupt requests that the processor can recognize (Fig. 7).

DMA latency time equals the execution time of the longest instruction, assuming that the Request Enable clock came just after a request was submitted. Interrupt latency equals DMA latency plus one DMA cycle. This definition assumes that both an interrupt and DMA request were submitted simultaneously just after the Request clock and before execution of the longest instruction. The DMA transfer rate is equal to the inverse of the time required to pass once through the DMA sequence.

The interrupt and DMA implementations described have been kept simple in order to illustrate the problems and their solutions. However, many improvements can easily be added because of the microprogram control.

For example, the interrupt capability could be extended by the use of one 6701 as a last-in, first-out stack pointer for program-counter storage, and use of microcode to implement priority determination and program selection. Likewise the DMA sequences can be expanded to include such features as the use of memory locations as indirect DMA address and word counters. ■■

References

1. Wyland, David C., "Design Your Own Microcomputer," *Electronic Design* No. 20, Sept. 27, 1975, pp. 72-78.

INFORMATION RETRIEVAL NUMBER 33

Speed microprocessor responses without interrupt or DMA techniques. Let the processor's Ready line do the job, and build a simple floppy-disc interface.

Microcomputer designs don't require techniques based on minicomputer hardware to achieve high speeds. Though designers often employ speed-enhancing interrupt or direct-memory-access (DMA) techniques borrowed from the mini world, the same improvements can be obtained far more simply. All that's needed is a microprocessor whose operations can be suspended readily during data transfers. Microprocessors like Intel's 8080 permit just this kind of solution.

When applied to an 8080-based floppy-disc controller, the simple approach requires only about 20 ICs. By comparison, an interrupt structure uses 40 to 80 ICs, and a DMA approach needs 80 to 100. Moreover the 8080 exercises full format and timing control over floppy-disc functions, with all of the algorithms contained in less than 512 words of ROM.

The alternatives

Interrupt structures often require hardware that is external to the microprocessor, as well as special programming (Fig. 1). Further, high-speed applications can easily require all of the microprocessor's real-time capability. For this reason, other interrupt sources usually must be disabled during the execution of the high-speed routine. Also, it may be necessary to save—in advance—sensitive registers to increase the speed of the interrupt service routine.

After an interrupt in the application program, a series of vectors (either hardware or software) transfer program control to the interrupt-service routine. This routine is the actual program that performs the synchronized I/O transfer. After the servicing of the interrupt, control returns to the application program to prepare again for the next high-speed interrupt service. As many as 100 bytes of code may be needed to handle the high-speed interrupt. This doesn't include the code for standard I/O that would be required without interrupt synchronization.

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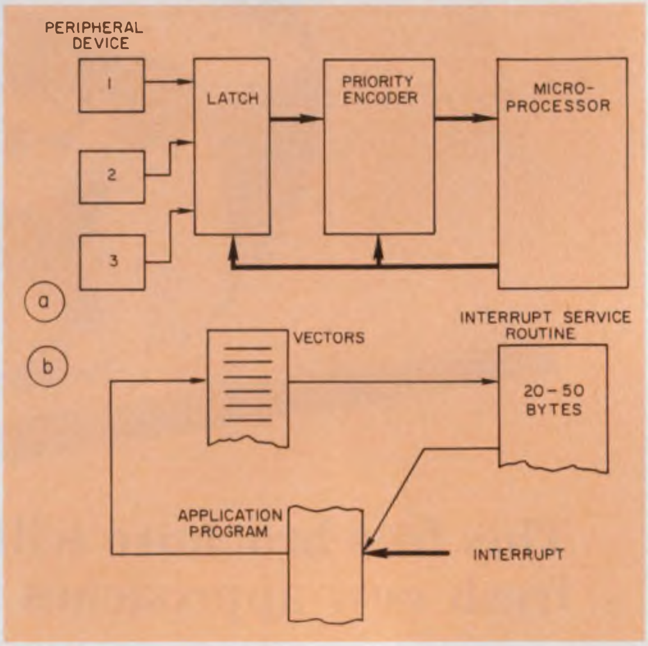
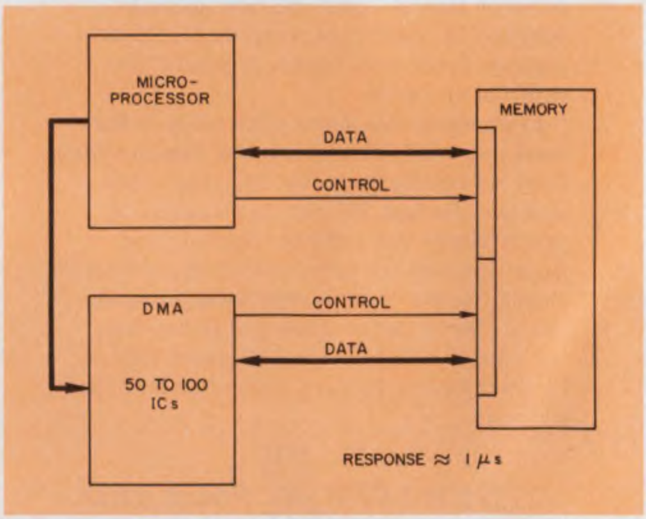


1. **Interrupt techniques may entail the addition** of such external circuits as storage latches and priority encoders (a). Typical response time is 32 μs. However, the major portion of an interrupt structure resides in software (b). Interrupt techniques can achieve typical data rates of about 31-k bytes per second.



2. **Direct-memory access, or DMA, requires a separate,** external controller that communicates directly with memory. When built with standard ICs, the controller can use up to 100 circuits.

Debugging of this interrupt service is extremely difficult, since it cannot be effectively simulated on a separate computer. In fact, debugging is a very time-consuming effort, requiring the use of all of the system's hardware or a trial-and-error method using oscilloscopes and other external hardware. This difficulty alone has discouraged designers. The typical speed for an interrupt interface is approximately 31,000 bytes per second.

Unlike the interface for a high-speed interrupt, the direct-memory-access interface isn't really part of a microprocessor or microcomputer system. It actually is a separate hardware controller that communicates directly with the computer memory (Fig. 2). The only function a microprocessor has in these cases is to initialize the data channel.

Once DMA has begun, the microprocessor must be able to disconnect itself from the associated memory, so as not to inhibit the transfer. Thus debugging focuses on the hardware, because the only software functions employed are those needed for DMA-channel controls. The typical data-transfer rates are limited primarily by the memory. For example, memories for most single-chip MOS processors operate at 415 ns to 1 μs. So the data rate can be in excess of 100-k bytes per second.

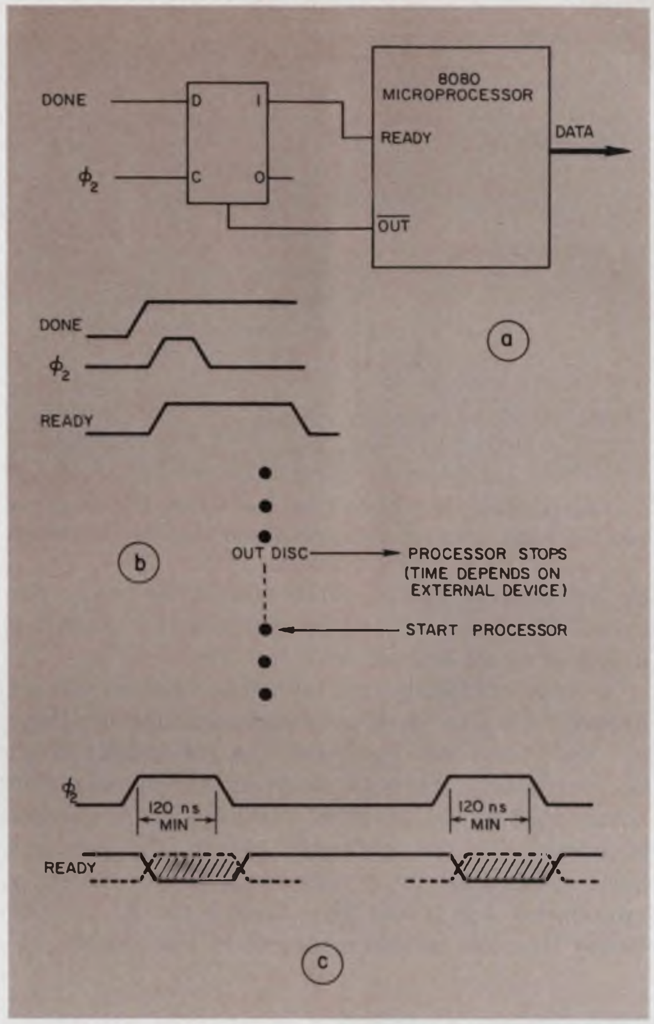
A simple solution

An alternative approach—one that requires the μP to halt for each transfer—takes full advantage of the processor. The technique can be applied to any microprocessor that has Ready-line synchronization or otherwise allows the stopping of the processor for data transfers. The hardware to implement this synchronization appears in Fig. 3. The block diagram shows that a simple, external flip-flop can synchronize the microprocessor.

The circuit operates as follows: An I/O instruction—in this case an output from the microprocessor—clears the flip-flop, halting the processor with the I/O data available on the microprocessor's data bus. The external device takes the data presented by the microprocessor and then returns a signal. Called DONE, the signal is used by the synchronizing flip-flop to raise the Ready line, letting the microprocessor continue. The microprocessor responds to an external input within one cycle—500 ns in our case.

Not only is this interface simple, but the microprocessor worst-case response is 1 μs. This response time is comparable to a DMA transfer, but with none of the associated hardware complexity. And the software is extremely simple; no difficult timing loops are required.

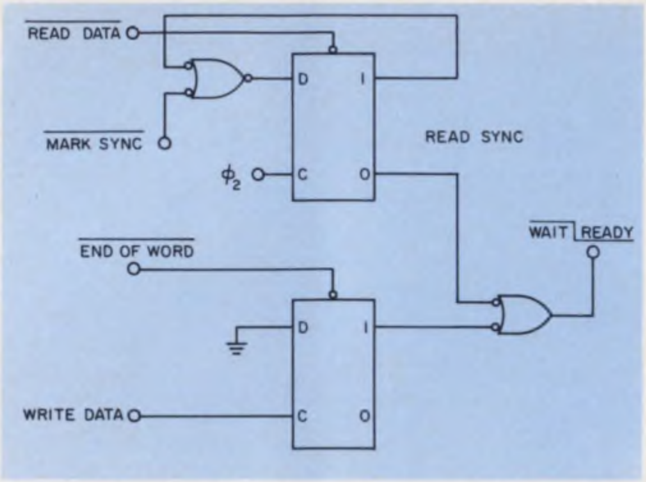
The output instruction actually stops the processor for a time that depends on the external device. If the microprocessor is already running at 100% utilization, there isn't time for other operations anyway. Thus the time lost by halting the processor is of no real consequence. And now software for the output or input is merely a standard I/O operation, with synchronization and data timing taken care of automatically. The data rate is 62-k bytes per second—a program-execution limitation.



3. **The alternative to DMA and interrupt techniques** employs a microprocessor's Ready line (a) to suspend the processor's operation during data transfers (b). The Ready line is sensed by the microprocessor during phase two of state T_2 or T_W, the Wait state (c). This straightforward approach has a response time of 1 μs, and it yields data rates of 62-k bytes per second.

Employing the Ready line

The Ready line on the 8080 processor was designed primarily to interface the processor to a slow memory or a slow I/O operation. But while the processor is stopped, the data bus is present on the processor's data lines. On an input instruction, the processor takes the data within 500 ns after starting or after the assertion of the Ready Signal. After the Ready line is raised,



4. **The synchronizing circuit for the Ready line** employs two flip-flops, one for the output and one for the input.

the microprocessor responds within the next clock cycle. Thus over-all response is about 1 μs when a 500-ns clock is used with the 8080.

A typical Ready-line synchronization circuit appears in Fig. 4. Two synchronizing flip-flops are used, one for input and one for output from the peripheral. In both cases all synchronization is handled by an external flip-flop. Even the requirement for an external D-type flip-flop has been eliminated by a new clock driver recently announced by Intel. The synchronizing of the Ready line can be taken care of by the new IC.

Programming constraints

The program must be able, of course, to accept synchronization by the external hardware. In the sample program (Fig. 5) the timing of each instruction in a critical loop has been calculated. This is necessary to ensure that the next I/O instruction is asserted in time. The routine allows the maximum data-transfer rate for the 8080 by employing the processor's stack pointer.

By adding the two halves of the loop, we see that the maximum time between instructions is 16 μs. Also the response to an external stimulus is 1 μs. And the data rate for this interface is twice that possible in any equivalent interrupt-driven interface.

Specifying the interface

Our floppy-disc application employs the IBM format (Fig. 6). Note the different types of sector information. Each has a unique indicator —a Mark—for Index, Data, Deleted Data and Address. A Mark doesn't contain a full set of clock pulses, and the missing clocks and Mark words, form synchronizing elements. Another critical item is the cycle redundancy check (CRC) character. This appears at the end of each data sector. It must be read to determine if there has been an error in reading or writing.

The data rate in this format is 4 μs per data bit, with the clock pulses coming between each data pulse (Fig. 7). The data rate of the standard floppy disc is 4 $\times$ 8 bits/byte, or 32 μs per 8-bit byte. However, to eliminate any possibility of timing problems, the interface is designed for twice that rate, or 16 μs per 8-bit byte—an effective transfer rate of 62-k bytes per second. And to eliminate the need for double buffering, the previously collected data word is read before the next clock pulse occurs. This results in the 2-μs interval at our double speed.

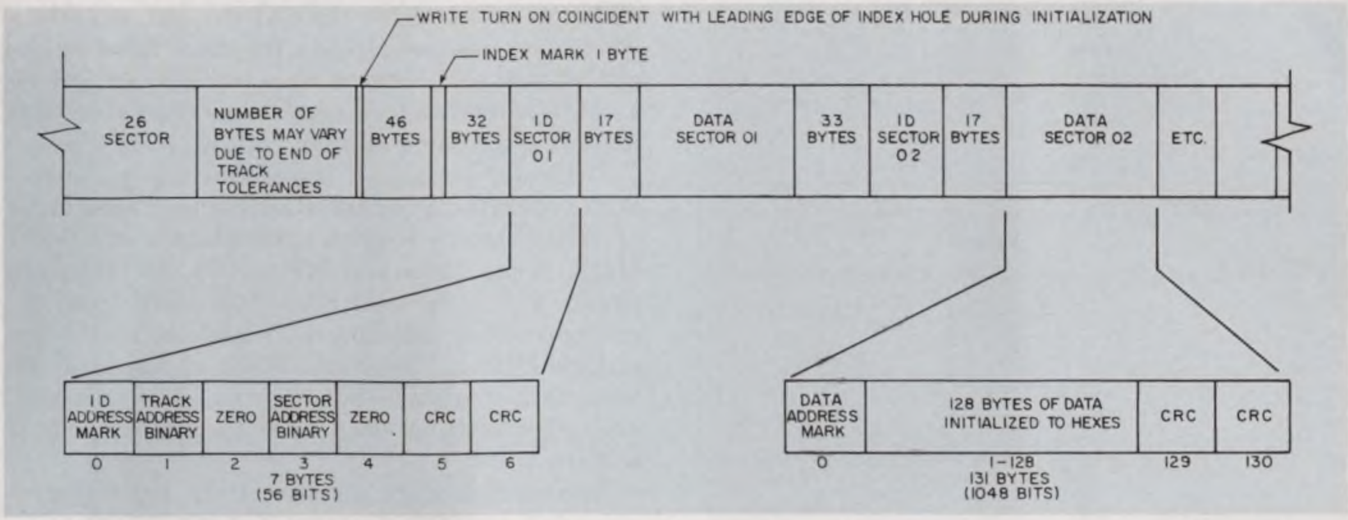
Solving interface problems

The "missing"—but implied—clock signal is detected by a retriggerable, monostable multivibrator. With the aid of a separate clock signal from the floppy disc (Fig. 7b), the detected signal is then used to synchronize an 8-bit register and to generate an end-of-word signal.

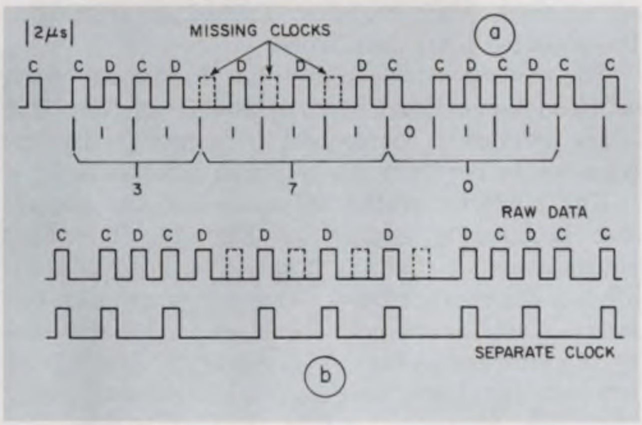
A 4-bit counter (Fig. 8) regenerates the missing pulses. The microprocessor's crystal clock

```
005161   333 011       ROVR:    IN DATAR     :READ ONE WORD—5.5
005163   157                    MOV L·A      :SAVE -2.5
005164   015                    DCR C        :BUMP CNTR -2.5
005165   345                    PUSH H       :STORE TWO WORDS -5.5
005166   333 011       DATCOL:  IN DATAR     :NEXT—AND CRC WORD 1 -5.5
005170   147                    MOV H·A      :SET UP WORD—2.5
005171   302 161 012            JNZ ROVR     :AGAIN—5
005174   333 011                IN DATAR     :CRC WORD 2
005176   333 011                IN DATAR     :CRC DELAY WORD
005200   333 007                IN STAT      :CHECK STATUS
005202   027                    RAL          :SET UP FLAG
005203   052 301 014            LHLD TEMP    :GET THE STACK POINTER
005206   371                    SPHL         :RESTORE SP
005207   332 217 012            JC CRER      :CRC ERROR
005212   311                    RET          :WE MADE IT
```

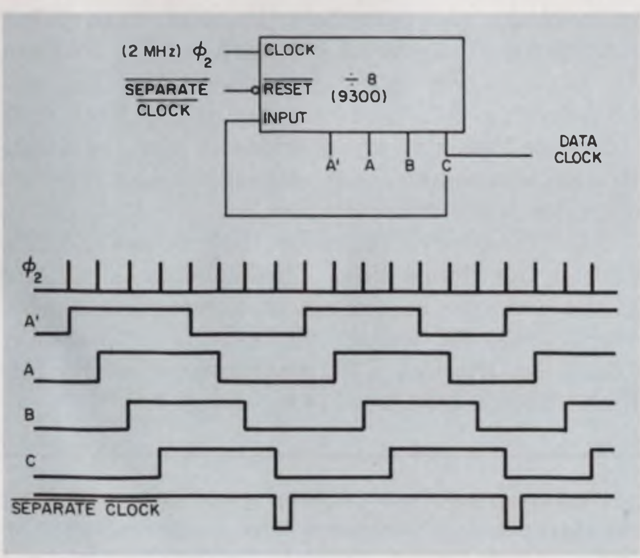
5. **The time of each instruction in a critical loop** must be calculated to ensure that I/O instructions are asserted soon enough. A portion of the read routine lists these times in microseconds.



6. **An IBM data format applies to our floppy-disc** example. Different sectors of information use an indicator known as a Mark. It relies on a series of implied—but not present—clock pulses for synchronization.



7. **The Data Mark has a transfer rate of 2 μs** per bit (a), or twice that of the usual format. This eliminates possible errors and the need for double buffering. The missing clock pulses are generated with the aid of a separate clock signal (b) from the floppy disc.



8. **A simple 4-bit counter,** synchronized to each separate-clock pulse from the floppy disc, regenerates the missing clocks.

provides the time base for the counter and thus, the floppy disc.

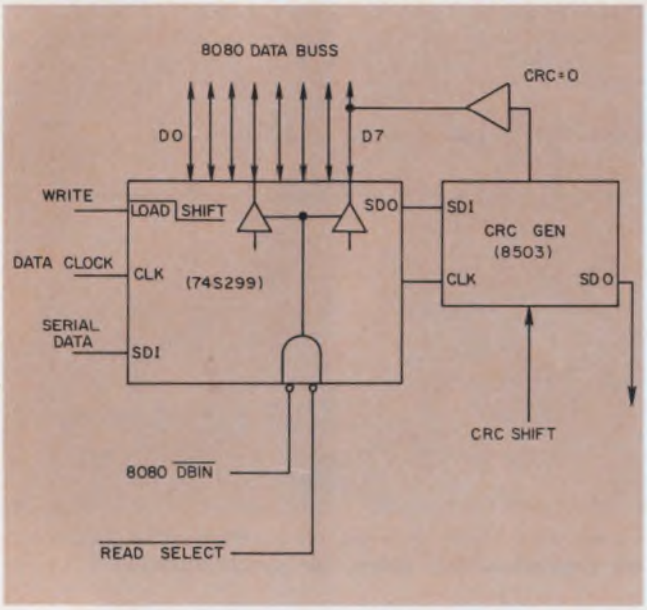
The counter is synchronized with the data received from the floppy disc, thereby providing a clock signal that doesn't have missing pulses. This counter and the crystal clock also generate the accurate timing pulses required for the Write operation to the floppy disc.

