The fastest storage scope opens new doors in combined real-time and stored measurements. Writing speed soars to 2500 cm/μs, with a bandwidth of 400 MHz. With four independent plug-ins, you can capture a fast pulse, then perform a spectral analysis. Work in variable persistence or bistable modes, too. See p. 79.
FEEL the pot . . .

CLICK the switch . . .

GANG the modules . . .

and add "quality-touch" appeal to your product.

FEEL THE POT . . . a smooth, quality feel, only from Bourns® 81/82 Model Potentiometers. Rotational torque range, only .3 to 2.0 oz. inch, is consistent for one, two, three or four cup assemblies.

Independent linearity of ±5% and low 1% CRV provide exceptional setability in both cermet and conductive plastic element types.

CLICK THE SWITCH* . . . one that really clicks, with positive action detent at either CW or CCW end. The Bourns Model 85/86 potentiometer/switch combination is rated at 2 amps in DPST style and 1 amp in DPDT. Contacts are constructed of fine silver with gold overlay. This provides exceptionally low contact resistance, for reliable operation at low level analog or logic signal levels — or any application requiring an "on-off" function.

GANG THE MODULES . . . potentiometers and switches. Up to 4 modules can be ganged on the same single or dual concentric shaft, without sacrifice to the satin-smooth feel or the sure-fire click. Other options include a wide choice of bushing and shaft styles, P.C. pins or solder lugs. Think of the possibilities! Now you can specify custom pots and switches assembled from "off-the-shelf" modules — at standard cost and leadtime.

Add "quality-touch" appeal to your equipment with BOURNS Model 80 Family of Modular Potentiometer/Switches. Write or call today for complete technical information, direct or through your Bourns distributor.

FEEL, CLICK, GANG . . . BEAUTIFUL!

TRIMPOT PRODUCTS DIVISION, BOURNS, INC., 1200 Columbia Avenue, Riverside, California 92507, Telephone (714) 781-5122 — TWX 910 332-1252.

*Patent pending
SURPRISE!

The World's First Rectangular LED Lamps

For the first time LEDs are offered in a rectangular epoxy package. Available in high-efficiency red, yellow and green, they feature a flat, high intensity, light emitting surface.

And, since they're end or side stackable, they're ideal for flush mounted panel indicators, backlighting legends, and linear arrays. Plus you get long life and solid state reliability. And they're in stock right now. Choose our 5082-4570 for yellow, the 5082-4670 for high efficiency red, or the 5082-4970 for green. Priced at $1.00* in quantities of 1000. *(U.S. Domestic prices only)

In the U.S., contact Hall-Mark, Schweber, Wilshire or the Wyle Distribution Group (Liberty-Elmar) for immediate delivery.
In Canada, contact Schweber Electronics or Zentronics, Ltd.

HEWLETT PACKARD
Sales and service from 172 offices in 65 countries.
TO-5 RELAY UPDATE:
Solve your energy crisis with TO-5 relays

Subminiaturization and pc board compatibility — two obvious advantages of Teledyne TO-5 relays. But there's another outstanding advantage: low coil power consumption. This feature is best illustrated in the above graph which shows our TO-5 relay power savings compared to other miniature relays. The Teledyne 412 Series dissipates about 30% less power than the .150” grid relay, and 50% less than the ½ crystal can. Our sensitive 432 Series is 65% less than the .150” grid. And 75% less than the ½ crystal can.

This means you can save over 6 watts in a typical system using, let's say, ten TO-5 relays. In the end, you gain significant advantages in terms of thermal and power supply considerations that can help prevent an "energy crisis" in your system.

Our complete line of TO-5 relays includes military and commercial/industrial types, with virtually all military versions qualified to established reliability MIL specs. For complete data, contact Teledyne Relays — the people who pioneered the TO-5 relay.

- Hybrid "T" Series
  SPDT & DPDT types with internal transistor driver and suppression diode
- "D" and "DD" Series
  Military and commercial/industrial versions with internal suppression and steering diodes
- Maglatch Series
  SPDT, DPDT, and 4PST magnetic latching types
- Centigrid® Series
  World's smallest relay — only .225" (5.72mm) high x .370" (9.40mm) square
- Hi-Rel Series
  Screened versions for space flight applications (NASA qualified)
- High Environment Series
  Hi-temperature, Hi-shock, and Hi-vibration types

TELEDYNE RELAYS
3155 West El Segundo Boulevard, Hawthorne, California 90250
Telephone (213) 973-4545
NEWS
15 News Scope
20 Electron-beam IC technology goes commercial in 1977.
22 Microcomputer control of a pinball machine makes troubleshooting simple.
24 A two-chip MOS calculator and clock-timer reduce pilot's in-flight workload.
26 Round one goes to Control Data in airborne-computer competition.
31 Washington Report

TECHNOLOGY
35 MICROPROCESSOR DESIGN
40 Focus on adhesives and coatings: Specifying these materials is tougher than for most components. Read these tips on the best way to cut through the hazy spec data.
50 Consider the 6100 CMOS microprocessor when an 8-bit μP can't deliver desired performance. The 12-bit word length and available software can ease system design.
60 Use conductive elastomers to simplify switch design and to make high-density connections from PC boards to LED displays, ICs and to other boards.
68 A 'simplified' notch-filter design? When you see a published application circuit that looks useful, beware! It might not work as well as you wish.
72 Ideas for Design: Inexpensive triggered-sweep generator updates recurring-sweep scopes. Interface CMOS to TTL with diodes and save the cost of expensive buffers. Remotely control a pocket calculator with a simple CMOS interface circuit.

PRODUCTS
78 Instrumentation: Scope combines fast storage and real-time operation.
82 Power Sources
84 Components
87 Packaging & Materials
90 Integrated Circuits
93 Data Processing
98 Discrete Semiconductors
100 Modules & Subassemblies

DEPARTMENTS
39 Editorial: The general and the lady
7 Across the Desk
104 New Literature
110 Advertisers' Index

Cover: Photo by Kolsky-Rose Studios, courtesy of Tektronix, Beaverton, OR.
Our Complementary While Everyone

Big Power-From Big Power People

| MJ15002 | $2.45 | MJ15001 | $2.45 |
| MJ15004 | $3.20 | MJ15003 | $3.20 |

The first new product family specifically designed for high power audio...L... of 1 A (MJ15003/4) or 0.5 A (MJ15001/2) at 100 V.

| MJ11011 | $4.10 | MJ11012 | $4.10 |
| MJ11013 | $4.60 | MJ11014 | $4.60 |
| MJ11015 | $5.25 | MJ11016 | $5.25 |

The '6609 is the first TRULY IDENTICAL performance/price complement to the industry-standard '3773.

2N6609 $2.59

2N3773 $2.59

2N6569 $6.50

MJ11011
$4.10
MJ11012
$4.10

MJ11013
$4.60
MJ11014
$4.60

MJ11015
$5.25
MJ11016
$5.25

All prices 250-999

Electronic Design 23, November 8, 1976
Power Went Big SOA
Else’s Went Nowhere

<table>
<thead>
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<th>IC: COLLECTOR CURRENT (AMPS)</th>
<th>VCE: COLLECTOR VOLTAGE (VOLTS)</th>
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Nothing in the world does it better than linear silicon power in making small signals bigger and better.

And nothing in the world does that better than new Motorola linear complements for 50 W and bigger jobs in motor controls, disc drives, audio amps and regulators.

Because nobody in the world expands state-of-the-silicon power art like us.

Do things better than ever — simplify circuits with direct-coupled complementary symmetry...realize higher frequency stability...accomplish low-distortion design...achieve high efficiency and reliable performance economically.

Do it with the ruggedest complementary SOA’s around.

Do it with your choice of the finest NPN or PNP devices in the business...discretes or Darlingtones.

Do it with equal performance at equal price!

Do it with Motorola linear silicon power. Because we’re bigger in it than anyone else.

Socko!

2N3773 $259

Electronic Design 23, November 8, 1976
A SMART WAY TO BEAT YOUR POWER SUPPLY SIZE PROBLEM

2½" thin, 2¾" narrow, 6¼" short

yet this converter produces 50 watts of regulated DC power from an input of 20-32 VDC! It weighs less than 2 pounds. This is only one of our wide variety of many small lightweight converters, inverters and power supplies—there are over 3500 models listed in our newest catalog, including size, weight, and prices. If you have a size problem, why not send for an Abbott catalog?

MIL SPEC ENVIRONMENT — All of the hermetically sealed power modules listed in our new catalog have been designed to meet the severe environmental conditions required by modern aerospace and military systems, including MIL-STD-810C. They are hermetically sealed and encapsulated in heavy steel containers. New high performance units meet MIL-STD-461A for conducted and radiated electromagnetic interference.

RELIABLE — Highest quality components are used in Abbott power modules to yield high MTBF’s (mean time between failure) as calculated in MIL-HDBK-217. Typical power modules have over 100,000 hours MTBF — proving that the quality was built in from the beginning.

WIDE RANGE OF OUTPUTS — Any voltage from 5 volts DC to 740 VDC is available by selecting the correct model you need from our catalog with any of a variety of inputs including:

- 60 VDC to DC
- 400 VDC to DC
- DC to DC
- DC to 400 VDC
- DC to 60 VDC

Send for our new 60 page FREE catalog.

Please see pages 1836-1848 of your 1976-77 EEM (ELECTRONIC ENGINEERS MASTER Catalog) or pages 676-682 Volume 2 of your 1976-77 GOLD BOOK for information on Abbott Modules.
Across the Desk

Yes, gallant reader, there is a TI library

Allyn T. Gallant (Across the Desk, ED No. 18, September 1, 1976) may have misunderstood Texas Instruments regarding its plans for a library service for users of the SR-52 programmable calculator. Until recently, information regarding PPX-52 was not available for public release.

The Professional Program Exchange for the SR-52 (PPX-52) is now operating and accepting members and programs. With hundreds of programs in dozens of professional categories available, chances are PPX-52 members will find many of their problems already solved. And more programs are being received each day.

For an annual fee of $15, a PPX-52 member will receive the first PPX-52 Program Catalog and frequent updates, three free programs of his choice, and a subscription to the PPX-52 EXCHANGE (a bimonthly newsletter). Members can order additional programs from the catalog for only $3.00, and will also be able to order optional SR-52 libraries (including the three new ones: Aviation, Navigation, Surveying) as well as accessories and supplies through PPX-52.

Stav Prodromou
Manager-Applications
Texas Instruments Inc.
P.O. Box 5012
Dallas, TX 75222

Contributors live on

Inventors, like great painters or musicians, it seems, are seldom appreciated during their life spans. But when "the chips are down," few are forgotten.

Those who would forget the great contributions to society by outstanding individuals like Anthony Lamb (see ED No. 15, July 19, 1976, p. 7) pass on like grains of sand, whereas the contributors stand out boldly like gold dust—if not today, then tomorrow or some time thereafter.

I for one salute Mr. Lamb for his contribution to a society who "can't see the forest for the trees."

Gill Hammond

Gates Learjet, Inc.
Mid-continent Airport
P.O. Box 1280
Wichita, KS 67201

Misplaced Caption Dept.

Does a 7474 have 14 pins or 16?


(continued on page 10)

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.
Finally.
A self-locking connector that's classified UL 94V-0 for flame resistance and UL 498 for 600 volts.
And recognizes that people aren't.
Our flame retardant Universal MATE-N-LOK series can take up to 600 volts with ease.

But people can't.

That's why, along with all the UL, CSA, and VDE/CEE credentials you need for worldwide and flame-retardant use, Universal MATE-N-LOK connectors offer you an exclusive safety feature:

A unique silo-design housing that makes it virtually impossible for you, or anybody else, to touch or mismate the pins and sockets.

So, in addition to reducing the potential of a fire, you're eliminating the chance of a short—or a shock.

With Universal MATE-N-LOK connectors, you get versatility too. Wire-to-pc board or wire-to-wire. Panel mount or free hanging. Mix pins and sockets in either half, for all types of keying combinations. And no matter how you apply them, Universal MATE-N-LOK connectors are greedy for power—with dual-wire capabilities and other features that let you pack more action into less space.

Of course, Universal MATE-N-LOK connectors, for sophisticated through non-critical applications, are backed by AMP technical service. Not just ordinary service, but the kind that says we'll help you with design problems. Application tooling. Training for your people. And troubleshooting. Just call us.

Find out more about how Universal MATE-N-LOK connectors—and AMP—can help you get more power to your products. Without getting power to the people who use them.

Call Customer Service at (717) 564-0100, or write: AMP Incorporated, Harrisburg, Pa. 17105.

AMP INCORPORATED
CIRCLE NUMBER 7

AMP and MATE-N-LOK are trademarks of AMP Incorporated.
General Electric wedge base lamps can save time, space, money.

These lamps are ideal for applications such as indicators, markers and general illumination where space is at a premium. Their wedge-based construction makes them easy to insert and remove. They don't require bulky, complicated sockets. And because the filament is always positioned the same in relation to the base, you get consistent illumination from lamp to lamp.

You can choose from over 25 types of GE wedge base lamps. Voltages range from 6.3 V to 28 V. Candlepower from 0.03 to 12 cd. Bulb sizes range from subminiature at 6mm to a heavy-duty bulb at 15mm.

To send for updated wedge base lamp technical information, circle number below or write GE for Bulletin #3-5259.

Check these 6 halogen cycle lamps GE has added to its low-voltage line.

General Electric now offers over 27 halogen cycle lamps that pack high light output in small packages. (In addition, GE offers 8 sealed beam halogen lamps primarily for aircraft applications.) Bulb diameters range from 5/8" to 1/2". Lengths from .520" to 2.25". Voltages from 3.5 to 28. O.V. And candlepower from 2.15 cd up to 250 cd.

They're ideal for you if you're designing applications such as optical systems, instrumentation, illuminators, fiber optics, card readers, displays and aircraft navigation. A variety of terminals are offered.

For updated technical information circle the number below or write GE for Bulletin #3-5357.

These three free GE catalogs include important data changes that could affect your present design. Send for yours today.

- #3-5169 June ’75 Miniature lamp catalog features 40 pages and 500 data changes for complete 500-lamp line.
- #3-6252R1 Feb. ’75 Sub-miniature lamp catalog features 24 pages and 91 changes for more than 210 lamps.
- #3-6254R Dec. ’74 Glow Lamp catalog features 8 pages and 50 changes for 83 Glow Lamp Indicator and Circuit Component lamps.

For up-to-date technical information on any of these items write: General Electric Company, Miniature Lamp Products Department #3382-L, Nela Park, Cleveland, Ohio 44112.

ACROSS THE DESK

Military or otherwise—look for a PC standard

Bill Walkup's statement (ED No. 16, August 2, 1976, p. 43) that there is no preferred-card (PC) standard—military or otherwise— or any progress toward a standard is wrong. MIL-STD-454E, "General Requirements for Electronic Equipment," calls out a matrix of 20 preferred card sizes, under requirement 17.

To develop a standard of PC board sizes, I suggest that anyone so inclined begin with a metric format for two reasons. First, the rise in popularity of the Eurocard has made equipment manufactured around this board size more attractive in recent years to the European market, and this should not be ignored by U.S. exporters. Second, since we will be converting to the metric system in this country, we should develop a standard which won't have to be changed within the next several years.

Bryan West
Sales Manager
Electronics Inc.
171 Bridge Rd.
Hauppauge, NY 11787

Electronics vs Art: Once a pun a time . . .

I've found your continuing program of bringing to light formerly obscure art depicting the life of the engineering profession to be very enlightening. It's occurred to me that the lost subtitle for the "Last Supper" probably reads something like, "On the occasion of your fortieth birthday, I would like to present you with this gold watch."

Painting isn't the only art that's concerned itself with electronics. As far back as 1741, the great chorus, "Let Us Break Their Bonds Asunder," was written to honor the untiring efforts of the semiconductor-reliability specialists. Even in the 18th century, they had a Handel on the problem.

John A. Carroll
Electronics Engineer
Dynamic Measurements Corp.
5 Lowell Ave.
Winchester, MA 01890

Electronic Design 23, November 8, 1976
A drove of (peripheral) drivers

National's interface products include a variety of circuits to solve peripheral drive problems of all kinds. For example, if you need a high voltage (30 V), high current (300 mA), high speed (25 ns) driver with TTL inputs, then try our DS75450 series. These dual peripheral drivers have and, NAND, OR, and NOR input configurations, and work nicely as power drivers, relay and lamp drivers, bus and memory drivers, etc.

Or, if you can sacrifice high speed for low cost, look into our DS75460 series of dual peripheral drivers. These circuits are functionally interchangeable with the DS75450 described above, but are rated at 65 ns, and are designed for applications that require a higher breakdown voltage (35 V).

If you've had latch-up problems and would like to broaden your system's operating margins, then our DS3611 series is for you: 300-mA sink capability; 80-V breakdown; and no latch-up even at 55 V. The circuits are functionally interchangeable with the DS75451 through DS75454.

Low-Cost Development System for SC/MP Microprocessor

The SC/MP Low-Cost Development System (LCDS) is a simple-to-use controller that provides a maximum of flexibility at a minimum—and very affordable—cost. It has everything needed to develop and test SC/MP hardware and software designs for your applications.

LCDS features easy interfacing and expansion. Four prewired edge connectors, for example, provide a plug-in interface for SC/MP family cards, and also let you interconnect additional SC/MP applications hardware. (There's room for a fifth connector, too, if you wish to add it.) You can also add a flat cable connector for coupling the LCDS to an external card cage.

Built-in control and monitor functions permit transfer of control between the LCDS resident firmware—subroutines that let you enter software debug commands via the control and display panel, or an optional Teletype—and your own application programs.

Expansion is easy, too, because of the cards offered for use with the LCDS. The 2K × 8 read/write memory and 4K × 8 ROM PROM cards, for example, provide additional memory; just plug them into the card bus.

The minimum LCDS comprises a SC/MP CPU card, scratchpad memory, ROM-based firmware, and control logic. Also included are a 16-key dual-function hexadecimal keyboard, all necessary function keys and control switches, and a six-digit hexadecimal display.

With the basic LCDS configuration alone, you can examine and alter the SC/MP registers and memory locations, run SC/MP programs in continuous or single instruction mode, and even operate with an optional Teletype using SC/MP DEBUG.

N8080 family rounds out National's microprocessor line

National's line of microprocessors is now the broadest in the industry: to the ranks of our bit-slice IMP, 16-bit PACES, 8-bit SC/MP and 4-bit TIPS, we have added our new N8080 family. Well suited to the broad spectrum of general purpose microprocessor applications, the 8-bit INS8080A CPU fits neatly between our cost-effective 8-bit SC/MP and the versatile 16-bit PACES CPUs.

The INS8080A CPU, with its full line of support circuitry, offers you a family approach to system design, multiple source availability, and total product support from National—RAMS, ROMS, PROMS, SO components, and a wide variety of linear and digital interface circuits.

In addition, we are backing our N8080 family with a full range of development tools, both hardware and software, for quick and easy assembly of basic design kits and implementation of development systems.

How about driving power from CMOS? Our DS3631 family of dual peripheral drivers does it, sinking 300 mA and withstanding 56 V at the outputs. Other features include CMOS-compatible pnp inputs; low Vcc dissipation; output circuit protection against Vcc loss; and operation between 4.75 V and 15 V. Pin-outs are identical to those of the DS75451, DS75461, and DS3611 series.

Finally, there are our telephone relay drivers—the DS3686 and DS3687. Both are duals rated at 65 V and 300 mA. The DS3686 is a positive-voltage driver; the DS3687, negative. (See National Anthem, No. 2, March 1976.)

You'll find complete information and specifications for these and many other products in our 464-page Interface Data Book ($4.00).
**Bi-FET™ 741 Op Amp:**

low input-bias current, 
low input-noise current, 
high input impedance

The LF13741 op amp is a Bi-FET™ version of the popular 741 circuit. But the use of our Bi-FET technology lets us place JFET input followers ahead of the bipolar stages, which results in very low input bias and noise currents—50 pA and 0.01 pAVHz, respectively (typ.)—and a very high input impedance of 5 x 10¹⁰Ω. The slew rate is 0.5 V/μs, and CMBW is 1 MHz.

This drop-in replacement for the 741 gives you that circuit’s general operating characteristics, but you’ll find that the LF13741 is easier to apply and will save you money if you’ve been using external, discrete JFETS with a 741 to get better input characteristics.

The LF13741 excels in those applications that require a low input-current moderate-speed amplifier or comparator such as transducer amplifiers, photocell circuitry, buffers in sample-and-hold systems, long-interval timers, and low-drift peak detectors.

**Durawatt™ RF line for CB rigs**

Specifically designed for a citizens band transmitter line-up, these eight Durawatt™ and Durawatt 92-Plus™ power transistors offer a unique combination of special processing, power capability, and package types.

For example, the complete family of pre-drivers, drivers, and output types is interrelated through tuned roll-off processing, which rejects spurious responses and provides for optimum performance.

In addition, all family members have dissipation ratings that meet worst-case conditions: infinite vswr at rated output power. Under worst-case conditions, when a 4-W a-m rig loses its antenna the output stage must withstand 30-W dissipation; the driver, 4 W; and the pre-driver, 0.8 W. Our transistors are designed to take such punishment and are rated at such levels; the output devices, in particular, are the strongest you can buy.

Finally, the family members are available in a variety of package types to meet your performance needs in an economic way. Our two pre-driver types, for instance, are a TO-92 NCBT13 and a Durawatt 92-Plus NCBX14; the three drivers include a TO-126 NCB14, a TO-39 NCB514, and a TO-202 NCBV14; and the three output types are the TO-126 NCBJ35, the TO-39 NCB535, and the TO-39 NCBW35.

The accompanying tables present a summary of National’s wide range of semiconductor memory products. They show at a glance whether or not we supply a given memory type, its organization(s), and its production status.

The letters in the tables represent memory organizations, as shown in the legend below the tables. Letters without asterisks show memories that are in volume production. The asterisks indicate products yet to enter production, although some of these are already in the sampling phase.

A letter with an asterisk preceded by the same letter without an asterisk indicates that another version of the same device is to be put into production. The second version may differ from the first in speed, pin-out, number of leads, etc. Keep in mind, too, that a single letter entry in the tables may represent a number of product types differing, again, in speed, pin-out, number of leads, etc.

In addition to the memory products shown in the tables, National supplies shift registers, PLAS, character generators, code converters, etc. Full information and specifications for our complete line of memory products will be found in our Memory Data Book ($3.00); for information on asterisked products, contact your local National representative.

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**Memories at a glance**

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<tr>
<th>TOTAL</th>
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<td>BITs</td>
<td>MOS (static)</td>
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<tr>
<td>64</td>
<td>D</td>
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<td>256</td>
<td>G.I</td>
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<tr>
<td>1024</td>
<td>G.G.I</td>
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<td>4096</td>
<td>P.O</td>
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<table>
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<td>M.N</td>
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<td>1024</td>
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**Organization Codes**

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<td>B</td>
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<td>256 bits</td>
<td>D = 256 x 1</td>
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<td></td>
<td>E = 64 x 4</td>
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<td></td>
<td>F = 32 x 8</td>
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<td>1024 bits</td>
<td>G = 1024 x 1</td>
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<td></td>
<td>H = 512 x 2</td>
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<td></td>
<td>I = 256 x 4</td>
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<td></td>
<td>J = 128 x 8</td>
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</tbody>
</table>

| 16,384 bits | T = 16,384 x 1 |
|            | U = 4,096 x 4 |
|            | V = 2,048 x 8 |
|            | W = 1,024 x 16 |

A Review of New Products and Literature from National Semiconductor

**NEW PRODUCTS AND TECHNOLOGY**

- **Bi-FET™ 741 Op Amp**: Low input-bias current, low input-noise current, high input impedance.
- **Durawatt™ RF line for CB rigs**: Specifically designed for a citizens band transmitter line-up, offering unique combinations of special processing, power capability, and package types.
- **Memories at a glance**: Summary of National's wide range of semiconductor memory products.

**DATA BOOKS**

- Memory Data Book ($3.00)

**ORGANIZATION CODES**

- Provides codes for various memory types and their specifications.

---

**ELECTRONIC DESIGN** November 8, 1976
APPLICATIONS CORNER

Control Mode Entry Via Keyboard

Pushbutton entry of control mode is a popular feature of modern instrumentation because it is a convenience to the instrument user and its designer as well. In the application shown on this page, we use our MM74C922 keyboard encoder to scan and debounce the pushbuttons for a mutually exclusive (one mode at a time) control group.

Keyboard encoders broaden CMOS line

Our MM54C922/MM74C922 (16 key) and MM54C923/MM74C923 (20 key) encoders provide all the logic you need to encode an array of spst switches. An external capacitor or clock implements the scan, and diodes in the switch array are not needed to eliminate ghost switches.

Features of the new encoders include:
- On-chip, row pull-up devices, which allow the use of switches with up to 50-kΩ on resistance; two-key rollover between any two switches; internal debounce circuitry that needs only a single external capacitor; on- or off-chip clocking; LPTTL-compatible Tri-State® outputs (for easy expansion and bus operation) with a last-key register; and -3 V to +15 V operation.

Dual and Quad Numeric Displays

National's new NSN (dual digit) and NSB (quad digit) series of displays are third-generation designs: the dice are mounted on a PC board and topped with a reflective cavity. Available in 0.3-, 0.5-, and 0.7-inch heights, each end-stackable module mounts the digits with their decimal points, and with or without polarity indication.

Four drive modes are available for the NSN series—common anode or common cathode, either multiplexed or direct. For the NSB series, the drive is common anode or cathode, multiplexed.

You will find the NSN and NSB multidigit displays cost-effective in a wide variety of applications that includes CB and TV channel indicators, data terminal displays, and instrumentation in general.

One feature of the MM74C922 is that it permits the use of inexpensive form-A contact (n-o. spst) pushbutton switches. But in addition, the MM74C922 eliminates the need for a mode storage register because its output retains the last mode entered. If the instrument's mode controller uses a rom or PLA sequencer, then the MM74C922's output is directly usable as part of the rom address, and points to the start address of the selected mode routine.

