EXCLUSIVELY FOR DESIGNERS AND DESIGN MANAGERS IN ELECTRONICS

EDN

Sampling scopes are getting better all the time

National Computer Conference makes its debut

The role of the minicomputer in data communications

A CAHNERS PUBLICATION

MAY 20, 1973

whatever your computer says...

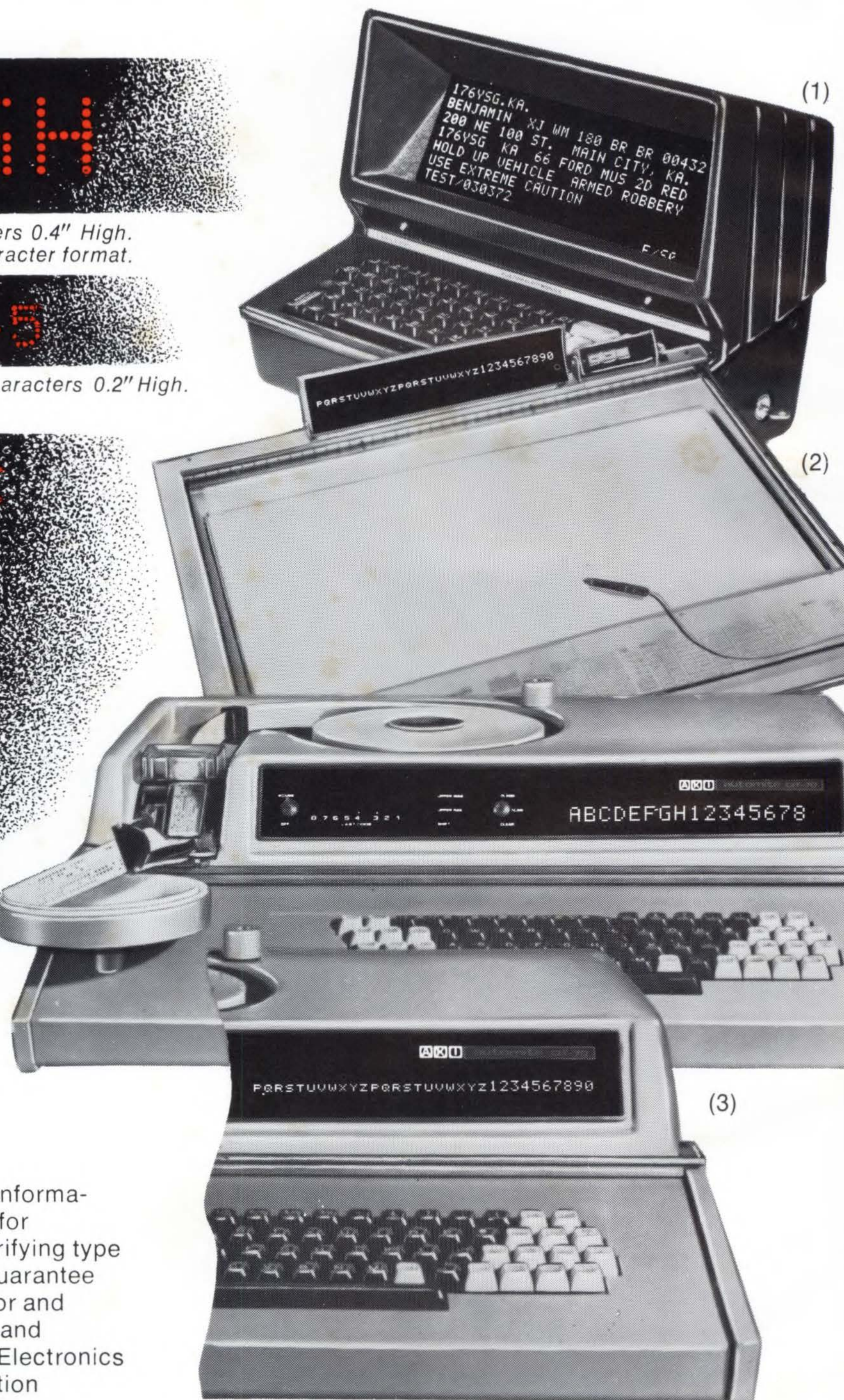
SELF-SCAN® SAYS IT BEST

PANEL DISPLAYS

16/18 Character Position Panel, 5 x 7 Dot Matrix, Characters 0.4" High. Available as numeric only or alphanumeric panel with 64-character format.

32/37, 80 Character Position Panel, 5 x 7 Dot Matrix, Characters 0.2" High. Alphanumeric panel with 64-character format.

SELF-SCAN Panel Display Subsystem, 256 Character Capacity, 5 x 7 Dot Matrix, Characters 0.25" High. 64-character format, available with all drive electronics including memory, character generator, and timing.



Whether it's a police officer in a patrol car requesting information on a suspect, an architect specifying coordinates for plumbing fixtures in a new building, or a type setter verifying type for a mail-order catalog, SELF-SCAN panel displays guarantee the most accurate transfer of data between the operator and the computer. If you need a computer display and demand error-free communications, follow the lead of Kustom Electronics (1) in Chanute, Kansas; Science Accessories Corporation (2) in Southport, Connecticut; Automix Keyboards (3) in Bellevue, Washington, and the many other SELF-SCAN panel display users. Have a Burroughs salesman demonstrate his "terminal in a briefcase." You'll see why the SELF-SCAN panel display is the most effective man/machine interface device available today.

Burroughs Corporation, Electronic Components Division, Plainfield, New Jersey 07061. (201) 757-3400.

Burroughs

Circle No. 1

MAY 20, 1973
VOLUME 18, NUMBER 10

EDN with EEE
EXCLUSIVELY FOR DESIGNERS AND DESIGN MANAGERS IN ELECTRONICS

COVER

The explosive growth of minicomputer based data-communication systems is illustrated by the cover photo supplied by Data General Corp., Southboro, MA. Minicomputers interface with large host computers, peripheral devices and communication facilities to provide efficient, flexible data communications. The article on pg. 32 discusses this important role.