A single IC—the 8-bit register—handles both the serialization and deserialization of the signal from the floppy disc to the microcomputer (Fig. 9). This register has a common I/O; the same eight pins are used for parallel data input and output. Three-state data lines are compatible with the 8080 microprocessor data bus.

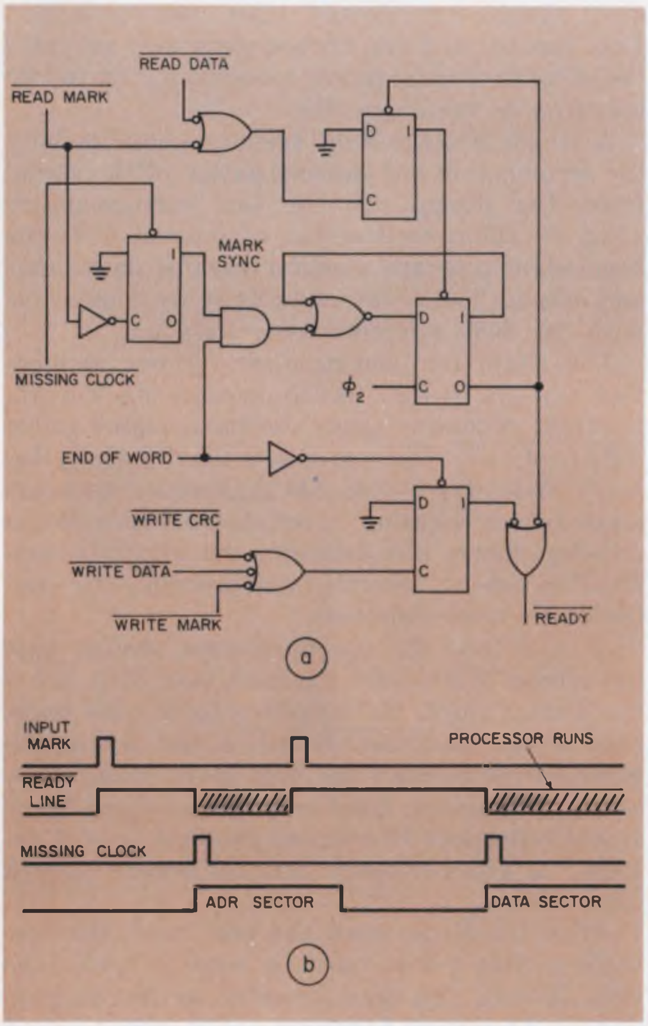
The Ready-line synchronizer for our application appears in Fig. 10. To detect a Mark word, the microprocessor sends the input signal called $\overline{\text{READ MARK}}$. This signal sets the flip-flop called Mark Sync, which suspends microprocessor operation until a "missing" clock signal occurs. When missing pulses are detected, the synchronizing flip-flop resets, allowing the processor to read the Mark word collected.

At this time the microprocessor verifies that the correct Mark word has been read. If it is not the correct word, the microprocessor loops back, sending out the $\overline{\text{READ MARK}}$ signal. Again, the processor stops until the next Mark word is received. The timing diagram shows an input Mark signal being sent two times. The first time it detects the address sector and the second time a data sector.

After the Mark word has been read, the succeeding data words must be read to verify the data format, the data transfer or the address sector. Therefore a second input signal called $\overline{\text{READ DATA}}$ is sent in a manner similar to that of the Mark operation just described. However, the input-data synchronizer resets at the end of



9. **An 8-bit shift register,** synchronized by the "missing" clocks, provides the parallel-to-serial conversion of the signal from the floppy disc. The second IC generates the cycle-redundancy-check character.



10. **The Ready-line synchronizer** for the floppy-disc application employs only four flip-flops and a few gates (a). The input Mark signal is sent twice (b) to detect address and data sectors.

each data word rather than at the end of a Mark word. The processor reads the data word at the end of each serial string in less than 1 μs, giving a 100% safety factor even for a floppy disc having twice the usual storage capacity.

The lower portion of the synchronizer controls Write operations for the Ready line. Three types of Write signals require synchronization: Write Mark, Write Data and Write CRC. Write Data simply writes the next 8-bit data word from the microprocessor into the shift register at the appropriate time. The Write Mark signal loads an 8-bit shift register (not shown), and this generates the missing clock lines for the writing of a Mark word.

Also on this shift register, Data Bit 6 is provided for one of the inputs, thereby allowing the software to create any of the three missing clock words required. The Write CRC command converts the CRC generator from a coded mode to a 16-bit serial shift register. The latter shifts out the collected CRC data word.

The control of the floppy disc functions—such as Head Load, Head Step In and Head Step Out—are handled in the usual I/O fashion, with flip-flops set to perform the required functions.

Key portions of the software for the floppy-disc application appear in Fig. 11. The first routine verifies that the floppy-disc head is actually on the correct track. The sequence is as follows: Wait for an address Mark; read the rest of the address sector; save the critical words of interest, the track and sector addresses; verify that there are no errors; then drop into a routine that steps the head to the desired track. Note that no critical timing loops are required. The only requirement is that the program return within 16 μs, so it can read the next data block.

Fig. 11b shows the code used to read a data block from the floppy disc and to store it in memory at the maximum transfer rate. This routine uses the processor's stack pointer to store 16 bits or two bytes per operation (thereby transferring data at 16 μs per byte). Note that this code lists timing intervals in the comment, so the programmer can actually count the instruction times that will result.

Fig. 11c shows the code that writes a data file on the floppy disc. This routine is similar to the previous one. However, a preamble of zero words must be written before the actual data file. Also, the last CRC character must be followed with a zero word. ■■

11. **Excerpts from the program,** compiled by an 8080 macroassembler, illustrate the three major routines. The first, a search routine, checks to see that the disc head is properly positioned (a). The next routine reads a block of data in the disc and stores it in memory (b). The third routine writes data into the floppy disc (c).

```
004403  365          STRT:    PUSH PSW      :SAVE A REG
004404  323 012               OUT HDDN      :LOWER HEAD
004406  315 222 011           CALL LDDLY    :WAIT FOR HEAD
004411  176                   MOV A - M     :TRK ADR
004412  376 112               CPI 112Q      :TEST FOR TOO LARGE ADR
004414  322 147 011           JNC NOADER    :ADR ERROR—TOO LARGE
004417  315 242 011           CALL SEEK     :STEP TO TRK
004422  315 222 011           CALL LDDLY    :WAIT TO SETTLE
004425  333 010               IN RDMRK      :SYNC AFTER STEP
004427  333 010      TSTRD:   IN RDMRK      :READ MARKS
004431  376 376               CPI 376Q      :WAIT FOR ADR
004433  302 027 011           JNZ TSTRD     :LOOP
004436  333 011               IN DATAR      :TRK ADR
004440  107                   MOV B - A     :SAVE TRK ADR
004441  333 011               IN DATAR      :ZEROS
004443  333 011               IN DATAR      :SECTOR ADR
004445  333 011               IN DATAR      :ZEROS
004447  333 011               IN DATAR      :CRC
004451  333 011               IN DATAR      :CRC
004453  333 011               IN DATAR      :CRC DELAY WORD
004455  333 007               IN STAT       :CHECK CRC
004457  027                   RAL           :SET UP FLAG
004460  332 165 011           JC ERROR      :CRC ERROR
004463  072 300 014           LDA ADR       :GET EXISTING ADR
```

(a)

```
                              :ROUTINE TO READ A DATA SECTOR
005064  333 010      READ:    IN RDMRK      :ENTER SECTOR ADR IN B
005066  376 376               CPI 376Q      :LOOK FOR ADR MARK
005070  302 064 012           JNZ READ      :LOOP BACK
005073  333 011               IN DATAR      :SKIP TRK ADR
005075  333 011               IN DATAR      :SKIP ZERO WORD
005077  333 011               IN DATAR      :READ SECTOR ADR
005101  270                   CMP B         :TEST SECTOR
005102  302 064 012           JNZ READ      :WRONG SECTOR—LOOP
005105  333 011               IN DATAR      :ZEROS
005107  333 011               IN DATAR      :CRC
005111  333 011               IN DATAR      :CRC
005113  016 013               MVI C . 13Q   :SET UP JUNK-IN-GAP COUNTER
005115  333 011               IN DATAR      :CRC DONE GAP WORD #1
005117  333 007               IN STAT       :CHECK CRC
005121  027                   RAL           :SET UP FLAG
005122  332 217 012           JC CRER       :CRC ERROR
005125  333 011      CRAPLP:  IN DATAR      :SKIP THE JUNK-IN-THE-GAP -13 WORDS
005127  015                   DCR C         :DONE? -2.5
005130  302 125 012           JNZ CRAPLP    :NOPE LOOP BACK -5
005133  041 000 000           LXI H - 0     :CLR H AND L
005136  071                   DAD SP        :ADD STACK POINTER
005137  042 301 014           SHLD TEMP     :SAVE SP
005142  016 100               MVI C - 1000  :SET DATA CNTR
005144  061 000 014           LXI SP - BUFF :POINT TO BUFFER
005147  333 010               IN RDMRK      :WAIT FOR DATA
005151  376 373               CPI 373Q      :TEST FOR DATA MARK -3.5
005153  302 213 012           JNZ CRERX     :NOT A CRC ERROR BUT GET OUT FOR NOW -5
005156  333 011               IN DATAR      :FIRST WORD -5.5
005160  147                   MOV H - A     :SET UP -2.5
005161  333 011      ROVR:    IN DATAR      :READ ONE WORD—5.5
005163  157                   MOV L - A     :SAVE -2.5
005164  015                   DCR C         :BUMP CNTR -2.5
005165  345                   PUSH H        :STORE TWO WORDS -5.5
005166  333 011      DATCOL:  IN DATAR      :NEXT—AND CRC WORD 1 -5.5
005170  147                   MOV H - A     :SET UP WORD—2.5
005171  302 161 012           JNZ ROVR      :AGAIN—5
005174  333 011               IN DATAR      :CRC WORD 2
005176  333 011               IN DATAR      :CRC DELAY WORD
005200  333 007               IN STAT       :CHECK STATUS
005202  027                   RAL           :SET UP FLAG
005203  052 301 014           LHLD TEMP     :GET THE STACK POINTER
005206  371                   SPHL          :RESTORE SP
005207  332 217 012           JC CRER       :CRC ERROR
005212  311                   RET           :WE MADE IT
005213  052 301 014  CRERX:   LHLD TEMP     :GET THE STACK POINTER
005216  371                   SPHL          :RESTORE SP
```

(b)

```
005024  174          OVR:     MOV A - H     :SET UP NEXT WORD -2.5
005025  323 014               OUT DATAW     :WAIT FOR DISC—5.5
005027  341          DATWT:   POP H         :GET TWO WORDS -5
005030  175                   MOV A - L     :NEXT WORD -2.5
005031  323 014               OUT DATAW     :WAIT FOR DISC—5.5
005033  015                   DCR C         :BUMP CNTR—2.5
005034  302 024 012           JNZ OVR       :OVERS—5
005037  174                   MOV A - H     :SET UP LAST WORD
005040  323 014               OUT DATAW     :OUT LAST WORD
005042  323 016               OUT CRC       :SHIFT OUT CRC
005044  323 016               OUT CRC       :IBID
005046  257                   XRA A         :CLEAR THE A
005047  323 014               OUT DATAW     :WRITE OFF —LAST WORD IS ZEROS
005051  052 301 014           LHLD TEMP     :GET SP
005054  371                   SPHL          :RESTORE SP
005055  311                   RET           :FAREWELL
```

(c)

INFORMATION RETRIEVAL NUMBER 34

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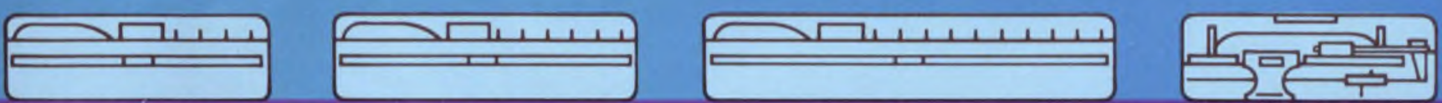

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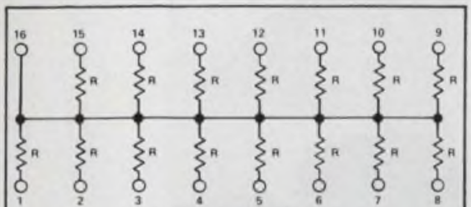
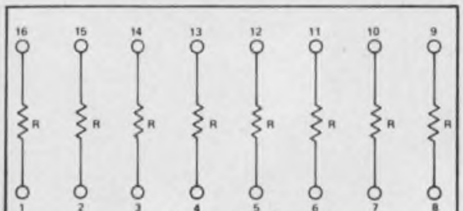
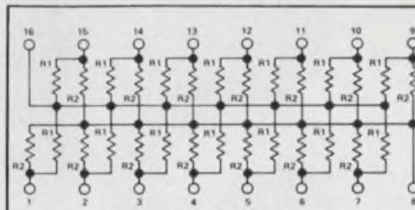
PARALLEL TERMINATION
Two basic configurations (314E-14 pin; 316E-16 pin). Each available in eight R1/R2 combinations for a wide range of impedance values.


Series 316A


Series 316B


Series 316E

Standard Resistance Values
R (Ohms), ± 2% Tolerance

22	43	82	160	330	620	1200	2400	4700	8200	16K	33K
24	47	91	180	360	680	1300	2700	5100	9100	18K	47K
27	51	100	200	390	750	1500	3000	5600	10K	20K	68K
30	56	110	220	430	820	1600	3300	6000	11K	22K	100K
33	62	120	240	470	910	1800	3600	6200	12K	24K	
36	68	130	270	510	1000	2000	3900	6800	13K	27K	
39	75	150	300	560	1100	2200	4300	7500	15K	30K	

Characteristic Impedance Z_0

R1/R2	Z_0	R1/R2	Z_0
81/130	50	160/260	100
120/200	75	180/390	123
90/660	80	220/330	132
130/210	80	330/680	222

SENSE AMP TERMINATOR
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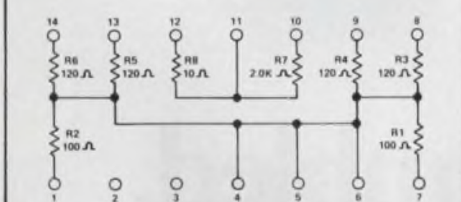
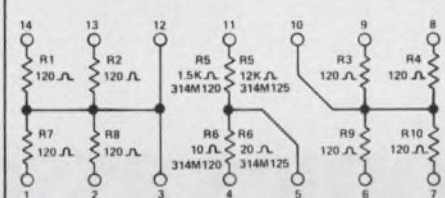
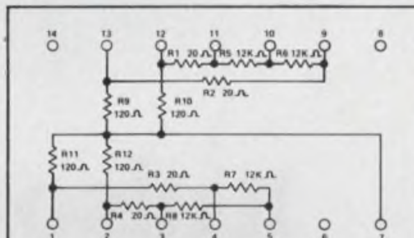

314M110


314M120 or 314M125

SENSE AMP TERMINATOR
For sense line applications with two 711 dual voltage comparators.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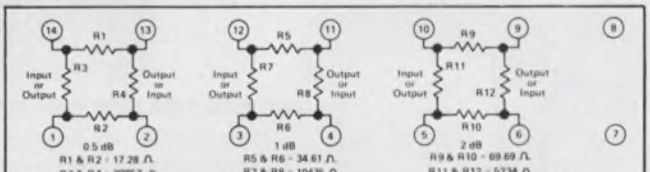
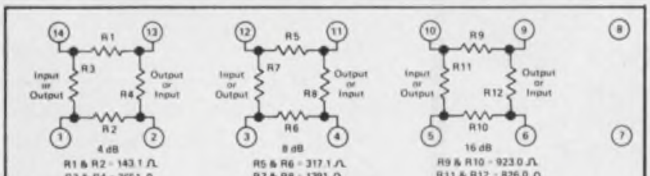

314Z1001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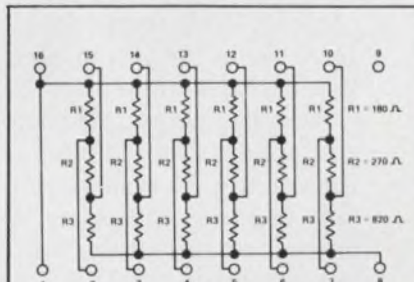
316T110

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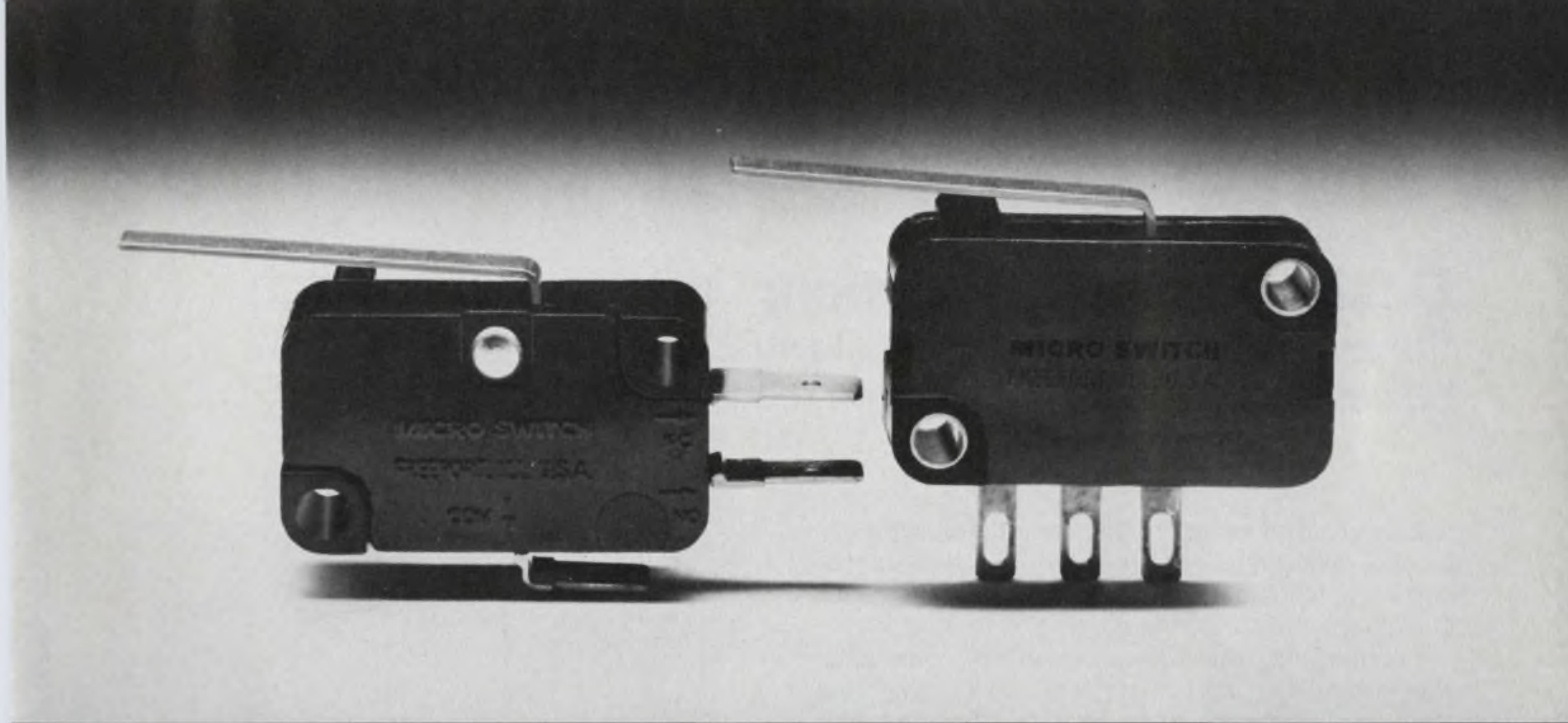
INFORMATION RETRIEVAL NUMBER 155

◄ INFORMATION RETRIEVAL NUMBER 157



One of these is a new solid state switch. It's important that you can't tell which one.

The switch on the left is the V3. A mechanically-actuated snap-action switch the size of a postage stamp. It was an industry first when MICRO SWITCH introduced it in 1943. And it's gone on to become the industry standard, with hundreds of millions in use worldwide.

The switch on the right looks like the V3. Mounts like the V3. It's even actuated like the V3. And that's exactly where the similarities end. Because it's all solid state inside.