The MM74C922's data output strobe can reset or initialize the controller to enter the control mode from the top. And if a microprocessor controls the system, then the MM74C922 can scan, debounce, and encode the mode keys, and also provide an interrupt to the processor to indicate a mode change.

If you wish to display the instrument's mode, connect the MM74C922's output directly to a 1-of-n decoder such as our MM74C42 or MM74C154, which can directly drive led lamps. But if the mode is to be displayed in a seven-segment format, connect the MM74C922's output to some appropriate driver such as our MM74C48. (Remember to add current-limiting resistors between the MM74C48's output and the seven-segment display.) Both techniques are cost effective approaches to pushbutton mode entry.

Termination networks for data lines

Our RA24 and RA28 thin-film resistor arrays are designed for use as digital transmission line terminators. The RA24 is a 24-resistor network in a 14-lead, molded Epoxy B dip; the RA28 is a 28-resistor network in a 16-lead dip. Other than the resistor count and the number of leads, the two types are identical.

Both feature low inductance (5-ns risetime, typical), excellent tracking (2 ppm/C typical, -55° to +125°C), and low cost. Resistor matching is to 0.2% typical, and package dissipation is 2 W at 25°C.

Two versions—the RA24-3k6.2kN and RA28-3k6.2kN—are tailored for programmable instrumentation terminations per ieee specification 488-1975 for bus-organized peripheral control.

Single-chip quad analog switches

National's LF13331 and LF13201 series of spst analog switches are the industry's first single-chip, quad, JFET switches. Our bi-FET™ technology makes them possible, and yields performance generally superior to that of CMOS (particularly the on-resistance and leakage parameters) at lower-than-CMOS prices. In addition, these parts do not exhibit the latch-up problems common to CMOS switches.

Available in various combinations of normally closed and normally open configurations, the switches maintain a constant on resistance (150 Ω) over their analog input range of ±10 V, and to 100 kHz. The inputs operate from minimum TTL levels, and feature a break-before-make action. The LF13201 series is pin-compatible with DG201 types.
New Pressure Transducer Housings are Second Generation Designs

Our new housings for the LX1700 series pressure transducers create small and lightweight, yet rugged, alternatives in pressure transducer packaging. Designated the PX7-1 (a zinc casting) and PX7N-1 (in nylon), these new packages, in combination with the LX1700 transducers, are well suited to applications such as air conditioning and refrigeration compressor control, compressed-air tank monitoring and control, gasoline and diesel engine diagnostics, 3–15 psig pneumatic measurement and control, etc.

The housings are available in absolute, gauge, and differential (PX7D-1, nylon) configurations for pressure ranges from ±5 psi to 0–300 psi. Mechanical features include an internal, captive O-ring seal, and a ½" NPT male pressure connector. A 13-inch cable for electrical connection makes testing easy; the 5-pin connector at the cable end is keyed, locked, and strain relieved.

INDEX

Please send me the information that I have checked:

□ SC/MP LCDs, Pg. A, Col. 2
□ N8080 MPU, Pg. A, Col. 2
□ DS75450 Perph. Drvrs., Pg. A, Col. 1
□ DS75460 Perph. Drvrs., Pg. A, Col. 1
□ DS3611 Perph. Drvrs., Pg. A, Col. 1
□ DS3631 Perph. Drvrs., Pg. A, Col. 1
□ DS6866/87 Rly. Drvrs., Pg. A, Col. 1
□ LF13741 Op Amp, Pg. B, Col. 1
□ Durawatt CB RF Line, Pg. B, Col. 1
□ MM74C922/923 Encoders, Pg. C, Col. 1
□ Dual/Quad Displays, Pg. C, Col. 1
□ RA24/28 Term. Nets., Pg. C, Col. 2
□ LF13201/331 Switches, Pg. C, Col. 3
□ LX1700/PX7 Transducers, Pg. D, Col. 1
□ MM5382/83 Calen. Clks., Pg. D, Col. 3

Please send me the literature that I have checked:

□ AN-146 FM Remote Speaker System
□ AN-158 CMOS Line Drivers
□ AN-159 Data Acquisition System Interface to Computers
□ AN-160 Increasing Throughput for IMP-16 Serial Input/Output

Digital calendar-clock circuits

The MM5382 and MM5383 digital calendar clock circuits provide the timing, control, and interface circuitry for a minimum-cost, solid state, digital clock radio.

The circuits have four display modes: time; alarm; date; and sleep—as well as a four-year calendar display. The timekeeping function operates in either a 12-hour or a 24-hour mode. The MM5382 is the 12-hour version, and has a month-date format; the MM5383 is the 24-hour version, and has a date-month format.

Outputs consist of a presettable 59-minute sleep timer (e.g., a timed radio turn-off) and an alarm tone. A power failure indication warns the user that the time displayed may be in error.

Other features include: alarm display; brightness control; 24-hour alarm set; pm indication; fast and slow set controls; and a nine-minute snooze alarm. (The MM5383 has an alarm on indicator.) Both circuits provide open drain outputs for the direct drive of LED displays to 15 mA.
Japan's 2-way CATV uses fiber optic cables

An interactive CATV network using fiber-optic cables will begin demonstration runs in Tokyo on Nov. 15. The network will provide two-way services ranging from request entertainment through computer-assisted instruction, cashless shopping, medical assistance, police and fire protection and remote telemetering.

By 1978 a full-fledged, 300-subscriber system will be installed in the Higashi Ikoma area in a model city near Osaka. Tests will be carried out through 1979. Later, it is hoped, operational systems will be built throughout Japan.

The system is being developed by the Japanese Ministry of International Trade and Industry, with consulting assistance on fiber-optic technology supplied by Arthur D. Little of Cambridge, MA.

With a Panafacom U-400 computer providing the controls, the test subscribers will use a keyboard installed in their homes to obtain a variety of two-way services.

- Special TV programs by request. Via the home keyboard, the subscriber can trigger the computer to activate the video information storage and transmission unit, switching the designated program for automatic transmission.
- Request special data. A variety of specialized information, including news, is transmitted to the subscriber in still-picture form.
- Computer-assisted instruction. Questions and assignments appear on the screen of a multichannel home TV receiver with a built-in memory.
- Cashless transactions. Store and restaurant bills, rent and utility charges are among those that can be paid through the system; deductions are made automatically from the bank account of the subscriber.
- TV shopping and reservations.
- Burglar and fire alarms. Detectors installed in each home trigger the computer, which advises the police.

The Panafacom U-400 can address 256,000 bytes of memory; has a data transfer rate of 2 megabits/s; can do single or double precision arithmetic, and has a 16-bit word length.

The 300-subscriber network will consist of three main optical trunk cables, each containing 36 fibers and connecting the head-end to a subcenter. Each subcenter containing a video switch and associated control equipment, there will be up to 14 distribution cables radiating out, each of which can serve 12 subscribers (with 24 fibers per distribution cable). The final subscriber drop will be comprised of a two-fiber cable (one fiber each for upstream and downstream transmission) brought to an optical junction box where it is connected to the distribution cable.

In addition, independent optical fiber cable lines will be laid to local points such as a school, hospital, or town hall, so that service programs may be originated at these points and then transmitted via optical fiber to the head-end for distribution to subscribers, using a "mobile" TV camera.

SAW devices go into commercial production

The first commercial quantity production of a surface acoustic wave (SAW) device is in progress at Crystal Technology Inc., Mountain View, CA. The device is a SAW output modulation filter which is to be used in color-and-sound video games.

The Model CT155B filter reduces all intermodulation products of a video signal outside the channel boundaries to less than the 30 dB required by the FCC.

Another SAW device produced by Crystal Technology is a low insertion loss i-f filter—the CTI 43B—for color TV receivers. This is produced in the laboratory and only prototypes are currently available.

UV PROM doubles size and adds I/O ports

By introducing an ultraviolet-erasable PROM with twice the storage capacity of anything previously available Intel has leap-frogged the rest of the industry.

In addition to its high density, the new 16-k UV PROM, designated the 8755, also offers several I/O ports on the same chip, a feature not found in any other PROM.

The 8755 is designed for use with the company's third generation microprocessor, the 8085. It provides a 2 k x 8 erasable storage capability and accesses any word in less than 450 ns.

The 8755 is pin-compatible with the company's 8555 mask-programmed ROM and I/O circuit. It runs from a single +5-V supply and is housed in a 40-pin DIP. There are two 8-bit wide I/O ports built into the PROM and ROM chips and those ports are totally programmable—each bit, under software control, can act as an input or output. Also contained on the 8755 are a set of address latches, which are designed specifically to interface to the multiplexed bus structure of the 8085 μP.

With the introduction of the 8755, a 2708-compatible UV PROM won't be far behind, said a company spokesman. The 2708 was the largest UV PROM available until now, with a capacity of 1 k x 8 bits.

Conversion efficiency μP for CdS-CuS solar cell

The goal of low-cost solar electricity was brought one step closer to reality last month with the announcement by scientists at the University of Delaware (in Newark) that they had achieved a conversion efficiency (sunlight to electricity) of 7.8% using a thin-film solar cell made of cadmium sulfide-copper sulfide (CdS-CuS).
This figure is higher than any reproducible efficiency attainment so far with this type of cell, and is reported to be the first significant improvement in cadmium-sulfide photovoltaic efficiency since the early 1960s. (See "Major Solar-Cell Programs Strive to Lower Cost, Improve Efficiency," ED No. 6, Mar. 15, 1976, p. 24).

Scientists have plugged away all these years on CdS-CuS cells—despite the fact that single-crystal silicon delivers higher efficiency—because of the advantages it offers. One of these is low cost.

The cost of the basic material (the largest single cost factor in solar cells) is lower for CdS-CuS than it is for silicon—single-crystal silicon currently costs over $150/m² while the raw material used in the experimental work at the University of Delaware costs $1.12/m². In addition, thin-film cells are amenable to mass production techniques, a vital requirement if photovoltaic energy is ever to supplant conventional sources on a large scale.

The increased efficiency of the cadmium-sulfide cell was achieved at the University of Delaware by reducing the cell’s reflection characteristics, which results in more sunlight being absorbed in the photovoltaic material. This was done by shrinking the area covered by the fine wire grid fixed to the upper (sun-facing) surface of the cell. The grid plays an essential role in making electrical contact to the cell’s upper surface.

New laser rods better than neodymium YAG

A laser rod that may replace neodymium YAG in solid-state lasers has been successfully fabricated on a product for the first time. The new rod is composed of yttrium aluminate doped with neodymium.

In contrast to the YAG rods, the aluminate has lower thermal losses, does not require an external polarizer, and can store higher energy when operated in the Q-switched mode.

While the aluminate material has been known for some time, fabrication on an experimental laboratory basis has been too costly. But under an Air Force contract with Lambda-Airtron in Morris Plains, NJ, production-line technology has been developed that has brought the cost down. The first production run turned out 40 rods of b and c-type material.

Dr. Roger Belt, Airtron’s research director, explains that the yttrium aluminate material has several orientations and the b and c types are of principal interest for lasers. The neodymium YAG rod, on the other hand, is a cubic material and is cut along one direction.

The yttrium aluminate does not require a polarizer because the material is anisotropic, which produces polarizing effects.

The aluminate rods have been operated at much higher power outputs than the YAG rods for single mode operation. Belt notes. This is important in applications where a Gaussian type of beam output is needed.

Cost of a four-inch aluminate rod is about $4000, Belt says, but in large production quantities this could be lowered substantially.

The Air Force Materials Laboratory, Wright-Patterson Air Force Base, OH, has the yttrium aluminate rods available for loan to qualified requesters.

News Briefs

To get better speed and density from circuits built with NMOS technology, a number of companies, including Motorola and Intel are looking toward depletion-load MOS transistors, which permit speed improvements and size reductions of 30%. Smaller size means better wafer yield, the manufacturers say. And better yields mean lower prices. . . . Integrated-injection logic (IIL) is starting to appear in many complex digital and linear ICs. The technology permits higher densities than MOS—and better speeds. Texas Instrument claims top honors for circuit complexity with its SBP9900 16-bit IIL microprocessor. The 100,000 square-mil chip offers twice the speed of its NMOS counterpart and dissipates less than half the power. New IIL products coming from TI and other vendors include 4-k RAMs, specialized control circuits and telecommunications ICs. . . . The logic workhorse of the industry—the 54/7400 TTL series—is losing its place to a combination of two other bipolar technologies—low-power and Schottky TTL. Called 54/74LS500, the new family provides higher speed than the standard TTL without any increase in power drain. Among the major IC manufacturers developing LS logic circuits—either proprietary or second source—are American Micro Devices, Motorola, National Semiconductor, Signetics, Texas Instruments and Teledyne Semiconducotor. . . . An all solid-state telephone is being developed by American Micro Devices that will consist of two or three MOS chips, a speaker and keyboard. The price will be lower than electromechanical telephones, the company says, due to a reduction of hand-assembly steps. One chip will be used for the number entry and dialing, another to detect an incoming ring signal and to stimulate electronically, through a speaker, the sound of a ringing bell. A third circuit will store telephone numbers.

Ultrasonics shows flaws in solids in 3-D

An ultrasonic device that provides a 3-D display of flaws deep inside solid materials, such as ship hulls and aircraft wings, has been developed at the Naval Research Laboratory in Washington, DC, by two scientists, Robert J. Sanford and Henry H. Chaskelis.

The technique uses a standard ultrasonic focused transducer—either lead zirconate or lead titanate. Sound waves, a quarter of an inch in diameter, are beamed into the solid object from first one direction and then another—perhaps 6 to 12 degrees apart, a distance that corresponds to the angular separation between the observer’s eyes at the object distance.

The returned signals, from each of the two positions, are displayed on a CRT, and a photograph is made from each position. The two photographs are then put into a stereoscope, and the merged, three-dimensional image, showing all the flaws in relation to each other, is displayed.
Introducing our new thumbwheel switch for 8-mm thumbs. It's a skinny switch that we call the 1800 Series. It has many of the features of our notorious 1776 Series — but simpler, more standardized, and cheaper.
For example, just $2.50 for one, less for more, with a choice of five codes, gloss or matte finish, with or without stops, and readable by 20/20 eyes from 10 feet away.

It's got PC board terminations for plug-in or solder connections, and it snaps into a panel for mounting (no tools needed). It mounts singly or ganged (up to 20 stations), and will give at least 500,000 detent operations before it tires.
So now we've left you with no excuse for not choosing EE CO when you need a thumbwheel switch. We've got more versions for more applications than any other switch maker in the country. And more offices to buy from (87 in the U.S. and Canada). For any thumbwheel switch, see us first.

WE'VE GOT YOUR SWITCH.
Compare Multiwire:

costs less than wirewrapping...
works better than multilayering.
Two major systems—wirewrapping and multilayering—have been used for complex electronic interconnection in the last 15 years. Despite improvements and refinements, each still has inherent disadvantages. That's why Multiwire was created by Photocircuits. It overcomes the disadvantages of wirewrapping and multilayering.

A Multiwire board is basically a customized pattern of insulated wires laid down on an adhesive-coated substrate by a machine operating under numerical control.

**Multiwire vs. wirewrapping.**

Today, interconnection costs are more important than ever. So take a long, hard look at a key advantage of Multiwire panels. They cost much less than wirewrapping in small or production quantities.

Here's an example of how much less: a Multiwire replacement of a 60 DIP wrapped-wire panel. Total tooling costs were just $750. In order quantities of 1000 pieces, the Multiwire boards at $45 each were more than $30 less than the wrapped-wire panel. (A 40% cost savings.) Multiwire prices also include a 100% continuity check.

But cost is not the only reason for the superiority of Multiwire over wirewrapping. There are also design advantages. For example, Multiwire offers two-dimensional packaging density equal to wirewrapping. But with Multiwire panels, you reduce board-to-board spacing. And Multiwire weighs much less too. So it can contribute substantially toward improving the envelope or three-dimensional package of your product.

Electrically, Multiwire is also superior. The extreme repeatability of the manufacturing process provides much higher electrical reliability as received—this is an important cost-saving factor. In addition, you get the controlled impedance characteristics required without variations.

**Multiwire vs. multilayering**

With Multiwire, reliability goes up and inspection cost goes down. Multiwire doesn't need extensive inspection—like multilayering does—for nicks, pinholes, hairline cracks, spacing violations and bridging. Yet Multiwire regularly yields better than 99% reliability at incoming inspection.

Compared to multilayering, designing a new Multiwire board is a far simpler operation. Component locations and a wiring list are all we need. Our computer-aided system does the rest.

Since the computer also takes care of deletions and/or additions, engineering changes are simplified. What's more, Multiwire makes it easier to find paths for interconnections, because the insulated wires can cross one another. For these reasons we can deliver finished Multiwire boards to your door in weeks rather than months.

The advantages of Multiwire over wirewrapping and multilayering vary from case to case. We'd like to help you evaluate possible time, cost, design and reliability benefits. For information and price estimates, call the Multiwire Marketing Department at 516-448-1111.

**Multiwire from Photocircuits**

Division of Kollmorgen Corporation, Glen Cove, New York 11542

CIRCLE NUMBER 10
Electron-beam IC technology goes commercial in 1977

The name of the game in integrated circuit (IC) technology these days is increasing the density of circuitry packed onto the surface of semiconductor chips only a few square millimeters in area. Such results are generally achieved by using optical photographic techniques for generating a photoetched master mask. These masks are then used to control the diffusion and etching processes required to produce ICs.

During the past few years, a number of IC research and development laboratories have been experimenting with electron beam techniques for mask etching. Electron beams can cut these masks to greater resolution and with higher quality than optical techniques, thus making possible chips with greater circuit density at greater production efficiency.

The increased production efficiency results from the ability to draw the mask pattern in final size directly onto a coated resist substrate.

Under a licensing agreement with Bell Laboratories, Murray Hill, NJ, the first of these electron-beam machines will soon enter the commercial market. Etec Corp. of Hayward, CA, and the Extrion Division of Varian Associates of Gloucester, MA, both plan to market a Bell Labs invention, the computer-controlled EBES (electron-beam exposure system).

EBES eliminates a complex series of steps necessary in current methods, including preparing large-sized artwork, photographically reducing this pattern, and repeatedly exposing the pattern at actual size upon a photosensitive plate. Etec expects to have its units available first; Extrion, about six months later in November, 1977.

In addition to generating masks, the 1/2-micron (10^-4 cm)-wide electron beam can be used to etch circuit patterns directly onto the semiconductor wafer. This process promises to reduce device-development time by eliminating the need for masks.

Software gets on the beam

A computer-aided design system by Calma Co., Sunnyvale, CA, can interface with the electron-beam lithographic equipment. This software development unit can also generate, as well as store on magnetic tape, the programs needed to support the Bell Labs EBES system or another analogous system manufactured by Cambridge Instruments, Melbourne, England.

The leading feature of the Calma software is a capability that permits the creation of all geometric shapes directly, removing the restrictions and laborious digitizing procedures generally required to produce nonorthogonal shapes," says Dr. Arthur Collmeyer, vice president for research and development at Calma.

This process is a "fracturing" technique, according to Collmeyer. A complex geometric shape is broken down into a collection of simple shapes. Each of these simpler shapes is coded into digital format.

Besides generating digital data the Calma system allows the designer a choice in the width of the interconnecting lines. The computer's taped algorithms serve to translate the designer's circuit layout into actual mask patterns.

Even though a somewhat different algorithm is used by the British-made electron-beam system, observes Collmeyer, the Calma software can accommodate, it, too.

Scanning the surface

The Bell Labs EBES is reportedly the only commercial electron-beam system to use a raster-scan technique. All other systems use a method known as vector scan. These two methods of beam control differ only in the procedure used in translating the beam of electrons across the face of the chip. In the TV-like raster scan, the beam must cover the entire chip surface whether or not the beam is writing. The vector-scan method, on the other hand, scans only those areas to be etched.

EBES writes its intricate pattern on a chromium-coated glass substrate covered with a film of chemical "resist" that is sensitive to the electron beam. The unexposed portions of the resist and the underlying chromium are then etched out by chemicals, leaving a negative mask pattern of chromium on the glass.
Give your data communications system a little goose and it'll put out ten times as much.

Open up the back of any Data General communications system, pop in our single-board DCU/50 Data Control Unit, run through a little step called COMGEN and stand back. Because that system can start pumping out ten times as much data. And possibly a good deal more.

What makes this all possible is a rather clever piece of engineering.

We've designed the DCU/50 as an intelligent programmable controller. So it takes over jobs the CPU used to do. Things like character handling and code conversion. Which frees up the CPU processing power and speeds up total systems throughput.

On the other hand, you may not need more throughput. Instead, you may need more lines or different types of lines. Both of which are just as easy to get. You just plug in some different boards.

We make modular synchronous and asynchronous multiplexors you can mix in any proportion. They can handle anything from one to sixteen lines, are fully software supported and work equally well with or without the DCU/50.

Which brings up a rather significant point. When you buy your communications equipment from Data General, you can get exactly what you need right now. And later, if you need more throughput, more lines or different types of lines, you won't have to throw out anything. All Data General communications hardware and software are completely compatible. So you can add on to what you already have.

Write for our free brochure, "The Sensible Way to Use Computers in Data Communications" and detailed information about the DCU/50 Data Control Unit.

And if that isn't enough information, we'll send a sales engineer who can also put out ten times as much.

Data General

Data General Europe, 15 Rue Le Sueur, Paris 75116, France. Data General Australia, Melbourne (03) 82-1361
μC-controlled pinball machine diagnoses its own troubles

A unique new microcomputer-controlled pinball machine by Mirco Games, Phoenix, incorporates new solid-state design and circuit features that give it a number of substantial advantages over its electromechanical, relay-operated counterparts. Called the "Spirit of '76," the pinball machine uses a 6800 microprocessor, a Motorola peripheral interface adapter, 8-k of basic memory, and includes these advantages:

- Maintenance is substantially simplified by incorporated diagnostic-program routines that identify trouble by coded numbers that appear on the same LED displays used for keeping game scores.
- Reliability is increased by the elimination of the usual "rat's nest" of wires and by the use of low-current, solid-state control of the lights, bells and solenoids that operate the flippers—arms that strike and move the ball during play.
- Operating costs are reduced by lowering the current requirements for the game to 3.5 A at 5 V—about one-tenth that used by the electromechanical machines.
- Weight is some 60 lb lighter than a comparable electromechanical machine, thanks to the elimination of stepping switches and relays and their wiring, and by the use of a smaller power supply. (Reduced weight saves considerable shipping costs.)
- Electromagnetic interference to radio and TV sets is lowered by using low-level microcomputer peripheral interface signals, in place of stepping switches and relays, to control the Darlington transistors that energize the 30-V machine solenoids.

Three diagnostic routines stored in the microcomputer program not only minimize the machine's downtime, but also check every working component in the machine.

The routines are entered using a special combination of diagnostic settings on switches located on the PC board holding the microcomputer, its interface ICs, and power transistors. The board is located behind the scoring panel.

Routine checks all bulbs

One diagnostic routine checks out all the bulbs in the machine simultaneously and rapidly detects any burned-out lamps. Another routine can determine if trouble is present in any one of the switches. In this case, coded numbers appear in the LED scoring displays. These numbers are referenced to a checklist that reveals both good and defective switches.

Another diagnostic routine briefly turns on all the solenoids in the machine in sequence to make sure they are all working. It also checks the LED digits by cycling the scoring digits from 0-to-9 and back to zero.

The microcomputer provides the machine owner, or operator, with readily controllable back-panel features.

Free-game scoring levels ranging from 40,000 to 104,000 points can be adjusted by resetting the proper back-panel switches. Other switches provide a range of one to four games per coin as well as a free-play mode for those locations that play without coins.

The μP can vary the levels of required playing skill. The flippers can be made to work faster or slower through microprocessor control of the energy applied to the flipper solenoids.
"As the first interactive small plotter, it was the only intelligent choice."

Problem: Until now, no small plotter could carry on an intelligent conversation.
Because most B-sized plotters have been pretty much the same: slow, unreliable, and dumb. Even with large off-line plotters you can wait hours, even days, for results... and if there's a mistake—start over.

Solution: Tektronix' new microprocessor-based 4662. For interactive plotting, page scaling, digitizing, and camera-ready output. Just $3995.†

The 4662 is the first smart buy among 11"x17" flatbed plotters. Its digital design and vector generation offer exceptional accuracy and repeatability without drift or slidewire dirt build-up. Its 1600-byte buffer lets the host work while the 4662 plots... at speeds up to 22 ips.

*It's the first B-sized plotter with graphic input.* Digitizing capability and built-in joystick mean you can input corrections in seconds, experiment with designs, and run off camera-ready copies practically as fast as you load paper.

*It's plug-to-plug compatible with virtually any RS-232 system... from minis to mainframes.* You can plot circles around any other B-sized plotter, for about the same price as the competition. For a demonstration, call your local Tektronix Sales Engineer, or write:

Tektronix, Inc.
Information Display Group
PO. Box 500
Beaverton, Oregon 97077
Tektronix Datatek NV
PO. Box 159
Badhoevedorp, The Netherlands

The 4662.
Plug it in.
It speaks for itself.
Calculator-timer makes life easier for light-aircraft pilots

Four principal design problems have been solved in the development of the TMS-1000, a combined calculator-timer from Martin Avionics Corp., Grapevine, TX, that decreases the light-aircraft pilot's workload during instrument flight. The problems were: packaging, design of a special keyboard, production of a highly visible LED display and electromagnetic interference from the calculator-timer's power supply that can disturb the aircraft's navigation and communications equipment.

"The most difficult problem we faced," says Bruce Martin, president of Martin Avionics, "was packaging a two-chip MOS calculator-timer system in a space sufficiently small to fit into the control yoke of a Beechcraft. Because the space available in the control yoke could not be modified, it was necessary to achieve high packaging density with a double-sided PC board.

"The converter that powered the system—it worked off an input voltage from 8 to 30 V—was packaged separately and mounted behind the aircraft panel."