DESIGN NEWS

DESIGN FEATURES

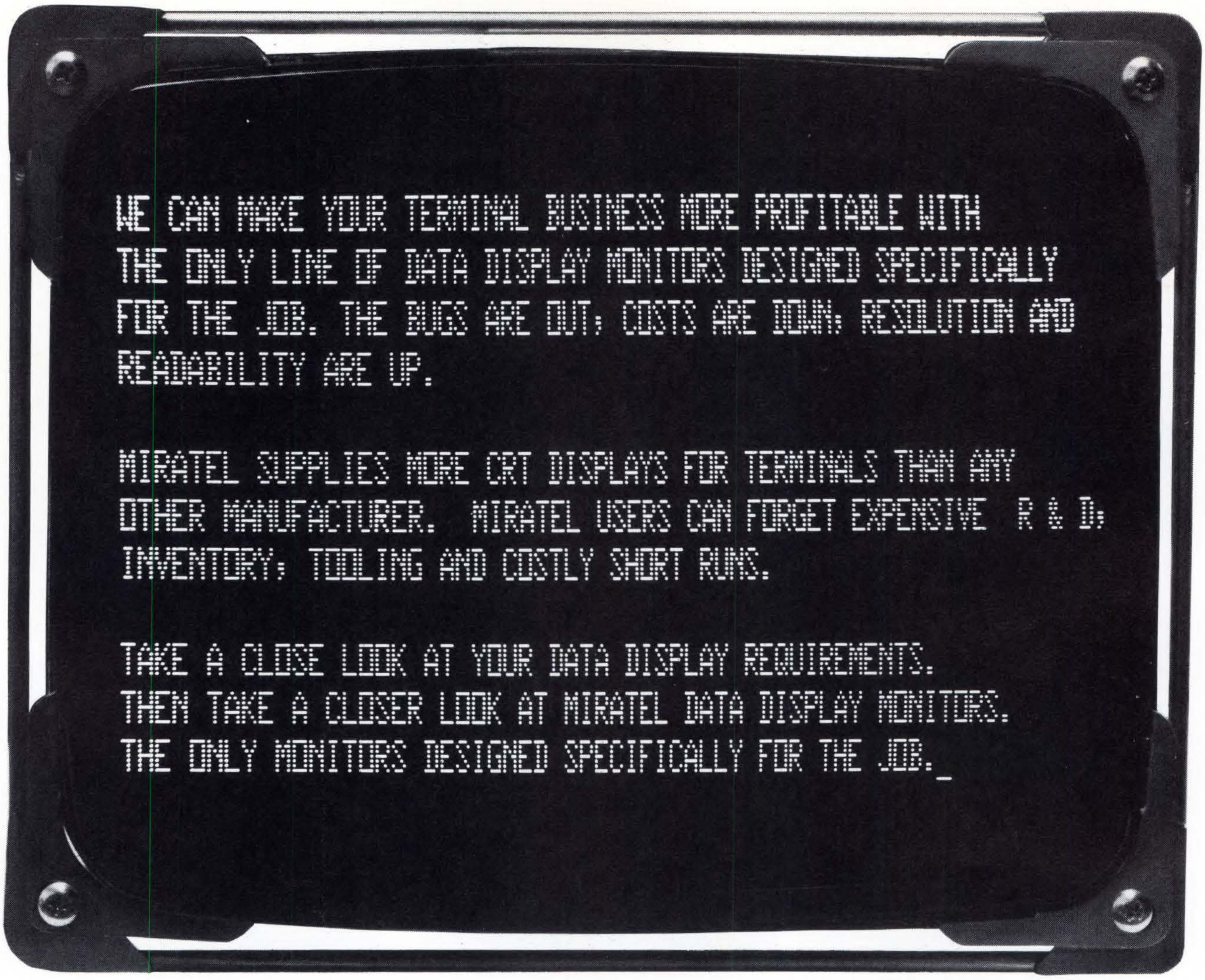
PROGRESS IN PRODUCTS

DESIGN PRODUCTS

DESIGN DEPARTMENTS

CP
BPA
ABP

 Norman L. Cahners; Chairman of the Board; Saul Goldweitz, President; H. V. Drumm, Executive Vice President/Magazines; Ned Johnson, Senior Vice President/Magazines. EDN/EEE (formerly Electrical Design News) is published semi-monthly. Editorial, Advertising offices, 221 Columbus Ave., Boston, Mass. 02116 (617) 536-7780. Subscription offices, 270 St. Paul St., Denver, Colo. 80206 (303) 388-8222. Printed at 85 W. Harrison St., Chicago, Ill. 60605. Controlled circulation postage paid at Chicago, Ill. Send form 3579 to Subscription office. EDN/EEE is circulated to electronic design engineers and engineering managers in electronic OEM industries. Plants having more than twenty employees and manufacturing electronically operated or controlled equipment of their own design are considered part of this industry. Engineers in such plants responsible for specification of components, materials and test equipment for electronic application may receive EDN/EEE without charge. Completed qualification form and company letterhead required. Subscriptions to others in continental United States, $2 per copy. $20 per year. Send requests for qualification forms and changes of address to subscription office in Denver, Colo.



(Actual photo, 9-inch Miratel display.)

Ball
MIRATEL

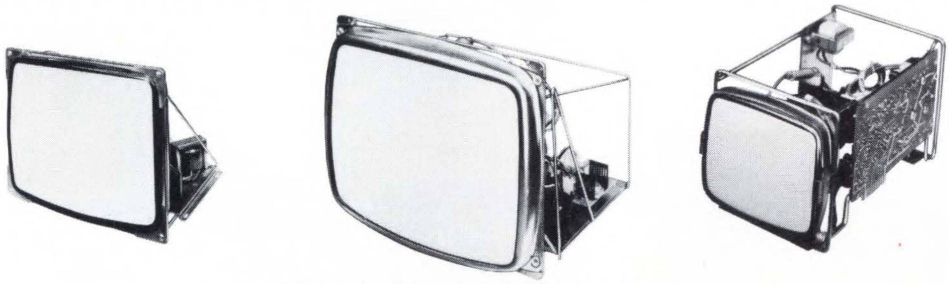
See us at the Computer Conference Booth 2003/2005

That's right. Miratel is the largest supplier of CRT data display units to computer terminal manufacturers. We take the headaches out of terminal building by supplementing your digital expertise with our display expertise.

The Miratel display family includes 5, 9, 12 and 15-inch monochrome CRTs, as well as the exciting new 25-inch RGB color display. Miratel monochrome displays are compact, packaged in a unique wire frame. This technique reduces size and weight, and simplifies incorporation into your terminal cabinet.

Miratel displays give page-like reproduction of alpha-numeric as well as graphic data. Low distortion and high contrast insure that the quality of your system is reflected in your terminal display.

Find out how to make your terminal business more profitable with Miratel data display monitors. Call or write for information.