Designed around a Hall-effect integrated circuit perfected by MICRO SWITCH, the XL has been made to provide every benefit of true solid state design without the necessity of getting out of mechanical control.

Because the XL is all solid state, there are no contacts to bounce or become contaminated. And the Hall-effect integrated circuit has been performance tested through over 12 billion operations without a single failure. Unlike standard mechanical switch designs, the XL can also interface directly with other solid state components. Its 20MA output eliminates the need for amplifiers, in most applications. And you can order it with either current sinking or current sourcing outputs.

It needs very little force for actuation—down to 10 grams. Even less with a lever. And the choice of actuator styles is the same as for the V3: over 500 different actuators in all. Including simple pin plunger, straight lever, simulated roller or roller lever.

Power supply requirements are also flexible. 5 VDC or 6 to 16 VDC with built-in regulator, over a temperature range of −40°C to +100°C.

So the XL obviously offers some unique advantages. It's just one of a wide range of MICRO SWITCH solid state designs that do. Including a complete range of magnetically operated solid state position sensors, like the ones pictured here.

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CIRCLE 231 FOR DATA
CIRCLE 232 FOR SALESMAN CALL

Design for fault isolation: Increasingly, the man who creates the circuit must ensure that it can be easily tested. Here are some techniques to do just that.

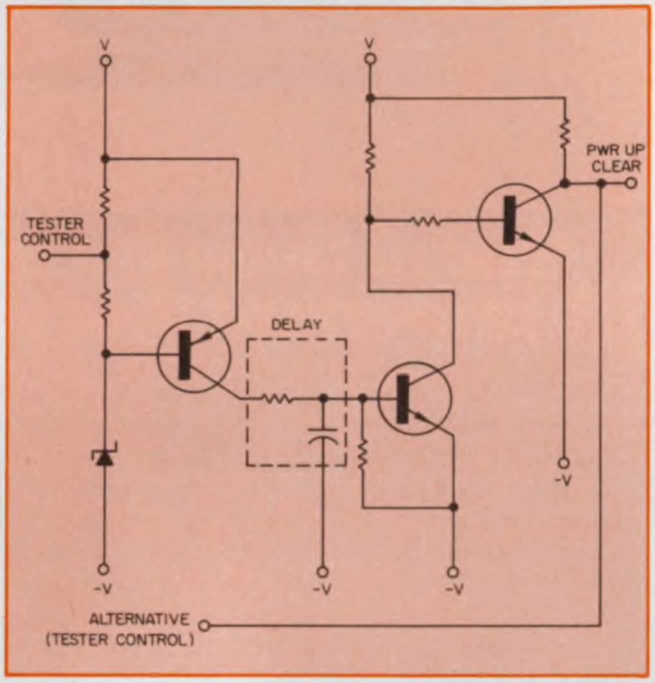
Largely overlooked in the search for solutions to the problem of fault isolation has been the designer who creates the circuits to be tested and diagnosed.

Fortunately, this situation is now changing. The realization is growing that the designer not only has a responsibility in this area, but also has available a number of rather simple-to-implement techniques that can significantly reduce the cost and complexity of fault isolation.

These techniques permit the subsequent fault-isolation test system to observe and control specific elements within a circuit so that meaningful tests can be made.

The difficulty and cost of fault isolation has risen in direct proportion to the density and complexity of today's circuitry. Dozens of IC devices of a circuit board can be the equivalent of hundreds of thousands of individual components and circuit connections. Moreover, most of the problem points are out of reach, and the effect of individual faults can be masked by intermittent failures, fanouts, and errors that occur only when a particular logic sequence is performed.

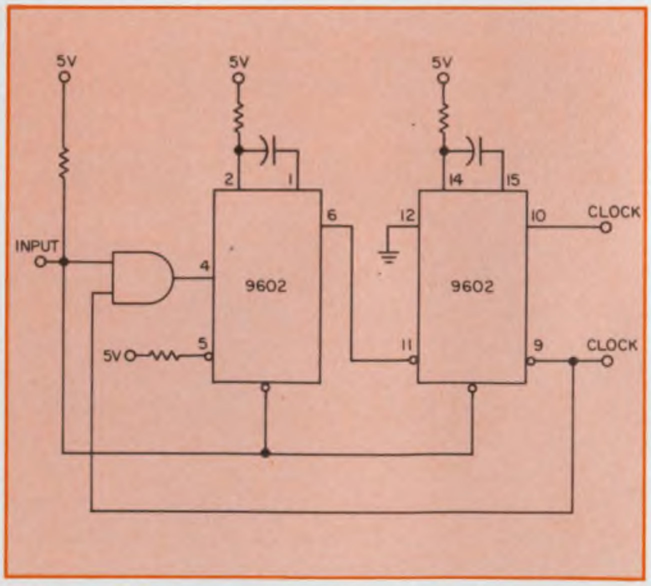
For the production department, fault isolation has long been a growing and frustrating problem. Go/no-go testing becomes a meaningless exercise when the percentage of no-go assemblies exceeds the half-way mark. Skilled personnel are siphoned into rework activities, and production-labor costs continue to climb in an industry that depends on IC technology for its future profits.



1. **In circuits that turn on in an arbitrary state,** a power-up clear can be provided to set a desired initial condition. Test-control signals can be designed to check both the circuit and clear.

Fault isolation and computers

Similar frustrations are being encountered in the field at repair centers and service depots. A 25¢ device may be the only item that needs replacement, but the cost to locate the faulty IC package often exceeds the value of the complete circuit board or assembly. And, again, there is the problem to find and train the skilled personnel needed to do the work. Not surprisingly, then,



2. **To test asynchronous circuits,** control lines can enable or disable the clock circuit.

Jai Hun Jhu, formerly with Technology Marketing, now General Manager, μP Div., Plessey Memories, 1674 McGaw Ave., Santa Ana, CA 92705.

a great deal of attention is now being applied to the technology of fault isolation.

Theoretical work, much of it performed at the university level, finds expression in computer-controlled diagnostic schemes. Do-it-yourself test systems are being replaced with more sophisticated equipment from companies who specialize in this field. Larger manufacturers are developing staffs, strictly for fault isolation, composed of experts in the theory and implementation of diagnostic techniques.

But the net effect of much of this activity has been to replace one cost problem with another. Computer software and programming can make the cure as expensive as the disease. New fault-isolation systems, with computer-like logic but without the need for computer programming, are now becoming available. At best, however, the new systems will just hold the line in the face of increasing circuit complexity.

All of these difficulties can be largely overcome, if the designer—with the support of production, service and management—recognizes the interplay between design and fault isolation, and takes advantage of the cost-savings opportunities at his disposal.

The designer may, for example, increase the size of an edgeboard connector to accommodate test points for factory-level tests. The extra cost will probably be insignificant compared with the easing of the fault-isolation problem.

In general, fault-isolation testing consists of the creation of a particular set of conditions or sequence of conditions that permit the designer to observe whether the circuit performs as intended.

To do this is not necessarily a simple matter, especially when the objective is to narrow the test to a particular component or device. The designer is primarily interested in the over-all performance of the circuit assembly, but the fault-isolator must have a way to control specific elements within the circuit to apply meaningful tests to individual devices or groups of components.

The first task of the designer, therefore, is to add to the controllability of his circuit.

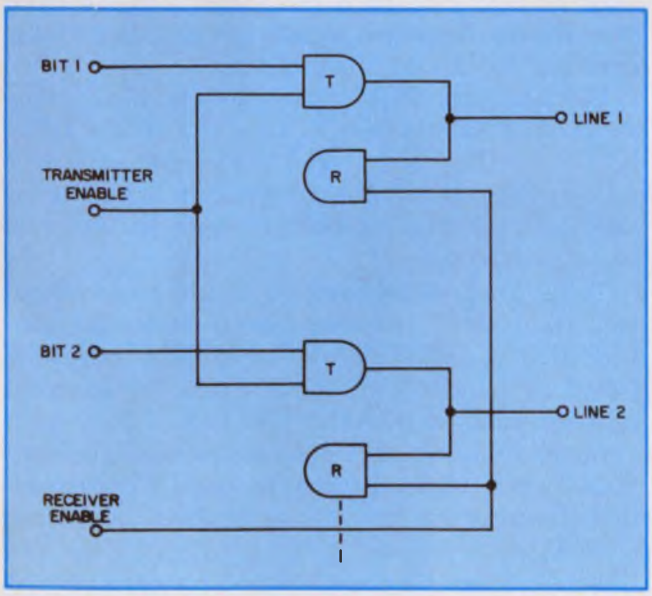
His second requirement is to increase the observability of the circuitry under test. Usually only a small fraction of the internal-circuit nodes are brought out for functional purposes. Obviously, it would be impossible to bring out all the nodes just for test purposes. The answer lies in a careful selection of extra test lines and a physical design that lends itself to easy probing with IC clips, oscilloscope leads, and other test-equipment connections.

Controllability and observability are separate, yet interrelated, functions, and the circuit designer can contribute importantly to both. A number of examples show how.

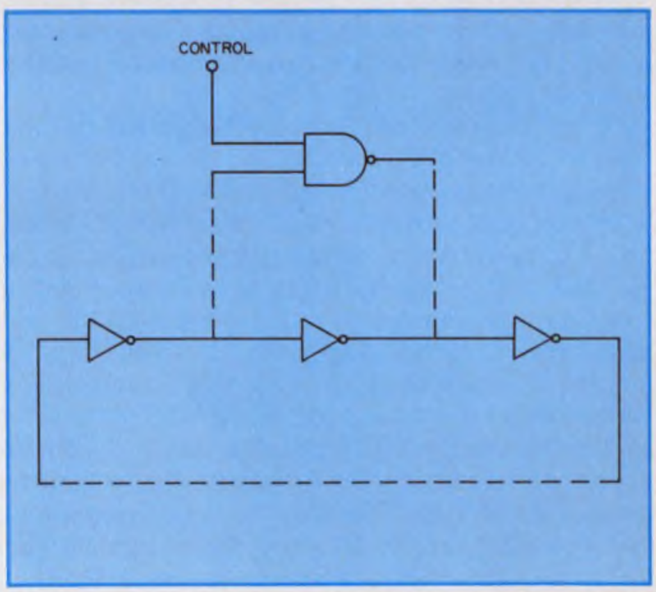
Designing for controllability

On power-up, flip-flops or any memory holding device can come up in any state. A long shift register will therefore require a long series of input pulses to flush out the unknowns. This extends the test time and a larger test-system memory may be required. The solution is to use a master-reset line, even if there is no need for the line in the circuit function. Bring the master reset line out to a pin for accessability.

Some circuits include a power-up clear to provide the initial condition. This circuit is active only when the power is initially applied to the board. Figure 1 shows two alternative ways to



3. **Test-system lines (1 and 2) are assigned** to check receivers and transmitters that share a bidirectional line.



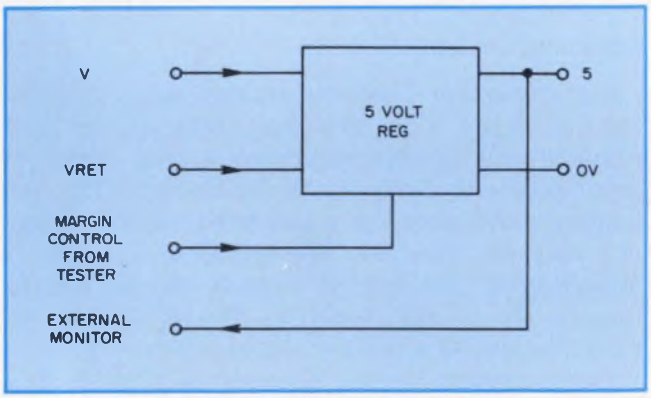
4. **Feedback loops are hard to test.** A control line can be used to stop errors at a gate during test.

provide external control signals to test both the power-up clear circuits and the reset line of the internal flip-flops.

Astable multivibrators that run asynchronously can make testing very difficult because there is no time reference with which to make consistent tests. The solution here is to design control lines to the clock circuit to enable or disable the clock, or to let one clock pulse go out at a time.

The control lines will let the fault-isolation system exercise the circuit one clock at a time, and thus process the data at the system's own speed. One typical clock circuit is shown in Fig. 2. The input, when LOW, disables the clock. When HIGH or left open, the input enables the clock. An alternative solution is to provide a port for an external clock, as well as a clock disable.

With dynamic MOS circuits, provision must be made to synchronize the test system and the device under test. In the case of built-in clocks, provide either alternate inputs for external clocks or some method to synchronize to the internal one.



5. **5-V regulators often fail** under marginal conditions so that provision should be made for limit tests.

With bidirectional lines—where the line is shared by both a receiver and a transmitter—testing becomes complicated unless there is prior knowledge as to which circuit is active. It is advisable, therefore, to bring out the enable terms so that the system can test or troubleshoot the receiver and transmitter independently. To do this, assign test-system lines one and two as output (response) pins and test transmitters (Fig. 3).

Troubleshooting of circuits with feedback loops can be very difficult because errors tend to propagate and feed back to the origin (or seemingly to the origin). To provide a method for fault isolation, the designer can use control points without the sacrifice of circuit performance or addition of parts. For instance, one of the inverters could be an AND gate that provides an external control within the loop so that the loop can be broken in the middle by an input signal (Fig. 4).

In Fig. 4, with the control line disabled during troubleshooting, errors will not propagate beyond the gate. (The control line is permanently enabled during normal operation.)

Regulators, ROMs and RAMs

It is common practice to place a +5-V regulator on a printed circuit board. However, designers often neglect to bring out a test point to check the regulator. Malfunctions in the V_{cc} regulator will cause massive errors or—worse—unpredictable, intermittent errors, commonly known as ghosts. It is therefore imperative to check the V_{cc} regulator on the board before diagnostic attempts are made.

It is also advisable to provide some control for voltage margin. Many circuit malfunctions occur at voltage margins. To eliminate "weak sisters" and thus enhance the reliability of the equipment, circuits should be exercised at marginal conditions before installation (Fig. 5).

Circuits that use ROMs to replace hard-wired logic tend to have many feedback loops. In many cases, technicians troubleshoot the ROMs along with the rest of the circuit—a practice that can lead to confusion. Therefore, it is best to install sockets for the ROMs so that the memories can be checked prior to installation on the board. This not only simplifies the test but also provides a breakpoint in the loops.

The sockets can also be used to connect to the test equipment during checkout. Thus the test system can be directed to generate ROM patterns while the system monitors the results coming back as inputs to the ROM. (Inputs to the ROM for address lines are usually a function of the previous ROM address pattern.)

Circuits with ROMs also tend to have many jumps and subroutines so that it is often difficult to verify whether the instruction sequence follows the right course. Single-step capability is easy to implement at points where an external break is advisable.

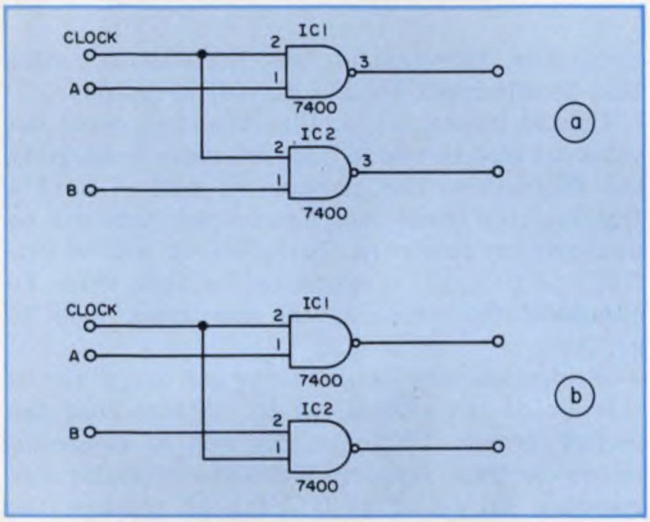
To test large RAM systems requires specialized test equipment. However small memories embedded in a large circuit board may be easily tested by provision of some access for external controls, such as READ or WRITE.

In the usual circuit implementation, a memory READ cycle forms a subcycle of a CPU instruction. Therefore, it may not be possible to exercise a READ cycle without going through all the motions. If it can be done without unbearable cost and long delay in the development cycle, provide pins for external READ and WRITE commands (data input and output can be monitored by means of an IC clip).

For dynamic MOS RAMs, refresh requirements present some degree of difficulty. The strategy here is to first thoroughly check out the refresh logic, then test the memory.

One shots, ghosts and fanouts

Verification of the pulse width of a one-shot circuit can be easily handled by test systems with programmable sample clocks. However, most test systems have a fixed resolution and a minimum sampling time period, which makes it easier to check a long than a very short pulse width. If possible, therefore, make the pulse width at least 1 μs, or greater.



6. **Two gates are laid out on a PC card** so that each uses the same test routine (a). This can't be done with setup in "b."

A common occurrence is for errors to disappear when a scope probe is placed in an IC pin. This can be traced to changes in dynamic and static loading characteristics. The problem can become worse if the test system is directly interfaced with the internal circuit outputs.

For instance, standard TTL fanouts are usually limited to 10. If the tester receiver(s) is connected directly to an output node with the maximum fanout, circuit behavior may become erratic. A CMOS buffer can prevent loading but this can increase the cost of the test system (CMOS chips are also very slow). The design engineer can resolve this problem by limiting the number of fanouts to one less than the nominal maximum.

Designing for observability

It may not always be possible to design circuit boards with identical edge connectors. However, as a general rule, boards should have a minimum number of connector varieties. Avoid connectors on more than one side of the board, multiple-connector types and connectors in the middle of the board.

Provision for extra test points is very important. However, the points must be easily accessible if they are to be of value. Use of extra edge-connector pins to bring out the test points can minimize test time and simplify the test fixture design.

More thought should be given as to what constitutes a good test point: Each test point should be an internal circuit node that can give the test system an important clue to the nature of possible failures (Fig. 6).

Most test-systems use IC clips to monitor circuit operations during troubleshooting. Often, the ICs are so close that it is impossible to use the clip. Sometimes discrete components get in the way or ICs are inserted in more than one direction. These problems must be avoided during the layout stage. At this stage, component locations should be numbered and the numbers should be easily visible on the board.

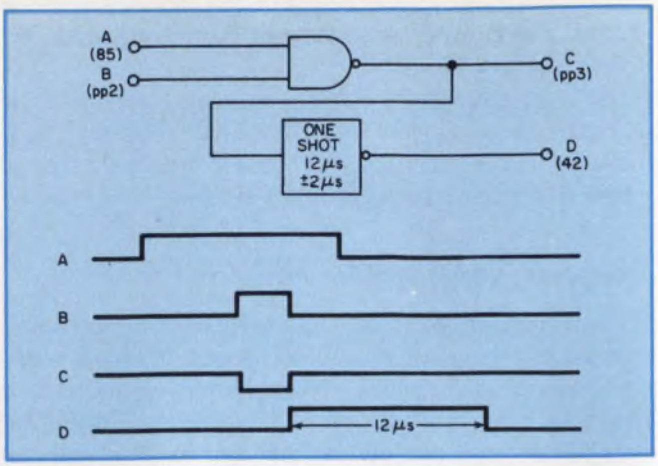
Jumper options can be tested most easily if all the jumping is done on the edge connector. However, if the board is not designed in this fashion, a set of parallel access lines should be provided, at the least, so that the tester automatically can exercise all the possible jumper configurations. Unused jumper options and their verification are often overlooked, and circuit malfunctions traceable to the jumper options are sometimes hard to diagnose.

It is common for a printed-circuit-board assembly to go through engineering changes after it has been put into production. Some of the changes will be temporary fixes. The manner in which these changes are incorporated will affect the tests. If an IC clip is to be used during testing, it is advisable to avoid the "dead-bug" method. If a "bed-of-nails" fixture is to be used, consideration must be given to accessibility before jumpers are added.

Design for simplicity

To ease diagnosis and test-program generation on an automatic tester, circuits can be laid out to use a common test routine. For example, in Fig. 6a an automatic card tester with an IC-clip probe is used for diagnostics. The two 7400 gates are laid out on the printed-circuit board in such a way that a test routine for one chip can also be used for the other (the clock is connected to pin 2 on both chips).

By contrast, the circuit in Fig. 6b has the clocks connected to pin 2 of one chip and pin 1 of the other so that a common test routine is



7. **Schematics are as important as tests.** Shown are all vital internal nodes, sources, destinations, and important circuit data, such as a one-shot's timing.

impossible. This example also pertains to testers that handle input signals as well as output.

Unused inputs, gates, flip-flops and other devices can also be tied to a known state to simplify the diagnostics. For example, if half of a 7474 flip-flop chip is not used, the output state will be unknown on power-up. Therefore, it will be difficult to program diagnostics for that chip. To eliminate the problem, tie the reset side to ground.

If identical pin assignments can be achieved throughout the system, as in systems that use mother boards, fixturing (as well as programming) becomes simpler. Since the stimulus and response pin definition is identical, most of the test-routine for one board can be used for the rest.