Because a light aircraft's yoke vibrates considerably, the keyboard's calculation and timing keys had to have sufficient travel for the pilot to feel certain he had made a positive input to the system.

Long-travel keys needed

The conventional, quick-action keyboard, with a key travel on the order of 0.008 in., proved unsatisfactory during field tests. So special long-travel momentary keyswitches with a movement of 0.050 in. were incorporated. They were housed in a TO-5 transistor can.

The normally poor contrast, or "washout," of the LED display in sunlight proved a stumbling block, at first. But installing two optical devices in the display assembly obtained satisfactory performance. One device, a circular polarizer, prevents light entering the display from re-emerging and reducing the LED display's contrast. The other optical device, an injection-molded prismatic lens, bends the light from the LED display upwards into the pilot's eyes from its chest-high location in the control yoke.

A major problem, the electromagnetic interference from the dc-to-dc-converter power supply, was finally solved with brute-force filtering—putting the power-supply components inside a sealed can and bringing out the supply leads through feedthrough capacitors. Both visual and audio alarms are incorporated into the TMS 1000 system. The two-chip, 28 and 40-pin system includes:

- A digital clock that can be set to any desired time down to the second.
- A four-function, reverse Polish notation calculator.
- Two scratch-pad memories for entering communication frequencies, navigational bearings or other data.
- An elapsed-time, or down-counting, timer.

The digital clock is used for such straightforward timing functions. A highly audible alarm mounted behind the panel can be set to sound off at the end of a period of time set into the clock.

The down-counting timer principally keeps track of the elapsed time during a precision-timed instrument approach. At the end of the elapsed period, the audible alarm and a flashing LED in one corner of the display signal the pilot it is time to decide to either complete his landing or take off again. ■ ■
PC Connectors give our family the edge. We can give you the edge with fast delivery and wide variety in off-the-shelf PC connectors.

In .100, .125, .156 and .200 inch spacing you can take your choice for motherboard or automatic wiring applications.

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GTE SYLVANIA
Round 1 goes to Control Data in airborne-computer competition

The winning model in the Navy's standard airborne computer competition is a high-speed, bipolar, \(\mu\)P-based machine with an AMD 2901 controller and low-power Schottky bipolar logic in both MSI and LSI. The winning manufacturer, Control Data Corp., will base the computer on its in-house CDC-480, and the Navy will designate it the AN/AYK-14.

Taking the first round over IBM, Lear Siegler and Sperry Univac also gives CDC the edge in supplying airborne computers for at least eight future Navy airborne weapons systems, beginning with the F-18 fighter (two each in 800 aircraft) and the Light Airborne Multi-Purpose System (LAMPS) Mark 3 helicopters (one each in 204 helicopters). The entire AYK-14 program will be open to competition again in 1980.

CDC's AYK-14 is organized into 16-bit words (plus two parity bits), but can be made into a 32-bit machine for high-performance systems. AMD 2901 high-speed bipolar microprocessors are the heart of the system. Four of them, each representing a 4-bit slice of the 16-bit words, are used for each computer.

**Navy knows what it wants**

Since the Navy is specifying core memory in the initial systems, CDC will use 14-mil cores that provide a cycle time of 900 ns and access time of 350 ns. NMOS semiconductor memory would double these speeds, but the Navy is worried about its volatility. MNOS does not have a volatility problem, but isn't far enough along in the development cycle.

The LAMPS will use the basic XN-1 version of the computer, which measures \(7.62 \times 10.125 \times 19\) inches, weighs 45 pounds, and contains 65-k words of core memory, with growth provisions to 96 k. The XN-2 for the F-18 fighter is slightly smaller, \(7.62 \times 10.125 \times 14\) inches, 32 pounds, and contains 32 k of core, expandable to 65 k.

All computers must be compatible with the 1553A multiplexed data bus specified for new Air Force and Navy aircraft. The AYK-14 is also software-compatible with Univac's UYK-20 Navy shipboard computer.

During benchmark testing, the Navy required at least 375,000 operations per second (OPS) for transferring data from registers to memory. The CDC version reportedly achieved 411,000 OPS in that mode and 670,000 OPS in register-to-register transfer.

As part of the Navy's reliability-assurance warranty (RAW) program, the manufactured computers will be subjected to probably the most stringent reliability requirements ever imposed on military avionics equipment—2200 flight hours meantime between failure (MTBF), or five years of operation, whichever comes first. This is part of the Navy's RAW program and is required for all AYK-14 computers used in operational aircraft, although not those used in test and evaluation aircraft.

RAWs are also required in any future alternate sourcing. All computers must be identical on a form, fit and function basis, right down to the shop-replaceable assembly (SRA) level—essentially the card on which the electronic components are mounted.

Beyond the F-18 and LAMPS, the AYK-14 is being specified principally for P-3 anti-submarine-warfare (ASW) patrol aircraft, which will require computers with up to 128 k of core. The AYK-14 architecture does permit the computer eventually to address 512 k of core, if needed. ■■
Complementary power Darlington pairs

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The microprogrammed state machine:

Get an Am 29811 and you've got it made.
If you make state machines—and you're tired of gates and flops and hassles and headaches—we've just made your life a lot easier.

Get an Am29811, add some Am2911's and you get an amazingly powerful, efficient microprogram controller. Throw in a couple other 16- and 20-pin packages, and throw away your state machine problems. For good.

**Look again:**

Sequence Control Instructions
- Jump to Zero
- *Jump to Branch Address
- Load Counter
- *Repeat Jump if Counter ≠ 0
- *Push PC or Push PC and Load Counter
- Jump to Map Address
- *Loop
- *Repeat Loop if Counter ≠ 0
- *Jump to Subroutine
- *Return
- *Jump to One-of-Two Subroutines
- *Jump and Pop Stack
- Jump to External Address
- Jump to Branch Address
- *Jump to One-of-Two Branch Addresses
- Continue

*Conditional Instructions

Terrific. But how much?
Am2911, $2.95 in volume.
Am29811, $2.60 in volume.
The entire controller shown, including 8-bits of loop counter and 8-input multiplexer is only $11.64. That's right. $11.64 total price.

If you want to know more about the Am2911 or the Am29811, just wire, write or phone. We'll send you a whole book about microprogrammed controllers. For free, of course.

Boy. Some guys really have it made.
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a convenient bench top power supply offering the voltage/current combination required for IC's & microprocessors

FEATURES:
- 10-turn controls for high resolution control of the 0—6V output and the tracked 20V outputs.
- Adjustable crowbar for the 0—6V output ... with indicator.
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- All three outputs available simultaneously and at full rating.
- Convection cooled.
- Two large recessed meters with switch, to monitor voltage and current.
- Rack mountable in a 5½” rack space (¾ width).

Price:
$475.00

THREE STABILIZED OUTPUTS

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<tr>
<td>0 to -20V d-c</td>
<td>1A</td>
<td>Tracking</td>
</tr>
</tbody>
</table>

For complete specifications, write Dept. FM-05

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CIRCLE NUMBER 16
Army eyes new integrated aircraft control

Controls for increasingly complex avionics functions in modern military aircraft are beginning to saturate the already crowded cockpit. All the services have been worrying about the problem, but the Army is doing something about it. It's sponsoring a new integrated control panel that will be multiplexed to as many as 10 avionics subsystems.

Grumman Aerospace and Collins Avionics Division of Rockwell International have been selected from the list of 14 bidders to begin the development of the system known as the Integrated Avionics Control System, or AN ASQ-( ) (V). Each company has $1.6 million from the Army Electronics Command for the development phase. One of them will be selected to do the production.

While the new system is being considered primarily for helicopters in the development stage, such as the advanced Attack Helicopter and Advanced Scout Helicopter, the Army also expects to retrofit it into such existing helicopters as the CH-47 Chinook and AH-1 Cobra.

ILLIAC IV super computer begins real-time operations

ILLIAC IV, the world's most powerful computer, has begun processing data relayed by communications satellites in real time and executing instructions interactively.

The experiment, supported by the Defense Advanced Research Projects Agency (DARPA), is part of anti-submarine warfare studies aimed at identifying and monitoring the acoustic signatures of enemy submarines. The data are collected from the ocean depths and relayed via commercial communications satellites to DARPA's Acoustic Research Center at the NASA Ames Research Center, Mountain View, CA.

The ILLIAC IV then processes the data at rates estimated at 150-million instructions per second. Although the computer has been operating since late 1975, it has been limited to batch processing until this new experiment, which uses its parallel-processing capability.

IR seekers compete with lasers for new weapons

Infrared seekers that home on the heat generated by enemy aircraft, tanks and other targets are being considered by the new Army weapons search and Development Command for at least two new Army weapons that are now scheduled to use laser target designators—the Copperhead artillery projectile and the Hellfire missile to be used on the Advanced Attack Helicopter (AAH).

The trouble with lasers is that the troops or aircraft doing the illumi
nating are vulnerable to enemy fire. To eliminate this hazard the Army may decide to put all the target acquisition capability in the warhead itself—letting it home on the target's own heat.

Raytheon and General Dynamics, Pomona Division have been selected to conduct parallel studies of an advanced passive IR seeker for Copperhead. The same seeker may also be used on the Army's proposed General Support Rocket System.

**Raytheon OKed for 2nd Pave Paws radar**

Raytheon has been funded by the Air Force to build a second Pave Paws phased-array radar following a General Accounting Office ruling on a protest by General Electric, the losing bidder.

GE claimed that it had submitted the lowest bid, but GAO ruled that the firm's costs were not realistic. Under the best and final-offer ceiling prices (130% of target costs), GE bid $79.3 million for a two-site system, while Raytheon bid $83.6 million. The Air Force estimated that although "most probable" costs were $75.6 million for GE and $77 million for Raytheon, GE had not considered all known technical risks.

GAO upheld the Air Force action, permitting the service to award a $28-million contract for the West Coast radar site at Pea'le Air Force Base, CA. Raytheon beat GE for the initial $46.6-million contract to build a radar array on the East Coast, at the Otis Air Force Base, MA, but the second site was held up pending resolution of GE's protest.

**Proposed Naval aircraft to use ECM, Elint**

A new land-based patrol aircraft with state-of-the-art electronic countermeasures (ECM) and electronic intelligence (Elint) equipment is being studied by the Defense Dept. as an alternative to the Navy's plans to convert its carrier-based aircraft to vertical and short-take-off-and-landing (V/STOL) versions.

The Land-based Multipurpose Naval Aircraft (LMNA) should be about the size of a Boeing 707 and equipped with air-to-air and air-to-surface missiles to repel anyone attempting to cut off sea lanes.

Approximately 180 of them can be built for $75-million each (before anticipated inflation), estimates William D. O'Neil of the Pentagon's Directorate of Defense Research & Engineering. This cost makes them competitive with carrier-based aircraft designed to do the same job.

For a radar that would permit the LMNA to detect and elude enemy fighters, O'Neil suggested a version of the radar used in the Airborne Warning and Control System (AWACS) or the E-2C.

**Capital Capsules:** The Air Force is studying a deep-space surveillance system with long-wavelength infrared (LWIR) sensors to supplement its existing Spacetrack network. The sensors may be placed in space to extend the range of the ground-based radars. The State Dept.'s Passport Office, which is planning to encode data magnetically on future passports, is launching a study of how the data can be "frozen" to be tamper-proof. The European Space Agency has voted to participate in NASA's Space Telescope program during which a 2.4-meter telescope will be orbited for deep space studies. ESA would provide an estimated 15% of the $400-million development and launch costs as well as some operating funds.
Now 1% time measurements are this easy...

Faster Timing Measurement
Differential time measurements are made faster when the new DM 44 with Delta Delayed Sweep* and direct numerical readout is included on a TEKTRONIX Portable Oscilloscope. At the same time, measurement repeatability is improved, the chance for computational errors is eliminated, and 1% accuracy is consistently achieved. Frequency measurement (on periodic waveforms) with 2% accuracy is obtained by simply pushing the 1/Time button.

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There's no need to carry a separate multimeter. DM 44-equipped TEKTRONIX Portables also measure dc voltage with 0.1% accuracy and temperature from −55°C to +150°C simultaneously with oscilloscope display of related waveforms. And you get ohms measurement with 0.25% accuracy as well.

Your Choice of Oscilloscope Performance
The DM 44 is available on five high-performance portable oscilloscopes to best match your performance and price needs. Choose bandwidth of 100, 200, or 250 MHz. Or select from two fast storage models. One actually stores single-shot signals at its full 100 MHz bandwidth.

Due to highly cost-effective design, the outstanding DM 44 option adds only $410 to the price of the basic portable oscilloscope chosen. All DM 44-equipped TEKTRONIX Portable Oscilloscopes, and seven more models as well, perform analysis on up to 16 channels in the digital domain by simply adding the LA 501W Logic Analyzer. Capabilities of the DM 44 are also available in the TEKTRONIX 7000 Series of plug-in oscilloscopes.

Let Us Show You
To see how the DM 44 makes faster, more accurate measurements in your application, contact your Tektronix Field Engineer. Or write to Tektronix, Inc., P.O. Box 500, Beaverton, Oregon 97077 for complete information. In Europe, write to Tektronix, Limited, P.O. Box 36, St. Peter Port, Guernsey, Channel Islands.

* Two independently adjustable delayed sweeps.
Our FIRE-PLUG™ connectors already meet UL 94V-0 flammability tests.

And you can’t beat our price.

These new Amphenol® connectors are classified 94V-0 for flame resistance by Underwriters Laboratories. That’s the most stringent test of plastic material flammability conducted by UL. And these connectors are also listed by CSA.

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They cost no more than what you’re buying now. FIRE-PLUG connectors are priced no higher than commercial connectors sold under the less stringent UL 94V-2 rating.

Interchangeable, too. FIRE-PLUG connectors are interchangeable, intermatable, and intermountable with the most popular types of commercial connectors.

Save time and labor with faster panel mounting. The FIRE-PLUG has mounting latches that flex easily. Only fingertip pressure is needed to push and lock the housing into a panel. Cable-to-cable styles are also available.


Semi-automatic crimping machine. Hand tools also available.

The right idea at the right time.
Separate I/O instructions for μPs will disappear in future systems

Chuck Peddle, microprocessor manager at MOS Technology, Norristown, PA, speaks on evolving μP I/O architectures and peripheral chips.

I believe that future μP systems will use memory-managed I/O instructions rather than hardware-controlled I/O. In fact, Intel and TI have, in effect, conceded that a memory-managed I/O is better. Their recently introduced peripheral chips for the 8080 use memory-managed I/O.

Hardware-controlled and memory-managed I/Os are the two major methods of program-controlled communication between a μP and a peripheral device. Hardware-controlled I/O is used in the 8080 μP system and the 8080's original peripheral chips use that method. The 6800 μP and our version, the 6502, use memory-managed I/O instructions.

In a hardware-controlled I/O system, the μP has a particular instruction, called an I/O command. During the execution of that instruction, the μP outputs an operand designating a particular peripheral device, along with a control signal that indicates which kind of I/O instruction will be performed.

The control signal tells the system either that data will transfer from one of the μP's registers to the peripheral device (a data-output instruction) or that data will transfer from the peripheral device into one of the μP's registers (a data-input instruction). The control signal must be separate from normal memory-data-transfer paths to be recognized by the I/O devices.

Memory-managed I/O uses less logic

A memory-managed I/O system needs none of the circuitry employed in a hardware-controlled I/O system to generate the control signals and

(continued on page 36)

Logic state analyzer presents loads of μP data

A logic-state analyzer called the Logicorder-32 crams address and data from 32 successive memory accesses, plus a triggering address and delay, onto a standard oscilloscope screen. All of this in hexadecimal notation for 16-bit words. Since the Logicorder really stores 64 accesses, you may choose which group of 32 you are looking at. Also the unit uses five toggle switches instead of 16, or the harder-to-use thumbwheel switches, to set 16-bit address and delay functions.

To enter a desired trigger address or delay, put its associated toggle switch in "slew." This resets an internal counter for that function. Four other toggle switches increment one hexadecimal digit of the counter at a time, until the desired number is reached.

The Logicorder's memory can be manually reset to enter new data or automatically reloaded two times a second to periodically update the display. The analyzer occupies one compartment in the Tektronix TM-500 series of modular instruments.

The Logicorder-32 sells for $895 and is available in 90 days.

Scanoptik, Inc., P.O. Box 1745, Rockville, MD 20850. (301) 977-9660.
MICROPROCESSOR DESIGN

(continued from page 35)

I/O data. Instead the programmer treats peripheral devices in the same manner as locations in memory. When data transfer from the μP registers to a peripheral device, the μP simply writes data into a “location in memory.” Only, in this case, the memory location is the peripheral device, and the operation can be called a data output. Similarly, when the programmer wants to transfer data from the external device to the μP, it simply reads data from a “location in memory,” in the peripheral device.

A memory-managed I/O system uses simpler circuitry than the hardware I/O in the 8080 because there is no need to generate an I/O control signal either from an I/O pin or by time-multiplexing the information during the status readout.

Likewise, additional circuitry on peripheral devices is not needed to interpret a control signal.

Instead, a memory-managed I/O uses the same control signals as the μP’s memory since every μP must have the logic to address and control memory.

Memory is differentiated from I/O by decoding addresses rather than by separate control signals. A unique address line is assigned to indicate I/O operation because in many systems there is no need to use all of the μP’s 16 address lines from memory.

If more than half of the addressing capability is needed for memory, then the advantages of memory-managed I/O start to disappear. This rarely happens in μP systems.

In our 6502, we assign the most-significant address line to ROM and the next most-significant line to I/O. So the I/O device has to decode only three address lines; one telling it that ROM has not been selected another to indicate that I/O is being performed and a third to indicate a particular I/O block. Additional address lines can be decoded to select I/O devices within a block, but much fewer than all 16 addresses need to be decoded.

Peripheral chips can be very useful

Peripheral chips designed for use in memory-managed I/O systems use fewer pins than those built for hardware-controlled I/O systems and are much more versatile. Registers that are μP-addressable are incorporated into these chips and, depending on the software program, configure the device to perform different functions.

One device, the asynchronous communications interface adaptor (ACIA), has been designed especially for memory-managed I/O systems to transfer data between a μP system and a serial communications line. The μP can write data into the ACIA’s control register that specify transmission rate, word length, parity, and number of stop bits. Other ACIA registers indicate the status of the transmit and receive data registers. All this logic fits into a 24-pin package.

The equivalent device for a hardware controlled I/O, the universal asynchronous receiver-transmitter (UART), requires a 40-pin package because dedicated external pins must be driven by the μP system to control operations.

μPs interface process controllers to a minicomputer

Retrofitting already existing Beckman Instruments series 8800 process controllers so that they can be supervised by a mini is now possible. With a minicomputer supervising the controllers, data may be manipulated or stored in memory, and any gross deviations from normal will automatically alert the operator.

Simply plug in a μP-based interface card, the Model 8000 computer interface, into each process controller.

The interface card converts the analog outputs from the process controller into a digital ASCII format and drives a 5-wire data bus. The bus, in turn, connects to a switching box that drives either an optional display panel or a standard RS-232 line running to a minicomputer and peripherals.

The bus uses time-sharing, bidirectional multiplexing, and up to 36 process controllers can sit on it.

For data-transfer reliability, all data sent from the minicomputer to controller, or vice versa, are echoed back to the originator. If there is a transmission error, the data are repeated. If the minicomputer system fails, control is transferred by the switching box to the optional display panel, for manual control.

36
For normal operations, the plant operator sits at an interactive CRT terminal controlling the minicomputer and accesses each process controller. The plant operator monitors the three signals sent by the process controller: the deviation around a setpoint, the integral of the deviation, and the derivative of the deviation. An alarm alerts the operator when a control point exceeds deviation limits. The CRT display indicates the process-variable setpoint, the controller output and the amount of deviation. With this information, the operator can make necessary corrections. 

Beckman Instruments, Inc., 2500 Harbor Blvd., Fullerton, CA 92634. (714) 871-4848.

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**Build a 6800-based system with four boards and a backplane**

An integrated set of cards, based on the 6800 µP, makes a computer having several advantages over competing types. The cards consist of CPU, ROM, RAM and support modules.

The 101CPU module contains the µP, and has parallel keyboard inputs and a dot matrix-printer output, rather than serial I/O lines that are common on other PC boards. Parallel I/O is more desirable if you need high speed operation because data are transferred 8 bits at a time, instead of one bit at a time in the serial mode.

You also get a total of 48 parallel-I/O lines plus 16 software-pollled interrupt lines. The board also comes with 1 k of EPROM (2708) and 4 k of RAM. The 101CPU also has fully buffered lines to drive external circuits. It costs $595, complete.

The 101ROM module has sockets for 14 k of PROM, and additionally has two kinds of serial asynchronous ports. One type uses EIA or current loop levels, with selectable transmission rates from 110 to 9600 baud. The second port has modem circuitry, including isolation transformers, for direct connection to a leased telephone line.

The 101RAM module comes with 16 k of static RAM memory, for $1095. The nearest equivalent, a Motorola product, uses dynamic RAMs and sells for $1495. Dynamic RAMs produce more noise on power-supply lines because they must be periodically refreshed. They are thus less desirable in this application.

The 101UNB program development module provides address traps and switch-selectable interrupt and restart vectors. The module contains additional communications ports, RAM and I/O.

The 101REG module contains power-supply regulators that work with rectifiers and filters on the motherboard to supply the required dc voltages. It costs $195, and the motherboard runs $445. A separate transformer must also be used, $88.

Revenue Control Sciences, 137 Richmond St., El Segundo, CA 90245. (213) 322-1893.

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**Micro Capsules**

Motorola is second sourcing the 2900 four-bit slice family. The company initially will offer the bit slice chip (MC2901), the microprogram sequencer (MC2909), and the one-by-two-port register (MC2918). ... Raytheon is introducing four new 2900 components: a 4-bit bus transceiver (2905), a transceiver plus parity (2906), a transceiver in a 20-pin DIP (2907), and a 4-bit register with TTL and three-state outputs (2918). Raytheon is also making the 93415, a 1-k × 1 high speed RAM. ... A µP-compatible, direct-memory-access or interrupt-driven-data transfer controller is on the market from Standard Microsystems Corp., Hauppauge, NY. The chip uses the 8080 bus structure. Control and status registers within the chip are set by software to enable single-character, multicharacter, or multiblock data-transfers between the chip and peripheral devices.
Stop noise problems with High Noise Immunity Logic.

Noisy environments simply cease to be a problem when you design with High Noise Immunity Logic from Teledyne. HiNIL provides high immunity to any and all types of electrical noise, without the cost and inconvenience of special filtering or shielding.

Use HiNIL in place of your conventional I/O logic. It interfaces easily with TTL, DTL, MOS and CMOS. It will protect your CMOS inputs against static charge damage and SCR latchup. And it gives you a guaranteed dc noise margin of 3.5 V (as compared to 1.0 V for CMOS and 0.4 V for TTL) without added filter circuits or tight supply regulation.

Or design entirely with HiNIL. You will get even better noise protection and a simpler design, and you can use a low cost, loosely regulated power supply. The complete HiNIL family includes more than 40 devices, with more being added all the time. They're available in ceramic or molded plastic DIPs.

Get complete details on the full family of HiNIL logic circuits from your local Teledyne Rep or Distributor. Or contact us at the address below.
The general and the lady

Once upon a time, during a state visit to Spain, Argentina’s Eva Peron was honored by Generalissimo Francisco Franco with a splendid parade, complete with marching bands, drumworks and all sorts of fanfare. That evening, at the end of a Lucullan feast, Franco proudly turned to Madame Peron and said: “Well, Eva, how did you like the parade?”

“Oh, it was lovely,” she answered, “really lovely. But I was just wondering. Why, when they marched under my balcony, did they keep shouting ‘Whore! Whore!’?”

“Oh that!” said Franco, with a wave of his hand. “Don’t let that bother you. They still call me ‘General,’ and I haven’t been in the army for 20 years.”

Well, as we know, Eva and Francisco didn’t seem to suffer from their reputations. But many of us suffer from ours. Sometimes, we even suffer from the reputations of others. For events leave reputations that live too long.

We remember too well the successes and failures of our colleagues. Joe is a fantastic engineer because we remember that he once designed a sensational product. (But everything he’s done since has been ho-hum.) Frank is a bum, because we cannot forget that we could never trigger that scope he designed in 1956. (But he has designed a whole series of successful instruments since then.) We remember to give Joe handsome salary hikes, while we remember to forget about Frank.

With companies too—vendors and customers—we act as if their present were their past. And we both suffer for it. A vendor who once supplied bad parts and gave lousy delivery might, today, deliver excellent components rapidly. And the customer who paid his invoice in 180 days, and then only after a series of dunning letters, might today be taking discounts for cash payments.

Of course, we can’t ignore history. If a vendor keeps shipping us bad parts, we ought to find a better vendor. If a manager has a long record of failures, it probably isn’t wise to hire him to teach us how to run our engineering departments. By the same token, if he has a fine track record, we might want to learn from him.

But history should not be our only guide. The present must be a factor.

George Rostky
Editor-in-Chief

*Most authoritative rumors hold that the lady was not a whore, but rather, a friendly waitress, renowned for her great service, in one of the less fashionable cabarets in Rosario.
The use of insulating and conductive adhesives and coatings in electronics is increasing. But specifying them can be a complicated and frustrating business. To begin with, an adhesive or coating suited for a specific application must meet requirements in at least six areas: mechanical, electrical, thermal, environmental, chemical and application compatibility. A fully defined spec is expected to list some 30 or 40 parameters, but very few do. The reason? The manufacture of adhesives, and to a lesser extent of coatings, is a highly proprietary business, with suppliers turning out what seem to be endless variations of the same basic formulas.

For any given adhesive application, a supplier might have 5 to 10 combinations of the same basic compound that are suitable in one or more respects. But these variations are seldom specified completely enough to be directly compared with another supplier’s product.

One supplier points out that he cannot afford to turn out test data for the many possibilities inherent in a given adhesive type. Moreover, generalities are not easy to make, for the same reason.