MIRATEL DIVISION

BALL BROTHERS RESEARCH CORPORATION • 1633 TERRACE DRIVE, ST. PAUL, MINNESOTA 55113 • (612) 633-1742

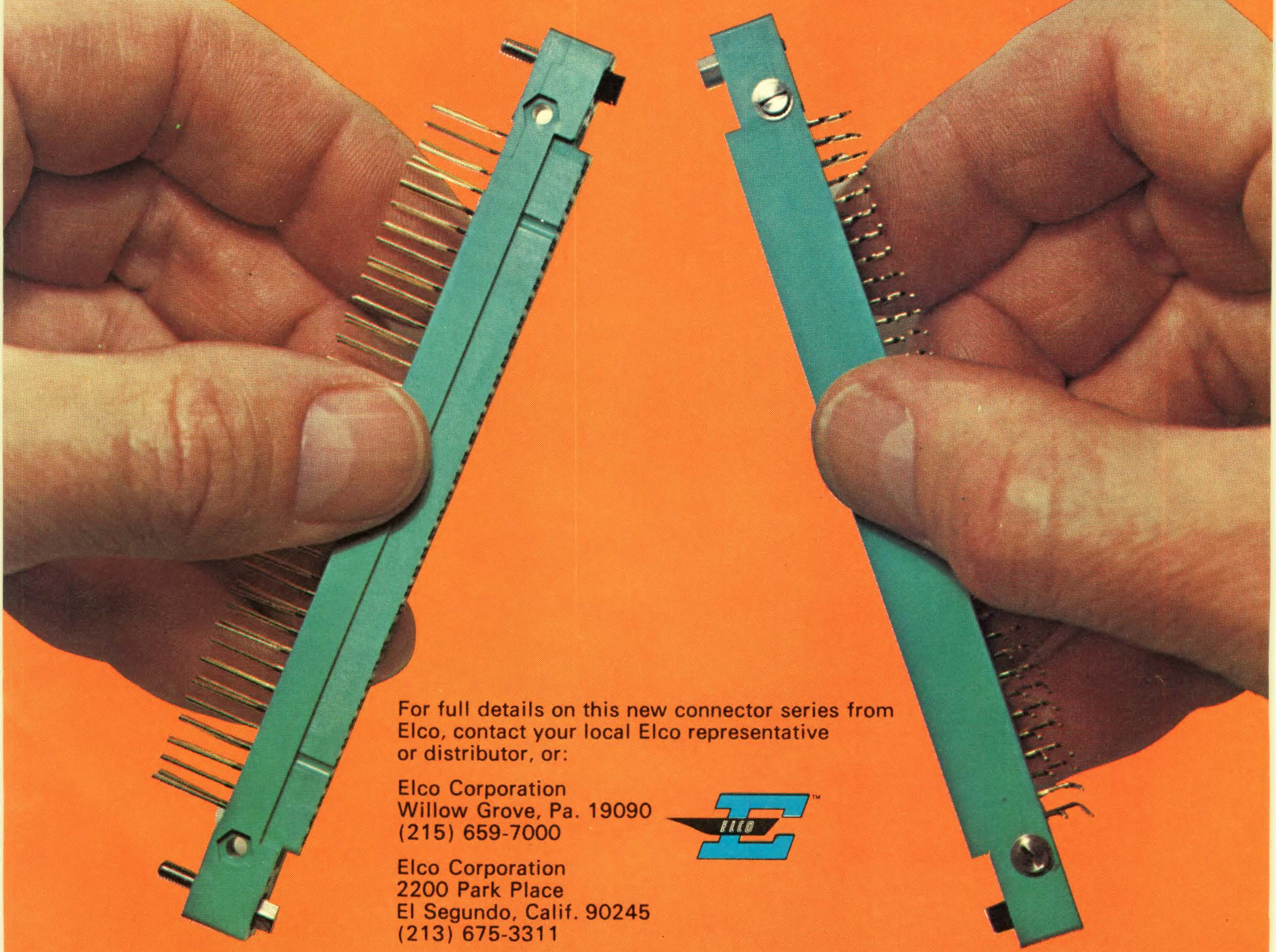
Circle No. 4

1. Can it be used for p.c. board-to-board, cable-to-board, and cable-to-cable applications?
2. Does it have one contact interface for all interconnect requirements?
3. Is it reliable?
4. Does it possess outstanding low force characteristics?
5. Can it be easily "peeled" apart without damage to contacts?
6. Does it have polarity and keying to prevent mismating?
7. Will it accept standard hardware?
8. Can it be mounted in any position?
9. Will it accept contacts crimped to wire?
10. Will it accept wire-wrapping?
11. Will it accept soldering to wire or printed-circuitry?
12. Does it feature the proven **Varicon**™ contacts?
13. Are the contacts on standard .100" square grid?
14. Do the contacts have a floating action for easy alignment?
15. Is there a choice of commonly used sizes or number of contacts, like 24, 48, 72 or 96?
16. Is it available "off the shelf" from a local Elco Distributor?

In numerical order, here are the answers to all of these questions: . . . Yes.

ELCO SAYS YES!

To the 16 most important questions asked about miniature printed-circuit connectors . . . their new **Series 8223**.



For full details on this new connector series from Elco, contact your local Elco representative or distributor, or:

Elco Corporation
Willow Grove, Pa. 19090
(215) 659-7000

Elco Corporation
2200 Park Place
El Segundo, Calif. 90245
(213) 675-3311

Operations in USA, Australia, Belgium, Canada, Denmark, England, France, Germany, Israel and Japan. Sales offices throughout the world. In Europe, Elco Belge, 77 Blancefloerlaan, Antwerp, Belgium, Tel. 03-190064. In the Far East, Elco International, TBR Building, 2-10-2 Nagata-cho, Chiyoda-ku, Tokyo 100, Japan, Tel. 580-2711/5.

Circle No. 5

For $395 how many functions should a Function Generator generate?

Fifteen. That's the number of waveforms you can get with Krohn-Hite's Model 5100A. How? A unique Symmetry Control that allows pulse rep rate to be set independently of pulse width and also provides independently adjustable triangle slopes. You can skew any of the basic sine, square, triangle and ramp waveforms by as much as 99% to produce 10 additional functions. Frequency range of 0.002 Hz to 3 MHz can be manually tuned or externally controlled for VC of 1000:1. When you compare the 5100A with the rest, there's quite a generation gap. For fast action, call The Wavemakers at (617) 491-3211, TWX 710-320-6583 Krohn-Hite Corporation, 580 Mass. Ave., Cambridge, Mass. 02139.

KROHN-HITE CORPORATION

SALES OFFICES: ALA., Huntsville (205) 534-9771; CAL., Santa Clara (408) 243-2891, Inglewood (213) 674-6850; COLO., Littleton (303) 795-0250; CONN., Glastonbury (203) 633-0777; FLA., Orlando (305) 894-4401; HAWAII, Honolulu (808) 941-1574; ILL., Des Plaines (312) 298-3600; IND., Indianapolis (317) 244-2456; MASS., Lexington (617) 861-8620; MICH., Detroit (313) 526-8800; MINN., Minneapolis (612) 884-4336; MO., St. Louis (314) 423-1234; N.C., Burlington (919) 227-2581; N.J., Bordertown (609) 298-6700; N.M., Albuquerque (505) 255-2440; N.Y., E. Syracuse (315) 437-6666, Rochester (716) 328-2230, Wappingers Falls (914) 297-7777, Vestal (607) 785-9947, Elmont (516) 488-2100; OHIO, Cleveland (216) 261-5440, Dayton (513) 426-5551; PA., Pittsburgh (412) 371-9449; TEX., Houston (713) 468-3877, Dallas (214) 356-3704; VA., Springfield (703) 321-8630; WASH., Seattle (206) 762-2310; CANADA, Montreal, Quebec (514) 636-4411, Toronto, Ontario (416) 444-9111, Stittsville, Ontario (613) 836-4411, Vancouver, British Columbia (604) 688-2619.