In any event, the designer should make an effort to simplify the connection scheme by assigning common power connections. Since most computer-controlled testers have the capability to change the input and output definition, the same interface fixture can be used for a number of different cards, as long as the cards have the same power connection.

Aside from test specifications and test procedures, a well-designed schematic can be a great help to test personnel. Schematics must be not just easy to follow, but should also provide test information as well. Such information can include a timing diagram, IC types and pin-out chart, a notation for I/O pins that is different from the internal connections, and the pulse width of one shots.

Figure 7 shows that "A" and "D" are edge-connections and that their pin numbers are 85 and 42, respectively; while "B" and "C" are internal connections and their source and designations are on page two and three, respectively. Also shown is a one-shot with its time-out classified as 12 μs with ± 2-μs tolerance. ■■

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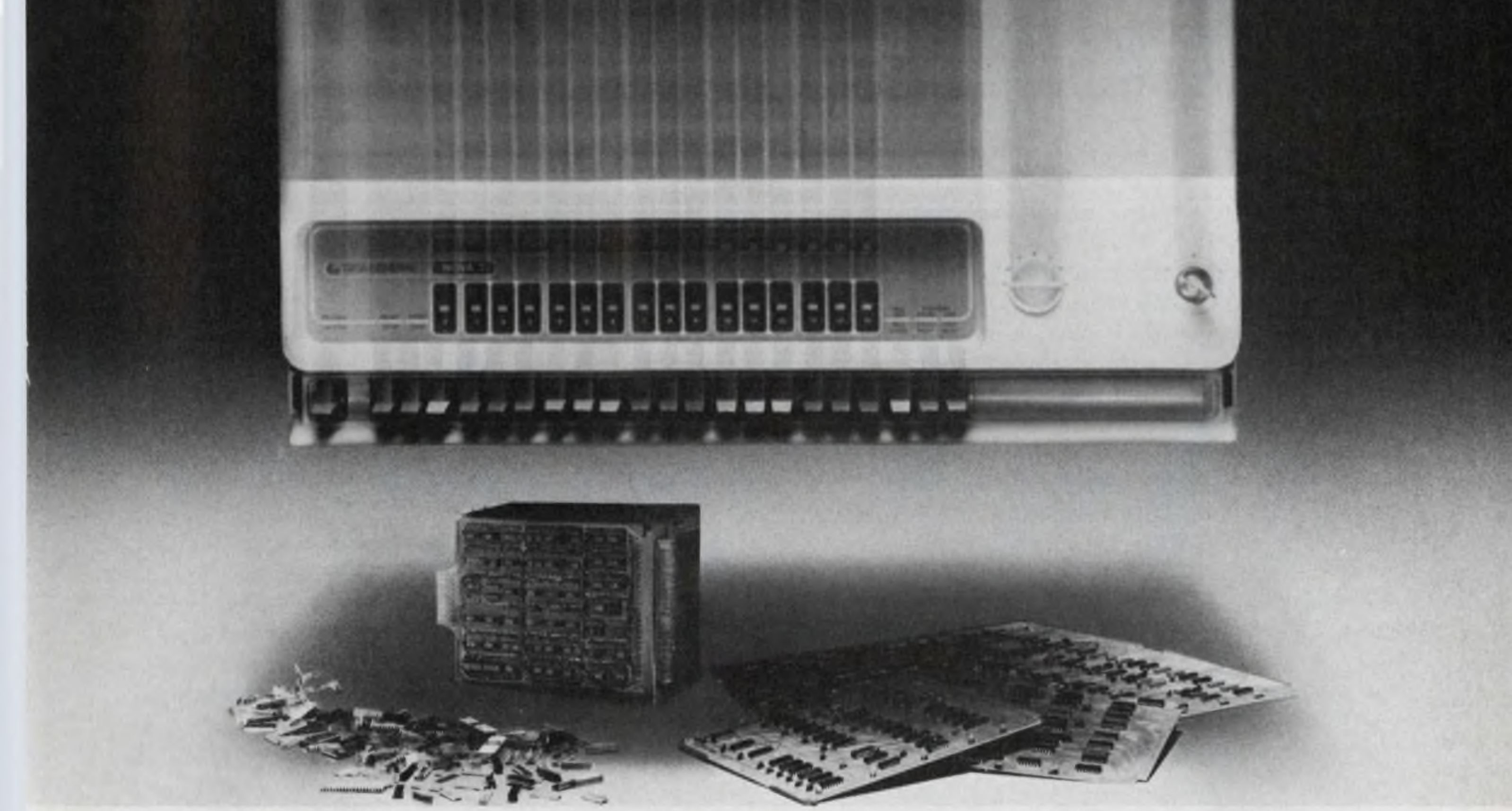

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Complacent about resistor reliability?

There are at least 18 ways these components can cause circuit problems. Here are tests to ensure reliability.

Fixed resistors of the molded-composition and film types generally have such a good reputation for reliability that many design engineers seldom question it—until it's too late. Their reputation, usually well-deserved, is kept that way because the leading manufacturers subject their resistors to stringent inspection and testing. Laxity in any phase of resistor testing can easily result in poor circuit performance when a completed assembly is put through environmental tests.

To ensure reliability, resistors must undergo at least 18 tests. Here they are:

Group 1
- Visual and mechanical inspection.
- Resistance value and tolerance.

Group 2
- Resistance-temperature characteristics.
- Resistance-voltage coefficient.
- Dielectric withstanding voltage.
- Insulation resistance.

Group 3
- Low-temperature operation.
- Temperature cycling.
- Steady-state humidity.
- Short-time overload.

Group 4
- Load life.

Group 5
- Terminal strength.
- Effect of solder heat temperature.

Group 6
- Solderability.

Group 7
- Shock and vibration.

Group 8
- Pulse applications.

Group 9
- Resistance to effects of solvents.

Group 10
- Temp/humidity cycling.

Because of the impracticality of testing every one of a large batch of resistors, select samples at random. For each test sequence, except the first group, pick 10 resistors of each type and resistance value.

The tests in Group 1—visual and mechanical inspection and resistance tolerance—are applied to all of the specimens. And within each group the tests should be made in the sequence shown. Some tests, such as groups 4, 6, 7, 8, 9 and 10, may damage or render the resistors unfit for further tests, thus they include only a single test.

In testing to compare the products of several manufacturers, use resistor samples with the narrowest standard tolerances. The resistance values should include the manufacturer's lowest and highest standard values as well as the "critical."

The critical resistance value is defined as the highest standard value that can safely dissipate full-rated wattage at 70 C when a maximum-rated, continuous-working voltage (RCWV) is applied. The maximum RCWV for dc or rms voltages is supplied by the manufacturers. Table 1 lists RCWV values for common hot-molded fixed resistors.

All resistors, except those that are truly hermetically sealed, absorb moisture. Since this can affect resistance values, you must remove the moisture. This operation on test samples, often called conditioning, is done by exposing the resistors to warm, dry air from a ventilated oven in an air-conditioned space. For the resistors in Table 1, apply dry 100-C air for the conditioning time listed. Longer drying may be required if the resistors have been stored for long periods under unusually high relative humidity.

Resistance to resistance change

Of course, a resistor's ohmic value and its tolerance range are the most important specifications. The ohmic values should be within the specified tolerance when measured at 25 C. And because composition and some film resistors exhibit a voltage coefficient, measure the resistance with standardized voltage levels, so the measurement error doesn't exceed one-tenth the allowable resistance tolerance.

The use of specific dc test voltages, as in Table

Don Bugalski, Manager Fixed Resistors, and **Jack Polakowski,** Fixed Resistor Applications Engineer, Allen-Bradley Co., Electronics Div., Milwaukee, WI 53205

Table 1. Test limits for hot-molded fixed resistors

Maximum continuous power rating at 70 C ambient watts	Maximum rated continuous working voltage (RCWV) dc or rms volts	Dielectric withstanding voltage volts at 30" Hg sea level	at 3.4" Hg 50,000 ft.	Insulation resistance test voltage volts ±10%	Short-time overload voltage limit volts	Recommended conditioning time at 100 C $^{+5}_{-0}$ C hours	Critical resistance value megohms
1/8	150	300	200	100	200	25	0.18
1/4	250	500	325	100	400	50	0.27
1/2	350	700	450	500	700	75	0.27
1	500	1000	625	500	1000	120	0.27
2	750	1500	625	500	1000	130	0.30
3	500	1000	625	500	1000	120	0.091
4	750	1500	625	500	1000	130	0.15

Table 2. Recommended resistance measurement voltages

Nominal resistance range	Test voltages (dc volts)
1.0 to 9.1 ohms	0.3
10 to 91 ohms	1.0
100 to 910 ohms	3.0
1K to 9.1K ohms	10.0
10K to 91K ohms	30.0
0.1 Meg. and Higher	100.0

Table 3. Temperature characteristic test sequence

Sequence	Ambient temperature °C
A	105
B	85
C	55
D	25
E	0
F	– 25
G	– 55

2, is recommended for all performance tests. Apply these voltages for the shortest possible time to avoid heating. Wherever practical, use the same instrument and the same temperature (within ±2 C) in all tests. Wheatstone-bridge test equipment is preferred.

To evaluate resistance-temperature characteristics, maintain the resistors within ±1 C at each of the ambient temperatures in Table 3 and in the sequence shown. The use of forced circulating air is recommended to assure temperature stability and uniformity. Make the resistance measurements 15 minutes after the air temperature has stabilized at each specified temperature. The percent difference in resistance, referred to the resistance at +25 C, is computed by the equation

$$\frac{(R - r) \times 100}{r},$$

where R is the resistance at the test temperature and r is the resistance at +25 C.

The resistance-voltage coefficient—often called instantaneous voltage coefficient—is normally important only in testing; it allows accurate comparison of the results. Measure the resistance values for calculating the voltage coefficient at one-tenth RCWV and full RCWV. And remember to apply the voltages for a short time to minimize heating. The voltage coefficient is calculated from

$$\text{Voltage coefficient \% per volt} = \frac{(R - r) \times 100}{R \times 0.9\ (\text{RCWV})},$$

where R is the resistance at full RCWV and r is the resistance at one-tenth RCWV.

The next test is to check the resistors' dielectric withstanding voltage. Clamp the resistors in the trough of a metallic 90-degree V-block. The resistor body should not extend beyond the ends of the trough, and the resistor leads should be parallel to the sides of the V-block.

Apply sine-wave voltage at commercial-line frequency and at the levels specified for the resistors under test (Table 1). The voltage should be applied between the V-block and both resistor terminals, with the terminals connected together. Raise the voltage at 100 V/s and hold it for 5 s.

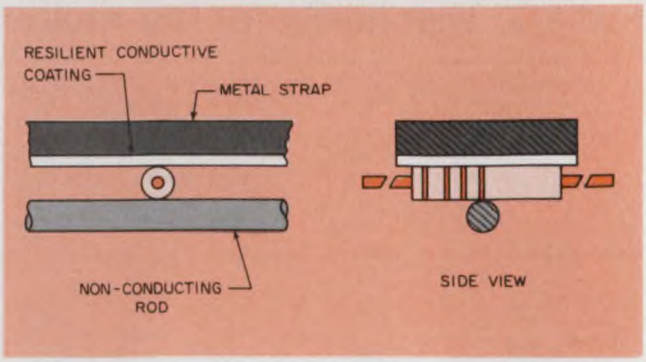
Note that Table 1 provides two sets of test voltages. One is for a sea-level pressure of about

30 in. of mercury, and the other is for atmospheric testing at about 3.4 in., which corresponds to an altitude of 50,000 ft.

A companion test to withstanding voltage is insulation resistance. Clamp the resistors between a round nonconducting rod, placed at right angles to the resistor body, and a resilient conductive material about 0.075-in. thick, bonded to a rigid metal strap (Fig. 1). Apply sufficient pressure to embed the resistor color bands in the resilient material and to provide intimate electrical contact along the entire axial length of the resistor body.

The metal strap and resilient conductive material should be as wide as the length of the resistor body, and the resistor should be placed in the center of the strap. The resistivity of the resilient conducting material must be less than 1000 Ω-cm.

Avoid excessive resistor handling to minimize the effects of perspiration or other contaminants. Connect the lead wires of the resistor together and measure the resistance between these leads and the metal strap. Use the manufacturer's specified dc test voltage. Table 1 provides test voltages for hot-molded resistors. Check the values obtained against the manufacturer's limits.



1. **To check insulation resistance,** the resistor should be clamped tightly against a resilient conductive surface to obtain a large-area contact with the resistor's body.

Testing for performance at extremes

To test for the effects of very low temperature, mount the resistors by their leads so there is at least 1 in. of free air space around each resistor, with no appreciable obstruction to the flow of air.

Measure the initial resistance. Then expose the resistors to an air stream of −65 C for 1 h, with no voltage applied. Follow this with 45 min of exposure, but with the RCWV applied. Allow the resistors to return to room temperature and to remain there for 24 h, then make a final measurement of resistance. Note any deviation from the manufacturer's spec.

Temperature cycling is an even more severe test of a resistor's ability to withstand temperature extremes without permanent change of resistance. Again, measure initial resistance with the resistors mounted for low-temperature evaluation. The temperature-cycling sequence in Table 4 is frequently used by manufacturers. It shows four steps. The temperatures in steps 1 and 3 are obtained by forced-air circulation. The heat source should push the air temperature within 2 min to the temperatures specified in the table. Measure the final resistance about 1 h after completion of the last cycle.

Moisture also can permanently change a resistor's value. Though the results of humidity tests are hard to reproduce and compare, the following procedure has proved effective as a steady-state test:

Measure the initial resistance values, avoiding excessive handling. Place the resistors in a chamber with relative humidity of 90 to 95% at an ambient temperature of 40 C for 240 h. Then remove the resistors from the chamber and allow them to dry at room ambient for 4 h. This removes only surface moisture. Final resistance measurements can then be made.

To determine if any resistance changes are permanent, the resistors may be conditioned, as described previously, and the values checked again.

A more realistic approach to humidity testing is sequential exposures of high temperature followed by high humidity. After measurement of the initial resistance, put the resistors in a dry oven at 130 C for 240 h. Immediately after this exposure, place the resistors in an atmosphere of 66 C and 100% relative humidity for 125 h. Then take final resistance measurements and observe for erratic behavior. This cycle may be repeated, depending on the severity of the intended application.

Testing under load

The testing thus far still does not assure long-life stability under load conditions. An actual load-life test is needed.

Do this test at an ambient temperature of 70 C, with the resistor leads soldered to lightweight terminals. Bolt the clamps of metal-clad resistors to 4-in.-square steel plates, 0.05 in. thick, one plate for each resistor. The length of each lead should be about 1 in.

Arrange the resistors so heat from any one resistor doesn't influence the temperature of any other. And allow only the natural convection circulation of air to cool the resistors. Use RCWV.

Expose the resistors to the 70-C ambient temperature without load for 2 h, then make the initial resistance measurements. Apply dc RCWV

Table 4. Temperature cycling test sequence

Step	Temperature °C	Time minutes
1	$-55\ ^{+0}_{-3}$	30
2	+25 ±5	10
3	$+85\ ^{+3}_{-0}$	30
4	+25 ±5	10

Table 5. Capacitor energy-pulse test limits

Rated wattage	Energy watt-seconds	Approx applied dc volts	Capacitance μF
1/8	0.45	670	2
1/4	1.8	600	10
1/2	6.4	630	32
1	16.0	1000	32
2	44.0	1650	32

intermittently—1-1/2 h ON and 1/2 h OFF—for a total of 1000 h. Take resistance measurements near the end of OFF periods after 50, 100, 250, 500, 750 and 1000 h. Keep the resistor ambient temperature at 70 C throughout.

For intermittent short-time overload testing, apply for 5 s a well-regulated dc or sine-wave voltage that is 2.5 times the RCWV but does not exceed the limit values in Table 1. Measure the resistance before and about 30 min after application of the test voltage.

For circuit applications that experience repeated pulses with peak values in excess of steady-state ratings, design special tests. These should last ideally for at least 1000 h under conditions that accurately represent the peak value, pulse waveform, repetition rate and environmental conditions that must be met. Even more severe conditions than expected are recommended to establish safety factors.

However, a good way to test easily for pulse capabilities is to use a capacitor-discharge technique for the stress signals. Charge a noninductive capacitor at successively higher voltages and discharge it through the resistor. The circuit should have a minimum and consistent inductance value. Make resistance measurements initially and after each capacitor discharge.

Some recommended test levels are listed in Table 5. Resistors are subjected to a single energy pulse from a capacitor discharge. The resistor samples should have a nominal resistance of at least 150 Ω. A change in resistance of more than 4% is considered excessive. The actual applied voltage can be computed from the equation

$$V = \sqrt{\frac{2E}{C}},$$

where C = capacitance in farads and E = energy in watt-seconds (Table 5).

A resistor may be accurate, stable, resist moisture and take the stress of overloads, but if its leads break off easily or its resistance changes when the leads are stressed, the component is obviously too unreliable to be put to use.

To test lead strength, measure the initial resistance and then hold the resistor by one lead and gradually apply a pulling force of 5 lb to the other lead along the longitudinal axis of the resistor. Maintain the force for 5 s. For 1/8-W resistors, use only 2 lb. The leads, of course, should not come off.

Follow this pull test with a bend test. Bend the leads 90 degrees at a point 1/4 in. from the resistor body in a radius of about 1/32 in. (Fig. 2a). Then clamp the free end of the lead up to 3/64-in. from the bend (Fig. 2b).

Now rotate the resistor body 360 degrees about its longitudinal axis in alternating directions three times. Each rotation should be done in about 5 s. After the last rotation, measure the resistance—assuming, of course, that the lead has not broken off. The resistance should not have changed appreciably.

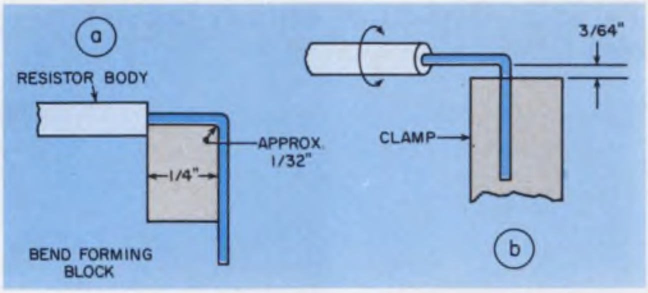
Solder heat is another stress that resistors must withstand. Measure initial resistance, then immerse the resistor leads, one at a time, for about 3 s each in molten solder at 350 C (250 C for 1/8-W resistors). Immerse to a distance of 1/8 to 3/16 in. from the resistor body. Now measure the final resistance about 24 h after the immersions; it should not exceed the manufacturer's specified limits.

Leads must be solderable

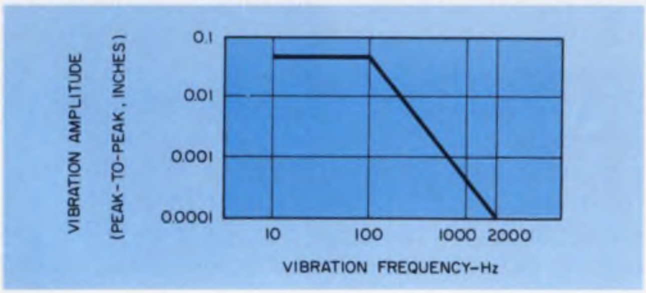
To evaluate solderability, use either a heated still pot or a recirculating-flow soldering machine, both capable of maintaining the solder at a uniform temperature of 232 C. If a still pot is used, the stirring-paddle and skimmer material should not contaminate the solder.

The flux must consist of a minimum of 35% by weight of waterwhite rosin dissolved in 99% isopropyl alcohol. The solder should be 60% tin and 40% lead.

Test both leads of each resistor "as received," with normal care taken to prevent contamina-



2. **To test the twist strength of the terminal leads,** first bend the leads (a), and then twist slowly three times for 360 degrees in alternate directions (b).



3. **The resistors should be subjected to a vibration test** over the frequency range and vibration amplitudes as shown in this graph.

tion that might influence test results. The leads should be immersed first in flux for 5 to 10 s at room temperature. Skim off any scum or dross accumulation on the solder surface.

If the solder isn't circulating, stir it with the paddle to keep its temperature uniform. Then dip the fluxed leads into the solder only once to the same depth they were immersed in flux. The rate of immersing into the molten solder should be about 1 in./s with a dwell time of 5 s.

After this soldering operation, allow the leads to cool in air. Remove residual flux from the leads by bathing in clean isopropyl alcohol and, if necessary, wiping with a soft cloth. Examine the surface of each lead for uniform coverage with a 10-power optical magnification system.

Shock and vibration testing

In addition to pull and bend stresses, resistors must contend with vibration and shock. To test for shock effects, mount them on rigid holding fixtures. Resistor leads should be supported 1/4 in. from the resistor body. Test leads to the resistors must be 22 AWG or smaller. Apply a sawtooth shock with a peak value of 100 g and duration of 6 ms. The actual velocity change must be within 10% of the ideal change of 9.7 ft/s.