The best approach, recommended by both suppliers and a number of experienced adhesive users, is to provide the supplier with sufficient information for him to settle on a recommendation within a range of two or three formulations.

Information that suppliers consider helpful answers the following questions:

- What is the electronic component or device to be used for?
- What is the material or substrate of the parts to be bonded?
- Is a flexible, semiflexible or rigid adhesive needed?
- How does the designer intend to apply the adhesives? Will he use a dip, spray, paint, or fluid bed?
- What equipment does the user have? Can he oven-cure parts? Can he afford to invest in new equipment?
- What are the continuous operating temperatures of the finished product, transient elevated temperatures, if any, and the temperature during storage?
- In what ambient will the product be used: benign, solvent, chemical, or humid?
- Are there any required specs, such as MIL standards?

Adhesive specs tend to include only the key properties of the cured material, and, surprisingly enough, some specs don’t even include the bond strength.

But the material is only a part of specifying an adhesive. There are two other important facets: the preparation of the surfaces to be bonded and the choice of an adhesive-application system that is affordable and compatible with the surfaces to be bonded.

Failure to properly clean the surface to be bonded is the most frequent cause of poor joint performance; close behind is the failure to keep the surface clean until the bond is made.

**Bond specs are often vague**

Yet much of this preparation information is available only by contacting the adhesive manufacturer personally. And, while the cleaning is important, it is frequently not specified in detail.

The manner of applying the adhesive—brushing, spraying, dipping—can result in considerable variations not only in labor cost, but also in equipment requirements that can run into thousands of dollars. Yet these details are neglected.

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Jim McDermott
Eastern Editor

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Electronic Design 23, November 8, 1976
by many adhesive and coating suppliers.

The bond strengths specified pertain to specific kinds of mating surfaces, prepared in a specific manner, and can vary widely with different surface preparation and cure conditions. But the suppliers don't always let the designer know. The designer is frequently misled by "testmanship"—the specs don't fully describe the test methods used to obtain the values. Or, in some instances, extensive tests are developed that produce impressive, but insignificant, numbers.

When using adhesives, the designers must make many tradeoffs. But these are generally passed on by word of mouth, not the literature.

Usually these tradeoffs are compromises involving adhesive performance, physical performance, applications cost and processing ease. Since the designer often ignores the latter two, a cheaper material can end up costing more than the more expensive material: Factors such as application time, equipment use, scrap and training time must be included in the picture.

With coatings, the tradeoffs are similar. The designer must juggle environmental protection, temperature cycling resistance, processing ease and material costs. He might trade good chemical resistance for coating flexibility, or water-absorption for flexibility.

With adhesives, compromises must also be made between a bond's high tensile strength and high peel strength.

The retention of bond strength over a certain time is often quoted for unstressed specimens in the technical literature. But this quoted strength can be substantially reduced if the bond is aged under cyclic loads at various temperatures.

Specs for such adhesives as epoxies and other polymers indicate production of heat—an exotherm—during the curing cycle, but not how much.

The designer should also carefully check the specs for the elevated temperatures required for a heat-cured adhesive. This type of adhesive can only be used if the temperature tolerance of the components or semiconductors is satisfactory above the cure point.

Dielectric and conducting adhesives

At least four basic kinds of adhesives are used in the electronics industry: acrylies, cyanacrylates, epoxies and silicones. When used in their basic formulated state, these adhesives are all dielectrics with good insulating qualities.

But now many adhesive manufacturers fill these adhesives with conductive particles, such as silver, copper, gold, platinum, graphite and carbon. This permits them to be used as conductive bonds in applications ranging from bonding EMI...
shielding to assembling components like waveguide systems. 

The acrylics can be obtained as thermosetting systems or as solvent-dispersed modified systems to be used primarily for coatings. 

The cyanoacrylates set instantly and are widely advertised as “a drop that holds a ton.” But they are highly specialized in application, and once the adhesive sets it cannot be reversed. They have poor high-temperature and moisture resistance and don’t satisfactorily fill gaps between mating parts.

The silicones are generally used as sealants and gaskets. They have good high-temperature and low-temperature characteristics. For example, one-part, room-temperature-vulcanizing (RTV) adhesives/sealants have a useful temperature range of −65 to 260°C.

RTVs are used for bonding and sealing wires, terminals and other electronic equipment components. Most RTVs are cured by exposure to air moisture. But when sealed in a container, they have an exceptionally long pot life.

Two-component silicones are also available, but their principal electronics use is in encapsulation. They have a higher upper temperature rating of 300°C.

Epoxies are the strongest of all the adhesives and provide the best metal-to-metal bonds. One-part epoxies must be kept refrigerated to obtain a good “pot” life. But they must be cured at elevated temperatures.

Two-part epoxies are room-temperature cured, but require careful mixing of the two components before curing begins. These epoxies can also be heated for improved bonding and other characteristics.

Electrically conducting epoxies are used principally as “epoxy solder” that is frequently applied to bond materials not normally compatible with regular solders—usually because of heat-sensitivity.

Epoxy solders are supplied as one or two-component systems. The two-component systems, which can be cured at room temperature, are used for temperature-sensitive devices.

The conductive filler most used for epoxies and other adhesives is a silver powder. Other powdered materials, such as copper or aluminum, tend to oxidize after curing and reduce joint conductivity.

The silver epoxy’s conductivity is good. For example, typical volume resistance for Emerson and Cuming’s Eccobond Solder 56C is about $2 \times 10^4$ Ω-cm.

**Silver-epoxy is widely used**

Applications include the assembling of waveguide plumbing (see photo), bonding a tantalum slug to the can of a tantalum capacitor and making connections to heat-sensitive semiconductors.

Adhesives experts caution that the conductivity of such a joint is substantially affected by the cleanliness or other preparation required of the parts to be joined.

For nonmetallic surfaces, the pretreatment usually consists of a solvent wash or a good vapor degreasing to remove undesirable films or materials from a PC board. When bonding metallic surfaces together, in particular aluminum, note that a more complex treatment is needed for maximum conductivity and strength.

In this case, chemical pretreatment as well as abrasive cleaning might be necessary. It may also be necessary to provide chromate conversion or an anodized surface on the mating metals. But this varies with adhesives, so ask the manufacturer.
Until about three years ago, the bonding of semiconductor chips in hybrid and other micro-electronic devices was usually performed by eutectic or solder-type operations. These operations raise the chip temperature to almost 400 °C for extended periods of time and often degrade semiconductor characteristics.

As a result, conductive-epoxy die bonding, with its substantially lower temperatures, is now used for such electronic products as hybrid devices, LEDs and digital watch assemblies.

At present, there are two schools of thought regarding adhesive die bonding. Herbert S. Kraus, president of Ablestik Laboratories, Gardena, CA, believes that the adhesive should be a single-component system even though it requires elevated curing temperatures.

Kraus cites the advantages of such a system: the adhesive can be dispensed without being weighed and mixed; and waste adhesive material that results from two component, mixed systems is eliminated.

DuPont apparently agrees with Kraus. The company makes a series of single-component epoxy-based compositions that are used for bonding semiconductor chips to substrates and for attaching wire leads and discrete components. Thermal stability of the DuPont materials bonds is good up to 250 °C.

The DuPont silver compositions 5504, 5815, 6838, 8072 and gold 9294 are all electrically conductive with sheet resistivities of less than 0.1 Ω per square mil thickness.

Where a device to be bonded must be insulated from the substrate, an 8762 adhesive containing powdered alumina serves to maximize heat transfer.

All of these single-component types require typical cures ranging from about 45 minutes at 200 °C to 24 hours at 100 °C.

Some military and space applications don't permit the use of silver die bonding because of silver migration. In these cases, gold and occasionally palladium or platinum are used as the conductive filler. However, all three are more expensive than silver and are poorer electrical and thermal conductors.

Over on the side of two-component, conductive epoxy adheres for bonding is Frank Kuleza, president of Epoxy Technology, Watertown, MA.

Except for convenience, the one-component systems have limitations, Kuleza insists, and points out that one-component systems require refrigeration and in addition have relatively high curing temperatures and times.

To support his argument, Kuleza points to Epoxy Tech's H20E, a two-component silver epoxy widely used for assembly in the digital watch field. Although the two components must be mixed, the ratio is one-to-one by weight or volume and is not critical. And the two-component material can be cured in 45 seconds at 175 °C or in 12 hours at 50 °C.

The epoxy bonds with both single and two-component systems can be adversely affected by the thermal-compression techniques used for bonding wires to the chips. With thermal compression, the chip adhesive might reach 400 °C and soften. One answer here is to specify an epoxy that is formulated with sufficient viscosity at that temperature to remain in place. Another answer often used by hybrid fabricators is ultrasonic wire bonding.

Conductive coatings fight EMI

Conductive coatings for electronic applications, with a few exceptions, have the same dielectric materials as adhesives. These include the epoxies, acrylics and latex resins that also have a conductive filler.

But these coatings are supplied with a low or even watery viscosity, so that they can be sprayed, brushed, dipped, or silk-screened to provide a conductive surface on plastics, ceramics, glass and other nonconductive materials.

Conductive coatings are becoming more important in the prevention of electromagnetic and radio-frequency interference (see ED No. 20, Sept. 27, 1976, p. 24) particularly for electronic products with plastic housing or cabinets. These plastics are transparent to EMI.

To prevent EMI from being radiated from a
plastic-housed device like an electric drill or shaver, or from reaching the sensitive circuitry of electronic measuring instruments, the interior of the plastic housing is coated with a conductive film. This is the most cost-effective method of EMI-proofing complex shapes or large areas.

These anti-EMI coatings consist of particles of silver, copper, metal alloys, graphite or carbon dispersed in a liquid binder resin. The effectiveness of representative coatings, from Acheson Colloids, is shown in the comparison chart.

Ballpark figures for coating costs per square foot are: silver, $2; copper, $0.75; graphite, $0.50; carbon, $0.25. Approximate relative costs per square foot for competing methods of EMI shielding include: metal spray, $2.75; vacuum metallizing, $1.25; plating, $1.00.

The most stable of these coatings uses silver as the conductive element and is generally the easiest to apply or repair.

Some conductive coatings might require complex mixing equipment to ensure uniformity during application. This can be an overlooked pitfall in large production runs.

Also, some coatings have a tendency to cause the plasticizer to leak from the plastic substrate into the coating, reducing the effectiveness of the shielding.

Durability of most anti-EMI coatings is good. Tests by Acheson Colloids, Port Huron, MI, on silver coatings have shown no degradation after 96 hours of salt spray, water immersion and exposure to ozone.

**Conformal coatings protect circuit boards**

Conformal dielectric coatings protect PC boards and their components from such hostile environments as moisture, chemical fumes, fungus, abrasion, salt, and even skin oils deposited in handling.

Circuit boards that formerly needed no coatings might require them today for other reasons. For example, Underwriters’ Laboratories requires coatings on any 110-V board with conductors not separated by at least 0.25 inch.

Ideally, conformal coatings should provide many good electrical properties, high humidity resistance, ease of application, low temperature cure, suitable physical properties, transparency, removability or repairability, fungus resistance, hydrolytic stability and thermal-shock resistance.

Five principal types of coatings are MIL-spec approved: acrylics, polyurethanes, epoxies, silicones, and Parylene, a proprietary product of Union Carbide. Polyimide and diallyl phthalate coatings are also available.

Many designers experienced in the use of conformal coatings agree that although the MIL...
types cost more initially, they offer desirable features like high reliability.

What the specs don’t mention is that while these coatings are good at sealing out moisture, they are excellent at sealing it in. As a result, PC boards must be carefully cleaned and baked. Also, if the boards are to be handled after cleaning, they should be stored untouched in a desiccant cabinet or sealed in polyethylene bags.

Acrylic coatings are good from a production standpoint because they can be applied easily. They are solvent-based. An acrylic film forms when the solvent evaporates, and curing is rapid. Thus, several coats can be given fairly quickly.

If the PC board needs to be repaired, the cured acrylic film can be softened by soaking the board in a solvent like trichlore or methylene chloride. However, be careful of the environment in which acrylic-coated boards are to be used because low solvent resistance is a drawback of these films.

Because of their good electrical properties and resistance to temperature and humidity extremes, silicone materials are suited for PC-board conformal coatings and are useful in harsh environments. For example, a General Electric silicone rubber gel was chosen to protect the PC boards for Chrysler’s electronic Spark Control Computer located under the auto’s hood.

To provide a conformal coating that combines a good moisture barrier with the shock resistance of silicone rubber, Dow Corning has developed the R-4-3117 coating, the first in a new family of “elastoplastic” silicone resins.

Dow’s R-4-3117 is a tough but flexible coating for electronic parts, components and assemblies that provides environmental protection from -65 to 200 C.

Supplied as 75% solid in a solvent of xylene, the coating gives greater protection against damage and abrasion than regular silicone rubber coatings. It can be applied with standard brushing, dipping, spraying or flow-coating. A dip coat gives a typical thickness of 2 to 4 mils.

The coating is cured at room temperature, with 40% relative humidity, and has a tack-free surface within one hour. Optimum room temperature cure is 24 hours, but tack-free curing can be obtained in 10 minutes with a catalyst and oven curing.

Circuits coated with R-4-3117 can be repaired by soaking the faulty area in the solvent. To replace a single component, a pin-type soldering iron can be applied directly through the coating, which is then cleaned and recoated.

Silicones have disadvantages, though

While silicones have many advantages, including ease of handling, they are not as strong as the organic polymers like the epoxies and polyurethanes. To combine the best of the silicone and organic polymer worlds, a new family of high-strength composites has been developed by the SWS Silicones Corp., Adrian, MI.

Known as Silgan elastomers, the new materials combine low viscosity and ease of handling with the high tensile and tear strengths associated with organic polymers.

The Silgan elastomers cure at room temperature without exotherm and with low shrinkage, and are available as one and two-part compounds. Their maximum service temperature is 125 C, lower than the 200 C for Dow’s elastoplastic silicone resin. But the Silgan tensile strength is three times as great. These elastomers achieve their unusually high strength because they contain rod-like organic particles dispersed in a liquid silicone matrix.

A major problem with PC-board conformal coatings is obtaining a complete and uniform coating over, around and under all the components. For this reason, a fairly slow speed of immersion in dipping is usually required so that the coating can adequately displace the air surrounding the components. Immersing the board too quickly will trap air and leave bubbles in the coating.

Epoxy coatings are tough

Epoxy coatings are available as two-component systems or as one-part epoxy powders that have been developed especially for application to electronic components with an automatic, fluidized bed-dipping equipment. The epoxy powders require that the compound be preheated to 145 C. Cure times range from 2 minutes at 170 C to

Shielding effectiveness of conductive coatings varies with material type and coating thickness. Typical attenuations of Acheson Colloids’ formulation on a 0.125-in.-thick polycarbonate sheet are shown.
20 minutes at 110 C.

Epoxies have high abrasion resistance, high chemical resistance and good humidity resistance. But they are difficult to repair. Also, when applied to components on a PC board, the epoxy shrinks slightly during the curing period. Therefore, if fragile components are present, they must be protected with a softer buffer material like silicone to prevent breakage.

Polyurethane coating materials are available either as a single or two-component system. Their resistance to chemical activity and humidity is high, and their dielectric properties are stable.

But their good chemical resistance is a drawback. If a PC board must be repaired the highly active stripping compound can easily corrode the PC conductors and other metals with which it comes in contact.

Another limitation is that the boards must be carefully prepared for polyurethanes because traces of moisture can cause blistering in humid environments.

The single-component urethanes have production limitations in that they can require up to 9 or 10 days at room temperature to fully cure. The two-component urethanes can be cured in up to three hours, but only at elevated temperatures.

Voids create problems

Problems with voids are not unusual for either spray or dip conformal coatings. But this problem has been solved by one of the newest coatings, a proprietary product of Union Carbide called Parylene—generically poly-para-xylene.

Parylene, in contrast to the competitive materials, is applied with a vacuum deposition technique at room temperature. A number of PC boards can be put into the chamber at one time, and the Parylene is vaporized and deposited out as a solid coating. No curing is required.

Because the Parylene has a low viscosity, it penetrates and covers all portions of the board—in the corners and underneath the components.

The general coating thickness used for PC boards is 0.5 mil, but the thickness can vary from a few angstroms to as high as 3 mils, although seldom over 1 mil.

While the cost of the Parylene is some $250 per pound—more than 10 times that of other materials—less of it is used. However, expensive deposition equipment is required.

Tensile strength is good: 9000 psi for Parylene N and 13,000 psi for Parylene C. Both require a 200% elongation to break. And the dielectric and moisture-barrier properties are very good.

Because the coating is applied at room temperature, thermal stress is negligible. However, the coating does not strip easily, so repair work can get complicated. **

Next more information?

The companies and products cited in this report have, of necessity, received only brief coverage. They have been selected for their illustrative qualities. Many companies not mentioned might offer similar products. Readers may consult manufacturers from this partial listing and from ELECTRONIC DESIGN'S GOLD BOOK for further details:

Abelstik Laboratories, 833 W. 182 St., Gardenia, CA 90248
(213) 321-6252. Circle No. 407
Acme Chemicals & Insulation Co., Div. of Allied Products, 166 Chapel St., New Haven, CT 06513. (203) 562-3118. Circle No. 408
Adhesive Products Corp., 1660 Boone Ave., Bronx, NY 10461. (212) 542-6500. Circle No. 409
Allaco Products Div., Bacon Industries Inc., 192 Pleasant St., Watertown, MA 02172. (617) 925-2550. Circle No. 410
LB Allen Co., 9329 Berne, Schiller Park, IL 60176. (312) 678-3097. Circle No. 412
Ambroid Co., Inc., 612 Montello St., Brockton, MA 01853. (617) 583-6165. Circle No. 416
Applied Plastics, 612 E. Franklin Ave., El Segundo, CA 90245. (213) 322-8350. Circle No. 414
Armstrong Cork, W. Liberty & Chariot, Lancaster, PA 17604. (717) 397-0611. Circle No. 415
Asthomine Inc., 350 Middlesex Ave., Wilmington, MA 01887. Circle No. 416
Attain India Rubber, 571 W. Polk St., Chicago, IL 60661. (312) 427-8290. Circle No. 419
Attaco Research Corp., 5390 Cherokee Ave., Alexandria, VA 22314. (703) 354-3400. Circle No. 418
Avdel Corp., 50 Lackawanna Ave., Parsippany, NJ 07054, (201) 263-8100. Circle No. 412
Bacon Industries, 192 Pleasant, Watertown, MA 02172, (617) 926-2550. Circle No. 412
Cadillac Plastic/Chemicals, 15841 2nd Ave., Detroit, MI 48203. (313) 869-9500. Circle No. 417
Carbone Co., 350 Hanley Indl., St. Louis, MO 63144. (314) 644-1000. Circle No. 422
Carlton & Co., Inc., P.O. Box 191, Greenwich, CT 06830. Circle No. 424
Chase & Sons Inc., 19 Highland, Randolph, MA 02368. (617) 963-2600. Circle No. 426
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Chemronics Inc., 77 Dragon Ct., Woburn, MA 01801. (617) 935-4850. Circle No. 428
Conap Inc., 1405 Buffalo St., Olean, NY 14760. (716) 372-9976. Circle No. 430
Corkpak Co., Inc., 70 Argyle Ave., New Rochelle, NY 10804. (914) 632-1713. Circle No. 431
Cotronics Corp., 37 W. 39th St., New York, NY 10018. (212) 993-9376. Circle No. 430
Crossroad Industrial Products Co., 300 Science Park, New Haven, CT 06511. Circle No. 433
Dow Chemical Co., 2020 Dow Center, Midland, MI 48640. Circle No. 435
Du Pont, 1007 Market St., Wilmington, DE 19898. (302) 774-2421. Circle No. 437
Dunlop Co., 363 S. Sacramento Ave., Hebron, CA 92031. Circle No. 438
Electro Materials Corp. of America, 605 Center Ave., Mamaroneck, NY 10543. (914) 698-6344. Circle No. 441
Emerson & Cuming Inc., 60 Wilpale St., Canton MA 02021. (617) 828-3300. Circle No. 443
Epoxyrite Corp., 1901 Via Burton, Anaheim, CA 92806. Circle No. 444
Epoxy Technology Inc., 65 Grove St., Watertown, MA 02172. Circle No. 445
Everidian Inc., 2607 Austin Hwy., San Antonio, TX 78210. Circle No. 446
Evolite Corp., 420 Fairfield Ave., Stamford, CT 06902. (203) 357-4613. Circle No. 447
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Consider the 6100 CMOS microprocessor when an 8-bit μP can’t deliver desired performance. The 12-bit word length and available software can ease system design.

When the 6100 microprocessor was introduced about a year ago, it offered the user three advantages over most existing μP circuits: static CMOS circuitry, 12-bit word lengths and the use of an already existing and popular instruction set. It was and still is the only μP that can emulate the software operation of a full minicomputer—Digital Equipment Corporation’s PDP-8 E.

The microprocessor is a single-chip CMOS circuit built with a self-aligned, silicon-gate process. Internal circuitry is completely static, and the μP can operate at any speed between dc and the maximum operating frequency (8 MHz). Only one supply, from 4 to 11 V, is required for operation, and the on-chip oscillator needs only an external crystal. While low power consumption (less than 10 mW with a 4 MHz clock and +5 V supply) is a standard feature of the CMOS processor, full MIL temperature range performance is an added bonus. All on-chip input and output buffers permit simple interfaces to all TTL logic families.

12-bit words add flexibility

Because the 6100 has a 12-bit data word, several advantages in data-acquisition applications are readily apparent. In many systems, 10 or 12-bit analog-to-digital converters are used to prepare signals for digital storage. However, most available μPs have 8-bit word lengths, and you must use at least two data words and some extra control circuitry and instructions to get the data. The 6100, however, requires only one instruction and only one memory location to store the data.

To keep the μP pin count to a reasonable 40, the address and data paths are multiplexed on the same 12-line bus (Fig. 1a). The 6100’s timing and state control lines provide all external signals needed to communicate with memory and peripheral devices (Fig. 1b).

Many other available circuits are intended as direct support for the μP (Table 1): the 6402/3, a CMOS universal, asynchronous receiver transmitting (UART); the 6101, a parallel interface element (PIE); the 6610, 6611 and 6612, 256 × 4 field-programmable CMOS PROMs; and the 6312, a 1024 × 12 mask-programmable ROM for program storage. Of course, you can choose from a wide selection of CMOS RAMs, including 256×4 and 1024×1 models.

Building a microcomputer based on the 6100 is straightforward. All the CMOS parts are static and require only a single supply. A complete system can be built with the μP, a ROM, a RAM and a PIE (Fig. 2). The ROM should be located in the higher part of memory, including 7777,, to define the restart location after a reset. An output on the ROM, RSEL, defines the area in the 4-k memory field dedicated to RAM.

The ROMs and RAMs designed for the 6100 have address latches built onto their chips, so external parts won’t be needed. The PIE has two read, two write and four sense lines to control inputs and outputs, as well as four programmable flag outputs. Only one sense line and two flag lines are used in the system shown in Fig. 2, which leaves two read, two write and three sense lines for external I/O control.

If a UART is added, the amount of programming for the serial I/O can be reduced. And since the UART has its own crystal for synchronization, it can operate independently of the system clock. To control the UART, the PIE needs one read, one write, and two sense lines, which leaves all the others for external control.

The PIE can also handle priority-vector interrupts. To add either two or more vector interrupts or more I/O control, additional PIEs can be connected to the system bus. Each PIE must have a different address, but up to 31 units can be connected in a system.

Software simplifies the control panel

One special feature of the 6100 is the provision for a dedicated control panel. The limited number of pins on the single-chip μP prevents the contents of internal registers from being read by displays without help from the software. Since a control-panel memory can be included the 6100
can display the registers without relying on the main memory. A $256 \times 12$ ROM and $16 \times 12$ RAM, separate from the main memory, are all that's needed to duplicate the full PDP-8/E control panel (Fig. 3).

The control panel communicates with the processor via the Control-Panel Request (CPREQ) line. This line functions somewhat like the Interrupt-Request (INTREQ) signal, but with some important differences: The CPREQ bypasses the interrupt-enable system and forces the processor

![Diagram](image)

**Figure 3.** The control panel communicates with the processor via the Control-Panel Request (CPREQ) line.

NOTE: PINS 1, 26 = Vcc; GND. PINS 16 TO 20, 21 TO 25, 27 AND 28 = DATA & ADDRESS BUS; I1, I5 = CLOCK OSC. ALL OTHERS = CONTROL AND HANDSHAKING LINES.

1. By using a shared address and data bus, the pin count of the 6100 µP can be kept to 40 (a). Timing waveforms are more complex than for many of the static µPs since the multiplexed bus must be controlled.

**Table 1. System components for the 6100**

<table>
<thead>
<tr>
<th>Part number</th>
<th>Description</th>
<th>100-up price</th>
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<tbody>
<tr>
<td>HM-6100</td>
<td>12-Bit CMOS microprocessor (single chip)</td>
<td>$25.20</td>
</tr>
<tr>
<td>HD-6101</td>
<td>CMOS parallel interface element</td>
<td>$8.85</td>
</tr>
<tr>
<td>HD-6402/03</td>
<td>CMOS universal asynchronous receiver/transmitter</td>
<td>$6.95</td>
</tr>
<tr>
<td>HM-6312</td>
<td>1024 x 12 CMOS read-only memory</td>
<td>Consult factory</td>
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<tr>
<td>HM-6508</td>
<td>16-pin 1024 x 1 CMOS random-access memory</td>
<td>$6.80</td>
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<tr>
<td>HM-6518</td>
<td>18-pin 1024 x 1 &quot; &quot; &quot; &quot; &quot; &quot; &quot; &quot; &quot; &quot;</td>
<td>$6.80</td>
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<tr>
<td>HM-6501/51</td>
<td>22-pin 256 x 4 &quot; &quot; &quot; &quot; &quot; &quot; &quot; &quot; &quot; &quot;</td>
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<td>HM-6561</td>
<td>18-pin 256 x 4 &quot; &quot; &quot; &quot; &quot; &quot; &quot; &quot; &quot; &quot;</td>
<td>$6.80</td>
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<tr>
<td>HM-6562</td>
<td>16-pin 256 x 4 &quot; &quot; &quot; &quot; &quot; &quot; &quot; &quot; &quot; &quot;</td>
<td>$6.80</td>
</tr>
<tr>
<td>HM-6610/11</td>
<td>16-pin 256 x 4 CMOS field programmable read only memory</td>
<td>In development</td>
</tr>
<tr>
<td>HM-6612</td>
<td>18-pin 256 x 4 CMOS field programmable read only memory</td>
<td>In development</td>
</tr>
</tbody>
</table>
2. Just four circuits are needed to build a minimal operating system—the 6100, a ROM, a RAM and a PIE. A bare-bones system can operate for a week on a set of flashlight batteries.