Circle No. 6

Introducing the first American fuseholder to meet Europe's IEC standards.

The "shock-safe" 3AG fuseholder.

Our new fuseholder isn't really red, white and blue. Its standard color is black, just like all other fuseholders.

But there the similarity ends.

For this Littelfuse fuseholder is the only American-made holder designed to meet current International Electrotechnic Commission standards.

IEC's Publication No. 65, accepted by all European countries, requires fuseholders to offer absolute protection against electric shock, even under fault conditions.

And that's exactly what our new 3AG "Shock-Safe" fuseholder does! Several safety features have been incorporated into the fuseholder design to protect the user from any possibility of touching live parts.

In addition, our "Shock-Safe" fuseholder offers another important form of protection by assuring your acceptance in European markets. For if the fuseholder used in your product doesn't meet IEC standards, that product could be rejected by European testing and approval boards, which refer to Publication No. 65 for the purchase of equipment.

The "Shock-Safe" fuseholder #345001 has been designed to retrofit existing panel mounting holes and is the **only** 3AG fuseholder currently available for continuous operation to **20 amperes** and **300 volts.**

"Shock-Safe" fuseholders from Littelfuse.

A basic necessity if you're selling the European market.

For more information, send for Product Bulletin #1000 or contact your local Littelfuse distributor.

LITTELFUSE

Subsidiary of Tracor

800 E. Northwest Highway • (312) 824-1188 • Des Plaines, Illinois 60016

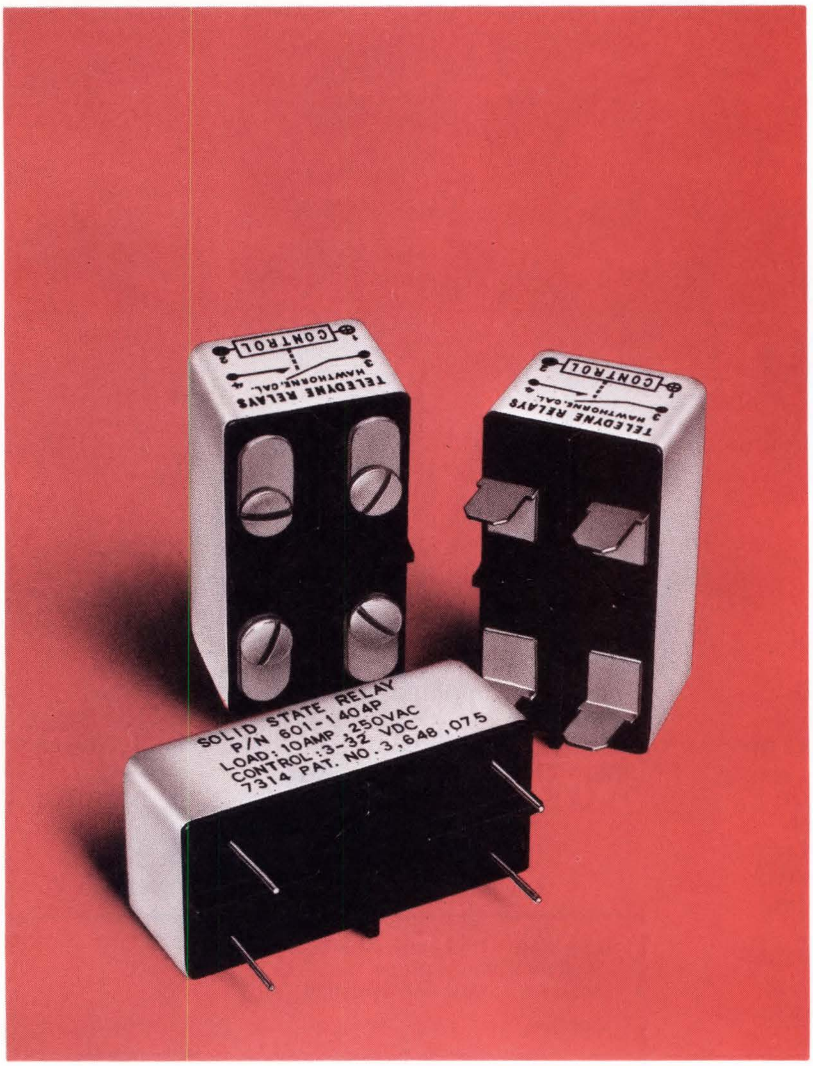
Circle No. 7

◆ **Circle No. 8**

Circle No. 15

The best of both worlds

10 AMP SOLID STATE RELAY FEATURING: OPTICAL ISOLATION AND ADAPTIVE PACKAGE DESIGN



The new 601-1400 series features LED optical isolation and synchronous/zero voltage switching to virtually eliminate RFI for any resistive or reactive load, up to 10 amps steady state. 1000% surge current capability assures maximum reliability without derating for the toughest loads — lamps, solenoids, motors, transformers, etc. High dv/dt rating assures maximum output transient immunity. The 601-1400's sensitive control input is TTL compatible, accepting drives from 3 to 32 VDC.

Teledyne offers designers the most versatile package in the industry — the "adaptive" configuration with either screw or quick disconnect terminals for chassis or panel mounting, or solder pins for PC boards. And the 1″ x 2″ x .9″ size makes it the **smallest 10 amp AC solid state relay available.**

Build total solid state reliability into your equipment with this latest addition to the Teledyne line of application engineered relays. Our engineers are ready to back this product with complete applications assistance. Write or phone.

TELEDYNE RELAYS

3155 West El Segundo Boulevard Hawthorne, California 90250
Telephone (213) 679-2205

Circle No. 9

A new dimension in design

According to a report by the Arthur D. Little organization, there are now more than 1000 automated tellers in U.S. banks and probably twice that many more on order.

Most of these are simply cash dispensers into which the user inserts a magnetically identifiable credit card of some kind, and then on a keyboard punches in the amount of cash he wants. The trend, though, and what many bankers are eyeing favorably, is the multifunction automated teller, which does far more than just dispense cash. It allows the user to do things such as make deposits, transfer funds from one of his accounts to another and possibly even pay some of his bills.

The potential for such systems is staggering when one considers that there are over 50,000 banking offices in the U.S., plus an even greater number of shopping centers, department stores and post offices, which are also possible locations for automated tellers.

Devices, such as these automated tellers, along with point-of-sale terminals and similar items, represent what might be called a new dimension in electronic systems—and their expected explosive growth poses a challenge for designers. All of these items require a substantial amount of processing and computing power. They require it, though, in a form that is on the one hand highly flexible and adaptable and on the other hand reasonably inexpensive, since cost effectiveness is the name of the game with these commercial electronic systems.