Measure the initial resistance. Then subject the mounted resistors to 10 impacts in two directions: parallel and perpendicular to the longitudinal axis of the resistor. Provide electrical monitoring during the test to detect resistor discontinuities of 0.1 ms or greater. After the shock cycle make final measurements and examine for mechanical failures.

To evaluate vibration characteristics, the test fixtures with the resistors mounted on them must be free of mechanical resonances over the frequency range of 10 to 2000 Hz.

After measuring the initial resistance, subject the mounted resistors to the vibration amplitude and frequency range shown in Fig. 3. The vibration waveform should be a simpler harmonic motion with an amplitude that provides 20 g of peak acceleration but does not exceed 0.06-in. peak-to-peak displacement.

Vary the frequency approximately logarithmically between 10 and 2000 Hz with a return sweep to 10 Hz. The entire sweep cycle should be traversed in approximately 20 min. Continue this sweep cycle for 6 h in two directions—parallel and perpendicular to the longitudinal axis of the resistor. Test interruptions are permitted, provided the requirements for rate of change and total test duration are met.

Here again, provide electrical monitoring to detect resistor discontinuities of 0.1 ms or greater. Make the final measurements and examinations for mechanical failures after the tests.

Resistors must resist solvents

To test for the actions of common solvents, inspect the resistors visually first for color coding. This is so comparison can be with after-test results should the solvents remove the codes. In addition measure the initial resistance values at ambient room temperature. Then heat the resistors in an oven at 120 C for 4 h.

Immediately thereafter immerse the resistors completely in ultrasonically (25 kHz) agitated liquids at approximately 40 C, one solution at a time, in this order:

1.	Methyl chloroform	10 min.
2.	A 50-50 mixture of isopropyl alcohol and freon alcohol	5 min.
3.	Toluene or xylene	30 min.
4.	Trichloroethylene	30 min.
5.	Tap water	30 min.

Avoid mechanical abrasion during the tests. At the conclusion of the immersions, allow the resistors to dry for 4 h. Then measure resistance values and examine the color code for changes.

Because of the popularity of Freon TMC, many manufacturers test resistors with a one minute immersion in this solvent. However a separate test group of resistors should be used for this or any other special solvents the resistors may be subjected to. ■■

Choosing the best enclosure: Here are do's and don'ts for putting equipment in a sturdy, eye-catching, low-cost package.

Selecting the right cabinet or rack for an instrument or circuit calls for a dual personality—well, almost. To do the job right, you must be both design engineer and purchasing agent. You must analyze the cabinet or rack construction from the standpoints of size, material, eye appeal and cost.

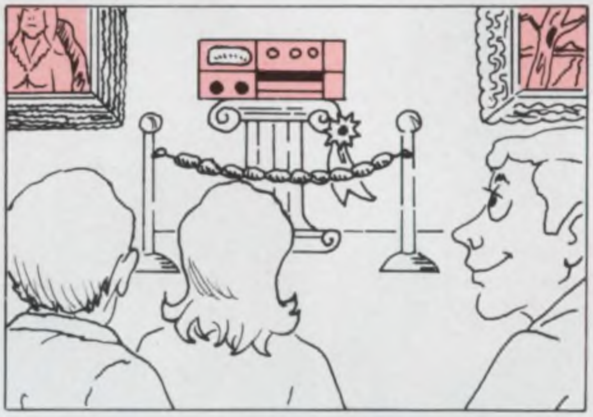
As a design engineer, you want the enclosure that best fits the equipment while providing good user efficiency. On the other hand, as a purchasing agent, you must watch out for expensive custom options; you want the best unit for the lowest possible cost.

If you can't find an enclosure that fits the equipment, consider minor equipment changes instead of custom cases. Depending on the number of enclosures needed, it might pay to redesign a portion of the circuit rather than buy a custom case.

Here are some do's and don'ts that can help minimize cost and simplify selection of the right enclosure. The list contains many often-overlooked design details. After checking these, you'll probably come up with several more of your own.

Allen Hehs, Technical Director, Bud Radio, Inc., 4605 E. 355th St., Willoughby, OH 44094.

Eye appeal



Do's

1. Consult with the vendor when it comes to finishing or coloring the enclosure. It's important to know the environment the equipment will be operated in so the proper primer can be chosen to resist corrosion. For color selection, use Federal Color Chart No. 595. The lowest-cost colorings are "self-texturing" enamels, in which the resins are ground into the vehicle. To cut costs, use the vendor's standard paint whenever possible.
2. Decide how much "sophistication" you want in cabinet or rack styling. If you know the final location of the product—executive office, showroom, computer room, laboratory, production area, etc.—consider that factor.
3. Look through vendors' catalogs to see what is available from stock. Nearly every stock unit can be modified, for a price.

Don'ts

1. Try not to specify paint by brand name, unless the vendor can't supply an equivalent covering. Remember, air-dry paints (except lacquers) require dust-free rooms. Also, baking cycles change, depending upon oven type and paint formula. If you order a specific paint, you'll be responsible for the results—good or bad. Don't order a textured paint and then use silk-screening for lettering; the resulting resolution is very poor.
2. Avoid loading up the enclosure with fancy trim, two-tone paint, odd shapes, etc. You pay extra for these.
3. Don't purchase a completely painted unit and then modify it by punching holes, drilling, etc. Any operations like these will probably destroy the finish.

Mechanical extras

Do's

1. If slides are needed, tell the vendor the load to be moved, distance of travel and whether a tilting or disconnect feature is required. G forces should also be indicated for internal components.
2. Indicate panel size and the amount of air to be moved per minute if you plan to cool equipment with a blower. For casters, indicate load. Other accessories, such as drawers, handles, shelves, brackets, etc., are usually available in company catalogs.
3. For large room-like enclosures, try using aluminum extrusions with corner connectors. The engineering and fabricating costs are less than for similar steel structures, and the weight is up to 65% less, too.

Don'ts

1. Don't specify the slide loosely. If you aren't sure what type to use, explain the conditions and constraints to the vendor's applications engineering staff. Let the vendor help you select the slide.
2. Avoid constraining the vendor unnecessarily with tight noise-level and motor-shielding specifics. Check with the vendor for his specs on acoustic noise and his standard for shielded blowers and fans—he might be able to do the job at lower cost.
3. Minimize the use of aluminum extrusions, unless the vendor is extremely familiar with this construction method. The extrusions are trickier to use than steel, and they won't bear as much weight.

The inside specs

Do's

1. Allow an internal radius equal to the thickness of the material used.
2. Understand that sheared edges are not perfect but are generally accepted "as is" for materials up to 3/16-in. thick. Indicate areas where additional finishing is needed.
3. Allow for burrs on cut edges, unless special dies and punches are used for each metal thickness.
4. Specify in detail the amount of visible welding you can accept. Use such phrases as (a) "Remove weld marks completely;" (b) "Weld marks to be not over ±0.005-in. deep," and (c) "Weld marks not to be visible from 36-in. distance."
5. Make your smoothness requirements as minimal as possible. A 30-to-60-microinch finish is usually adequate.
6. Outline the requirements for mechanical loads, g forces, environment, etc. If heavy loads are expected, show their distribution.

Don'ts

1. Avoid specifying formed radii, unless they are actually needed.
2. Don't use the phrase "sheared edges not acceptable," unless this is absolutely necessary. And then use the wording only for material thicker than 1/8 in.
3. Try not to demand a general requirement like "deburr all over," since this involves finishing both sides and is expensive.
4. Avoid MIL specs and certified welding, unless they are true requirements, since these procedures add substantially to the cost. Omit general terms like "no visible weld marks are permitted."
5. Try not to make rigid demands for surface "roughness," since textured finishes usually cover blemishes.
6. Don't forget to indicate which loading factors are important. Anti-tilt devices or provisions for bolting the unit to a floor or rack may be required.

(continued on page 102)

The outside specs

Do's

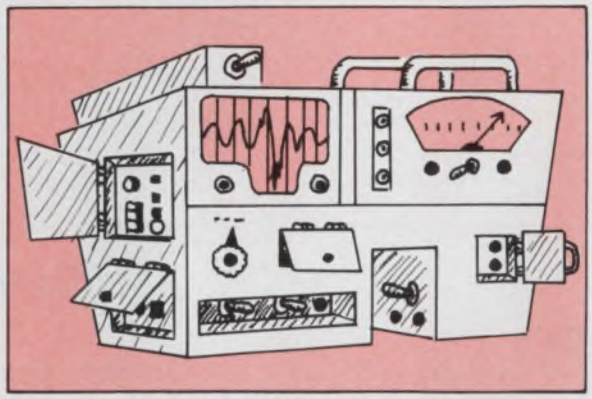
1. Outline in general terms the purpose of the enclosure and the approximate quantity needed.

2. Make a simple sketch to indicate physical dimensions (allow a tolerance of ±2 in. on height, width and depth, so you can use a low-cost standard case).

3. Indicate the placement of brackets, holes, cutouts, louvres, etc., together with acceptable tolerances.

4. Specify the material as loosely as possible and the range of gauges for various sections of the enclosure. Have the vendor indicate the alloys he intends to use, subject to your final approval. Specify exact alloys only if stresses, strains or other considerations require their use.

5. Use fractional tolerances when expressing dimensions, especially when measured from a formed edge.



Don'ts

1. Try not to make the enclosure design too elaborate or detailed, until you are familiar with the production capability of the vendor.

2. Avoid specifications that are so tight that they make it difficult for the vendor to quote on a standard product. The savings of standard vs custom designs can often be 10:1.

3. Don't specify hole tolerances for fasteners or louvres, unless absolutely necessary. Remember, practical tolerances vary with the thickness of the materials used.

4. Minimize the use of specific aluminum alloys. Vendors usually have thousands of pounds of material that they have purchased in volume at low prices. A small-quantity purchase of a specific alloy can increase cost substantiallly.

5. Try not to use two or three-place decimal dimensions from formed edges or between spot welds or tack welds. And don't make the tolerances from hole to hole tighter than the tolerance for the hole sizes themselves.

Available standards

Do's

1. Use EIA* specs, like RS-310-B, for racks, panels and other enclosures. These specs are for metric as well as English units. For large-quantity orders, it's less expensive to use tapped screw holes than threaded-screw receptacles.

2. Minimize the use of NEMA** standards. They apply more to electrical than electronic equipment.

Don'ts

1. Avoid the use of tolerances other than those listed in EIA standards, unless you are prepared to pay extra. The EIA standards have replaced RETMA† standards and Western Electric spacing.††

2. Don't confuse the different NEMA enclosure specifications. There are many different types and tradeoffs. For instance, don't use an expensive NEMA Type 4 case to meet the hose-test requirements in definition IC-1-2.68; all you really might need is the lower-cost Type 1 enclosure.

*EIA: Electronic Industries Association, 2001 Eye St., Washington, DC 20006.

**NEMA: National Electrical Manufacturers Association, 155 E. 44th St., New York, NY 10017.

†Radio Electronics and Television Manufacturers Association (original name of EIA).

††Western Electric spacing is the same as the EIA "Wide Mounting-Hole Spacing for Racks and Cabinets" specification.

Wrapping and unwrapping wiring tools are easily made from tubing

Inexpensive manual wire-wrapping and unwrapping tools that do a professional job can be constructed from small-diameter nickel, aluminum or brass tubing available at most hobby shops. The tubing costs approximately 25 cents for a 12-in. length. Tubing with ODs of 1/16, 3/32, 1/8, 5/32 and 3/16 in., cut into 2-in. lengths, is used. Epoxy the 1/8 tubing inside the 5/32 tubing, and then fasten both inside the 3/16 tubing to form a handle. Make two such handles.

To form the wire-wrapping stem, apply epoxy to a length of 1/16 tubing, insert it into 3/32 tubing and carefully crimp one end of only the 3/32 tubing until there is a noticeable gap between the two tubes. Make the crimp about 3/16-in. long. Select a drill bit about the size of the wire you intend to wrap—a 0.020-in. drill is suitable for 30-AWG wire.

First, drill a hole through only the 3/32 tubing at right angles to the stem at the back of the crimp, and then drill a hole through the gap toward the previously drilled hole (see figure). With a file, shape the tubing at the drilled back of the crimp so a wire inserted from the front slides easily out the back. Finally epoxy 1 in. of the stem inside the handle and allow sufficient curing time before use.

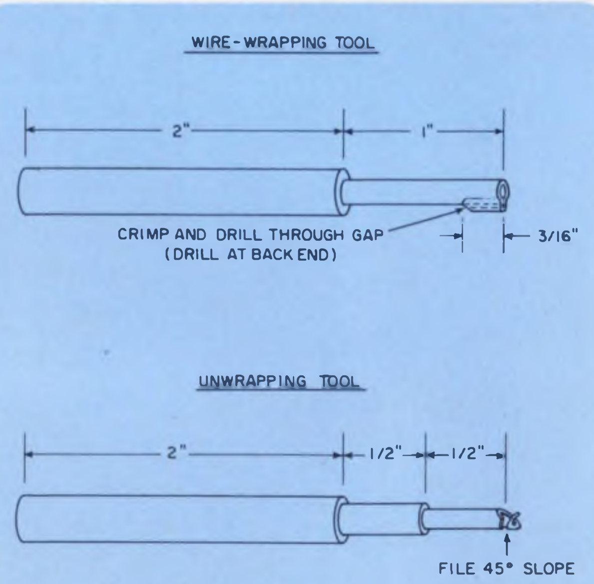
The unwrapping tool is made to remove right-handed wire wrapping. One end of 1/16 tubing is filed to approximately a 45-degree slope. Position the tube with the slope to your right and face it upwards. On the side of the tubing closest to you, at mid-point of the slope and perpendicular to it, file a notch half way through the slope and form a counterclockwise groove that winds part way around the tubing. The groove depth should cut partially through the tubing at the start and taper off as it lengthens.

Epoxy 1-1/2 in. of the square end of this 1/16 tubing into 3/32 tubing and 1-1/2 in. of the 3/32 tubing into the handle, and allow sufficient curing time before use.

With constant use, the tools wear. However, the faces of the tool can be reformed—about five minutes' work with a file. At least for the 1/16 and 3/32-in. tubing, nickel should be used, because it is harder than brass or aluminum.

David L. Holmes, Systems Engineer, Communications Electronics Div/DOKS, Hq. Strategic Air Command, Offutt AFB, NE 68113.

CIRCLE NO. 311



Wrapping and unwrapping tools are easily made from metal tubing available in hobby shops.

Programmable sawtooth generator settable at high and low output levels

Many circuits can generate sawtooth waves, but seldom can they be programmed easily to provide a wave that oscillates between two desired voltages—V_U, the higher voltage, and V_L, the lower voltage.

The circuit in Fig. 1 is programmed by voltages V_{R1} and V_{R2}. It consists of an integrator, IC_1; a comparator, IC_2; and inverter, IC_3, and a switch, IC_4, where $V_U = V_{R2} + V_{D3}$ and $V_L = V_{R1} - V_{D2}$.

Pin 3 of IC_2 is at V_U during the rising portion of the waveform. Since pin 2 is at a much lower voltage than V_U, the output of IC_2 is $\simeq V_{CC}$ (Fig. 2). This output is applied to pin 2 of IC_3. And with only V_{R1} on pin 3, the IC_3 output is approximately zero, which holds the switch, IC_4, open.

When the integrator output reaches V_U, the output of IC_2 changes to near 0 V, and its pin 3 drops to V_L. Then IC_3's output goes to V_{CC}, which turns on the IC_4 switch to discharge C_1. When the integrator output falls to V_L, pin 6 of IC_2 goes back to approximately V_{CC}, the switch opens and the ramp part of the waveform is again generated.

The ramp rise time is given by

$$t_1 = \frac{R_1C_1\ (V_U - V_L)}{V_{R1} - V_{D1}}.$$

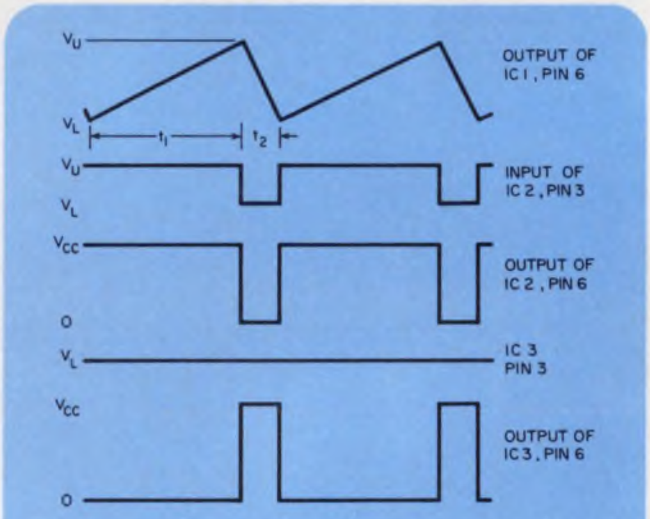
The fall time, t_2, is determined by the slower of either the time constant of C_1 and the IC_4 switch resistance or the slewing-rate limit of IC_1, IC_2 or IC_3.

Since the IC_2 and IC_3 outputs are pulses with amplitudes that range from near zero to the power-supply voltage, these ICs should be fast. Thus 531s are used. Because in the author's application the maximum required sawtooth excursion was only 1 V, the slower 741 was used for the integrator. In this circuit the fall time is about 2 μs.

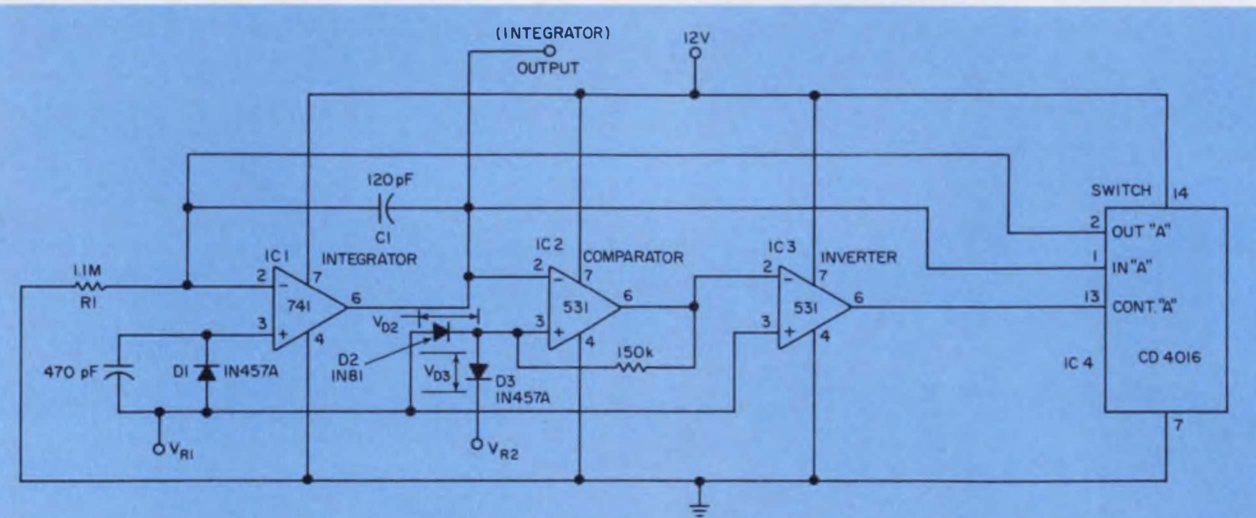
The circuit can be synchronized with negative pulses to pin 2 of IC_3.

Jack E. Holzschuh, Project Engineer, Dept. of the Navy, Naval Undersea Center, Hawaii Laboratory, P.O. Box 997, Kailua, Hawaii 96734.

CIRCLE NO. 312



2. **The outputs of IC_2 and IC_3 swing from near ground to the supply-voltage level;** and the fall time, t_2, is about 2 μs.



1. **A sawtooth voltage-generator can be programmed** to provide an output between selected high and low voltage levels. The ramp rise time depends on R_1C_1 and the upper and lower voltage levels.

Power-failure alarm operates a long time on a single 1.5-V cell

A power-failure alert is often a vital need, especially in hospitals and laboratories. The warning circuit shown drains only about 50 μA from a single-cell battery when the ac power is normal. This low drain allows more than three-year life from many battery types.

Capacitor C_1 and resistor R_2 form a positive-feedback loop to make an LM3909 oscillate. However, with ac line power, charge accumulates on C_1 to keep pin 8 slightly more positive than pin 2. This cuts off the input transistor of the LM-3909 and the complementary, direct-coupled circuit of the IC almost completely turns off.