3. You can make a complete front panel for the 6100 by using a second memory system that does not require any space in the main memory. Even debug programs can be stored in the panel memory.

to ignore the IOT, ION and IOF instructions. Once a CPREQ is granted, the DMAREQ (direct-memory-access request) or INTREQ commands will not be recognized until the CPREQ instruction has been fully serviced.

When a CPREQ is granted, the value of the program counter is stored in location 0000, of the panel memory and resumes operation at location 7777, of the panel memory. The panel memory is a second RAM, ROM bank (4-k words, maximum) organized with RAMs in the lower pages and ROMs or PROMs in the higher pages. The service routine then can be easily stored in memory locations, starting with 7777.

While the CPU is in the panel mode, the control-panel memory select (CPSEL) line—not the main memory select (MEMSEL) line—is active. However, during the execute phase of indirectly addressed AND, TAD, ISZ or DCA instructions, the MEMSEL line activates, thus permitting access to the main memory. Therefore, the CPSEL line should be used as an indicator to distinguish between main and control-panel usage.

To exit from the control panel routine, simply have the 6100 execute the following sequence:

ION
JMP I 0000, (Loc 0000, in CPMEM).
The ION command resets the internal CPREQ, and the indirectly addressed location 0000 holds the count of the PC just before the CPREQ signal is acknowledged. The value in location 0000 returns to the 6100's PC, and the original program flow continues.

Several options, such as test, maintenance and diagnostic routines, can be added to the control panel program. The panel can also be considered a portable device that can be plugged into a socket on the processor board either to help troubleshoot a down system or simply to observe system operation.

Memory organization permits easy expansion

The 6100 has a basic addressing capacity of 4-k, 12-bit words. Each location has a unique four-digit octal address (from 0000 to 7777).
A look inside the 6100 microprocessor

Since the 6100 microprocessor was designed to emulate the PDP-8/E minicomputer made by Digital Equipment Corp., it should come as no surprise that the μP is also architecturally identical. The 6100 has six 12-bit registers, an arithmetic-and-logic unit (ALU), all the gating and timing logic, and the instruction-decode and control ROM.

The accumulator register (one of the six just mentioned) is the central focus point of the 6100. All the arithmetic and logic operations are performed in it. For any ALU operation, the data held in the accumulator and the data fetched from memory are combined and stored (temporarily) back in the accumulator. Under software control, the accumulator can be cleared, set, complemented, tested, incremented or rotated. The accumulator also serves as an input/output register since all I/O transfers must pass through it.

A one-bit extension called the link is built into the accumulator. It can be complemented with a carry out of the ALU or cleared, set, complemented, tested and rotated along with the rest of the accumulator—all under program control. The link also serves as the carry output for two's complement arithmetic.

The other 12-bit registers include the MQ, a programmable register that can be used as a temporary storage location. The TEMP register can be used for microprogram control and helps to avoid race conditions. The MAR register holds the current address of the memory location selected for reading or writing. And, of course, both arithmetic and logic operations are done in the 12-bit ALU, as well as shifting left or right.

The PC (program counter) register holds the address of the memory location from which the next instruction will be fetched. During normal operation (an instruction fetch), the contents of the PC are transferred to the MAR, and the PC gets incremented by one. Of course, a jump or skip instruction modifies the procedure. Also included on the chip is a 12-bit instruction register (IR) that holds the instruction to be executed.

Data and addresses share a common 12-line bus that feeds directly into a 12-bit multiplexer. The multiplexer, in turn, is controlled by the major-state generator and control ROM. All timing and state signals needed by the 6100 are generated by an on-chip clock (only a 4-MHz crystal is required). An internal dividing circuit reduces the clock so that the internal states are 500 ns long.

Programmed data transfers, the easiest means of controlling data I/O, require the least hardware support. However, to use this form of I/O, the 6100 must remain in an idle state (wait loop), while the I/O device completes its last transfer and prepares for the next. Interrupts can reduce or totally eliminate the time waiting for device status signals.

Whenever the INTREQ input is driven LOW, the interrupt system permits external signals to divert the program to a preselected subroutine. If no higher priority requests for an interrupt exist, the current request is granted when the 6100 completes its current instruction. After reacting to an interrupt request, the Interrupt-Enable flip-flop in the 6100 gets reset so that no other interrupts can be acknowledged until the current interrupt is serviced and the system goes back to program control.

However, to make the memory space easier to operate, the locations are split into 37 pages, each with 177 addresses (in decimal notation, 32 pages of 128 locations each). The memory size can be extended to 32 k by using a memory-controller circuit to organize the memory as eight 4-k blocks called memory fields, 0, to 7. Defining a memory location then requires three bits from the controller to specify the field, the five most significant bits of the word for the page number, and the lower-order seven bits for the relative page address.

The 6100 is compatible with several ROMs and RAMs developed by both Harris and Intersil. The 6312 is a 12-k, mask-programmable ROM with an access time of 500 ns. Both the address and data lines are multiplexed on the same pins. Included on the ROM is a RAM-select output that defines an area in the memory-field dedicated to RAM. The ROM can operate over the full military temperature range with a supply of 4 to 11 V.

(text continued on p. 55)
Instruction set and addressing schemes

Instructions of the 6100 are 12 bits long and can be broken into three major groups: memory reference instructions (MRI), operate instructions (O1) and input/output transfer instructions (IOT). All of the over 70 instructions are software compatible with the PDP-8/E command set. The basic PDP-8/E paper-tape soft... are supplied by Digital Equipment Corp. can operate with the 6100.

The MRI instructions either operate on the contents of a memory location or use the contents to operate on the AC or PC. Each MRI is broken into two parts: Bits 0 to 2 represent the operation code, the other nine bits the operand address.

Operate instructions are broken into three groups of microinstructions. Group 1 commands perform logic operations on the contents of the accumulator and link registers and are identified by a 0 in the bit-3 position. Group 2 microinstructions primarily test the contents of the accumulator or link and then conditionally skip the next sequential instruction. They require a 1 in the bit-3 position and a 0 in the bit-11 position. The Group 3 microinstructions perform logic operations on the contents of the AC and MQ registers and have a 1 in the bit-3 and bit-11 positions.

Operate microinstructions from a certain group can be microprogrammed with other microinstructions from that same group, thus reducing the number of lines of code. The actual code for a microprogrammed combination of two or more microinstructions is a logic OR of the octal codes for the individual commands.

IOT instructions initiate the operation of peripheral devices and transfer data between peripherals and the 6100. The instruction word is broken into three parts: Bits 0 to 2 are set to 110, bits 3 to 8 indicate the device selection code to control the desired peripheral (up to 64), and bits 9 through 11 contain the specific operation code that determines the actual I/O operation.

Direct memory accesses (DMAs), sometimes called data breaks, can also be implemented in the 6100 system. Data can be sent directly to a high speed peripheral, such as a magnetic disc or tape unit. Since the 6100 only sets up the transfer, transfers occur on a “cycle stealing” basis with no μP intervention.

The 6100 has a direct addressing capability of 4 k words of memory. However, to permit combining operations and data, the memory is broken into 32 pages of 128 words each.

Only three addressing modes are possible:
- Direct addressing. In this mode, bit 4 of the instruction word can be checked. If the bit is 1, the page address is interpreted as the current page; if 0, the address is defined on page 0. By this method 256 memory locations can be directly addressed (128 on page 0 and 128 on the current page.
- Indirect addressing. With this mode, all 4 k of memory can be addressed. When bit 3 is 0 the operand address is obtained by first referencing a “pointer” address that is located either on the current page or page 0 of the memory. The address of the data or instruction to be handled is in the location specified by the pointer.
- Auto-indexed addressing. Within the 6100, provisions have been made for an external stack of eight registers (memory locations 0010 to 0017, octal) that can be used for indexing applications. Whenever these locations are indexed indirectly, the contents are incremented by 1 and restored before they are used as an operand address.

### Memory reference instructions

<table>
<thead>
<tr>
<th>Mnemonic</th>
<th>Octal code</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>AND</td>
<td>0000</td>
<td>Logic AND</td>
</tr>
<tr>
<td>TAD</td>
<td>1000</td>
<td>Binary ADD</td>
</tr>
<tr>
<td>ISZ</td>
<td>2000</td>
<td>Increment, and skip if zero</td>
</tr>
<tr>
<td>DCA</td>
<td>3000</td>
<td>Deposit and clear AC</td>
</tr>
<tr>
<td>JMS</td>
<td>4000</td>
<td>Jump to subroutine</td>
</tr>
<tr>
<td>JMP</td>
<td>5000</td>
<td>Jump</td>
</tr>
<tr>
<td>IOT</td>
<td>6000</td>
<td>In/out transfer</td>
</tr>
<tr>
<td>OPR</td>
<td>7000</td>
<td>Operate</td>
</tr>
</tbody>
</table>

### Operate instructions

<table>
<thead>
<tr>
<th>Mnemonic</th>
<th>Octal code</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOP</td>
<td>7000</td>
<td>No operation</td>
</tr>
<tr>
<td>IAC</td>
<td>7001</td>
<td>Increment accum.</td>
</tr>
<tr>
<td>RAL</td>
<td>7004</td>
<td>Rotate accum. left</td>
</tr>
<tr>
<td>RTL</td>
<td>7006</td>
<td>Rotate two left</td>
</tr>
<tr>
<td>RAR</td>
<td>7010</td>
<td>Rotate accum. right</td>
</tr>
<tr>
<td>RTR</td>
<td>7012</td>
<td>Rotate two right</td>
</tr>
<tr>
<td>BSW</td>
<td>7002</td>
<td>Byte swap</td>
</tr>
<tr>
<td>CML</td>
<td>7020</td>
<td>Complement link</td>
</tr>
<tr>
<td>CMA</td>
<td>7040</td>
<td>Complement accum.</td>
</tr>
<tr>
<td>CIA</td>
<td>7041</td>
<td>Complement and increment accum.</td>
</tr>
<tr>
<td>CLL</td>
<td>7100</td>
<td>Clear link</td>
</tr>
<tr>
<td>CLL RAL</td>
<td>7104</td>
<td>Clear link - rotate accum. left</td>
</tr>
<tr>
<td>CLL RTL</td>
<td>7106</td>
<td>Clear link - rotate two left</td>
</tr>
<tr>
<td>CLL RAR</td>
<td>7110</td>
<td>Clear link - rotate accum. right</td>
</tr>
<tr>
<td>CLL RTR</td>
<td>7112</td>
<td>Clear link - rotate two right</td>
</tr>
<tr>
<td>STL</td>
<td>7120</td>
<td>Set the link</td>
</tr>
<tr>
<td>CLA</td>
<td>7200</td>
<td>Clear accum.</td>
</tr>
<tr>
<td>CLA IAC</td>
<td>7201</td>
<td>Clear accum. - Increment accum.</td>
</tr>
<tr>
<td>GLT</td>
<td>7204</td>
<td>Get the link</td>
</tr>
<tr>
<td>GLA CLL</td>
<td>7300</td>
<td>Clear accum. - clear link</td>
</tr>
<tr>
<td>STA</td>
<td>7240</td>
<td>Set the accm.</td>
</tr>
<tr>
<td>NOP</td>
<td>7400</td>
<td>No operation</td>
</tr>
<tr>
<td>HLT</td>
<td>7402</td>
<td>Halt</td>
</tr>
<tr>
<td>ORS</td>
<td>7404</td>
<td>OR with switch register</td>
</tr>
<tr>
<td>SKP</td>
<td>7410</td>
<td>Skip</td>
</tr>
<tr>
<td>SNL</td>
<td>7420</td>
<td>Skip on nonzero link</td>
</tr>
<tr>
<td>SZL</td>
<td>7430</td>
<td>Skip on zero link</td>
</tr>
<tr>
<td>SZA</td>
<td>7440</td>
<td>Skip on zero accum.</td>
</tr>
<tr>
<td>SNA</td>
<td>7450</td>
<td>Skip on nonzero accum.</td>
</tr>
<tr>
<td>SZA SNL</td>
<td>7460</td>
<td>Skip on nonzero or skip</td>
</tr>
<tr>
<td>SNA SZL</td>
<td>7470</td>
<td>Skip on nonzero link or both</td>
</tr>
</tbody>
</table>
Two available CMOS RAMs are the 6508 and 6518—1-k × 1-bit units. The 6508 comes in a 16-pin DIP, the 6518 in an 18-pin DIP. Both have maximum access times of 450 ns and their data retention is guaranteed for supply voltages as low as 2 V. Several 256 × 4 static RAMs in 16, 18 or 22-pin DIPs are also available. All these static RAMs have a maximum access time of 450 ns and, like the 6508 and 6518, are guaranteed to retain data with voltage supplies as low as 2 V.

Coming soon in a 16-pin DIP is a 256 × 4 fusible-link PROM built with CMOS devices. It consumes only 50 mW and will be pin compatible with the 16-pin RAMs (except for its PE input). The three-state output version, the 6611, and the open-drain version, the 6610, will both feature an access time of 450 ns.

### System communication is easy

The 6402 and 6403 UARTs can interface the 6100 with an asynchronous-serial data channel (Fig. 4a). The receiver section converts serial start, data, parity and stop bits to parallel data and verifies proper code transmission, parity and stop bits. Conversely, the transmitter puts parallel data into serial form and automatically inserts start, parity and stop bits. The data word length can be 5, 6, 7 or 8 bits, and parity can be even or odd. Both the parity checking and generation can be inhibited and you can have 1.5 stop bits when transmitting a 5-bit code or 1 or 2 stop bits when handling 6, 7 or 8-bit codes.

Power requirements for either the 6402 or 6403 are a low 10 mW at clock frequencies up to 2 MHz (125 kbaud). Although there are some slight control differences between the 6402 and 6403, they function identically.

The 6101 PIE (Fig. 4b) provides addressing, interrupt and control for a variety of peripheral functions. Data transfers are controlled by the 6101's IOT instructions, control lines and 12-bit bus. The PIE consumes less than 5 μW in standby and about 5 mW when fully active. It is housed in a 40-pin DIP.

The basic timing of the 6100 is controlled either by the on-chip crystal oscillator or by an external frequency source. Several input lines control the μP's operation. The Reset input clears the AC, loads 7777, in the PC and halts the processor. The Run/Halt can start and stop the μP operation, while the Wait line can pause the unit in 250-ns steps so that slower memory circuits or peripherals can be connected to the μP.

The DMAREQ input signals the processor to transfer control of the busses to the external device on a cycle-steal basis with no processor intervention. The 6100 acknowledges that the request has been granted by generating a DMAGNT signal at the end of the current instruction. All fur-

<table>
<thead>
<tr>
<th>Input/output instructions</th>
<th>Teletypewriter keyboard/reader</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>KCF 6030 Clear keyboard/reader flag. do not start reader</td>
</tr>
<tr>
<td></td>
<td>KSF 6031 Clear keyboard/reader flag = 1</td>
</tr>
<tr>
<td></td>
<td>KCC 6032 Clear AC and keyboard/reader flag, set reader run</td>
</tr>
<tr>
<td></td>
<td>KRS 6034 Read keyboard/reader buffer static</td>
</tr>
<tr>
<td></td>
<td>KIE 6035 AC 11 to keyboard/reader interrupt enable FF</td>
</tr>
<tr>
<td></td>
<td>KRB 6036 Clear AC, read keyboard buffer, clear keyboard flags</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Teletypewriter teleprinter/punch</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPF 6040 Set teleprinter/punch flag</td>
</tr>
<tr>
<td>TCF 6042 Clear teleprinter/punch flag</td>
</tr>
<tr>
<td>TPC 6044 Load teleprinter/punch buffer select and print</td>
</tr>
<tr>
<td>SPI 6045 Skip if teletypewriter interrupt</td>
</tr>
<tr>
<td>TLS 6046 Load teleprinter/punch buffer, select and print and clear teleprinter/punch flag</td>
</tr>
</tbody>
</table>
4. Connecting the CMOS UART (a) or the PIE (b) is very straightforward. The UART can operate at clock frequen-

ther instruction fetches are suspended until the DMAREQ line is released.

An interrupt from an external device activates the 6100's INTREQ input, and the 6100 responds with a INTGNT signal at the end of the current instruction to acknowledge the interrupt. The current contents of the PC are dumped into location 0000, and the program fetches instructions, starting with location 0001. To return to the original program, the PC value must be retrieved from 0000. If nested interrupts are required, the addresses for the PC dumps must be stored in a software stack. Any IOT instruction will reset the INTGNT signal.

Peripherals are controlled and timed by the μP output (see the example of a teletypewriter interface in Fig. 5). The load-external-memory-address register (LXMAR) command latches the address appearing on the system bus. Four select lines distinguish which peripheral the μP has selected for a data transfer: one for memory (MEMSEL), one for the control panel (CPSEL), one for the switch register (SWSEL) and one for external devices used during IOT (DEVSEL).

Three other control lines designate data being transferred to the μP (XTA), data being transferred from the μP (XTB) and data ready for writing or reading (XTC). Other outputs signify the internal state of the μP.

After each instruction is completed, the μP internally scans its internal priority network to determine the next operation. The request lines, RESET, CPREQ, RW HCT, DMAREQ and INTREQ, are sampled in the last cycle of an instruction execution. The worst response time to an external request can be calculated as the time required to execute the longest instruction, preceded by any six-state execution cycle (14 μs at 4 MHz).

If no external requests are pending, the next instruction in the normal program flow is executed. All indirect and auto-index, memory-reference instructions go through a common state sequence to generate the effective address of the operand. The subsequent sequence, known as the execute phase, is controlled by the functional class of the instruction. Internal and external IOT instructions have identical state sequences. Device addresses and the control bit are available in the external address register for internal IOT instructions.

Prototyping is simple, says Simon

The Simon prototyping microcomputer system is a 6100-based computer that has a buffered bus structure with three-state TTL-compatible I/O lines. It provides a simple way to evaluate 6100-family systems and components.

The basic system, described in Table 2, comes
5. This short program helps to interface the 6100 with a serial ASCII device such as a teletypewriter. When information is entered via the keyboard, the 6100 echoes the characters back on the printer.

with a control panel (similar to DEC’s PDP-8/E), 4 k words of CMOS memory (with battery back-up for nonvolatility) and a PDP-8/E compatible teletypewriter interface designed for a 20-mA current loop.

All these functions fit on three boards. A fourth board slot inside the Simon cabinet can accommodate user-designed circuits. A built-in 5-V power supply can handle the three boards, the front panel and almost any built-in user circuit.

Simon executes the basic PDP-8/E paper-tape software supplied by DEC. However, to write a program using the Simon system, the symbolic editor can be used to generate the ASCII symbolic program by interactive entering and editing. Next, the symbolic program gets assembled by the PAL-III program—a two-pass assembler.

On the first pass of the assembler, all user symbols are defined and stored in an assembler symbol table. During the second pass, the binary equivalent of the input source language is generated and, if desired, punched.

Two service programs, ODT and DDT, can be used to run the user program and to use the teletypewriter keyboard to control program execution, examine registers, change register contents and make alterations to the user program. With DDT, you can debug the programs by using the symbolic language of the source program, whereas the ODT gives you the octal representation.

A cross-assembler, FOPAL-III, is identical to PAL-III but can run on any computer that supports Fortran. ■ ■

Previous articles in this series covered the 8080, F-8, 6800, 2650 and the 1802 microprocessors. The next article will discuss the PACE.

<table>
<thead>
<tr>
<th>Part number</th>
<th>Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>0656-SW PDP-8/E</td>
<td>Extended software kit: Binary loader, PAL III assembler, Symbolic editor, DDT—dynamic debugger, ODT (low)—octal debugger, ODT (high)—octal debugger, RIM and binary punch, Octal memory dump, PDP-8 23-bit floating-point package.</td>
<td>$212.50</td>
</tr>
<tr>
<td>1656-SW FOCAL-8:</td>
<td>An interactive algebraic language. It is similar to Basic &amp; Fortran in many respects.</td>
<td>$152.50</td>
</tr>
<tr>
<td>2656-SW PDP-8/E</td>
<td>Diagnostic software: This software package consists of programs to perform extensive tests on the processor, memory and the teletype writer.</td>
<td>$400.00</td>
</tr>
<tr>
<td>3656-SW FOPAL-III:</td>
<td>This is a cross assembler written in standard Fortran.</td>
<td>$125.00</td>
</tr>
<tr>
<td>6900-S SIMON:</td>
<td>Prototyping system used for software and hardware development. (Includes 0656-SW)</td>
<td>$3300.00</td>
</tr>
</tbody>
</table>

DECUS: Digital Equipment Computer Users Society—This is a library of users programs. Listed are some of the categories available to any users:

- Programming language, monitor, programming system
- Text editing, text manipulation
- Debugging, disassembly, simulation, trace, dump
- Binary loading, binary punching
- Duplication, verification
- Numerical function, numerical input-output
- Utility
- Display
- Data management, symbol manipulation, sorting
- Probability, statics, curve-fitting
- Scientific application, engineering application
- Hardware control
- Games, demonstration
- Plotting
- Desk calculator, business applications
- Maintenance

Table 2. Software support
Who provides the industry's broadest line of electronic packaging hardware... including A New High-Density Lever Switch?

SAE does! We’re proud to announce the development of a completely new and patented switching concept called the SAE switch (which stands for Side And Edge™). The switch consists of multiple positions; each actuated by a lever that interconnects opposite sides of a PCB with a horseshoe-shaped terminal.

Based upon the layout of the circuit board, the switch allows for SPST, SPDT, SPST-DB and DPDT contact closures.

Mounting in either a horizontal or vertical position, the SAE switch reduces overall front panel area; eliminates the need for interconnecting cables or connectors, as well as knobs or dials. Levers are on .140” or .156” centers for easy actuation.

Available in an unlimited number of switching positions in length and in up to three board widths, the switch can accommodate 150 switching positions in only 34 square inches! Our new brochure gives the complete details... send for it now!

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For your copy of our reliability report or complete resistor network data, write: CTS OF BERNE, INC., 406 Parr Road, Berne, Indiana 46711. Phone (219) 589-3111.
Use conductive elastomers to simplify switch design and to make high-density connections from PC boards to LED displays, ICs and other boards.

Conductive elastomers have had a strong influence on the design of electronic circuits and devices in the last few years. Their unique mechanical and electrical properties have already facilitated their use as signal-measurement and transmission probes, RFI shields and static arrestors.

More recently, conductive elastomers have been used to connect PC boards to LEDs flat packs, leadless ICs, other PC boards, and replace switches.

They significantly reduce materials and manufacturing costs as well as improve product reliability.

Because of the amorphous nature of these materials, they can be shaped many ways. It is not necessary, for instance, to arrange connectors in a linear pattern or bring sets of printed-circuit connectors to an edge tab.

In addition, fabrication techniques produce elastomers having characteristics that permit 7000, or more, interconnections per square inch.

These materials are made in many shapes

Conductive elastomers are easily formed into sheets, films, rods and foams. Various sizes, thicknesses, densities and even precision-molded dimensions can be specified. The material makes a better electrical connector than a metal-to-metal connector because it conforms to the contacting surfaces; consequently, a wider area carries current at the point of contact. The material flexes indefinitely without changing its mechanical or electrical properties, yet is soft enough to dampen shock and vibration.

Moreover, these elastomers won't corrode, and many of them are self-sealing—tears and punctures close up tightly enough to keep out adverse elements. Also the conductivity is not affected by particles of dirt or other contaminants.

Yet with all of these desirable properties, the material is made from only two substances.

Charles H. Kuist, Vice President, R&D, Chomerics, Inc., 77 Dragon Court, Woburn, MA 01801.
Alternate layers of conducting and nonconducting elastomers produce a material that connects PC board contacts to external components.

Conductive elastomers are blends of normally insulating elastomers, called matrix materials, and minute particles of conductive materials called fillers. The filler density is high enough that the particles are in constant contact and form discrete, low-resistance paths from one surface of the material to the other.

The most popular matrix material for electrical-contact applications is silicone rubber, which remains stable at temperatures ranging from -100 to 400 F, and resists moisture, oxygen, ozone, and ultraviolet light. Other matrix materials are polyurethane, ethylene-propylene-diamene (EPDM) rubber, butyl rubber, neoprene, and vinyl. All offer specific advantages for specific applications.

The fillers are selected for their required resistivities and include carbon—the most widely used and the least expensive—silver or silver compounds, gold and nickel. Tin, zinc, and conductive oxides have been tried but have proved much less effective. The filler can account for up to 85% of the weight of a conductive elastomer and usually has a thermal conductivity 5 to 10 times that of the matrix material alone.

Reduce mechanical assembly costs

A conductive elastomer can be used as a switch element in a digital watch (Fig. 1). In this application, the elastomer is formed into pads made of a mixture of silicone rubber and metal powder (Table 1, Material A). The material replaces beryllium-copper spring fingers used in an earlier version.