To meet these needs, semiconductor manufacturers are coming to market with microprocessors and at least one minicomputer manufacturer is selling "bare-bones" minis. All of these are powerful, flexible, compact components whose uses are limited only by the equipment designer's ingenuity and capability.

Never before have designers had such off-the-shelf "components" to design into their systems. They can now bring computer capability to bear in applications where it was previously unheard of—or thought of—and at reasonable cost. But to do so will require a knowledge of and familiarity with things that are alien to many designers today. Words like software, and programming, and polling and priority interupt will have to become more than just words. A working knowledge of these and a lot of other areas previously considered as strictly within the domain of computer people will be essential for engineers using the new processors.

That old expression, "the race belongs to the swift," could be converted in this case to, "the race belongs to the prepared."

Frank Egan

Editor

STAFF

Publisher
Hugh R. Roome

Editorial Staff
Frank Egan, *Editor*
Roy Forsberg, *Managing Editor*
Bob Cushman, *Special Features Editor*
Roger Allan, *Associate Editor*
John Bond, *Associate Editor*
Earle Dilatush, *Associate Editor*
Bill Furlow, *Associate Editor*
Art Stapp, *West Coast Editor*

Art Staff
Dan Kicilinski, *Director*
Patricia Rawlins, *Illustrator*
Elizabeth Garrenton, *Illustrator*
Richard Pierro, *Illustrator*

Production Staff
Wayne Hulitzky, *Director*
William Tomaselli, *Manager*
Susan Kennedy, *Assistant*

Circulation
Anthony Pertusi, *Manager*

Marketing Services
Ira Siegel, *Manager*

Editorial Consultant
John Peter

Editorial Office Addresses
Executive (617) 536-7780
221 Columbus Ave.
Boston, MA 02116

New York (212) 689-3250
205 E. 42nd St.
New York, NY 10017

West Coast (213) 933-9525
5670 Wilshire Blvd.
Los Angeles, CA 90036

with Cinch edge connectors you've got it made.

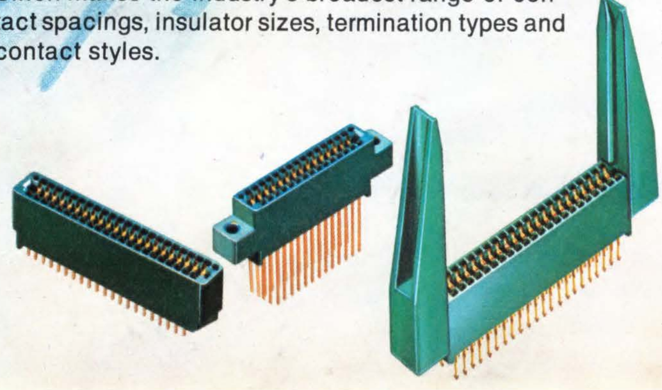
. . . because we've already made it for you.

Your best combination of cost and reliability lies in a connector that already exists—that has been tooled, tested and has proven itself in use. Next best is a custom combination of available insulators and contacts that provide the functions you require. Either way you've got it made with Cinch because Cinch makes the industry's broadest range of contact spacings, insulator sizes, termination types and contact styles.

Whether you'll need large quantities for long range production scheduling—or smaller quantities for immediate delivery (through our nationwide network of stocking distributors), you'll save yourself a lot of trouble if you think of Cinch first.

Get a copy of the latest Cinch edge connector catalog from your local Cinch sales office, or write to Cinch Manufacturing, an Electronic Components Division of TRW Inc., 1501 Morse Avenue, Elk Grove Village, Illinois 60007; phone (312) 438-8800.

CM-7306



TRW® CINCH CONNECTORS

Circle No. 18

Miida

Miida 6854 4½ digits

LABORATORY GRADE DMM. Accuracy 0.005% ± 0.01% of FS on 200m VDC range. Stability ± 0.008% of reading on 200mV/2V/20V ranges, guaranteed for 6 mos. Autoranging to 19999 up-level, down-level 01800. BCD output. CMR 140dB(DC), NMR 40dB. VAC accuracy 0.2% of reading ± 0.1% of FS ± 1 digit (45Hz to 10kHz). Our customers tell us this is the finest value in 4½ digits in the U.S. Check us out.

$689

Miida 6454 Full 4 digits

AC/DC/BATTERY HIGH ACCURACY DMM. Accuracy 0.01% of reading ± 0.01% of FS ± 1 digit on VDC ranges of 1/10/100/1000V. Stability 0.02% of reading on 1V range for 180 days (0.01% on 10V, 0.02% on 100, 1000V). VAC accuracy from 0.03% ± 0.2% of FS ± 1 digit up to 100V; to 0.5% ± 0.5% of FS ± 1 digit (45Hz to 20kHz) on 600 V range.

$495

overdesigned DMM's for picky people

Mee-Dah. Miida. The best spec-ed digital instrumentation you'll ever find, and always belligerently competitive in price. Watch this name: Miida. It's worth a lot to you.

Now, three DMM's to prove the point. All automatic ranging. All our special dual-slope integration design, with superior accuracy and stability. All with options and technical conveniences unmatched elsewhere. And **SERVICE BY HONEYWELL** throughout the U.S.

This ad can carry only a few specs, unless we make it into a data sheet. So, why don't you get the data sheets on DMMs from H-P, Fluke, S-D, and any smaller houses you favor—and also get Miida's. Compare, and make your decision on the obvious facts. Fair enough? You can get Miida's facts and rep addresses by writing or calling Tom Williams. Be picky.

Miida 6354 3½ digits

0.1% DC ACCURACY. 0.5% AC accuracy to 20kHz. Calibration guaranteed for 6 months. Fully automatic ranging. DC amps from 20 μA to 2A (with shunt). Available with rechargeable battery pack and many accessories. To our knowledge, this is the lowest price 3½ digit DMM in the U.S. today.

$289

Miida Electronics

2 Hammarskjold Plaza • New York, N.Y. 10017 • (212) 973-7152

MFD. BY TAKEDA-RIKEN INDUSTRIES, LTD.

Circle No. 12

THE SUPER 70

The new 1-1/4-inch cermet trimmer that replaces all these...

55	**215**	**949**	**3051**	**AB-MH**
56	**235**	**993**	**3052**	**AB-NP**
58	**272**	**995**	**3059**	**AB-NX**
78	**276**	**2855**	**6011**	**AB-RP**
140	**450**	**3011**	**6022**	**AB-RH**
185	**650**	**3012**	**AB-MP**	**ET-12**

...with the most advanced features, too!

- Improved wiper and unique slider block design
- Excellent setability and stability
- TEMPCO of 100 PPM/°C
- 1 W @ 85°C
- Five configurations
- Conforms to MIL-R-22097.

Send for data sheet and quantity price information, or contact your local Spectrol representative or distributor.