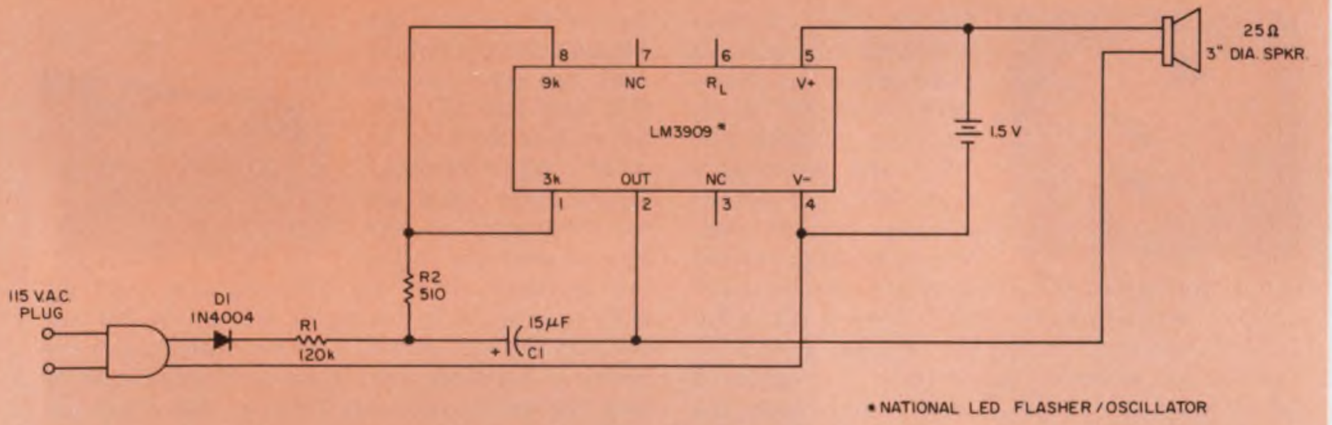
When line power fails long enough to allow the charge on C_1 to disappear and reverse its polarity somewhat, the IC oscillates. The very small reverse voltage on C_1 and the short time that it is reversed cause no damage to C_1, even if it is electrolytic.

Current from the line charges only the capacitor and produces very little flow in the 1.5-V cell. The circuit is safe to leave plugged-in for years.

The alarm tends to oscillate at the speaker's self-resonant frequency. A louder and clearer tone results if the speaker enclosure is built to augment the speaker resonance. This can be done by adjustment of the enclosure size with baffles and ports.

Peter Lefferts, Design Engineer, MS 220, National Semiconductor Corp., 2900 Semiconductor Dr., Santa Clara, CA 95051.

CIRCLE NO. 313



Low-drain power-alarm circuit operates on a 1.5-V cell for as long as three years.

IFD Winner of July 5, 1975

Robert W. Hilsher, Assistant Engineer, Dept. 487, Bendix Communications Div., E. Joppa Rd., Baltimore, MD 21204. His idea "Constant Period with Variable Duty Cycle Obtained from 555 Timer with Single Control" has been voted the Most Valuable of Issue Award.

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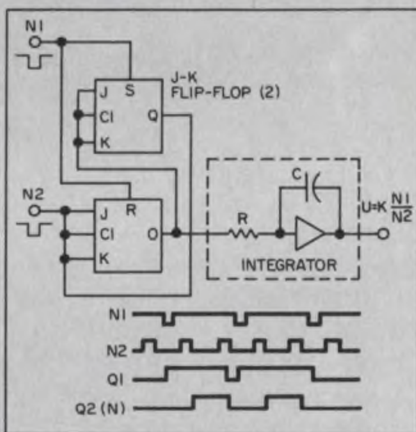
INFORMATION RETRIEVAL NUMBER 42

Ratio ratemeter has high accuracy

A ratio ratemeter that is accurate to better than 1% with regularly distributed input pulses and 2% with statistically averaged pulses has been designed by the Radiation Centre, University of Birmingham, England. The output of the circuit (see figure) is proportional to N_1/N_2, where N_1 and N_2 are average rates of the applied input pulse trains.



The ratemeter consists of a logic circuit and an integrator. The logic circuit converts the two input trains into a single train whose pulse rate is equal to N_1. The pulse width is equal to the time intervals between two adjacent pulses in the N_2 train.

Operation of the ratio ratemeter is satisfactory as long as at least two N_2 pulses appear for every time interval, or the gap between two successive pulses N_1. For regularly distributed input pulses, it is sufficient to satisfy the following conditions: $2N_1 < N_2$. For random pulse trains, 2N should be much less than N_2.

Heartbeat drives pacemaker signal

A pacemaker that uses a delayed, amplified signal generated by the patient's own heartbeat—conventional pacemakers are driven by a pulse generator—has been developed at the Royal County Hospital in Brighton and Sussex University's Medical Research Centre, England.

The new device picks up an electrical pulse produced when the atrium—the chamber above a ventricle—contracts to fill the ventricle prior to its contraction. The unit delays the atrial pulse for the proper fraction of a second and uses this signal, amplified, as the stimulus for the ventricle. If the ventricular beat fails, a fail-safe pulse generator takes over.

This technique has two advantages. First, the ventricle contracts at the correct time after the atrium has filled it. And, second, because the atrial beat adjusts to the body's needs, the pacemaker is physiologically compatible.

The pacemaker's catheter, which picks up the signals from the atrium, also picks up a signal from the ventricle but electronically screens this out, preventing the much greater electrical activity of the ventricle from confusing the pacemaker.

Cambridge Instruments, Cambridge, England, is currently building five nonimplantable commercial models for further hospital trials. The research team at Sussex is miniaturizing the electronic package and battery so it can be implanted.

Road-guidance system directs by minicomputer

An automatic highway guidance system, known as ALI, provides information on directions, weather ahead and traffic. Developed by Blaupunke Werke GmbH of West Germany, the system also indicates the best speed to make the fastest time.

Each car in the system has a radio transceiver with a 20-cm ferrite antenna. An indicator panel conveys information to the driver, who keys in a four-character code that represents his destination. The first character defines one of 16 zones in Germany; the second, one of 16 areas within each zone; and the remaining two, an area about three square miles. Resolution is sufficient to direct the driver to within 1.5 miles of 65,000 destinations.

Messages from the system's minicomputers are preceded by a series of rapid flags to draw the driver's attention. An analog scale indicates changes of direction. Communication to roadside beacons is performed by buried inductance loops.

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INFORMATION RETRIEVAL NUMBER 43

TI's New TMS 4051
The fully TTL compatible 4K RAM
in the 18-pin space saver package

Available now in the 18-pin space-saver package: A fully TTL compatible 4K RAM. In addition to the high board density achievable with the compact 18-pin package, board space is also minimized because the TMS 4051 is fully TTL compatible and fewer parts are necessary. Fewer parts, less wiring, and a smaller PC board mean the TMS 4051 will save you money.

Easiest 4K dynamic RAM to use.
The TMS 4051 is fully compatible and will plug directly into your Series 74 TTL system. No longer is a high voltage clock driver needed to interface from TTL to MOS. All TMS 4051 inputs (including the single clock) and output interface directly with TTL.

Reduce parts. Save PC board space.
In addition to eliminating the need for clock driver ICs, the TMS 4051 requires no external address multiplexers or address registers. The on-chip address registers provide full direct addressing eliminating system timing headaches. The TMS 4051's common data I/O eliminates the need for an external I/O multiplexer making it ideal for bus-oriented and microprocessor based systems. And the space saver package alone yields as much as 30% board savings over 22-pin 4K RAMs.

TI's 18-PIN 4K RAM FAMILY

		ACCESS TIME (MAX)	READ OR WRITE CYCLE (MIN)
TMS 4051	TTL CLOCK	300 ns	470 ns
TMS 4051-1	TTL CLOCK	250 ns	430 ns
TMS 4050	HI-LEVEL CLOCK	300 ns	470 ns
TMS 4050-1	HI-LEVEL CLOCK	250 ns	430 ns
TMS 4050-2	HI-LEVEL CLOCK	200 ns	400 ns

Availability is now.
TMS 4051 adds to TI's pioneering experience and volume production of 4K RAMs. TMS 4051 uses the same proven single transistor cell design as TI's popular TMS 4030 and 4060. Result: High density. High yield. Lower cost to you. The TMS 4051 is available in 300 mil wide 18-pin plastic and ceramic packages.

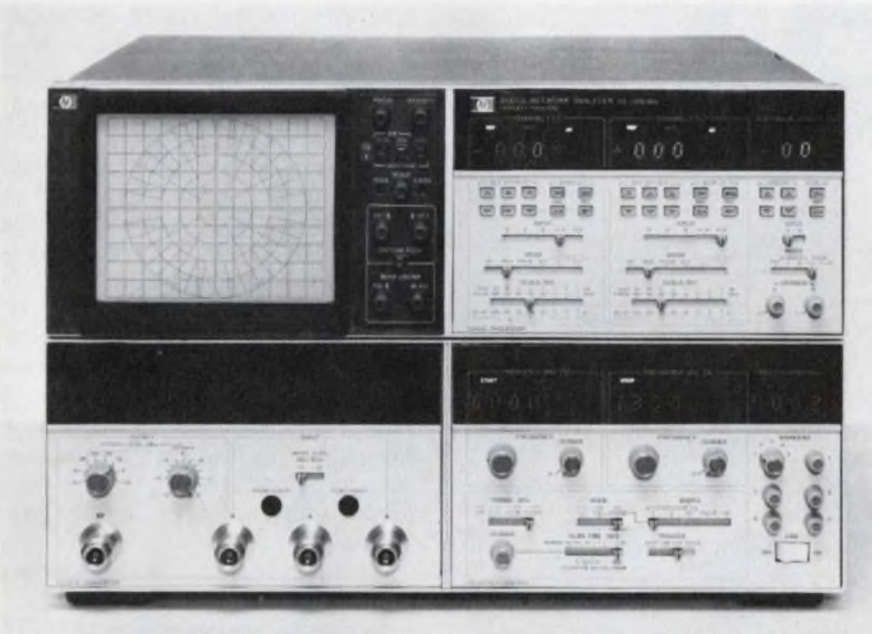
Proven reliability.
The TMS 4051 uses TI's reliable N-channel silicon gate process, the same as TI's other RAMs. And TI has proven field reliability.

For a 24-page reliability report of TI's 4K RAM family or a data sheet, write on your letterhead to: Texas Instruments Incorporated P.O. Box 5012, M/S 308, Dallas, Texas 75222.

TEXAS INSTRUMENTS
INCORPORATED

83090

Analyzer brings new power to network-behavior measurement



Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, CA 94304. (415) 493-1501. See text.

With the broadest frequency coverage, widest displayed dynamic range and a line-up of performance features hitherto unavailable, Hewlett-Packard's Model 8505A brings new measurement power to network analysis.

The HP unit measures magnitude and phase—from 500 kHz to 1.3 GHz—of the transmission and reflection properties of active and passive networks. And you can also use the analyzer to measure group delay and deviation from linear phase.

Three channels (two independent and one reference input)—each with 100-dB of dynamic range—let you display on a CRT, two parameters simultaneously, and you can see ratios over the full dynamic range without switching.

Either of two coordinate systems, rectilinear or polar, can be selected to view the input parameter as a function of frequency. Or you can display one parameter in rectilinear and the other in polar format.

Fully integrated, the 8505A contains a swept source, which can operate in several modes, a built-in counter for direct readout of frequency to the top frequency, and various digital displays of the measurement parameters.

Internal RAMs let you select independent operating conditions for the sweep, so that two, independent start-stop sweeps can be programmed. You can also set any of five independent markers, and the counter will measure the marker frequency while the unit is sweeping.

Other digital displays read magnitude, phase or delay at the marker setting with resolutions of 0.01 dB, 0.1° and 0.1 ns, respectively. The group delay and linear-phase deviation features are also fully calibrated and direct reading—no calculation is needed. Pushbuttons for each digit of display provide calibrated offsets (up or down) of the reference in steps as fine as the specified resolutions.

Linear phase is measured with an electronic line stretcher built into the HP analyzer (no cable lengths to jockey) and settable with pushbuttons up to almost five wavelengths.

Noteworthy is the ability to use the 8505A as a calculator based automatic network analyzer. In this application, the system (called the 8507A) offers an "accuracy enhancement program" which measures and stores system errors, then applies the information to the measured data to boost accuracy.

Another notable feature of the automatic system is a "learn" mode: Each 8505A control setting is read by the calculator and put into memory. Consequently, you don't need to know any programming language—you "write" the program by just twirling the analyzer's dials and storing the settings.

Other popular analyzers cover a smaller frequency and dynamic range compared with the HP unit. And few analyzers include the sweep generator and frequency-marker capability in the same box. These are usually separate, add-on units. Included are HP's own 8407A, the General Radio 1710 and the Rohde & Schwarz ZWD swept diagraph.

Price of the basic 8505A is $22,500. Another $2950 buys programmability through the HP-IB interface bus. Options include an S-parameter test set, a three-way power splitter, a transmission/reflection bridge and various calibration kits. Delivery of the Hewlett-Packard 8505A starts in January.

CIRCLE NO. 304

Unit automatically makes white-noise tests

Marconi Instruments, 100 Stonehurst Ct., Northvale, NJ 07647. (201) 767-7250. $6900; 60 days.

Model 2090C white-noise test set provides an automatic measurement capability for all noise loading tests. The unit retains the accuracy of the company's manually operated 2090B and, in addition, has the automatic, programmable mode of operation and a digital readout. It conforms to the CCIR and Intelsat recommendations for white-noise testing, as well as current DCA and Bell standards. The 2-1/2-digit readout is presented as a front-panel display and shows the unit of the selected measurement function alongside its value. Outputs are also provided in both BCD and analog form for recording purposes.

CIRCLE NO. 306

Cassette recorder accepts four channels

Dallas Instruments, P.O. Box 38189, Dallas, TX 75238. (214) 341-2990. $3600; 4-6 wks.

Model T-5 portable magnetic tape recording system provides four channels of FM and direct signal record and playback. The system uses a tape cassette in the convenient Philips format and provides up to one-hour recording time. The deck has a digital tape counter and is pushbutton operated. The system has both record and reproduce electronics and covers the frequency range of dc to 1000 Hz in FM mode and 100 to 10,000 Hz in the direct mode of operation.

CIRCLE NO. 307

Smart timer/counter brings new benefits

Dana Laboratories, 2401 Campus Dr., Irvine, CA 92664. (714) 833-1234. 9015, $2995; 9035, $3495; 90 days.

Series 9000 microprocessing timer/counter is a standard timer/counter, a reciprocating counter and a calculator all in one package. Two models handle frequencies to 100 and 512 MHz, respectively. The instruments feature a calculator-type keyboard for function control, rather than traditional knobs, buttons or switches. The keyboard is located in a front-panel drawer and disappears from view when not in use. An 11-digit, 0.43-in. yellow LED display provides numeric information while LED lamps are used as status indicators. Interface options include a general purpose interface bus (GPIB) system, a parallel BCD format, a serial ASCII and a "do-it-yourself" high speed option. With another option, the 9000 calculates rise and fall times and pulse widths. Standard is automatic trigger. Or you can key in trigger levels for unusual waveforms. Stability is 3 $\times$ 10^{-7} per month. Higher stability is optional.

CIRCLE NO. 308

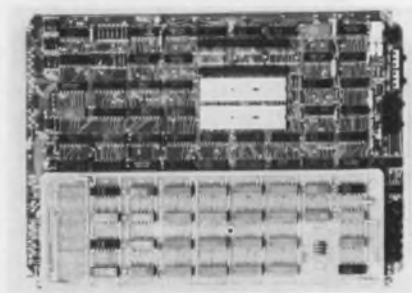
Test system checks microprocessors

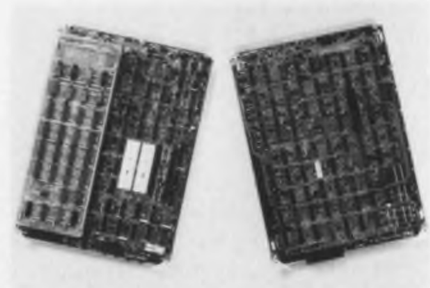
Instrumentation Engineering, 769 Susquehanna Ave., Franklin Lakes, NJ 07417. (201) 891-9300.

Model 103/system 390-series computer-controlled test system performs high-speed functional tests and fault diagnostics on microprocessors and other complex digital logic circuits on printed circuit boards. The system uses a two-family digital word general/receiver (DWG/R) that enables the user to test as many as four different levels of logic simultaneously. The DWG/R contains bidirectional pins so that it can test bidirectional busses on microprocessor PCBs in real time.

CIRCLE NO. 309

Computer series offers low cost, high performance





General Automation, 1055 S. East St., Anaheim, CA 92805. (714) 778-4800. P&A: See text.

A series of four micro and minicomputers offers full 16-bit operation with the speed of MSI TTL processors but at the cost of 8-bit PMOS microprocessors. The General Automation GA-16 series provides an instruction execution time of less than 2 μs.

There are four units—the 110, 220, 330 and 440. The 110 and 220 are single and dual-board microcomputers that come with 1-k of solid-state RAM as standard. The board size is only 7.75 × 11 in., and the computers cost $531 and $765, respectively.

Capabilities of the 110 include 91 basic microprogrammed instructions, 16 general-purpose registers, memory expansion to 64-k words, 11 addressing modes. A complete set of arithmetic and logic instructions and auto restart capability are just some of the features.

The Model 220 includes all this and more—a microconsole ROM, TTY controller and serial I/O port and DMA capability of the larger SPC-16 series of minicomputers.

The other two units in the series, the 330 and 440, are housed in 5.25 × 19 × 21.25-in. and 8.75 × 19 × 21.25-in. rack-mounting cabinets, respectively. The 330 comes with 4-k of core memory and costs $1950, while the 440 equipped with 16-k costs $5370.

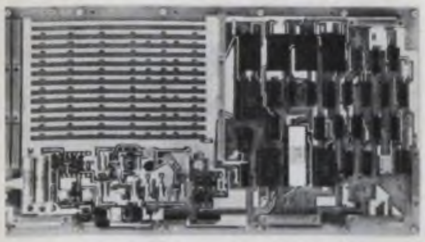
The 330 has no operator controls, save for the on-off switch, while the 440 has a full operator's console with keyboard and displays. Both computers can directly address 1 million words of memory, and they have a memory cycle time of 720 ns.

All of the software and I/O devices for General Automation's SPC-16 minicomputer line are directly compatible with the GA-16 series. This will save considerable time and effort in designing systems and getting them on-line. Prices for the GA-16 series machines are given for maximum-discount quantity purchases. Single unit prices are about 40% higher.

All four computers are based on a two-chip NMOS LSI processor developed by General Automation and a subsidiary, Synertek. The processor chips consist of a 16-bit register arithmetic and logic chip and a control read-only memory. Together they have a complexity of about 20,000 components.

CIRCLE NO. 305

8-bit microcomputer fits on one board



Monolithic Systems Corp., 14 Inverness Drive East, Englewood, CO 80110. (308) 770-7400. $820 (unit qty); 4 wks.

A new 8-bit microcomputer, the MSC8080, includes a general-purpose wire-wrappable section, which simplifies the task of interfacing the computer to a particular system. This single-board unit uses an Intel 8080 microprocessor and includes interfaces for input, output, optional memory and control panel. Room is provided for 1 k × 8 of PROM, and a number of preprogrammed PROMs are available as options. A power inverter on the board supplies all necessary processor voltage levels from a single +5-V input.

CIRCLE NO. 320

Microcomputer system comes with software

Mostek Corp., 13300 Branch View Lane, Dallas, TX 75234. (214) 620-2454. $995.

Mostek's new general-evaluation microprocessor system, GEMS-8, consists of a processor board designed around the MK 5065, 8-bit microprocessor, a programmer-aid-routine ROM and a 12-k × 8 memory board with direct interface to the processor board. Software support includes a resident assembler, which can generate object tapes from source tapes, a dump-to-dump memory in ASCII format and a text editor that allows users to generate and modify the source text prior to assembly. The processor needs a power-supply of +5 and ±12 V. The available 51 basic instructions have a typical execution time of 7 μs. The processor can address 32-k × 8 memory spaces with a 1-k RAM located on the board. Triple-level architecture allows rapid interrupt servicing.

CIRCLE NO. 321

DATA PROCESSING

Interface converts printer to data terminal

Bedford Computer Systems, Inc., Three Preston Court, Bedford, MA 01730. (612) 275-0870. $1125 (unit qty).

The Model 1200 printer control converts the Qume Q-30 or Diablo HyType-I printer mechanisms into low-cost receive-only data terminals. Options can augment the basic terminal into a stand-alone interactive keyboard-entry work station. The basic package includes a power supply with sufficient power for the printer; an interface module, which is contained in the power-supply assembly; and all required interface cables. The printer control operates in ASCII code with a full or half-duplex mode over an asynchronous serial RS-232 interface.

CIRCLE NO. 322

Microprocessor system uses 16-bit chips

General Instrument Corp., 600 W. John St., Hicksville, NY 11802. (516) 733-3000.