Although the elastomer pads are more expensive than metal connectors, they eliminate so much soldering labor that they considerably re-
### Table 1. Properties of conductive elastomers

<table>
<thead>
<tr>
<th>Property</th>
<th>Switch Elements Material A carbon, silicone</th>
<th>Display Mounting Material B silver-plated-copper spheres, silicone</th>
<th>High-Density Interconnectors, Material C Type A</th>
<th>Type B</th>
<th>Type C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness, in.</td>
<td>0.020 min</td>
<td>0.030 min</td>
<td>0.005 nom</td>
<td>0.010 nom</td>
<td>0.030 nom</td>
</tr>
<tr>
<td>Density, gm/cc</td>
<td>3.65</td>
<td>200</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Tensile strength, lb/in.²</td>
<td>200</td>
<td>200</td>
<td>10 to 15</td>
<td>10 to 15</td>
<td>10 to 15</td>
</tr>
<tr>
<td>Tear strength, lb/in.</td>
<td>120</td>
<td>-</td>
<td>10 to 15</td>
<td>10 to 15</td>
<td>10 to 15</td>
</tr>
<tr>
<td>Elongation, %</td>
<td>60-70</td>
<td>42</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hardness, Shore A</td>
<td>30-50</td>
<td>25 to 40</td>
<td>45</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>Deflection at 100 lb/in.², % of thickness</td>
<td>200</td>
<td>10 to 15</td>
<td>10 to 15</td>
<td>10 to 15</td>
<td>10 to 15</td>
</tr>
<tr>
<td>Recommended pressure, lb/in.² (max)</td>
<td>14</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Compression set, % Note 3</td>
<td>14</td>
<td>10</td>
<td>10 to 125</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Continuous use temperature, C</td>
<td>-55 to 125</td>
<td>-55 to 125</td>
<td>-55 to 125</td>
<td>-55 to 125</td>
<td>-55 to 125</td>
</tr>
<tr>
<td>Shock resistance, G (max)</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Contact size, in.² (min)</td>
<td>-</td>
<td>-</td>
<td>0.006</td>
<td>0.012</td>
<td>0.024</td>
</tr>
<tr>
<td>Contact spacing, in. (min)</td>
<td>-</td>
<td>-</td>
<td>0.006</td>
<td>0.012</td>
<td>0.024</td>
</tr>
<tr>
<td>Conductive path width, in. (min)</td>
<td>-</td>
<td>0.010</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Spacing between path centers, in. (min)</td>
<td>-</td>
<td>0.020</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Recommended compression, % (max)</td>
<td>-</td>
<td>25</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Current carrying capacity per sq. in. of conducting surface, A</td>
<td>50</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>DC voltage resistivity, ohm-cm (max)</td>
<td>0.010</td>
<td>-</td>
<td>0.05</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>VA for minimum pad size (max)</td>
<td>-</td>
<td>-</td>
<td>200</td>
<td>500</td>
<td>700</td>
</tr>
<tr>
<td>Breakdown voltage between adjacent contacts, V</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Current carrying capacity per path, mA Note 1</td>
<td>-</td>
<td>&gt;50</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Resistance along path, ohm/in. Note 1</td>
<td>-</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Breakdown voltage between adjacent paths, V Note 1</td>
<td>-</td>
<td>600</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Capacitance between adjacent paths, pF/in. Note 1</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Note 1:** For 0.010-in. conductive paths on 0.020-in. centers.

**Note 2:** Maximum thickness depends on geometry.

**Note 3:** % of original height loss after 25% deflection for 72 h at 125 C.

---

4. These are just a few of the many unusual shapes that are possible with conductive rubber paths vulcanized into a nonconductive rubber base.

5. An elastomer can conduct only in the direction to which pressure is applied. The filler consists of spherical metal balls that only come in contact with each other under pressure.
6. The resistance between opposing contacts is less than 1 Ω. And resistance between adjacent contacts is greater than 1000 MΩ with this material.

Table 2. Manufacturers of conductive elastomers

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Address</th>
<th>Phone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chomerics</td>
<td>77 Dragon Ct. Woburn, MA 01801</td>
<td>(617) 935-4850</td>
</tr>
<tr>
<td>Emerson &amp; Cuming, Inc.</td>
<td>869 Washington St. Canton, MA 02021</td>
<td>(617) 828-3300</td>
</tr>
<tr>
<td>Metex Corp.</td>
<td>970 New Durham Rd. Edison, NJ 08817</td>
<td>(201) 287-0800</td>
</tr>
<tr>
<td>Spectrum Control, Inc.</td>
<td>152 E. Main St. Fairview, PA 16415</td>
<td>(814) 474-5593</td>
</tr>
<tr>
<td>Instrument Specialties Co., Inc.</td>
<td>244 Bergen Blvd. Little Falls, NJ 07424</td>
<td>(201) 256-3500</td>
</tr>
<tr>
<td>Tecknit</td>
<td>129 Dermody St. Cranford, NJ 07016</td>
<td>(201) 272-5500</td>
</tr>
</tbody>
</table>

duce over-all package costs.

The pads are retained in slots in the watch’s plastic housing, but for other applications the elastomer can be laminated to metal surfaces or bonded with adhesives.

Another elastomer material, called Cho-strel, has conductive-rubber paths vulcanized into a nonconductive rubber base (Table 1, Material B). The material is only 0.030 in. thick, can be easily compressed, but will not separate even under severe pressure. As shown in Fig. 2, the material can be die cut into any desired shape.

This one-dimensional discrete-path conductive elastomer is used for mounting displays close to an outside surface to enhance the appearance of digital-panel meters and other products (Fig. 3). Such up-front mounting is difficult to achieve with conventional spring-clip connectors.

Because it is produced in a variety of shapes and sizes (Fig. 4), this elastomer can be used in place of metal-edge connectors for such applications as interconnecting linear arrays, flexible circuits, PC boards, LCD and gas-discharge displays, and calculator keyboards. For these applications, designers have a choice of conductive-path widths and path spacing and can design their contact configurations accordingly. The typical path width is 0.01 inch and spacing is on

7. An elastomer for high density connections requires no orientation during assembly. Since it flexes up to 15% of its thickness under pressure, variations in connector flatness up to this limit may be accommodated.
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0.02-inch centers.
The material is able to flex up to 40% of the material thickness under a pressure of 100 lb in². This flexibility allows the material to mate surfaces varying in flatness. The flatter the contact plane, the higher the connector density.

High-density interconnections

A conductive elastomer can exhibit short-range conduction—conductive paths are created through, not across the material—to make high-density interconnections.

The material consists of a silicone matrix and a filler of spherical metal particles with carefully controlled diameters, which are dispersed to form small clusters (Fig. 5).

Since there is no continuous contact across the face of the elastomer, the contacting area must be wide enough to touch enough clusters so that a conduction path can be made through the elastomer. When the contacting area for this material exceeds 85 square mils, enough clusters carry current through the elastomer. The connection reliability is above 99.9% for a contact area above the minimum square mils.

When the die-cut sheet is sandwiched between opposing contacts, the resistance through the sheet will be less than 1 Ω, and the resistance between adjacent contacts greater than 1000 MΩ (Table 1, Material C).

As shown in Fig. 6, this construction allows the electrical interconnection of any configuration of independent contact pairs. The contact pairs must be separated by a distance equal to or greater than the thickness of the elastomer.

Another advantage of this high-density interconnection is that it requires no particular orientation at assembly (Fig. 7). Contacts that vary in height, up to the limit of elastomer deformation—15% of its thickness—still produce reliable connections.

Since the elastomer’s silicone is flexible, greater thermal expansion or contraction can be tolerated than with other high-density connectors.

The material will handle 6-mil contacts on 12-mil centers, so that nearly 7000 connections per square inch can be made. It should be possible to make an elastomer that will handle 4-mil contacts on 8-mil centers.

For such interconnections the cost per contact decreases as the number of contacts increases.

While typical applications involve interconnecting electronic devices and substrates, the elastomer is being considered as an alternative to conventional IC-wire bonding. If this alternative proves successful, it will not only reduce package costs by eliminating the gold wire and associated labor but will also permit salvaging an IC package in the event of defective assembly. **
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A ‘simplified’ notch-filter design?
When you see a published application circuit that looks useful, beware! It might not work as well as you wish.

Anyone who has searched through the literature for notch filters has probably run across a gyrator circuit (Fig. 1a).\(^1\)\(^2\)\(^3\) The circuit appears straightforward enough and looks better than the twin-tee filter (Fig. 1b). The twin tee requires you to match capacitors for best performance. The gyrator circuit has no capacitor-matching requirements, and it uses op amps that are widely available at low cost.

But getting the gyrator circuit to perform is not as easy as it looks.

**Gyrator-circuit operation**

The circuit gyrates (transforms) capacitor \(C_2\) to look like an inductor \((L = R_2 R_3 C_2)\) in series with \(R_1\) and \(R_5\) (assume gyrator amplifier \(A_1\)'s gain \(K\), equals 1). At series resonance \((X_C_1 = X_L)\), the output will be zero if

\[
\left(\frac{R_1 + R_6}{R_6}\right) = \frac{R_2}{R_1},
\]

and the op amps are ideal.

The center frequency may be changed by varying the ratio of \(R_1\) and \(R_5\) with a pot.

One such gyrator with a \(Q\) of 10 and a center frequency of 1 kHz was constructed with a dual op amp. But the notch attenuation was only 6 to 10 dB. What was wrong? Let’s look again at our previous assumptions:

a) \(K = 1\), and

b) the op amps are ideal, or:

- \(A_{OL} = \infty\), open-loop gain.
- \(BW_{OL} = \infty\), open-loop bandwidth.
- Distortion = 0%.

Where did we go wrong?

First, let’s look at the problem of poor attenuation at the center frequency. The gain of the circuit can be simplified to:

\[
A = \left| \frac{E_0}{E_i} \right| \approx \frac{4Q^2(1 - K)}{1 + 4Q^2(1 - K)}
\]

1. The notch filter (a) as it appears in application notes for op amps seems quite simple. The classical twin-tee notch filter (b) requires that the capacitors and resistors be matched for maximum notch attenuation.

---

Robert E. Williams, Research Instructor, Dept. of Ophthalmology, Baylor College of Medicine, 1200 Moursund, Houston, TX 77054.

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*Electronic Design* 23, November 8, 1976
The circuit gain at the center frequency is very sensitive to small changes in \( K \). If, for example, \( K = 0.999 \), instead of 1, circuit gain will be 4/14, with a \( Q \) of 10, instead of zero.

The closed-loop gain of \( A_2 \) can easily be lower than 0.999 since a 741-type op amp can have an open-loop gain of only 1000 at 1 kHz, the spec-sheet typical. The gain of the gyrator circuit must be boosted to compensate for this possibility. However, the gyrator gain must not be boosted too far. As \( K \) approaches the value \( 1 + 1/4Q^2 \), then \( E_{o}/E_{i} \) approaches infinity.

Next, look at the voltage gain from the circuit input to the gyrator output when the input frequency equals the notch-center frequency:

\[
\frac{V_2}{E_i} = \frac{R_2}{R_1 + R_2} \sqrt{1 + \left(\frac{(R_1 + R_2)}{R_2} Q\right)^2} \approx Q
\]

An input signal at the notch frequency can be within the amplitude range of the over-all circuit, yet may overdrive \( A_2 \)'s output when high notch \( Q \) is specified. With increasing \( Q \), the input-to-output voltage gain, \( A \), approaches unity, but the \( V_2/E_i \) gain increases linearly. Of course, this reduces the attainable attenuation in the notch and produces a distorted waveform at the filter's output.

**Here is a workable solution**

The circuit of Fig. 2 illustrates a workable solution to both problems. The input circuit of \( A \), divides by \( Q \) so that the gyrator amplifier will operate linearly. The output circuit of \( A_1 \), amplifies by \( Q \) so that the total circuit will have unity gain in the pass band.

You must adjust three pots in this circuit for best performance. First, adjust \( R_1 \) for the desired notch frequency. Next, alternately vary \( R_2 \) and \( R_c \) for maximum attenuation at the notch frequency.

Pot \( R_1 \), is added to set \( A_2 \)'s gain exactly equal to unity. Pot \( R_c \) adjusts the resistor ratio around \( A_1 \) so that the notch-frequency attenuation is maximum.

So the simple becomes complicated. A two-op-amp notch filter expands into a four-op-amp notch having, possibly, three potentiometers.

Oh well, you can always use a twin tee. ■

**References**

Replacing four 2102s

If you’re designing the 2102 into any application, stop. Look at our new SEMI 4804A.

It will quadruple your density, cut your power per bit in half. One SEMI 4804A static 1K x 4 RAM replaces four 2102s (or 2112s). It operates on 5V (but will protect data down to 1.5 Vdd), reads and cycles in 450 nsec., and is packaged in an 18-pin DIP.

The SEMI 4804A is second-sourced, and is available now from your local EMM SEMI distributor. (If you need 4K x 1 organization, ask about our new SEMI 4801. That’s available immediately, too.)

Write or call today for full details.
Reliability test results:

Matrix Reliability Test:
"TRW's 2,000 VDC - 16,000 VDC metallized polyester capacitors indicate MTBF (90% confidence limit) greater than 250,000 hours at rated voltage."

TRW's X675HV series is designed to meet the requirements of voltage multipliers and high voltage filters in high density, high voltage power supplies, instrumentation, data displays, pulse modulators and copiers.

They're smaller, lighter, self-healing and eliminate wet components which can bleed, crack and wreck a board.

The standard design is metallized polyester with axial leads, tape wrap and epoxy endfill case. Insulation resistance is 30,000 megohms x MFD and the dissipation factor is less than 1% at 1000 Hz.

The X675HV series can replace traditional dielectrics in many applications with substantial savings in size at comparable lower costs. On quantity orders, modifications can be made to your specifications.

Want to know more? Use the coupon for complete specs on the X675HV series — or information on any dielectric you require.

TRW Capacitors
An Electronic Components Division of TRW, Inc.
301 West "O" Street,
Ogallala, Nebraska 69153.

Please send me specs on your new X675HV capacitors
I'd also like a copy of the matrix test results
Please have someone contact me.

Name

Firm Name

Address

City State Zip
Inexpensive triggered-sweep generator updates recurring-sweep scopes

Here's a way to make the trace on your old Eico, Heath, or similar recurring-sweep unit stand still. The circuit (see figure) provides a stable, triggered sweep at moderate speeds with good linearity.

Transistor Q₁ conducts in the quiescent state of the circuit and "shorts" the sweep-timing capacitor. When a triggering signal exceeds approximately 6 V at the input of G₁, the Schmitt trigger (made of G₁ and G₂) switches, causing flip-flop G₃/G₄ to change state. This state change turns off and holds off Q₄.

Constant-current source Q₂ then can charge a selected timing capacitor, C₁, C₃, or C₉. The rising capacitor voltage drives the scope's horizontal amplifier through the Darlington follower, Q₃ and Q₄.

This drive signal also appears at the input of a second Schmitt trigger, G₃ and G₄. Upon reaching approximately 6 V, this signal resets flip-flop G₃/G₄, which turns on Q₁, causing it to discharge the timing capacitor.

Another sweep cannot be initiated until the first one is completed, because one of the G₃ inputs inhibits triggering, when the flip-flop's G₃ output is HIGH.

The charging rate for the timing capacitor is regulated by the variable 20-kΩ potentiometer in the Q₃-emitter circuit. With the values shown, the variable control can provide a 10:1 variation in sweep time for each capacitor. Sweep rates from 10 μs div to 10 ms div may be selected for a 10-division horizontal display.

The Darlington output of Q₄ is returned to a negative power source to keep the Darlington in conduction for improved linearity. Diodes D₃ and D₄ provide input protection for G₃; diodes D₁, D, and D₅ establish bias for Q₄.

The CMOS gates are contained in two CD-4001AE chips; two gates are unused. The unused gates may be connected to provide retrace blanking at high sweep speeds.

Of course, other sweep speeds may be obtained with timing-capacitor values other than those shown. Trim resistors and capacitors may be added for more accurate calibration.

Also, the trigger source can be switch-selected for polarity or for external, or line, sources. You can make this sweep generator as simple or as fancy as you wish.

W. J. Woodward, Senior Engineer, Savannah River Laboratory, E. I. du Pont de Nemours & Co., Aiken, SC 29801.

CIRCLE No. 311
Sprague puts more passive component families into dual in-line packages than any other manufacturer.

Call Sprague First!

Solid-electrolyte tantalum capacitors with 2 or 4 sections per package. Standard ratings are 6.8 μF @ 35V, 15 μF @ 20V, 22 μF @ 15V, 33 μF @ 10V. Capacitance tolerance, ±20%. Operating temperature range, −55°C to −85°C. Write for Bulletin 3542 or circle 151 on reader service card.

Monolithic® construction... alternate layers of ceramic dielectric material and metallic electrodes are fired into a solid homogenous block. 2, 4, 7, or 8 capacitor sections per package. Standard ratings, 10 pF to 0.1 μF @ 100V. Capacitance tolerance, ±20%. Write for Bulletin 6242 or circle 152 on reader service card.

Solid tantalum and Monolythic® ceramic alternating isolated sections. Choice of 4 or 8 sections per package. Standard tantalum ratings, 6.8 μF @ 35V, 15 μF @ 20V, 22 μF @ 15V, 33 μF @ 10V. Ceramic ratings .01, .047, .1 μF @ 100V. Cap. tol., ±20%. Write for Engineering Bulletin 6642 or circle 153 on reader service card.

Metanet® metal-film resistors and Monolythic® ceramic capacitors in bypassed pull-up, R-C coupling, speed-up, and active terminator networks. Resistor ratings, 100 to 6800 Ω with 125 mW power dissipation. Capacitor ratings, 100 pF to .01 μF @ 100V. Write for Engineering Bulletin 6612 or circle 154 on reader service card.

Noble metal film resistors encased in protective glass. Choice of 7 or 8 resistors per 14- or 16-pin package. Resistance values, 50Ω to 100,000Ω. Power dissipation, 125 mW. Standard resistance tolerance, ±5%. Operating temperature range, −55°C to +70°C. Write for Bulletin 7042 or circle 155 on reader service card.

Noble metal film resistors in pull-up, pull-down, interface, and terminating configurations, for applications requiring repetitive resistance patterns. 14- or 16-pins. Up to 28 resistors per package. Individual resistors from 50 to 100,000Ω. Dissipation, 125 mW. Write for Bulletin 7042 or circle 156 on reader service card.

Four transformers in 16-pin package. All cores have exclusive protective coating. Inductance values from 10 to 1000 μH. ET product values of 5 volt-μsec. Choice of four turns ratios... 1:1, 2:1, 3:1, 4:1. Operating temperature range, 0°C to +70°C. Write for Engineering Bulletin 40400 or circle 157 on reader service card.

Lumped constant delay lines... ideal for timing and pulse synchronization circuits. 14- or 16-pin packages with delays of 50, 100, or 150 nanoseconds at a characteristic impedance of 100Ω. Working voltage, 50 VDC. Operating temp. range, 0°C to +70°C. Write for Bulletin 45004 or circle 158 on reader service card.

Interface CMOS to TTL with diodes and save the cost of expensive buffers

The next time you have to interface CMOS ICs to TTL, don't search for a buffer chip or a discrete-transistor level changer. Put some inexpensive junction diodes to work and save a bundle. Connect almost any signal diode between the CMOS output and the TTL input (Fig. 1). A diode array, such as Fairchild's monolithic CA3039, works very well.

When the CMOS output is HIGH, the diode is reverse biased, and the TTL input assumes a HIGH level. When the CMOS output goes LOW, the diode conducts, and the current is provided by the TTL input.

The CMOS output has good current-sinking characteristics, so that the small forward current of the diode is easily handled. The 0.6-V drop across the diode is well below the specified LOW level for TTL. The diodes must be able to handle the highest reverse bias: The CMOS, \( V_{ee} \), can be as high as 15 V.

Sudarshan Sar pangal, Electronic Engineer, Power Group and Puttaiah, Electrical Engineer, Telemetry Group, Isro Satellite Systems Project, Peenya Industrial Estate, Peenya 562 140, Bangalore, India.

CIRCLE NO. 312

1. An inexpensive CMOS-TTL interface can be made of a diode array or of individual signal diodes. The diodes must be able to withstand a reverse voltage equal to \( V_{ee} \) and to have a forward drop less than the TTL LOW level.

Remotely control a pocket calculator with a simple CMOS interface circuit

Pocket calculators, when properly interfaced, can accept inputs from a digital multimeter or frequency counter and process the data. One frequent requirement is the calculation of mean value. This is especially useful to obtain a "smoothed" value, \( \bar{E} \), of a noisy signal, \( E_n \), as expressed by

\[
\bar{E} = \frac{1}{N} \sum_{i=1}^{N} E_i.
\]

The basic instructions to the calculator to perform this averaging is as follows:

- C CE—clear calculator
- E, —data entry
- +
- E, —""
- +
- .
- .

\[ E_n \] = —sum of entries
\[ \div \] = —divide
\[ N \] = —number samples entry
\[ = \] = —display of mean value

In the figure, a standard arrangement of 9-V-operated calculator-chip, keyboard matrix, LED-display and segment driver are supplemented with additional CMOS hardware to achieve the remote-control operation. The digit outputs, \( D_i \), through's \( D_{11} \), of the calculator chip are sequential nonoverlapping pulses. Pulse \( D_{11} \) appears first. The pulses multiplex the display digits and also provide control signals for the calculator-chip input, KO, which enters the functions, and KN, which enters the numbers.

Entry of the number 6, for example, requires a contact closure at the corresponding keyboard cross point and pulse \( D_i \) to cause the entry of a
The most important part of every Honeywell tape system.

Common sense is basic to the Honeywell tape engineering philosophy. When we innovate for one tape product, we believe it's only common sense to apply that technology to other tape products in our broad line—lab, portables, high environmental and airborne recorders. The result is almost always a solution exactly right for your recording needs.

But if it's not, common sense dictates that we provide you with a custom tape system. Our consistent success with custom tape applications is common knowledge in the industry.

For more information and a catalog of our high-performance common-sense tape solutions, write or call Chuck Miller at Honeywell Test Instruments Division, P. O. Box 5227, Denver, Colorado 80217. (303) 771-4700.

Honeywell
IDEAS FOR DESIGN (CONTINUED)

number 6 via the calculator chip's KN input. The contact must remain closed for the keyboard de-bounce time (about 25 ms).

In remote-control operation, D₁₁ resets the 74C93 CMOS counter. Pulses D₁ to D₁₁ are ORed with diodes and provide a pulse train, DS, which is counted by the 74C93. The counter output is a binary-code equivalent of the 1-out-of-N output code of the calculator chip.

The output of the counter is compared via a 74C85 with an external input, ABCD. When equal, the 74C85's output, labeled A = B, goes high. A program-initiate pulse, PP, directed by input E, allows entry of numbers or functions into KN or KO, respectively. The width of PP must at least equal the keyboard debounce time. Signal E, when LOW, interprets signals ABCD as functions, and when HIGH, as numbers, as follows:

<table>
<thead>
<tr>
<th>E = 0</th>
<th>E = 1</th>
<th>DCBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>0</td>
<td>0000</td>
</tr>
<tr>
<td>MS</td>
<td>1</td>
<td>1001</td>
</tr>
<tr>
<td>C/CE</td>
<td>2</td>
<td>1000</td>
</tr>
<tr>
<td>MR</td>
<td>3</td>
<td>0111</td>
</tr>
<tr>
<td>+</td>
<td>4</td>
<td>0110</td>
</tr>
<tr>
<td>×</td>
<td>5</td>
<td>0101</td>
</tr>
<tr>
<td>=</td>
<td>6</td>
<td>0100</td>
</tr>
<tr>
<td>+</td>
<td>8</td>
<td>0011</td>
</tr>
<tr>
<td>–</td>
<td>9</td>
<td>0001</td>
</tr>
</tbody>
</table>

Peter A. Ernst, Institut fur Regelungstechnik, Universität Erlangen-Nürnberg, Cauerstrasse 7, 8520 Erlangen, Germany.

A standard pocket-calculator configuration is easily converted for the remote input of data and function control. A CMOS counter, comparator and several gates interface the calculator to external data.

IFD Winner of July 5, 1976

Michael S. McNatt, Senior Engineer, LaBarge Inc., Electronics Div., 6540 E. Apache, P.O. Box 36, Tulsa, OK 74101. His idea “Computer Sound Effects Generated with Only Four ICs” has been voted the Most Valuable of Issue Award.

Vote for the Best Idea in this issue by circling the number of your selection on the Reader Service Card at the back of this issue.

SEND US YOUR IDEAS FOR DESIGN. You may win a grand total of $1050 (cash)! Here's how: Submit your IFD describing a new or important circuit or design technique, the clever use of a new component or test equipment, packaging tips, cost-saving ideas to our Ideas for Design editor. Ideas can only be considered for publication if they are submitted exclusively to ELECTRONIC DESIGN. You will receive $20 for each published idea, $30 more if it is voted best of issue by our readers. The best-of-issue winners become eligible for the Idea of the Year award of $1000.

ELECTRONIC DESIGN cannot assume responsibility for circuits shown nor represent freedom from patent infringement.
Check our standard features:

- 10 models, 1.8V to 56V with power levels ranging up to 225 watts.
- 115/220 Vac input by external barrier strip change.
- 50/60-Hz operation with no derating.
- Logic shutdown for system applications.
- Extra long hold-up time.
- Low ripple and noise through use of double-stage filtering.
- Wide-range output voltage adjustment.
- Built-in adjustable overvoltage protection.
- Superior line and load regulation.
- Internal adjustable current limiting.
- UL component recognition.
- High power-to-weight ratio.
- 20-kHz switching.
- Rack adaptors available.
- Immediate delivery.
- Made in U.S.A. of quality components.
- Five-year warranty, backed by worldwide service organization.