Spectrol

SPECTROL ELECTRONICS GROUP

UNITED STATES Spectrol Electronics Corporation 17070 E. Gale Avenue, City of Industry, Calif. 91745, U.S.A. • (213) 964-6565 • TWX (910) 584-1314

UNITED KINGDOM Spectrol Reliance Ltd. Drakes Way, Swindon, Wiltshire, England • Swindon 21351 • TELEX: 44692

ITALY SP Elettronica spa Via Carlo Pisacane 7, 20016 Pero (Milan) Italy • 35 30 241 • TELEX: 32242

Circle No. 13

this new 72-page Cherry Products Handbook is actually five catalogs in one.

Packed in a unique new "tell-all" format is everything you could possibly want to know about Cherry's: **1. Unique Snap Switch Selector-Locator** that lets you choose—in seconds!—the right switch for any application. **2. Thumbwheel and Leverwheel Switches** in nine basic series available in hundreds of variations and specials. **3. Keyboards . . . Keyboard Switches** . . . and unique new Matrix Keyboards. **4. Matrix Selector Switches** for rapid circuit selection and programming. **5. Gold "Crosspoint" Contact Switches** for low energy circuits.

. . . and it's yours for the asking: Just TWX 910-235-1572 . . . . . . or PHONE 312-689-7702 and ask for Frank

CHERRY®

CHERRY ELECTRICAL PRODUCTS CORP.
3600 Sunset Ave., Waukegan, Ill. 60085

Cherry affiliates worldwide • Hirose Cherry Precision Co., Ltd., Tokyo • G. W. Engineering Pty. Ltd., Sydney
Cherry Electrical Products (U.K.) Ltd., St. Albans, Herts • Cherry Mikroschalter GmbH, Bayreuth, Germany

Circle No. 14

Raytheon Semiconductor is dominant in beam leads.

No gimmicks. Just products.

Raytheon Semiconductor's beam lead product line gives designers a choice like they've never had before. More than a hundred standard types in both military and commercial versions.

Now you can appreciate the quality, reliability, high yield and related economy of Raytheon Semiconductor beam leads. And do away with costly, low yield chip-and-wire on your hybrid modules.

We're adding to this list every week.

Transistors

BT918	NPN UHF Amp
BT929	NPN Low-level Amp
BT930	NPN Low-level Amp
BT2221A	NPN General Purpose Amp
BT2222A	NPN General Purpose Amp
BT2369A	NPN Hi-speed Switch
BT2483	NPN Low-level Amp
BT2484	NPN Low-level Amp
BT2604	PNP Low-level Amp
BT2605	PNP Low-level Amp
BT2906A	PNP General Purpose Amp
BT2907A	PNP General Purpose Amp
BT2946	PNP Chopper
BT3906	PNP Hi-gain Amp
BT4856	N-channel FET*
BT4857	N-channel FET*
BT4858	N-channel FET*
BT5109	NPN UHF Power Amp

*Available in second half of 1973.

Diodes

BD914	2 Anode, 2 Cathode Leads
B2D914	1 Anode & Cathode, 2 Open Leads
BD3600	2 Anode, 2 Cathode Leads
B2D3600	1 Anode & Cathode, 2 Open Leads
BZ752	5.6V Zener
BZ758	10V Zener
BZ821T	6.2V Temp Comp Zener
BZ969	22V Zener

Linears

RM101ABL	Op Amp
RM104BL	Negative Voltage Regulator
RM105BL	Positive Voltage Regulator
RM106BL	Voltage Comparator
RM709BL	Hi-gain Op Amp
RM710BL	Hi-speed Differential Voltage Comparator
RM711BL	Dual Differential Voltage Comparator
RM741BL	Op Amp
RM1741BL	Op Amp
RF9601BL	Monostable Multivibrator
RF8601BL	Monostable Multivibrator
RC4131BL	Hi-gain Op Amp
RM4132BL	Micropower Op Amp

TTL

RF50BL	J-K Flip-flop (AND Inputs)
RF60BL	J-K Flip-flop (NOR Inputs)
RF100BL	Dual J-K Flip-flop (Separate Clocks)
RF110BL	Dual J-K Flip-flop (Common Clock)
RF200BL	J-K Flip-flop (AND Inputs)
RF210BL	J-K Flip-flop (OR Inputs)
RG40BL	Dual 4-input NAND Gate
RG50BL	AND-OR Inverter Quad 2-input Gate
RG80BL	Dual Pulse Shaper AND Gate
RG130BL	Dual 4-input Line Driver
RG140BL	Quad 2-input NAND Gate
RG200BL	Expandable Single 8 NAND Gate
RG220BL	Quad 2-input NAND Gate
RG231BL	Quad 2-input A01 Gate
RG240BL	Dual 4-input NAND Gate
RG250BL	Expandable Quad 2 A01 Gate
RG310BL	Expandable Dual Output 2-input A01 Gate
RG320BL	Triple 3-input NAND Gate
RG380BL	Hex Inverter
RL10BL	Fast Full Adder
RL20BL	Dependent Carry Fast Adder
RL30BL	Independent Carry Fast Adder
RL60BL	4-bit Storage Register
RL70BL	4-bit Storage Register
RG3380BL	Hex Inverter
RG3390BL	Dual 4-input AND Gate (Split Outputs)
RG3410BL	Quad 2-input NOR Gate
RR5102BL	64-bit Bipolar RAM

Arrays

Universal 60-gate Arrays. Many MSI functions from registers to counters, both custom and standard functions.

Don't compromise your next design. Be dominant with Raytheon Semiconductor beam lead products. Contact your local Raytheon Semiconductor sales office or clip the coupon for more information.

RAYTHEON

Raytheon Semiconductor
350 Ellis Street
Mountain View, CA 94040
Phone (415) 968-9211

☐ Send me a copy of your Beam Lead brochure.

☐ Send me a mechanical sample.

NAME

TITLE

COMPANY

ADDRESS

CITY/STATE/ZIP

EDN

Digital storage techniques used in medical pulse analyzer

Designers of medical electronic equipment are forever admonished to keep the end user—with his capabilities and limitations—in mind as they design their devices. A recently developed defibrillator analyzer is a good example of how such an awareness can be combined with the latest in components and some clever design to produce an equipment that serves a widespread need.

As with all hospital equipment, defibrillators must be checked periodically to determine that they are working properly. To accomplish this, a variety of test instruments have been developed over the past few years.

As shown in **Fig. 1,** there are other parameters besides energy level which are important to know with respect to a defibrillator output pulse. These include peak voltage and duration of current flow, as well as quality. Is the waveform clean or, as in **Fig. 2,** is there arcing or spiking present, indicating perhaps a shorting choke, a defective relay or intermittent cables?

It is essential to know these things to determine whether a defibrillator is capable of reliable performance, and in order to know these things, it is necessary to visually analyze the defibrillator waveform.

This can be done with an oscilloscope and a camera attachment. However, the set-up and operation of such an arrangement is complex.