The Series 1600 microprocessor system is based on a 16-bit microprocessor chip and built with GI's n-channel ion-implant Giant II process. The processor design uses eight 16-bit general-purpose registers. All registers are program accessible and can be used as accumulators or address registers. Six of the registers can be used by the running program, one is used as the memory stack pointer and the eighth is used as the program counter. The memory stack pointer provides last-in, first-out storage in the main memory. The general registers and high-speed pipelined ALU and its status register form the data-processing logic for all series 1600 microprocessors. Compatible assembler/simulator software is available for popular minicomputer systems and large time-sharing machines. Comprehensive subroutine libraries, diagnostics, utility programs and an on-line debug program for direct program checkout of the 1600 system are also available.

CIRCLE NO. 323

Low-cost CRT terminal offers full features

KKM Corp., Micro Application Systems Div., Box 213, Grand Forks, ND 58201. (701) 772-5944. See text; 60 day.

The MAS/T1 CRT terminal is designed as a low-cost teletypewriter replacement. It costs only $649 in singles and can perform in many minicomputer applications where intelligence and other features are an unnecessary luxury. Standard features include full cursor control, character and line insertion/deletion, tab control, selectable speeds to 9600 baud, and solid/blinking underline cursor. The MAS/T1 display uses a 5 × 7 dot matrix and has a 12-line-by-80-character capacity on a 9-in. video display (24 by 80 capacity and 12-in. display are available options). RS-232 compatible output is standard. Other outputs or the ability to add on I/O devices (cassette, floppy disc, or printer) are available as options. The terminal can do a self-test, functioning in either on-line or local modes to indicate whether it is operational.

CIRCLE NO. 324

UV PROM eraser handles five devices at a time

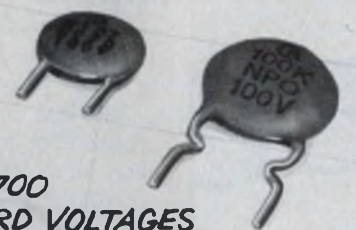
Prometrics Inc., 5345 N. Kedzie Ave., Chicago, IL 60625. (312) 539-3373.

Up to five UV-erasable PROMs are erased in 5 to 10 min with complete safety to devices and personnel. An adjustable timer shuts off the UV source when the set-in time has elapsed. And the unit's housing is designed to prevent UV leakage. An interlock shuts off the UV when unit is opened. Devices rated at 6 W-s/cm² integrated erasure dose, such as the 1702A/4702A, require less than 5 min for complete erasure; 10-W-s/cm² devices, such as the 2704 and 2708, erase in less than 10 min.

CIRCLE NO. 325

STABILITY YOU CAN COUNT ON...

MURATA'S
TEMPERATURE COMPENSATING
CERAMIC CAPACITORS.



- NPO TO N4700
- ALL STANDARD VOLTAGES
- FAST DELIVERIES
- RELIABILITY BACKED BY 30 YEARS OF EXPERIENCE

muRata
CORPORATION OF AMERICA
Rockmart Industrial Park, Rockmart, Georgia 30153
Phone: 404-684-7143 Telex: 54-2999

INFORMATION RETRIEVAL NUMBER 49

MINI-ROTARY SWITCHES

New ROTARY SWITCHES feature adjustable stops & are only 6/10" in diameter. Molded-in terminals prevent contamination. For PC or hand wired use. Available in one through 4 poles with 36° detent; waterproof types too! 10,000 operations @ rated .5 amps, 125 VAC load.

Call (617) 685-4371 for more detailed information.

MRC SERIES

INFORMATION RETRIEVAL NUMBER 50

PUSHBUTTON SWITCHES

Light touch MOMENTARY PUSHBUTTON switches designed for electronic test equipment, data entry, etc. Upwards to 10 million life cycle. A unique magnetic action eliminates springs. Contains glass encapsulated reeds and shielded to avoid interaction.

Call (617) 685-4371 for other technical data and pricing.

MSPM SERIES

INFORMATION RETRIEVAL NUMBER 51

ALCO ELECTRONIC PRODUCTS, INC.
NO. ANDOVER, MASS. 01845 U.S.A.
Tel. (617) 685-4371 TWX 710 342 0552
A SUBSIDIARY OF AUGAT INC.

Price/Performance Breakthrough

Actual Size

8 bit A/D's now only $59^{00}

Micro Networks MN5120 Series of successive approximation 8 Bit A/D converters is now less than half the cost of the previously available Dip A/D converters.

The outstanding features include:

- Completely Adjustment Free...no external components or trim pots required, just plug in.
- Linearity...±½ LSB from 0 to 70C, no TC specs needed.
- High Speed...6 μsec setting time.
- Low Power...680mw typical—a savings of 30 to 50% over modular units.
- Hermetic Sealed Dip...for long term stability.

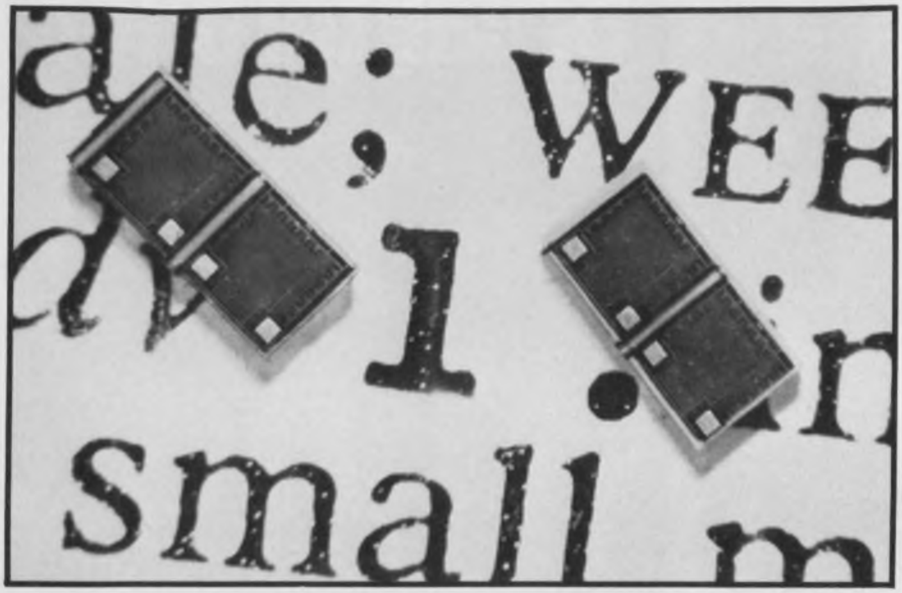
The MN5120 Series of A/D converters with its high performance and low cost makes it ideal for commercial and industrial applications, typical of which are: medical instrumentation, process control, computer peripherals, and interface circuits. All units are 100% electrically tested at 0, 25, and 70C for linearity and accuracy.

For complete data write or call—Jerry Flynn: Tel: 617 852-5400.

MICRO NETWORKS CORPORATION
324 Clark Street, Worcester, MA. 01606

INFORMATION RETRIEVAL NUMBER 52

Mini resistor chips offer the tops in accuracy and stability



Vishay Resistor Products, 63 Lincoln Hwy., Malvern, PA 19355. (215) 644-1300. See text.

Buy a chip resistor today and try to get another exactly like it next year. Vishay says you can do the improbable with its V50X50 Series of Microchip precision resistors.

These resistor chips are built with Vishay's proprietary Bulk-Metal process that is said to permit accuracies and repeatabilities to within 0.01% and stabilities of 5 ppm/°C over the −55 to +150 C range. The chips measure only 50 × 50 × 15 mils and conform to or exceed all the requirements of MIL-R-55342A.

Resistance values ranging from 500 Ω to 5 kΩ are available, and chips with values from 1 Ω to 10 kΩ will be offered shortly. Power ratings for the chip start at 0.05 W at 70 C, when it is bonded to the ceramic substrate, and are derated to zero at 150 C.

Tracking of resistance values is to within 3 ppm over the full operating temperature range. End terminations of the resistor chips consist of gold plating over copper bonding pads and measure 6 × 6 mils. Each resistor chip has a moisture resistance of 0.5% ΔR, which improves to 0.005% ΔR under hermetic seal packaging conditions. Resistance shelf life is very long, with aging down to only 50 ppm/year.

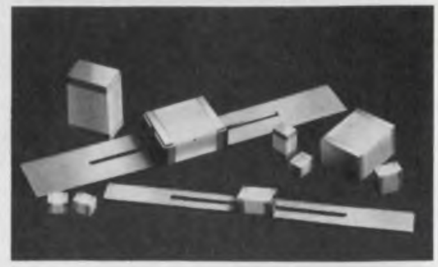
Suggested termination for the chip is by thermal pulse welding of a 1-mil-diameter gold wire to the pads. The proprietary process used to form the resistors provides a form of stress control that counterbalances the temperature coefficient of the resistor element—thus keeping the value almost constant.

Two versions of the chip are available: a fully calibrated, finished chip made to exact user specifications and an uncalibrated chip for the user who can trim the chip to exact value before insertion or who must do active trimming after bonding. Fixtures and work stations will be available in the near future.

Prices for these tight-tolerance units start at $3 each in 100-piece lots for 1-to-2-kΩ values and $3.30 for 2-to-5-kΩ values. V50X50 resistor chips are available from 8 to 12 weeks for evaluation orders and 12 to 16 weeks for volume production.

CIRCLE NO. 301

Chip capacitors resonant free to 10 GHz

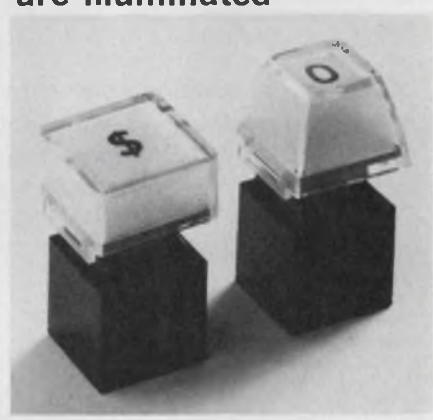


Johanson, Monolithic Dielectrics Div., Box 6456, Burbank, CA 91505. (213) 848-4465. $0.76 to $2.95 (1000 up); stock to 6 wks.

High-Q microwave ceramic chip capacitors with easy-to-mount ribbon leads offer resonance-free performance to 10 GHz. Chip sizes available are from 0.055 × 0.055 × 0.050-in. to 0.11 × 0.11 × 0.10-in. with a maximum capacity of 100 pF in the smallest size to 1000 pF in the largest.

CIRCLE NO. 326

Pushbutton switches are illuminated



Mechanical Enterprises, Inc., 8000 Forbes Pl., Springfield, VA 22151. (703) 321-8282. $0.60; T-5 (10,000 up)

Self-contained lights indicate keyboard switch action on sealed mercury M-5 and gold-plated contact T-5 pushbutton switch series. Clear plastic keytops, either box-shaped or truncated, contain a light diffuser made of thin polyester film that holds the switch legend. In large quantities, the legends are printed on the diffuser; for short runs, press-types can be used. The operator's fingertips never contact the legends. Switches mount on 3/4-in. centers. T-1 bi-pin incandescent lamps are used to illuminate the switches. The plastic keytops snap off for bulb replacement.

CIRCLE NO. 327

Cermet film resistors meet MIL-R-39017

Allen-Bradley Co., 1201 S. Second St., Milwaukee, WI 53204. (414) 671-2000. See text.

Allen-Bradley's Type CC cermet film fixed resistor MIL-Style RLR-07 has now been approved to MIL-R-39017 standards for resistance values from 10 Ω through 1 MΩ. No other has been approved beyond 470 kΩ, A-B indicated. Six-week delivery time is being quoted for these resistors, compared with six to 13 weeks generally required for similar types. The resistors are offered in both 2% and 5% tolerances with a temperature coefficient of ±100 ppm/°C. The 1/4-W resistor measures 0.25-L × 0.09-D in. and is priced at 16 cents each in 1000-piece quantities. It is expected to be offered through A-B appointed electronic distributor locations this fall.

CIRCLE NO. 328

Chip capacitors meet MIL marking standard

American Technical Ceramics, One Norden Lane, Huntington Station, NY 11746. (516) 271-9600.

A new method of marking chip capacitors enables ATC to fully identify even its smallest microminiature rf chip capacitors—the ATC Case A, 55-mil cube—with the manufacturer's identification, capacity and tolerance code. Marking meets MIL-STD-202, Method 215 and is unaffected by all commonly used solvents and temperatures to 1500 F. ATC says it is the only capacitor manufacturer with such a marking capability. These marked rf chip capacitors are available in 40 different design values. Four kits contain Case A and Case B (110-mil cube) sizes with values ranging from 0.1 to 220 pF.

CIRCLE NO. 329

MOSFET analog switches made for ±5 and ±10 V

Signetics, 811 E. Arques Ave., Sunnyvale, CA 94086. (408) 739-7700. From $0.90 (100-up); stock.

Four D-MOS FET analog switches handle ±5 or ±10-V applications. The SD212 and SD213 are characterized for ±5-V analog switching or sample-and-hold. The SD214 and SD215 cover the same applications for ±10-V signals. The SD212 and SD214 do not have zener diode protection on the gates while the SD213 and SD215 do. All devices have an on-resistance of 35 Ω, typical. Input capacitance is 2 pF typically, output capacitance is 0.5 pF and feedback capacitance only 0.2 pF. Isolation from input to output is −120 dB typical at 3 kHz.

CIRCLE NO. 330

Power Darlingtons made for inductive loads

Semicoa, 333 McCormick Ave., Costa Mesa, CA 92626. (714) 979-1900. From $18 (100-up); stock.

The SCA108 series of 10-A Darlingtons is designed for driving inductive loads. The transistors have a V_{CEO} of 100 V, a secondary breakdown of 5 A at 70 C (at rated BV_{eco}), an f_t of 60 MHz and leakage currents of less than 10 nA at 25 C. The Darlingtons have betas from 10,000 to 70,000 minimum. An SCA0108 will drive 20 mH at 2 A or 50 mH at 1 A. The SCA0108 is available in an isolated or nonisolated TO-5 package for 25-W dissipation at 75 C, or in TO-3, TO-66 and TO-59 packages.

CIRCLE NO. 331

N-channel JFET has on resistance of 2.5 Ω

Teledyne Crystalonics, 147 Sherman St., Cambridge, MA 02140. (617) 491-1670. $13.40 (100-up); stock.

The 2N6568 silicon n-channel junction FET is designed for an ultra-low R_{on}. The FET ON resistance is specified as 2.5 Ω R_{DS}. It also has extremely high isolation resistance of greater than 5 GΩ.

CIRCLE NO. 332

JAN power transistors handle up to 10 A

Solid Power, 440 Eastern Pkwy., Farmingdale, NY 11735. (516) 694-2883. From $8.36; 2 to 8 wk.

The JAN, JANTX and JANTSV-2N3715 silicon power transistors handle collector currents of up to 10 A. The transistors have collector voltage ratings of up to 80 V and are housed in TO-3 packages.

CIRCLE NO. 333

Epoxy transistors have 125-MHz gain-bandwidth

Sprague Electric, 347 Marshall St., North Adams, MA 01247. (413) 664-4411. $0.17 (large qty.); stock.

The NPSA20 Econoline transistor is housed in a TO-92 one-piece molded epoxy package. It has straight, in-line leads with an emitter-base-collector configuration. Power dissipation for the transistor is 360 mW. The collector-to-emitter voltage is 40 V maximum and the gain-bandwidth product is 125 MHz. Maximum collector current at 25 C is 100 mA. The maximum collector-emitter saturation voltage is only 0.25 V at a collector current of 10 mA.

CIRCLE NO. 334

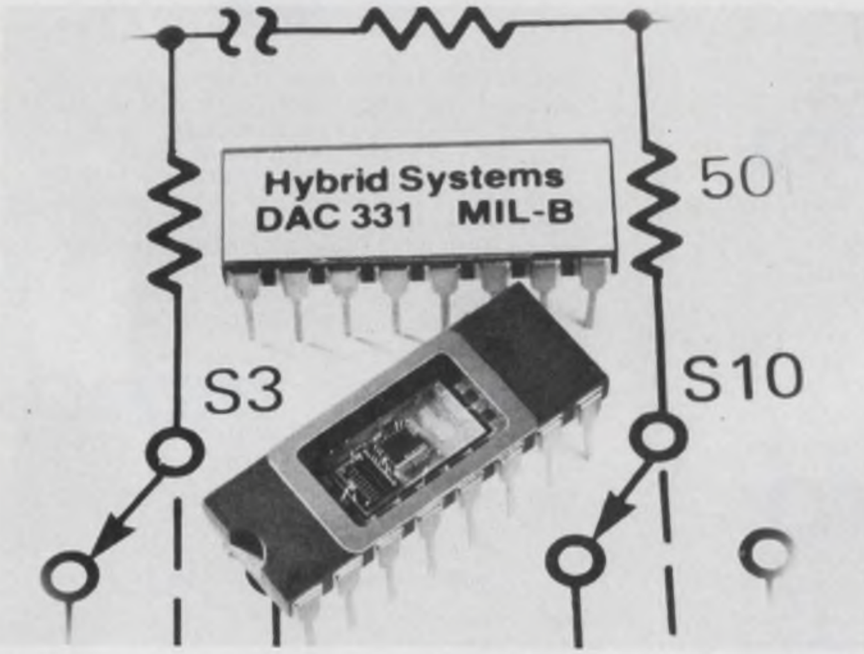
Reverse switching diodes handle pulses to 1200 A

Westinghouse Electric, Youngwood, PA 15697. (412) 925-7272. Sample prices for 600 V, 2000 A/μs unit: $83 (100 up).

The T40R reverse switching rectifier is optimized for short, high rate-of-rise pulse switching. The two-terminal switching units are available with peak pulse current ratings up to 1200 A, current rate-of-rise ratings up to 2000 A/μs and blocking voltage range up to 1000 V at 125 C. A typical value of turn-off time is 100 μs at 25 C. The reverse switching rectifiers are available with repetitive peak forward blocking voltage ratings of 600, 800 or 1000 V. Maximum pulse trigger voltage—the off-state threshold voltage where turn-on begins when a 500-V/μs trigger pulse is applied—is 1500 V. The units are available in a DO-5 type stud-mounted package.

CIRCLE NO. 335

Multiplying d/a converters meet MIL specs at low cost



Hybrid Systems, 87 Second Ave., Northwest Park, Burlington, MA 01803. (617) 272-1522. P&A: See text.

You can pay $200 or more for a multiplying digital-to-analog converter that meets military specs. But now there's a lower cost alternative. The DAC-331, a 10-bit current-output hybrid microelectronic unit made by Hybrid Systems, costs only $49 in single quantities and is processed to MIL-STD-883, Level C, requirements.

The converter is designed to maintain accuracy over the entire military temperature range of −55 to +125 C and is pin-compatible with the AD7520 made by Analog Devices (Norwood, MA).

There are two versions of the DAC-331, both with 10-bit resolution. The 331-8 has full-scale accuracy of ±0.3% over −25 to +85 C, or ±0.5% over the full MIL range. The 331-10 has an accuracy of ±0.2% over −25 to +85 C and ±0.4% over the full range. Either version can be processed to Level B or Level C of MIL-STD-883.

Analog output scaling is a nominal 40 μA/V. The reference input voltage can span a ±10-V range, and there is a feedthrough of 0.1% at 5 kHz, minimum. For a full-scale digital input change, the converters require only 2 μs to settle to within 0.05%.

Accuracy and stability errors are combined into a total spec. For the 331-8, these errors reach 0.2% of full-scale, while for the 331-10, they are only 0.1%. The output impedance is 25 kΩ.

The converters require only a single 3-to-10-V supply for operation and typically draw only 2.5 mA when operated at 5 V. Hermetically sealed ceramic 16-pin DIPs house the converters. These packages measure 0.75 × 0.3 × 0.1 in.

The AD7520, by comparison, is a monolithic CMOS multiplying d/a converter that costs $87 for a unit with 10-bit accuracy. Prices drop, though, to $42 if only 8-bit accuracy is needed. Both prices are for the MIL versions in unit qty. The gain tempco is 10 ppm/°C.

(continued on page 125)

Single unit prices for the DAC-331 series of converters start at \$39 for the 331-8-MIL-C, 8-bit unit processed to 883 Level C and \$49 for the 331-10-MIL-C, 10-bit converter also processed to Level C. Both converters are also available processed to 883 Level B with a price increase of approximately \$15, depending upon test requirements. All units are available from stock to two weeks.

Hybrid Systems CIRCLE NO. 302
Analog Devices CIRCLE NO. 303

Rf amplifier in TO-8 covers 5 to 500 MHz

Aydin Vector, P.O. Box 328, Newtown, PA 18940. (215) 968-4371. \$90 (1 to 9); stock to 2 wk.

The Model MHT-250 hybrid amplifier is housed in a 4-pin TO-8 package. It covers the frequency range of 5 to 500 MHz, has a noise figure of 2.5 dB, max, a power output of −2 dBm min., an input/output VSWR of 2:1 max and requires +15 V dc at 10 mA.