Check our specifications:

**AC Input Power:** 98 Vac-132 Vac, 187 Vac-250 Vac.
- Frequency: 47-63 Hz single phase. 360-440 Hz (double rms Ripple spec.) No derating. Voltage selectable by a single link on the front panel.
**Voltage Regulations:** Line: 0.03% over full AC input range. Load: 0.03% for zero to full load.
**Voltage Ripple:** Typical 2mV rms, 20mV pk-pk (20Hz to 20 MHz). Max. 5mV rms, 50mV pk-pk (20Hz to 20MHz).
**Temperature Coefficient:** 0.01% max. per °C.
**Stability:** 0.05% max. for 24 hours after warm-up.
**Transient Response Time:** Output voltage returns to within 1% in less than 1.2 ms following a step-load change from either 50% to 100% or 100% to 50% of full load.
**Overshoot:** No overshoot at turn-on, turn-off or power failure.
**Hold-Up Time:** Full regulated voltage holds up for 40ms after removal of power at full load, and nominal input and output voltages (80ms for half load).
**Overvoltage Protection:** Built-in adjustable overvoltage protection standard on all models.
**Efficiency:** Up to 76%.
**Remote Sensing:** Voltage drops can be compensated for up to the max. specified terminal voltage.
**Paralleling:** May be directly paralleled without derating.
**Soft-Start:** In-rush current is limited by soft start circuit.
The Teletype model 40 OEM printer. When you look at it from price and performance, you'll find it difficult to look at anything else.

The fact of the matter is simply this:
We don’t think any other printer can even come close to the model 40.

And that’s no idle boast. Not when you consider the facts.

Consider: Where else can you get a 132-column, heavy-duty impact printer that delivers over 300 lines per minute for less than $2000, or an 80-column printer for under $1400?

The big reason behind the model 40’s price/performance advantage is our unique design. Even though it operates at speeds of more than 300 lpm, wear and tear is less than you’d find in a conventional printer operating at considerably slower speed. Fewer moving parts and solid-state components add up to greater reliability and reduced maintenance.

Here’s something else to consider: Where else can you get a printer that delivers the kind of flexibility and reliability the model 40 offers?

For complete information, please contact our Sales Headquarters at 5555 Touhy Ave., Skokie, Ill. 60076. Or call Terminal Central at: (312) 982-2000.

The Teletype model 40 OEM printer. Nothing even comes close.
Scope combines fast storage and real-time operation

The only catch to using the speed (if it is a catch) is that the 7834's operation is limited to the central $8 \times 10$-division graticule of the CRT ($0.45 \text{ cm/div}$ in reduced-scan mode).

Perhaps more significant than the 7834's storage speed is its ability to function also as a real-time scope with a 400-MHz bandwidth, coupled with its ability to house up to four 7000-Series plug-ins.

In terms of performance, here are some benefits these capabilities bring:
- You can look at rise times up to 0.9 ns over the full-screen amplitude of eight graticule divisions ($0.9 \text{ cm/div}$).
- You can use real-time and spectrum analyzer plug-ins together to “step” simultaneously into the frequency and time domains of high-speed phenomena.
- You can zero in on a digital problem with a logic-analyzer plug-in, then pinpoint the electrical cause—be it noise or whatever—in the real-time mode.
- Or you can choose plug-ins for sampling, TDR, counting, multimeter functions, and more. Parameters associated with the displayed waveforms can be read out alongside the waveforms.

Want a detailed look at what you’ve captured? Go into the 7834’s bistable storage mode, which retains images for long periods, and analyze at your leisure. Got a slowly moving waveform? Use the variable-persistence mode and watch, without flicker, while your signal’s rise time creeps to new values, or the spectral content of the signal gently changes.

Take advantage of other 7834 features, and get even more flexibility. You can plug in two time bases and set up the scope to switch between the two bases. The result: a simultaneous display of nontime-related waveforms, actually a quasi-dual-beam mode.

By using the 7834’s remote-control features (erase, save and transfer), you open up more possibilities. You can either control the storage operation remotely in hazardous areas or control the image externally to display consecutive pulses (in pulsed laser work, for example).

Other features of the Tek unit—like a programmable readout that can be used to display identifiers such as test numbers or conditions—bring even more benefits. Buy your own for $6900 and learn all the details. Delivery takes 8 weeks.

CIRCLE NO. 301

Tektronix, P.O. Box 500, Beaverton, OR 97077. (503) 644-0161. See text.

With a stored writing rate of 2500 cm/µs, the Tektronix 7834 easily outstrips the present title holder to become the world’s fastest storage oscilloscope. The lead was formerly held by a teammate, the Tektronix 466, which writes at a much slower 1350 cm/µs.

With this new top speed—that is, the rate at which a clearly visible trace can be recorded on a CRT as a signal sweeps across—you can capture a single-shot signal with a rise time of 1.4 ns and a peak-to-peak amplitude of seven divisions.
All aerosols are not alike.

The constant progression of sophistication in electronics has demanded a parallel progression in standards of purity. Industrial cleaning is one very vital link in maintaining component and system purity and reliability.

Let's look at eight important criteria and compare Miller-Stephenson products to the general aerosol industrial cleaner industry.

**SOLVENTS:**
Miller-Stephenson — Most of our aerosols contain 80% Active Ingredient, 20% Propellant.
Other Aerosol Cleaners — Active Ingredient averages 70-75%.
Miller-Stephenson — Uses only Certified Virgin Solvent.
Other Aerosol Cleaners — Some utilize reclaimed solvents. Though lower in cost, reclaimed solvents usually contain foreign substances.

**PROPELLANTS:**
Miller-Stephenson — Uses only the highest purity, safest propellants. They are nonflammable - TWA 1000 ppm.
Other Aerosol Cleaners — Many use cheap, sometimes flammable, sometimes higher order of toxicity propellants.

**FILTERING:**
Miller-Stephenson — We double filter “Freon” solvent and propellant — first with a 0.5 micron filter, then with a Millipore 0.2 absolute filter.
Other Aerosol Cleaners — Some use no filters; others only a 0.5 micron filter.

**LOADING LINES:**
Miller-Stephenson — All loading lines are dedicated to the individual ingredients used.
Other Aerosol Cleaners — Loading lines are often used for multiple products and if not thoroughly flushed, contamination will occur.

**LOADING ENVIRONMENT:**
Miller-Stephenson — Class 100 Clean Room conditions.
Other Aerosol Cleaners — Normally uncontrolled — environmental contamination can occur.

**VOLUME PRODUCTION:**
Miller-Stephenson — Our principal raw materials come direct from DuPont tankers into our 5500 gallon storage tanks through a closed system direct to container. Other Aerosol Cleaners — Low volume suppliers often load from open 55-gallon drums thereby introducing possibility of contamination.

**CONTAINER:**
Miller-Stephenson — Our new seamless cans further reduce the possibility of contamination. Other Aerosol Cleaners — Cans with soldered seams may introduce residual contaminants.

**SAFETY IN SHIPPING:**
Miller-Stephenson — Most of our “Freon” aerosol solvents are non-regulated items, exempt from all Federal Regulations “Restricted Articles”. May be Shipped Air Transport.
Other Aerosol Cleaners — Do not meet Air Transport Regulations.

MS aerosol solvents have the lowest residual contamination in the industry — some approaching 5-7 ppm. The general range for the industry is 50-130 ppm.

*Freon* is Du Pont's registered trademark for its fluorocarbon compounds.

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**miller-stephenson**
Danbury, Connecticut 06810 (203) 743-4447

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☐ Enclosed is $5.00, please send my “Trial Units” of MS-180 & Cobra Brush.
☐ Please send FREE literature and prices.

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Company _________________________________

Address _________________________________

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CIRCLE NUMBER 36
INSTRUMENTATION

Amp improves rf instruments

Wavetek Indiana, 66 N. First Ave., Beech Grove, IN 46107. (317) 783-3221. $725; 60 days.

Model 2101 is a wideband amplifier that can improve the sensitivity of rf measurement instruments and upgrade the power capability of signal sources such as sweep and signal generators. The company claims that this amplifier covers twice the frequency range of other commercially priced units. Typical 3-dB bandwidth is 0.5 to 2500 MHz. Output power for a 1-dB gain compression is +17 dBm. The gain is 30 dB and gain flatness is ±1 dB to 1000 MHz and ±1.5 dB to 2400 MHz. The noise figure is less than 10 dB and max VSWR (input and output) is 2 up to 1000 MHz and 3 up to 2400 MHz.

CIRCLE NO. 302

A NEW GENERATION OF IMAGE SENSORS

SIMPLICITY OF USE

Requiring less than a dollars worth of circuitry to drive—and barely more than that for video processing—is just one of the key features of our new “G” series image sensors. Compare the non-critical single TTL clock needed for the “G” device to the complex multi-phase clocks prescribed by others.

CIRCLE NO. 303

HALF THE PRICE

Or even less will bring you 256, 512, 768, or 1024 sensor elements on 25μ centers or up to 1728 elements on 15μ centers in our “H” series.

SUPERIOR PERFORMANCE

Low dark current allowing low light level operation, on-chip noise cancellation, and smooth spectral response from visible through infrared makes this new generation the unquestionable choice.

APPLICATIONS

Page readers, facsimile, OCR, point of sale readers, non-contact measurements and inspection and many others.

RETICON

910 Benicia Avenue, Sunnyvale, California 94086
PHONE: (408) 738-4266  TWX: 910-339-9343
Power supply added to single board µP line

Intel, 3065 Bowers Ave., Santa Clara, CA 95051. (408) 246-7501. $270, $460; stock

The SBC630 and 635 are power supplies for Intel's SBC-80 single-board computer systems. They convert 115 V or 230 V ac to regulated ±12 and ±5 V dc and include system protective features. The SBC-630 is a supply for the basic system. It powers a fully loaded SBC-80/10 single-board computer and has residual capability for external logic functions. The SBC-630 also has an extra power output at +26.5 V to power relays and displays. The SBC-635 is a high current power supply for expanded systems. It powers a fully loaded SBC-80/10 board and up to three memory, I/O and combination boards. This unit connects to the modular backbone and card-cage assemblies used to package expanded SBC-80 systems.

CIRCLE NO. 304

Mini switcher packs 250 W of wallop

Powertec, 8168 DeSoto Ave., Chatsworth, CA 91311. (213) 882-0004. $395.

Model 9E5-50C-17 delivers 5 V ±10%, 50 A of switching-regulated power in a 2.25 × 4.94 × 15.88-in. 6-lb, 3-oz package. Input voltage is 115/230 V ac +10/−20% with a 20-ms hold-up. Ripple and noise is 50 mV pk-pk, regulation is 2 mV for a 30% line change and 0.2% for a full-load change. Transient response is ≤400 µs for recovery to 0.1% with a maximum deviation of 250 mV for a 50% load change. Over-all efficiency is 80% min.

CIRCLE NO. 305

Power CA3130 amps from on-board supply

Semiconductor Circuits, 306 River St., Haverhill, MA 01830. (617) 373-9104. $19.50 to $50.50 (qty 10); stock to 2 wk.

The 3130 series of encapsulated dc supplies can power up to 30 type CA3130 op amps. Of the five models now available, four are for board mounting and one is for bench work. Three of the board units provide dual 7.5-V outputs at 60, 150 and 300 mA. They range from 2 × 2 × 0.875 to 2.5 × 3.5 × 1.25 in. The other board-supply gives you three outputs: ±7.5 V at 200 mA and 5 V at 500 mA. It is 2.5 × 3.5 × 1.25 in. The bench supply delivers ±7.5 V at 300 mA. All models feature 0.1% line and load regulation, more than 150-kh MTBF, 1-mV rms typical PARD, less than 15-C case temp rise for high line and full load, short-circuit protected outputs and —25 to +71 C operation without derating. They operate from 105 to 125 V, 50 to 440 Hz inputs and their dual outputs can be connected for 15 V.

CIRCLE NO. 306

---

We have DYNAMIC MOS RAMS. THINK ABOUT IT.

The most complete line of Dynamic MOS RAMs available. From 1024 x 1 to 4096 x 1, 16, 18 and 22 pins. 4096 x 1, 16K x 1 available 1st quarter 77.

Clip to letterhead. Rush complete list of total memories in stock.

THINK SIGNOTICS
a subsidiary of U.S. Philips Corporation

CIRCLE NUMBER 38

tiny trimmers... tiny price!

MuRata’s new line of subminiature trimmers has established a standard of performance in the economical trimmer field second to none... Alumina-base, non-combustible design, extreme resistance to solvents, and a wide 100 ohm to 2 megohm range of resistances. What’s more, they are backed by MuRata’s world-wide reputation for quality you can count on. Find out how these new pots can be put to work for you. Send for complete technical information today.

MuRata CORPORATION OF AMERICA
Rockmart Industrial Park, Rockmart, Georgia 30153
Phone: 404-684-7821/Telex: 54-2999/TWX: 810-766-1340

CIRCLE NUMBER 39

Electronic Design 23, November 8, 1976
Unit tests grounding and insulation

Associated Research, 6125 W. Howard St., Chicago, IL 60645. (312) 647-7850. $375; stock.

The Model-4027 ac Hypot and continuity tester is designed for factory testing of line-powered electrical equipment in accordance with UL specifications. Continuity is indicated by a lamp. If continuity is passed, the unit’s high-voltage test circuit is energized to a pre-set value, or may be applied gradually. Both a visual and an audible signal indicate a high-voltage stress failure and the high-voltage test circuit immediately de-energizes. Leakage current is also monitored. The leakage current detector can be adjusted over a range of 0.5 to 5 mA. You can bypass leakage testing. The unit is housed in a 12.5 × 9.75 × 9.5-in. grounded steel cabinet with a removable hinged cover. Max output test voltage is 3 kV at 5 mA. Output is continuously variable from zero to maximum and is monitored on a 4.5-in. kV meter.

Fast efficient units stabilize your lines

Topaz Electronics, 3855 Ruffin Rd., San Diego, CA 92123. (714) 279-0111. Starts at $265.

The 75-series regulators provide protection against line voltages as low as 20% below normal, while regulating output voltage to within ±5% of nominal. They are 98% efficient. These solid-state units sense and correct for voltage variations in less than one cycle. The regulator’s output has less than 0.1% total harmonic distortion. Models are available in power ratings from 600 VA to 20 kVA for single-phase, and 6 to 100 kVA for three-phase.

Get ±15 V dc from any of four inputs

Stevens Arnold, 7 Elkins St., South Boston, MA 02127. (617) 268-1170. $165 (1-9); stock to 8 wks.

Standard input ratings of R-series dc/dc converters are 12-2, +2.5; 24-3, +4; 28 ±4; and 48 ±6 V dc. These 25-W low-noise, isolated units deliver regulated ±15 V dc at up to ±830 mA. The units feature 1-mV true-rms, or 40 mA pk-pk, wideband noise measured over a 5-Hz to 20-MHz system noise bandwidth. EMI/RFI is minimized by a multiple shielded transformer, continuous six-sided case shield, and a pi-type input filter. The switching frequency is over 20 kHz. Min isolation is 1 × 10^6 Ω and 500 V dc. The device boasts 65% power-transfer efficiency that is said to be at least 10% above the usual. Fault protection includes reverse input voltage, thermal output shutdown and nonlatching current limiting. You can balance the ±15-V outputs to within ±0.5%. Regulation is ±0.1% max.
It's new
It's flexible

It could be the answer to your complex switching needs.

It's the Series 1800 from Ledex Inc. Mix both high and low current switch modules in one ganged assembly!

Wiping contacts in the low current modules keep the switching surfaces clean so they can handle from 10mA/5 volts to as much as 1A/60 volts.

Rugged bridging contacts, in the high current modules, let you switch from 10mA/20 volts to 6A/250 VAC.

There's circuit flexibility too! Select 2p2t or 4p2t circuits with self-cleaning contacts. Bridging contacts provide 2NO, 2NC or 1 NO + 1NC circuits.

Program up to 20 modules per assembly with interrelated switching action.

Momentary, push/push, interlock, reciprocal, master and reciprocal + master release functions are available.

For front panel flexibility, choose either unlighted, single or dual bulb illumination; square or rectangle caps with full or split lens. Horizontal or vertical mounting plus a wide range of legends and cap colors lets you design that "just right" look for your new product.

Ask for catalog B-5508 and see if the Series 1800 is the answer to your complex switching needs.

LEDex INC.
123 Webster Street
Dayton, Ohio 45401
(513) 224-9891
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COMPONENTS

Linear-motion pots offer 0.25% linearity

New England Instrument Co., Kendall Lane, Natick, MA 01760. (617) 873-9711. $55.50: 1-in. stroke, 1% ind. lin. (100 up); 6-8 wks.

A line of standard 1/2-in. cylindrical linear-motion potentiometers features elements made of Resisto-film—a conductive-plastic film. Resistance ranges to 50 kΩ/ in. are standard with a 10% tolerance. Independent-linearity tolerances are 1, 0.5 and 0.25%. Electrical strokes as long as 6 in. are standard, and maximum shaft drive force is 1 oz. Resolution is essentially infinite, and operational life expectancy is 10-million strokes.

CIRCLE NO. 320

Ground-fault detectors plug into outlets

KABO Electronics, 123 Bacon St., Natick, MA 01760. (617) 653-0015. Stock.

The KABO RCO 39 leakage-current monitor will immediately disconnect power upon sensing current leakages in excess of 5 mA or upon sensing low line voltages. This unit is designed to plug directly into duplex wall receptacles, as when used with portable equipment. The KABO RCO 40 is physically modified to allow use at the end of an extension cord. It also disconnects power immediately upon sensing leakages in excess of 5 mA. Both units are fail safe and must be manually reset for further operation. Rated 120 V, 15 A, 60 Hz and 1800 W, all units are factory calibrated and carry a one-year factory warranty.

CIRCLE NO. 321
Toggle switches designed for GHz range


A family of low-cost toggle switches is specifically designed for high-frequency low-energy applications. Offered in two sizes, subminiature and miniature, the switches have low internal resistance, low inductance and low capacitance. The subminiature Giga-switch is capable of operating at frequencies to 2 GHz, while the miniature Att-switch is effective to 1 GHz. The switches are available in a standard DPDT style, or with a shorting strap across two terminals for use in attenuators. Both types can be mounted in single holes, but the Att-switch can be soldered into a PC board.

LC display for clocks allows portable use

UCE Inc., 20 N. Main, Norwalk, CT 06854. (203) 838-7509. $12 (1000 up).

A 3-1/2 digit liquid-crystal display for portable digital clocks is available with either light or dark digits on contrasting backgrounds. It reads to 11:59. Referred to as Series 3603, the display is designed for single-edge mounting either with PC connectors or conductive elastomers. Alternately, the leads may be directly solderable. The over-all size is 2.75 x 1.35 in. Individual characters are approximately 0.5-in. high by 0.34-in. wide. Normal room readability is 15 to 20 ft. Units are available for reflective or transmissive and semi-transmissive or semireflective displays. This allows application both in high ambient daylight, as well as backlighting for dark bedroom visibility. Reduced power consumption allows battery life of more than one year for portable clocks.

Position sensor detects verticality

Fifth Dimension, Inc., 707 Alexander Rd., Princeton, NJ 08540. (609) 452-1200. $0.75 to $2 (1000 up); stock.

The TS3 is an omnidirectional position sensor. It is designed to be size and functionally compatible with TTL, DTL or CMOS circuitry. A SPST contact is closed only when the switch is in an upright position. Canting the switch from the vertical in any direction causes the contact to open. A proprietary design feature provides positive on-off operation. Repeatability is said to be within ±3 degrees. Mercury contacts contribute to reliable operation. Results of testing to date indicate a life in excess of 50-million cycles, when switching low-level loads. Contact resistance is below 2 Ω.

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CIRCLE NO. 322
CIRCLE NO. 323
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Bipolars—from 256 to 8K bits
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4K and 8K
MOS EROMS
available 1st quarter 77.

Clip to letterhead. Send list of total memories in stock.

CIRCLE NUMBER 44
CIRCLE NUMBER 45

Electronics Design 23, November 8, 1976
COMPONENTS

Gas-discharge display claimed to be largest
Cherry Electrical Products, 3600 Sunset Ave., Waukegan, IL 60085. (312) 689-7702. $7.71 (2000-up).
A new 1-in.-high gas-discharge display added to the Plasma-Lux line of Cherry has five digits in one planar-edge connectable package. This orange seven-segment display, W05-0001, is the largest display currently on the market, according to Cherry, and can be read at distances to 50 ft. The W05-0001 design is not multiplexed, which allows it to be easily driven from a BCD-output thumbwheel switch or a BCD-to-7-segment decoder/driver. Decimal points between digits are an optional item in volume applications.

Resistor networks track to 5 ppm
Beckman, 2500 Harbor Blvd., Fullerton, CA 92634. (714) 871-4848. $0.81; 698-1. $0.65: 698-3 (100 up); stock.
Series 698 precision film-resistor networks are economic alternatives to individual, precision, thin-film discretes. Their performance equals that of matched precision discretes, but at the price of unmatched precision discretes, according to Beckman. The molded DIP networks offer 5-ppm tracking accuracy, 1% resistance tolerance, 0.5% resistor-ratio tolerance and a 50 ppm/°C temperature coefficient. Series 698-1 consists of 15 resistors with a common terminal; Series 698-3 has eight isolated, straight-through resistors. Both series also allow you to connect resistors within the network in series or parallel to vary resistance values. The networks meet all MIL-R-83401 requirements except power. Total package power dissipation at 25°C is 1.25 W for both models. Individual resistor power rating at 25°C is 0.125 W for the Series 698-1 and 0.2 W for Series 698-3. Operating and storage temperature range is -65 to 125°C.

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Current-ladder networks now second sourced
Hycomp Inc., 146 Main St., Box 250, Maynard, MA 01754. (617) 897-4578. $21: HC 130L/LA, $38: HC 20L/4306 (100 up).
A line of nichrome thin-film current ladder networks that are electrically and mechanically interchangeable with the Analog Devices’ AD 850 series is now offered by Hycomp. The HC 130 and the HC 130A (replacements for the AD 850 and AD 8510) are 12-bit binary and 3-decade BCD-weighted current ladders. The HC 420 and HC 430 (replacements for the AD 852 and AD 853) are 8-bit and 4-bit binary weighted current ladders. All units are available in DIP or flatpack versions.
Blower delivers air in a wide stream


An air blower dubbed Slot Formation delivers air in one 12.5-in.-wide continuous stream. It is rated at 150 cu ft/m at zero back pressure. Most other units must have two smaller separated airstreams to deliver the same amount of air, because they use squirrel-cage fans. The Slot Formation, in contrast, uses a tangential fan. In addition, this unit is shorter than equivalent units. The Slot Formation is 3.5 in. high, compared to others 5.25 in. high. The motor draws 80 W at 3150 rev/min.

CIRCLE NO. 328

Tool cuts and strips BX armored cable


The Roto-Split cuts and strips BX armored cable. The cable may be from 14 to 10 AWG, and have two or three conductors. The tool also cuts shielded flexible tubing. A built-in automatic stop enables the BX cable casing to be cut without damaging the insulated wires. The Roto-Split’s open channel construction also allows cable to be cut in the middle of a roll. The tool clamps the cable so no vise is required. The Roto-Split weighs 14 oz. The circular cutter is replaceable.

CIRCLE NO. 329

DIP-IC burn-in sockets operate at 200 C


A line of DIP burn-in sockets operates at 200 C. Dubbed the IS3900 series, they are available with 14, 16, 18, 20, 22, 24, 28, or 40 contacts. The glass-filled insulator houses contacts with large double-beam contact surfaces. The self-aligning beryllium-copper contacts take 5000 insertions and are plated with 50 μin. of gold. Contact resistance is 15 mΩ at 1 A. Insulation resistance is 5000 MΩ at 500 V dc, and dielectric withstand voltage is 1200 V rms at 60 Hz.

CIRCLE NO. 330

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For more information on the reliable XY-575 (OEM) recorder, request Bulletin E500. Esterline Angus Instrument Corporation, Box 24000, Indianapolis, IN 46224. Tel. 317-244-7611

CIRCLE NUMBER 47
ELECTRONIC DESIGN 23. NOVEMBER 8, 1976

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DON’T FORGET IT.

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CIRCLE NUMBER 48
from Electronic Measurements...

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We didn't acquire the largest selection without selling a lot of power supplies along the way. Our way, for 35 years, has been giving the user what he wants; and in a watts/dollar ratio that gives him no choice but E/M.

<table>
<thead>
<tr>
<th>Type</th>
<th>SINGLE PHASE</th>
<th>THREE PHASE</th>
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<tr>
<td>Watts</td>
<td>500 800 1600 2400</td>
<td>2500 5000 10 KW To 60 KW</td>
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<tr>
<td>Volts</td>
<td>0 to 7.5 V up to 600 V DC</td>
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<td>Amperes</td>
<td>0 to 0.75 A up to 3000 A DC</td>
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<tr>
<td>Height (in.)</td>
<td>3.50 3.50 5.25 7.00</td>
<td>7.00 8.75 12.25 To 4'</td>
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<td>Price ($)</td>
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<td>500 650 895 1100</td>
<td>1600 2300 2900 9500</td>
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Socket pivots 30° on a PC board


A single-wire connector, called SNAPLOX, consists of a socket that fits over a ball-ended plug. The connector can pivot 30° from the vertical in any direction. Sockets are made of a grooved PTFE sleeve that completely surrounds a silver-plated cavity with a solder pot at one end to make a connection with the wire. Plugs are serrated and splined for insertion into loosely tolerated holes in PC boards. They are palladium or gold-plated. Another version of the plug, for insertion into conductive metal chassis, is surrounded by an insulating PTFE bussing. Socket sleeves and bushings for chassis-mounted plugs can be coded in a range of 11 colors.

CIRCLE NO. 331

Sealing gaskets shield against EMI and RFI

Compac, 222 Middle Century Rd., Smithtown, NY 11787. (516) 360-3387. $4.08-$10.44 per pair (100-up).

A line of EMI/RFI shields and fluid-seal gasket pairs are made of woven aluminum wire screen impregnated with a rubber sealing material. The Compac gasket shields against interference when the aluminum screen contacts both mating assembled surfaces. The rubber material fills the gaps between the individual wires of the screen, making the joint pressure tight. The gasket thickness runs 0.020 + 0.004 in. The wide diameter measures 0.015 in. The gasket is usable over a temperature range from -40 F to 212 F.