As a result, the developers of the new defibrillator analyzer, Bio-Design, of Stoughton, MA, pursued the following train of thought: Suppose there were some way to use an electrocardiograph (ECG) as the recording device. Every hospital has at least two electrocardiographs and some have as many as 15 or 20, so an electrocardiograph should always be available. Unfortunately, ECGs do not lend themselves to recording the rapid defibrillator waveform. Even at a chart speed of 50 mm/sec, the defibrillator pulse would appear as a narrow spike (**Fig. 3**). This is definitely not suitable for analysis of the waveform. So instead, it was decided to use the technique of digital memory storage to store the defibrillator waveform and then read it out at a slower speed.

Fig. 4 is a block diagram of the defibrillator analyzer. The electrodes of the defibrillator under test are applied to the input discs of the defibrillator analyzer. The defibrillator is discharged into a 50Ω load resistor built into the analyzer, which simulates a patient's body resistance. An attenuator and buffer reduce the defibrillator output pulse to a level acceptable to the analyzer circuitry.

An output jack is provided at the buffer output to connect an oscilloscope for viewing the defibrillator pulse in real time. The buffer output signal is fed to the memory circuit which consists of an analog-to-digital

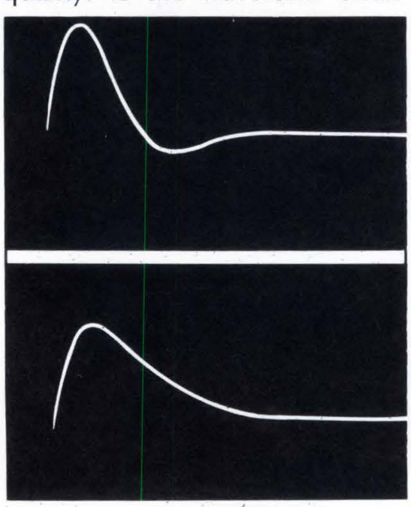


Fig. 1—Typical defibrillator waveforms are clean and smooth.

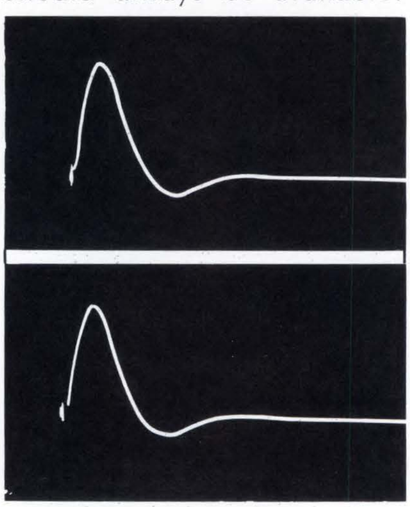


Fig. 2—Abnormal defibrillator waveforms show relay arcing on leading edge.

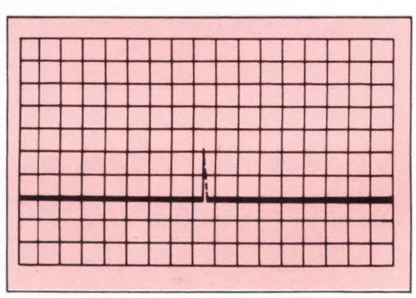


Fig. 3—Direct recording of a defibrillator pulse on an ECG would appear as a narrow spike.

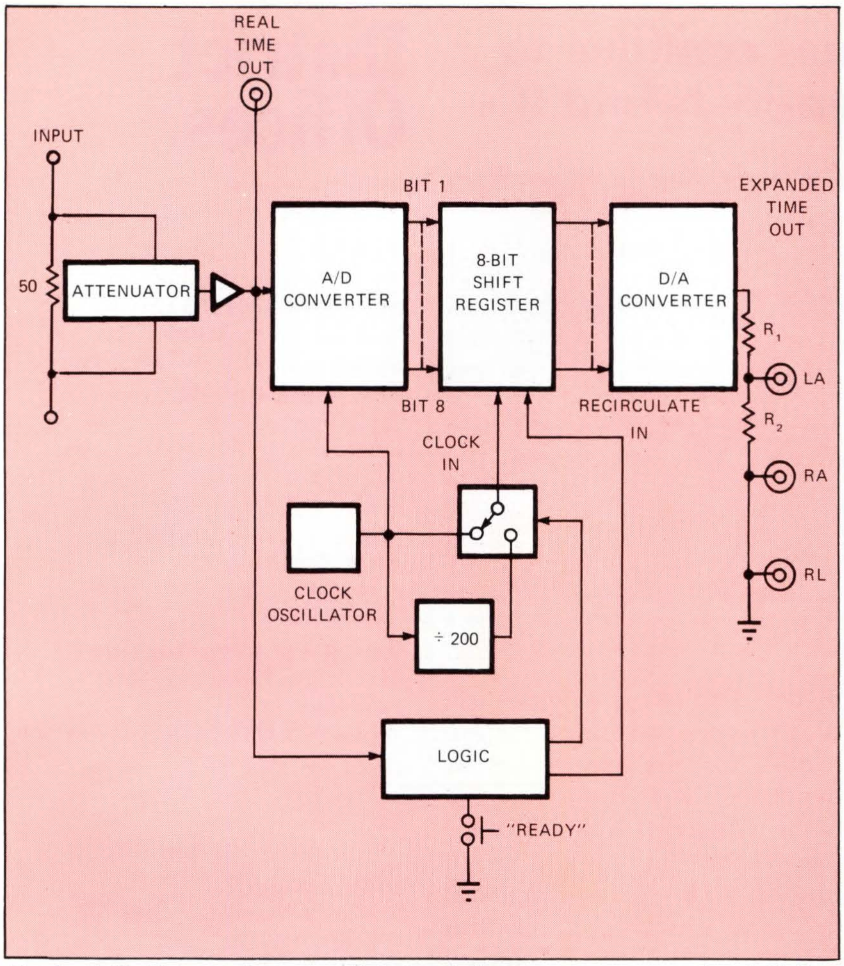


Fig. 4—Defibrillator analyzer uses digital techniques to reconstruct the defibrillator pulse for viewing at a lower speed.

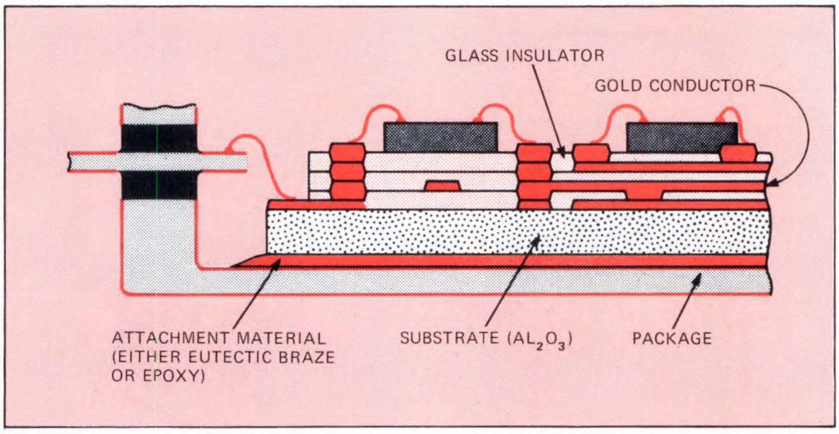
converter, an array of shift registers and a digital-to-analog converter. The defibrillator pulse is converted to digital information at a rate of 1 conversion every clock period. A clock period of 100 μsec is used. Thus, a digital "word" consisting of eight parallel bits is written into a memory comprised of eight parallel shift registers once every clock period.