CIRCLE NO. 336

Counter/controller can retain count for 10 days

Square D, Dept. SA, Milwaukee, WI 53201. (414) 332-2000. \$395; stock.

The Class 8854, Type PC-42 storage counter/controller runs from 120 V ac, 50 to 60 Hz. It consumes 15 VA and uses a rechargeable battery (charger included) to prevent loss of count. The battery will permit the unit to retain the count for 10 days if necessary. The unit uses CMOS circuitry, has an up/down reversible counter that counts between 0 and 15, an anticoincident circuit to allow simultaneous up and down counts and has a binary readout consisting of four LEDs in a 1248 code. The 10-A output relay switches when the chosen count is reached—de-energizing on count-up, energizing on count-down. The controller also has manual buttons to adjust the count up or down. The PC-42 is designed for heavy duty industrial applications and has a high electrical noise immunity. The PC-42 measures 8 × 9.5 × 4 in. and is panel-mountable.

CIRCLE NO. 337

INTEGRATED CIRCUITS

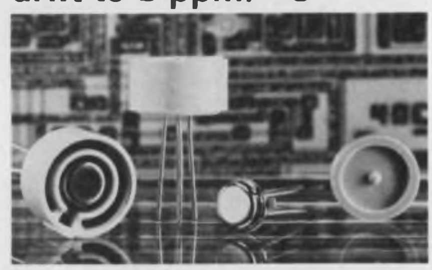
Preamp operates from 4-to-20-V supply

SGS-ATES Semiconductor, 435 Newtonville Ave., Newtonville, MA 02160. (617) 969-1610. $1.60 (100-999); stock.

The TDA1054 preamp, packaged in a 16-pin DIP, operates from supply levels ranging from 4 to 20 V. The IC has a 0.5-dB noise figure, 110-dB open-loop gain and 0.1% distortion. Supply ripple rejection is 30 dB and automatic level-control range is 54 dB.

CIRCLE NO. 338

Voltage reference holds drift to 1 ppm/°C



National Semiconductor, 2900 Semiconductor Dr., Santa Clara, CA 95051. (408) 732-5000. $3.25 to $35.00 (100); stock.

A monolithic temperature-stabilized voltage-reference IC outperforms standard zener diodes by a factor of 20. Called the LM199, the linear IC provides a 6.9-V reference and guarantees drift to be less than 1 ppm/°C. Long-term stability is better than 0.002%—the accuracy limit of the manufacturer's test system. Low-frequency noise is less than 10 μV, and the circuit requires only 300 mW at 25 C.

CIRCLE NO. 339

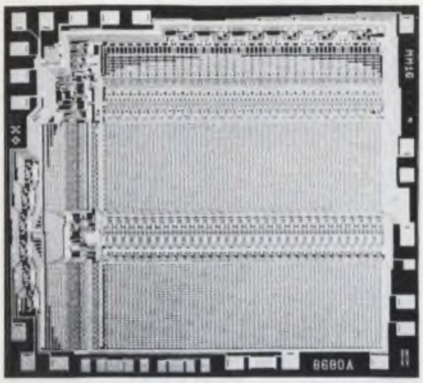
14-pin DIP holds wideband op amp

Optical Electronics Inc., P.O. Box 11140, Tucson, AZ 85734. (602) 624-8358. $36.50 (10-29); stock.

The Model 9916 op amp, packaged in a 14-pin DIP, features 150-MHz minimum guaranteed gain-bandwidth product, and 6-dB per octave uniform roll-off rate for high-frequency stability. It also has 60-dB open-loop gain at dc and $\pm$300-V/μs minimum slew rate.

CIRCLE NO. 340

4-k 'CMOS' RAM accesses in 70 ns



Toko, 1-17, 2-Chome, Higashi-Yuki-gaya, Ohta-ku, Tokyo, 145 Japan. P&A: See text.

The first 4096-bit RAM to employ both n and p-channel MOS devices—Toko's KM 8680—sets the pace for access and cycle times. The new silicon-gate dynamic RAM specs access at 70 ns typical and 100 ns maximum. Cycle time is 160 ns typical and 200 ns maximum.

Existing 4-k dynamic RAMs semploy NMOS, and they have top access and cycle times of 200 and 400 ns, respectively.

The new "CMOS" memory employs n-channel single-transistor cells for the storage matrix, and it includes p-channel devices in the peripheral circuitry. Transistor gate lengths of 6 μ have been achieved, and the entire chip measures just 3.5×3.9 mm.

The new RAM has a maximum, total power dissipation of only 350 mW, compared with a watt or so for some NMOS versions. In the standby mode, the KM 8680 needs only 3 mW. Refresh is required every 2 ms.

The 4096×1-bit KM 8680 comes in a 22-pin ceramic DIP, with Intel and TI 4-k-RAM pinouts. It uses ± 5 and 12-V supplies. However the 12-V supply can drop to as low as 5 V or rise as high as 16 V. So it's possible to have the memory operate, in fact, from just two supplies, +5 and −5 V.

Except for the chip-enable input, all input and output lines are TTL compatible.

Production quantities will be available in December. In sample quantities, the KM 8680 costs 6000 yen, or about $20. In quantities of 5000, unit prices drop to less than $14.

CIRCLE NO. 341

CMOS IC counts units or frequencies

Intersil, Inc., 10900 N. Tantau Ave., Cupertino, CA 95014. (408) 257-5450. $15.05 (100-999).

The ICM7208 CMOS circuit, a fully integrated counter-decoder-driver, can count units, frequencies or time intervals. It can directly drive a seven-decade multiplexed common-cathode LED display. The ICM7208 operates over a supply voltage range of 2 to 6 V. Its operating power dissipation is less than 10 mW; its quiescent power dissipation, less than 5 mW.

CIRCLE NO. 342

Interface inductive loads to TTL, MOS

Plessey Semiconductors, 1674 McGaw, Santa Ana, CA 92705. (714) 540-9979. $5.94 (100); stock.

Two bipolar devices provide a power interface between MOS and TTL devices and heavily resistive or inductive loads. The SP761B allows a direct 12-V MOS interface, while the SP762B permits a direct 5-V TTL interface. Both contain five current amplifiers, two of which include a common strobe input to control a high-current parallel output. The 12-V circuit delivers up to 150 mA with input current of approximately 3 mA. The 5-V circuit provides up to 200 mA with approximately 1 mA of input current. Both circuits can operate at speeds up to 1 MHz.

CIRCLE NO. 343

Multiply 16 × 16-bit numbers in 1 μs

Advanced Micro Devices, 901 Thompson Pl., Sunnyvale, CA 94086. (408) 732-2400. $23.25 (100).

With two Am25LS14 multipliers, a 16-bit by 16-bit multiplication can be accomplished in 1 μs. The new 8-bit circuit uses low-power Schottky techniques. The device takes an 8-bit multiplicand at its parallel X inputs and multiplies it by the multiplier that is clocked serially into the Y input. A two's-complement product is available at the serial output.

CIRCLE NO. 344

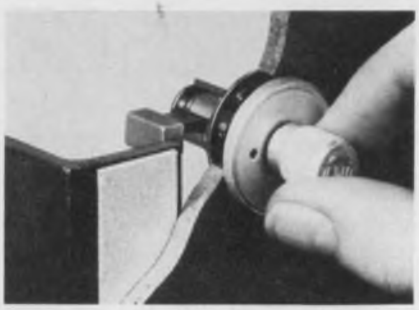
Microwave substrate has high dielectric constant

3M Co., P.O. Box 33600, St. Paul, MN 55133. (612) 733-1725. For a 0.025-in.-thick sheet, $81 (1 to 4 sheets); stock.

The "Epsilam-10" microwave substrate, a high dielectric constant laminate for stripline or microstrip use has a dielectric constant of 10.3 ±0.5. The copper-clad, ceramic-filled Teflon compound combines the flexible mechanical properties of a plastic with electrical properties similar to alumina. Its high dielectric constant allows for reduced package size and weight and increased circuit density. Epsilam-10 is supplied in 9 × 9 in. sheets with a choice of thicknesses—0.025 or 0.05 in. with 1-oz copper on two sides. The sheet size allows for multiple circuit layout and processing using typical resists and etchants. The material can be easily machined, drilled, routed or cut with shears or knife.

CIRCLE NO. 350

Pawl latch locks out noise, dust & vibration

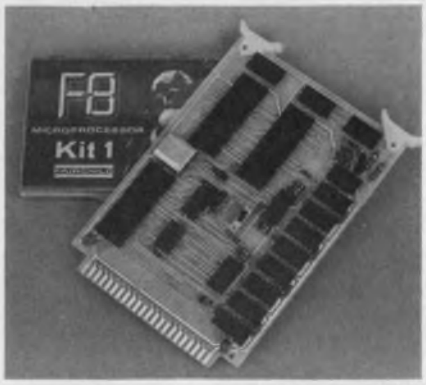


Rexnord Inc., Specialty Fastener Div., P.O. Box 98, Paramus, NJ 07652. (201) 845-6900. From $1.20 (1000-up); stock.

The Camloc 65L series pawl latch is designed to exert increasing pressure to hold gaskets to panels and access doors. One quarter turn locks the door and each additional turn pulls the door closer to the frame to apply the amount of latching pressure you need. The latch seals tight to lock out noise, dust and vibration. Each latch fits many frame requirements of varying thicknesses with a grip range that compensates for wear and aging gaskets.

CIRCLE NO. 354

Processor hardware kit just needs the ICs



Pronetics Corp., P.O. Box 28582, Dallas, TX 75228. (214) 276-1968. $65 (1 to 99); 2 wks.

The PS-710 F-8 kit module is a fully assembled printed-circuit card with sockets to accept the F-8 microprocessor kit ICs. It can be used for prototype and development systems or as a standard hardware module for production systems. All necessary functions are available on a standard edge connector to permit memory expansion.

CIRCLE NO. 355

INFORMATION RETRIEVAL NUMBER 82

INFORMATION RETRIEVAL NUMBER 83

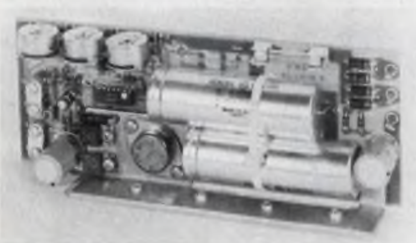
Isolated supplies meet UL 544 specs

Calex Mfg. Co., 3305 Vincent Rd., Pleasant Hill, CA 94523. (415) 932-3911. 7009, $69; 7010, $79; stock-2 wks.

Two new power supply modules are UL approved for use in medical and dental instruments. Listed as a recognized component under UL 544, Model 7009 is rated at +5 V, 1000 mA and Model 7010 is rated at ±15 V, ±200 mA. Special bobbins and winding techniques provide complete physical isolation between primary and secondary windings. Ac hot and neutral connections may be interchanged without any degradation of isolation. Isolation is specified as 10 pF of capacitance, 0.1-μA maximum leakage from input to output and a minimum voltage isolation rating of 5000 V.

CIRCLE NO. 356

Submodular supplies: 42 models, 7 packages



Power/Mate Corp., 514 S. River St., Hackensack, NJ 07601. (201) 343-6294. Start at $35.

By breaking a power supply into its submodular elements and then standardizing these elements, the company can offer custom power supplies economically and rapidly. The new SMS Series of submodular supplies consists of 42 different models in seven different package sizes. These provide a wide variety of voltages from 0 to 20.0 V and currents from 0 to 36.0 A. The series features built-in overvoltage protection, current limiting overload protection, and adjustable controls for voltage and other protective functions. Line and load regulation is better than 0.075% and the output ripple is better than 1 mV rms.

CIRCLE NO. 357

Open-frame source claims midget title

Power-One, 531 Dawson Dr., Camarillo, CA 93010. (805) 484-2806. $49.95; stock.

Said to be the world's smallest triple-output open-frame power supply, Model HTAA-16W provides 5 V at 2 A with OVP and ±9 to 15 V at 0.2 A. Total isolation between the 5 and ±9 to 15-V outputs allows the user to arrange polarities to suit his specific application. Size is 6.5 × 4 × 2.12 in. and weight is 2 lb. Standard features include 115/230 V ac ±10% input; ±0.05% line and load regulation, and full protection against short-circuit and overload. Maximum output ripple is 10 mV pk-pk while the full load operating temperature specifications are 0 to 50 C, derated to 71 C.

CIRCLE NO. 358

New Literature

Digital multimeters

Portable, 3-1/2-digit multimeters are highlighted in a four-page bulletin. United Systems, Dayton, OH

CIRCLE NO. 359

Solid-state current sensor

Features, applications, absolute maximum ratings, electrical characteristics, mounting dimensions and operating characteristics of solid-state current sensors are listed in a four-page bulletin. Micro Switch, Freeport, IL

CIRCLE NO. 360

Structural foam

"The Handbook of Engineering Structural Foam," 62-pages, describes and documents state-of-the-art design, materials and processing information. General Electric, Structural Foam Resins, Plastics Div., Pittsfield, MA

CIRCLE NO. 361

Chips and wafers

Specifications and data on wafer and chip processing, power ratings, testing, quality-assurance criteria, bonding and handling are given in a brochure. A guide cross-references standard packaged devices to chip types. Unitrode, Watertown, MA

CIRCLE NO. 362

NEW LITERATURE

Incandescent lamps

Specifications on nearly 300 industry standard and special subminiature incandescent lamps, sizes T-7/8 to T-3-1/4, are given in a 16-page catalog. IEE, Van Nuys, CA

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Power supplies

Switching regulated power supplies are highlighted in a six-page foldout. Deltron, North Wales, PA

CIRCLE NO. 364

IC logic panels

A 20-page catalog covers IC logic panels. Interdyne, Van Nuys, CA

CIRCLE NO. 365

Resistors

Thin-film resistor networks including general-purpose networks, precision ladder networks, network starter kits and user designed chip and packaged network specifications are covered in a 16-page guide. Analog Devices, Norwood, MA

CIRCLE NO. 366

Microcomputer kits

Specification sheets cover six different ready-to-assemble microcomputer kits. Cramer Electronics, Newton, MA

CIRCLE NO. 367

Thick-film materials

Conductor cermet pastes, high temperature metalizing, dielectrics, resistor compositions, solder creams and protective coatings are covered in a 35-page catalog. Transene Co., Rowley, MA

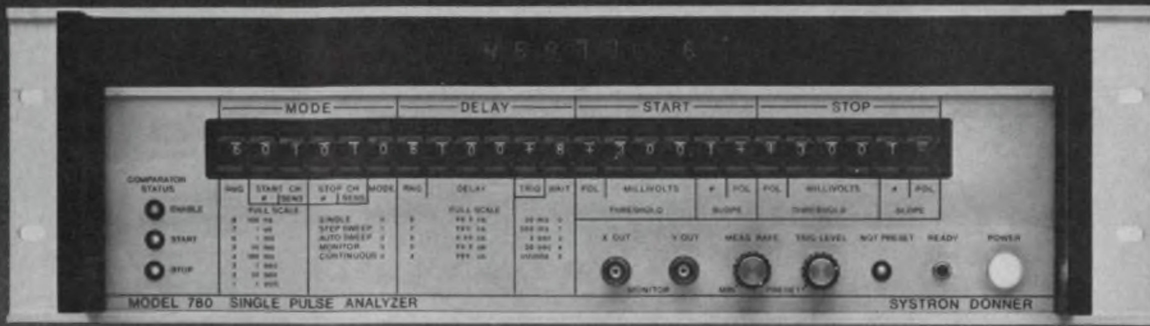
CIRCLE NO. 368

Mini and microcomputers

The U-Series minicomputer and L-16A 16-bit microcomputer are covered in two separate catalogs. Background information on Panafacom is supplied in another catalog. Panafacom, Ltd., Jiygaoka, Meguro-ku, Tokyo, Japan.

CIRCLE NO. 369

Q. what's new from the specialists in waveform analysis?



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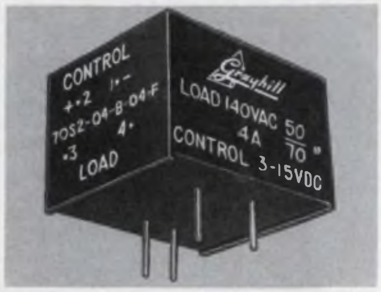
THIN-TRIM CAPACITORS 601



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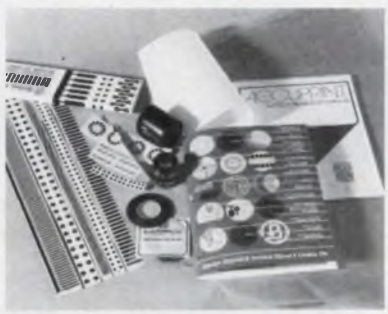

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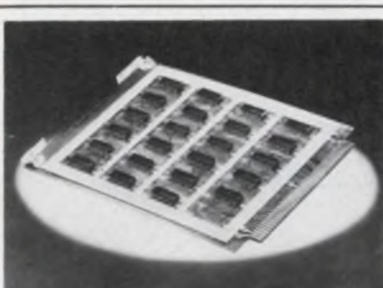

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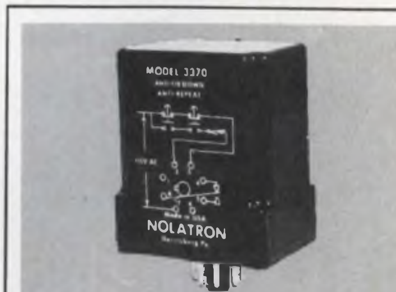

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Bulletin Board

Motorola Component Products is offering **microprocessor clock oscillators.** Models MC6870A, MC-6871A and MC6871B are designed to drive Motorola's M6800 μP; Model K1117A is recommended for Intel's 8080 CPU. Prices for the MC6870A have been reduced from $68.13 to $33 (1-4) and from $33.51 to $18.40 (50-99). The MC-6871A and B are lowered from $70.88 to $36 (1-4) and from $34.85 to $20 (50-99). The prices for the K1117A are the same as the MC6870A.

CIRCLE NO. 370

Siliconix has dropped prices by nearly one-third on its **3-1/2-digit LD110/LD111 a/d converter IC chip set** and **LD111/LD114 multiple-option** a/d **converter IC pair.**

CIRCLE NO. 371

The **Monroe 324 scientific microcomputer** has been reduced to $495.

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Signetics has announced that it will manufacture two device types selected from the Intel **3000 series** as part of a **bipolar microprocessor system set.**

CIRCLE NO. 376

New **Band-Selectable Fourier Analysis (BSFA) software** is now included in **Hewlett-Packard's** Model 5451B Fourier analyzer system.

CIRCLE NO. 373

National Semiconductor's Memory Systems group has begun volume production shipments of its **MOS-RAM 410,** featuring the MM2102 1k static memory chip.

CIRCLE NO. 374

Siltek is offering 68 types of **CMOS 4000B and 4500B series products.** All types are interchangeable with Motorola's 14500 series.

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Design Data from Manufacturers

Advertisements of booklets, brochures, catalogs and data sheets. To order use Reader-Service Card
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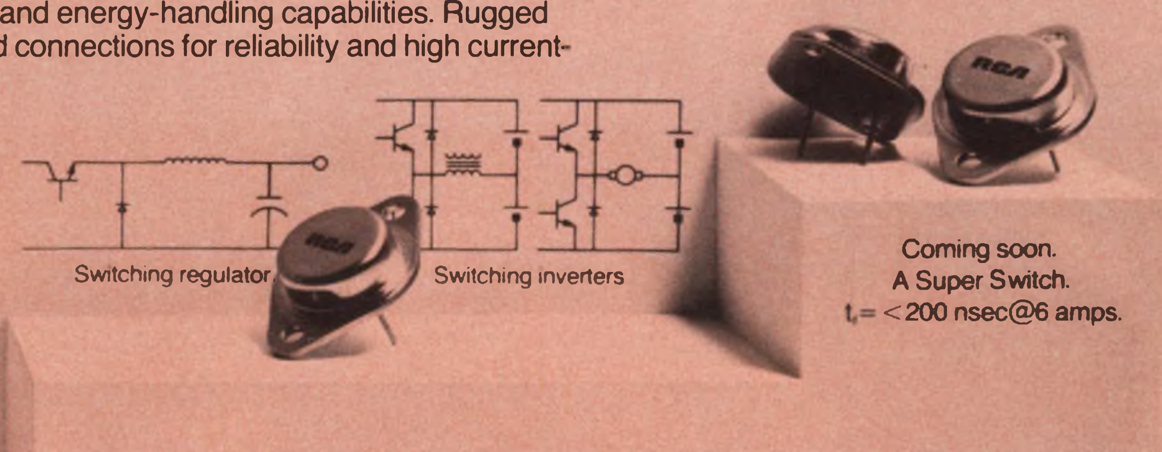

	I_C amps	V_{CER} volts	V_{CBO} volts	V_{CEO} (sus) volts	P_T watts	V_{CE} (sat) volts	t_r nsec	t_s μsec	t_f nsec	100+ price
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