CIRCLE NO. 332

Electronic Design 23, November 8, 1976

The Series 1000 metal PC card guide, when assembled into an aluminum-heat-sink guide bar, dissipates board heat. The card guides come in copper, stainless-steel, phosphor bronze, or beryllium. The spring-finger grip of the guide presses the edge of the PC card into contact with the guide bar. The guide bar's large contact area and mass, when mounted to a chassis, provides good test sinking for the board.

CIRCLE NO. 333

PC-board bus strip takes high temperatures

Bussco Engineering Inc., 119 Standard St., El Segundo, CA 90245. (213) 322-6580. See text; 3-4 wk.

A line of PC-board bus strips withstands temperatures up to 520°F for 30 s without delaminating or deteriorating. The E-series Models B10200/B10300 use high-temperature plastics and a thermosetting adhesive. They are available in vertical and flat-DIP styles with one or several conducting layers. Multilayer configurations provide distributed capacitance and reduce propagation delay time. A two-layer model that is 6 in. long and has per-layer pin spacing of 1 in. costs 70¢ in 1000-up quantities.

CIRCLE NO. 334

Cable clamps adjust to different bundle sizes

Thomas & Betts, 36 Butler St., Elizabeth, NJ 07207. (201) 354-4521. 46¢ (5000 up).

The ANC series cable clamps have an adjustable locking tab that accommodates a range of wire-bundle sizes. Their design allows removal and installation of additional wires without unscrewing or disassembling the clamp. The new clamps come in four sizes. They accommodate wire-bundle diameters from 3/16 through 1-1/8 in. The ANC series is made of nylon. They have a toothed locking device contained in a narrow channel which locks the hoop securely. To add a wire, the installer unsnaps the locking tab, lays in the wire, and pushes the locking tab back into the channel. The clamps are available in both screw-mounting and adhesive-backed styles.

CIRCLE NO. 335

PHOTO ETCH
PRINTED CIRCUIT KIT
Makes circuits THREE WAYS

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KIT CONTENTS: 5 x 5" black printing frame, 4 sheets 5 x 5" negatives in white, 5 x 5" resist image on copper clad circuit board, 5 x 5" etched circuit board, 4 x 5" resist image on copper clad circuit board, 5 x 5" etched circuit board.

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ER-2 PC patterns and tapes — refill 3.95  
ER-3 1/4 pound dry etchant — refill 1.49  
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CIRCLE NUMBER 50

THE TOTAL MEMORY SUPPLIER
WE HAVE BIPOLAR PLAS/FPLAS. SOMETHING TO REMEMBER.

Think Signetics
a subsidiary of U.S. Philips Corporation

CIRCLE NUMBER 51
Voltage-controlled amp has dual sections

Solid State Music, 210SA Walsh Ave., Santa Clara, CA 95050. (408) 246-2707. $6 (1-24); stock.

The SSM 2000 is a dual two-quadrant multiplier with each channel having separate control and differential signal inputs and current outputs. It can be used directly in voltage-controlled filters, two and four-quadrant multipliers, audio mixdown panels, and many other applications. The circuit has a control accuracy of 1% or better over its 80 dB control range and its dual design allows complete independent selection of the control characteristics of the two channels.

CIRCLE NO. 336

ECL line grows to 74 choices

Philips, P.O. Box 523, Eindhoven, the Netherlands. (040) 784616.

The addition of a number of Signetics’ types to its ECL 10,000 series now lets Philips offer 74 different types of integrated circuits in this series of emitter-coupled logic. ECL circuits feature speeds much faster than Schottky TTL, independent of loading. Typical operating frequencies are greater than 150 MHz. The ECL 10,000 series provides a complete family of SSI, interface elements, high performance MSI, and memories. The company now offers 13 memories. With the exception of some of the memories, which are available in ceramic encapsulation only, all types can be supplied in either plastic or ceramic encapsulation. The 16-pin DIP package is the standard for the series, with the exception of the GXB10155 which is 18-pin, and the GXB10181 which is 24-pin. Features of this line are its speed x power product, propagation-delay/rise-time ratio, noise immunity and immunity from power-supply variations. ECL 10,000 gives you complementary outputs and can directly drive twisted-pairs and transmission lines.

CIRCLE NO. 337

4, 8 & 16-channel muxes withstand ±20-V inputs

Datel Systems, 1020 Turnpike St., Canton, MA 02021. (617) 828-8000. From $14 (1 to 9); stock.

The MX series of 4, 8 and 16-channel analog multiplexers can withstand analog input overvoltages of ±20 V, a logic input overvoltage of ±4 V or a loss of multiplexer power with control and signal inputs applied. The units feature break-before-make switching to ensure that no two channels are ever momentarily shorted together. All models contain DTL/TTL and CMOS-compatible channel address decoding. Binary-coded logic inputs of 2, 3 and 4-bit words perform channel selection in the 4, 8 and 16-channel models, respectively. Each model has an inhibit input, which enables or disables the entire device. All models have transfer accuracies of 0.01% at channel sampling rates up to 200 kHz. The multiplexers handle input signals ranging between ±10 V. The dielectric isolation between channels holds crosstalk down by 86 dB. The MX series units have a typical channel ON resistance of 1.5 kΩ at 25 C, and remains less than 2 kΩ over the full 0-to-70-C range. Each MX series unit consumes 7.5 mW at standby and only 15 mW at a 100-KHz channel sampling rate. The power supply is nominally ±15 V, but can range between ±5 to ±20 V.

CIRCLE NO. 338

TO-99 op amps offer high GBW, slew rate

Hybrid Systems, Crosby Dr., Bedford, MA 01730. (617) 275-1570. $9.25, $11.25; stock to 3 wk.

Both of these amplifiers are wideband and have high slew rates. Each is housed in a TO-99 package. The A975 features a slew rate of 80 V/μs; the A970 has a gain bandwidth of 100 MHz and an open loop gain of 95 dB. Input impedance for both devices is greater than 100 MΩ. They operate over the range from 0 to 70 C.
3-terminal regulators have topnotch specs

National Semiconductor, 2900 Semiconductor Dr., Santa Clara, CA 95051. (408) 737-5000. $2.10 (100-up); stock.

The LM140LA series of three-terminal positive regulators reportedly has performance far superior to LM78L specifications. All units have an output voltage tolerance of 2%, a ripple rejection of 41 to 55 dB minimum, a line regulation of 0.04%/V, and a load regulation of 0.01%/mA. The available output voltages range from 5 to 24 V and with adequate heat sinking, the units can deliver up to 100 mA. Current limiting ensures the peak output current will remain at a safe level. Safe area protection for the output transistor also helps to prevent the IC from overheating. The LM140LA, LM240LA and LM940LA are all available in the low profile metal TO-99 package, and the LM240LA and LM340LA are also available in plastic TO-92 packages.

CIRCLE NO. 340

Universal game ICs create many variations

Texas Instruments, P.O. Box 5012, Dallas, TX 75222. (214) 238-2011. See text; stock.

A family of universal game circuits for video game applications offers users a wide range of games with easily changeable features and game rules. The first six circuits include the SN76423, a game logic chip with automatic random English; the SN76425, a horizontal and vertical sync generator; the SN76426, a character generator; the SN76427, a wall and ball generator; the SN76428, a game logic circuit with manual English; and the SN76460, a 0 to W (Win) at 20 digital scoring circuit. Combinations of these circuits allow games with multiple balls, multiple walls, multiple players, and obstacles. All devices are supplied in 300-mil-wide plastic DIPs. Prices in 100-unit quantities are: $1.25 for the 76423 and 428, $1.53 for the 76426 and 427, $1.89 for the 76425 and $4.54 for the 76460.

CIRCLE NO. 341

Hybrid regulator passes 5 A at 5 V

Fairchild Analog Products, 464 Ellis St., Mountain View, CA 94042. (415) 962-3816. $7.95 (100 qty); stock.

A new hybrid IC voltage-regulator module packs the capacity to regulate up to 5 A at 5 V, with built-in short-circuit and safe-area protection into a TO-3 can. The unit is pin-compatible with Fairchild’s line of 7800-series monolithic voltage-regulators. The 78H05KC offers all the advantages of a monolithic regulator at higher current levels. For automatic thermal-overload protection, a hybrid circuit limits the max junction-temperature of the power-output transistor. If the safe operating area is exceeded, the device shuts down, rather than failing or damaging other system components. This feature eliminates the need for costly output circuitry and overly conservative heat-sinking arrangements typical of high-current regulators.

CIRCLE NO. 342

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CIRCLE NUMBER 53

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CIRCLE NUMBER 54
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Unit duplicates and programs PROMs


A PROM programmer, the series 92, will duplicate MOS or bipolar PROMs when used alone. Through a 20-mA current loop driven by a teletypewriter orμP development system, the Series 92 can additionally program, list or verify PROMs. The unit consists of the M920 master-control unit and a plug-in personality module. The Series 92’s PROM duplicating function is controlled by a single pushbutton. Run and fail lights automatically indicate machine status and whether or not a PROM has been successfully programmed. The unit comes packaged in an attache case and weighs less than 15 lb. An M920 master-control unit costs $995. Personality modules range from $350 to $550.

C. Itoh Electronics, Inc., 280 Park Ave., New York, NY 10017. (212) 573-9466. $120; 1 wk.

The Model 102 impact printer is said to have an MTBF of 5-million lines. The unit prints 18 columns in 13-character font, at a speed of 2.7 line/s. The Model 102 prints in black and red, on 2.5-in.-wide paper. A transistorized, brushless, constant-speed dc motor that requires 15 V dc at 490 mA drives the unit. Printer dimensions are 3.375 x 5.75 x 4.875 in.

C. Itoh Electronics, Inc., 280 Park Ave., New York, NY 10017. (212) 573-9466. $120; 1 wk.

Disc controller takes up one slot in a mini

Minicomputer Technology, 1901 Old Middlefield Way, Mountain View, CA 94043. (415) 965-4567. $1900 (single qty).

The TDC803 disc controller enables Interdata minicomputers to handle four CalComp Trident disc drives. The TDC803 controller occupies one slot in the chassis of an Interdata computer. It generates cyclic redundancy check characters, senses the disc’s rotational position and has dual-access capability and an onboard logic probe. The manufacturer will integrate the disc drive and controller at additional cost.

C. Itoh Electronics, Inc., 280 Park Ave., New York, NY 10017. (212) 573-9466. $120; 1 wk.
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Signetics has made a positive commitment to stay ahead in technological leadership in Bipolar & MOS memories. No brag, just fact. With years of experience in supplying the needs of major customers and being a subsidiary of U.S. Philips Corporation, Signetics has the resources to make it happen.

Signetics has a total product line of memories—RAMs, ROMs, PROMs, FPLAs/PLAs and a long list of Shift Registers including 12 Static and 8 Dynamic from 100 to 1024 bits.

Signetics Bipolar & Static MOS RAMs. Signetics’ total line of Bipolar & MOS devices includes all the hard-to-find and in-demand devices. 24 Bipolars—8 to 1024 bits. 14 MOS Statics—256 x 4 to 1024 x 1. 1K x 4 and 4K x 1 available 1st quarter ’77.

Signetics Dynamic MOS RAMs. The most complete line of dynamic MOS RAMs from 1024 x 1 to 4096 x 1 (16, 18 and 22 pin). 1024 x 1 to 4096 x 1 organization. 16K x 1 available 1st quarter ’77.

Signetics Bipolar & MOS ROMs. These mask-programmable chips offer easy word expansion. 13 Bipolars in stock—256 to 16K bits. 7 MOS Statics in stock—up to 16K bits. Plus 4 character generators including 8K’s. Both TS and OC available.
Signetics Bipolar & MOS PROMs.
All readily available through a vast Signetics distributor programming network. The new 18-pin devices offer small size, high PC board packing density, low complexity, very low power, and low component and system cost. 17 Bipolars in stock from 256 to 8K bits, with 16K available 1st quarter '77. 4K and 8K MOS EROMS available 1st quarter '77.

Signetics Bipolar FPLAs/PLAs. All devices deliver increased do-it-yourself flexibility and greatest system reliability with fewer parts and connections. It’s easiest, fastest and simplest to modify and correct logic functions by limited editing of input/output connections within the package, and it’s second sourced. Both TS and OC are available and in stock.

Signetics Bipolar MIL-SPEC Memories.
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Computer Operations, Inc., 9700-B George Palmer Hwy., Lanham, MD 20801. (301) 459-2100. See text: 30 days.

A magnetic tape system is compatible with DEC's LSI-11 and PDP-11/03. The CO-3000 LSI system has a capacity of 148-k 16-bit words, in blocks of 256 words each. The system supports such DEC software as the RT-11 operating system and Macro, Edit, Linker, Fortran IV and Basic programs. The CO-3000 LSI consists of a tape controller and drive. The tape controller occupies a quad slot in the LSI-11. The transfer rate is 4-k, 16-bit word/s. A search for pre-numbered word blocks is done at 60 in./s. The controller will support a total of four drives. The first drive and controller cost $1995 and additional drives are $1395 (both one-up).
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**Log amp handles positive and negative inputs**

Teledyne Philbrick, Allied Dr. at Rte. 128, Dedham, MA 02028. (617) 329-1600. $60 (1 to 9); stock.

The 4356 log amplifier can act as a compression or expansion circuit. It can handle both positive or negative voltage or current inputs and provides an output voltage that is the log of the input. The output signal follows the log function over a dynamic range of greater than ±1000 to 1 from dc to 10 kHz. As a noise eliminator, the 4356 provides better than 40 dB of improvement in the signal-to-noise ratio when small dynamic range signals are measured in the presence of large-dynamic-range impulse noise. The modules have a log conformity of ±20 mV for input current of ±10 µA to ±10 mA. The 1.145 × 2.02 × 0.62 in. module requires ±15 V at ±8 mA, and functions over a 0-to-70-C range.

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RFL Industries, Inc., Boonton, NJ 07005. (201) 334-3100. $150; stock.

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**Synchro driver delivers up to 25 VA**

Magnetico, 182 Morris Ave., Hillside, NJ 07035. (201) 664-1166. $29 (500-up); stock to 4 wks.

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Burr-Brown, International Airport, Industrial Park, Tucson, AZ 85714. (602) 294-1431. From $36 (100-up); stock.

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<table>
<thead>
<tr>
<th>Category</th>
<th>Page</th>
<th>IRN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Components</td>
<td></td>
<td></td>
</tr>
<tr>
<td>audio indicators</td>
<td>96</td>
<td>60</td>
</tr>
<tr>
<td>capacitors</td>
<td>71</td>
<td>31</td>
</tr>
<tr>
<td>capacitors, ceramic</td>
<td>65</td>
<td>27</td>
</tr>
<tr>
<td>capacitors, ceramic</td>
<td>86</td>
<td>46</td>
</tr>
<tr>
<td>capacitors, electrolytic</td>
<td>58</td>
<td>23</td>
</tr>
<tr>
<td>capacitors, mica</td>
<td>107</td>
<td>78</td>
</tr>
<tr>
<td>display, LC</td>
<td>85</td>
<td>323</td>
</tr>
<tr>
<td>display, numerical</td>
<td>86</td>
<td>325</td>
</tr>
<tr>
<td>fans</td>
<td>92</td>
<td>55</td>
</tr>
<tr>
<td>filters, oscillators</td>
<td>91</td>
<td>53</td>
</tr>
<tr>
<td>fluorescent displays</td>
<td>66</td>
<td>28</td>
</tr>
<tr>
<td>ground-fault detectors</td>
<td>84</td>
<td>321</td>
</tr>
<tr>
<td>ladder networks</td>
<td>86</td>
<td>327</td>
</tr>
<tr>
<td>lamps</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>passive components</td>
<td>73</td>
<td>151</td>
</tr>
<tr>
<td>position sensor</td>
<td>85</td>
<td>324</td>
</tr>
<tr>
<td>potentiometers, II</td>
<td>32</td>
<td>252</td>
</tr>
<tr>
<td>potentiometers, linear</td>
<td>84</td>
<td>320</td>
</tr>
<tr>
<td>quartz crystals</td>
<td>106</td>
<td>76</td>
</tr>
<tr>
<td>reflective transducers</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>relays</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>resistor networks</td>
<td>59</td>
<td>24</td>
</tr>
<tr>
<td>resistor networks</td>
<td>85</td>
<td>326</td>
</tr>
<tr>
<td>switch modules</td>
<td>84</td>
<td>43</td>
</tr>
<tr>
<td>switch, rotary</td>
<td>100</td>
<td>65</td>
</tr>
<tr>
<td>switches, subminiature</td>
<td>111</td>
<td>253</td>
</tr>
<tr>
<td>switches, toggle</td>
<td>85</td>
<td>322</td>
</tr>
<tr>
<td>trimmers</td>
<td>82</td>
<td>39</td>
</tr>
<tr>
<td>Data Processing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>communication system</td>
<td>21</td>
<td>11</td>
</tr>
<tr>
<td>controllers</td>
<td>64</td>
<td>25</td>
</tr>
<tr>
<td>disc controller</td>
<td>93</td>
<td>346</td>
</tr>
<tr>
<td>mag tape system</td>
<td>97</td>
<td>352</td>
</tr>
<tr>
<td>PROM programmer</td>
<td>93</td>
<td>344</td>
</tr>
<tr>
<td>paper tape punch</td>
<td>97</td>
<td>351</td>
</tr>
<tr>
<td>printer, impact</td>
<td>93</td>
<td>345</td>
</tr>
<tr>
<td>tape system</td>
<td>75</td>
<td>33</td>
</tr>
<tr>
<td>teleprinter</td>
<td>78</td>
<td>35</td>
</tr>
<tr>
<td>Discrete Semiconductors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LEDs</td>
<td>47</td>
<td>20</td>
</tr>
<tr>
<td>npn, pnp devices</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>photocells</td>
<td>98</td>
<td>354</td>
</tr>
<tr>
<td>photoemitter/detector</td>
<td>98</td>
<td>356</td>
</tr>
<tr>
<td>power Darlingtons</td>
<td>27</td>
<td>14</td>
</tr>
<tr>
<td>power Schottkys</td>
<td>101</td>
<td>66</td>
</tr>
<tr>
<td>thyristors</td>
<td>98</td>
<td>355</td>
</tr>
<tr>
<td>zener diodes</td>
<td>98</td>
<td>353</td>
</tr>
<tr>
<td>Instrumentation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>amplifier</td>
<td>81</td>
<td>302</td>
</tr>
<tr>
<td>bridge</td>
<td>81</td>
<td>303</td>
</tr>
<tr>
<td>DMM</td>
<td>33</td>
<td>212</td>
</tr>
<tr>
<td>DMM, 4-1/2 digit</td>
<td>112</td>
<td>80</td>
</tr>
<tr>
<td>logic probe</td>
<td>107</td>
<td>77</td>
</tr>
<tr>
<td>oscilloscope</td>
<td>79</td>
<td>301</td>
</tr>
<tr>
<td>Integrated Circuits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>amplifier, voltage-cont.</td>
<td>90</td>
<td>336</td>
</tr>
<tr>
<td>HiNiL</td>
<td>38</td>
<td>19</td>
</tr>
<tr>
<td>IC</td>
<td>92</td>
<td>343</td>
</tr>
<tr>
<td>ICs</td>
<td>90</td>
<td>337</td>
</tr>
<tr>
<td>ICs, video game</td>
<td>91</td>
<td>341</td>
</tr>
<tr>
<td>image sensors</td>
<td>81</td>
<td>37</td>
</tr>
<tr>
<td>memories</td>
<td>70</td>
<td>30</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Category</th>
<th>Page</th>
<th>IRN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Components</td>
<td></td>
<td></td>
</tr>
<tr>
<td>multiplexers, IC</td>
<td>90</td>
<td>338</td>
</tr>
<tr>
<td>op amps</td>
<td>90</td>
<td>339</td>
</tr>
<tr>
<td>regulator, TO-3</td>
<td>91</td>
<td>342</td>
</tr>
<tr>
<td>regulators, voltage</td>
<td>91</td>
<td>340</td>
</tr>
<tr>
<td>Microprocessor Design</td>
<td></td>
<td></td>
</tr>
<tr>
<td>analyzer, logic state</td>
<td>35</td>
<td>508</td>
</tr>
<tr>
<td>µC system</td>
<td>37</td>
<td>510</td>
</tr>
<tr>
<td>Modules &amp; Subassemblies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>amplifier, differential</td>
<td>102</td>
<td>362</td>
</tr>
<tr>
<td>amplifier, log</td>
<td>100</td>
<td>357</td>
</tr>
<tr>
<td>converter, a/d</td>
<td>100</td>
<td>360</td>
</tr>
<tr>
<td>driver, synchro</td>
<td>100</td>
<td>359</td>
</tr>
<tr>
<td>graphics module, µP</td>
<td>102</td>
<td>363</td>
</tr>
<tr>
<td>temp controller</td>
<td>100</td>
<td>358</td>
</tr>
<tr>
<td>thermocouple reference</td>
<td>102</td>
<td>361</td>
</tr>
<tr>
<td>Packaging &amp; Materials</td>
<td></td>
<td></td>
</tr>
<tr>
<td>aerosols</td>
<td>80</td>
<td>36</td>
</tr>
<tr>
<td>barriers, thermoplastic</td>
<td>104</td>
<td>69</td>
</tr>
<tr>
<td>blower, air</td>
<td>87</td>
<td>328</td>
</tr>
<tr>
<td>bus strip</td>
<td>89</td>
<td>334</td>
</tr>
<tr>
<td>cabinets and cases</td>
<td>97</td>
<td>62</td>
</tr>
<tr>
<td>cable clamps</td>
<td>89</td>
<td>335</td>
</tr>
<tr>
<td>connectors</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>connectors, PC</td>
<td>104</td>
<td>71</td>
</tr>
<tr>
<td>connectors, PC</td>
<td>25</td>
<td>13</td>
</tr>
<tr>
<td>DIP sockets, hi temp</td>
<td>87</td>
<td>330</td>
</tr>
<tr>
<td>electronic kits (NL)</td>
<td>87</td>
<td>330</td>
</tr>
<tr>
<td>fiber optics catalog</td>
<td>83</td>
<td>40</td>
</tr>
<tr>
<td>gaskets, shielding</td>
<td>88</td>
<td>332</td>
</tr>
<tr>
<td>guides, PC card</td>
<td>89</td>
<td>33</td>
</tr>
<tr>
<td>interconnections</td>
<td>19</td>
<td>10</td>
</tr>
<tr>
<td>magnetic shielding</td>
<td>92</td>
<td>56</td>
</tr>
<tr>
<td>socket, PC board</td>
<td>88</td>
<td>331</td>
</tr>
<tr>
<td>terminal boards</td>
<td>64</td>
<td>26</td>
</tr>
<tr>
<td>tool, cable cutting</td>
<td>87</td>
<td>329</td>
</tr>
<tr>
<td>wire and cable</td>
<td>90</td>
<td>52</td>
</tr>
<tr>
<td>wrapped wiring</td>
<td>103</td>
<td>68</td>
</tr>
<tr>
<td>Power Sources</td>
<td></td>
<td></td>
</tr>
<tr>
<td>energy cells</td>
<td>103</td>
<td>69</td>
</tr>
<tr>
<td>power stabilizer, ac</td>
<td>83</td>
<td>308</td>
</tr>
<tr>
<td>power supplies</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>power supplies</td>
<td>93</td>
<td>57</td>
</tr>
<tr>
<td>power supply</td>
<td>82</td>
<td>304</td>
</tr>
<tr>
<td>power supply</td>
<td>82</td>
<td>306</td>
</tr>
<tr>
<td>power supply</td>
<td>83</td>
<td>307</td>
</tr>
<tr>
<td>power supply</td>
<td>83</td>
<td>309</td>
</tr>
<tr>
<td>power supply</td>
<td>98</td>
<td>63</td>
</tr>
<tr>
<td>switcher</td>
<td>82</td>
<td>305</td>
</tr>
</tbody>
</table>

**new literature**

- computer systems: 110, 374
- crimping tool: 104, 366
- electronic kits: 104, 371
- microprocessors: 106, 373
- power supplies for µPs: 106, 375
- resistor networks: 104, 372
- semiconductors: 104, 369
- test instruments: 104, 367
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<table>
<thead>
<tr>
<th>RCA No.</th>
<th>MIL-M-38510/</th>
<th>RCA No.</th>
<th>MIL-M-38510/</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD4000A</td>
<td>05201</td>
<td>CD4017A</td>
<td>05601</td>
</tr>
<tr>
<td>CD4001A</td>
<td>05202</td>
<td>CD4018A</td>
<td>05602</td>
</tr>
<tr>
<td>CD4002A</td>
<td>05203</td>
<td>CD4019A</td>
<td>05603</td>
</tr>
<tr>
<td>CD4007A</td>
<td>05301</td>
<td>CD4020A</td>
<td>05604</td>
</tr>
<tr>
<td>CD4008A</td>
<td>05501</td>
<td>CD4021A</td>
<td>05704</td>
</tr>
<tr>
<td>CD4010A</td>
<td>05502</td>
<td>CD4022A</td>
<td>05604</td>
</tr>
<tr>
<td>CD4011A</td>
<td>05001</td>
<td>CD4023A</td>
<td>05003</td>
</tr>
<tr>
<td>CD4012A</td>
<td>05002</td>
<td>CD4024A</td>
<td>05605</td>
</tr>
<tr>
<td>CD4013A</td>
<td>05101</td>
<td>CD4025A</td>
<td>05204</td>
</tr>
<tr>
<td>CD4014A</td>
<td>05702</td>
<td>CD4027A</td>
<td>05102</td>
</tr>
<tr>
<td>CD4015A</td>
<td>05703</td>
<td>CD4029A</td>
<td>05503</td>
</tr>
<tr>
<td>CD4050A</td>
<td>05504</td>
<td>CD4049A</td>
<td>05503</td>
</tr>
</tbody>
</table>

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