When the "ready" button is pushed, the electronic switch is set so that the clock oscillator is connected directly to the shift register clock input. Also, the logic is set so that the recirculate input is "off," allowing information to be read continuously into the shift registers at the fast clock frequency.

When the defibrillator is fired, the logic sequence starts. At the end of 20 msec, the logic turns on the recirculate input to the shift registers, inhibiting further information from being read into them. Simultaneously, the logic sets the electronic switch to the ÷ 200 position, reducing the shift register clock frequency by a factor of 200. The digital information now contained in the memory is recirculated at a rate determined by the new clock period of 20 msec.

The recirculated information is also read out continuously by the digital-to-analog converter, which produces an exact reproduction of the defibrillator output pulse, except that is stretched 200 times in duration. This permits recording on a relatively slow device such as an electrocardiograph. The output of the digital-to-analog converter is attenuated by means of R_1 and R_2 to a very low level, providing a convenient time scale on the ECG chart.—*FE*

Multi-layer techniques continue to improve for high-density hybrid ICs



Multilayer construction technique for hybrid circuit substrate can utilize up to 8 layers of conductors and insulators. (Drawing courtesy of General Instrument Corp.)

Demands for higher circuit densities in hybrid ICs have been increasing steadily, and many manufacturers are investigating ways to satisfy these demands. One older method that is gaining new popularity is the multi-layer approach.

Multi-layer construction involves the deposition of alternate layers of conductor patterns, such as gold, and thin and thick-film resistive materials atop one another. In this way fewer interconnections are needed, particularly for cross-overs, and density of the circuit is increased tremendously, by as much as 50% by one manufacturer's recent estimate. An added bonus is increased reliability due to the fewer connections required.

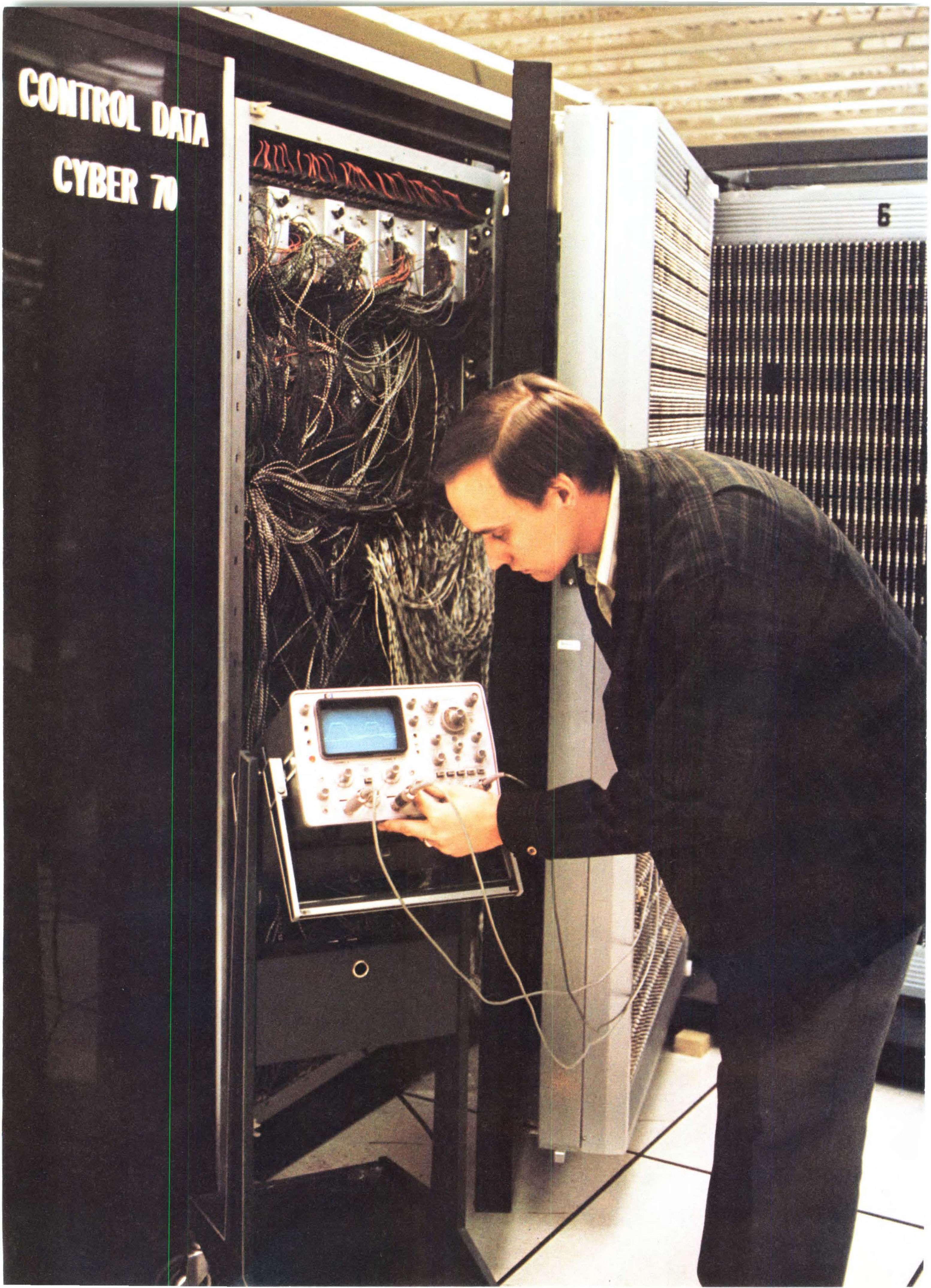
This technique is not new. Among its early developers was the then Unisem Div. of United Aircraft Corp. (now Norden Div.) back in 1968. However, it does require much technical expertise and is difficult to apply. Recent refinements in film materials have simplified the process somewhat, to the point where some half-dozen major hybrid manufacturers are using it quite successfully.

The alternate approach to higher densities is to make use of thinner and thinner line widths for the film materials deposited. But even here, a point is reached where technology cannot be pushed much further to be of any practical use. For example, thick-film pastes, which generally employ 10-mil widths, can't be pushed much beyond 5 mils. Anything less than that poses considerable trimming and reliability problems for the thick-film material.

One major hybrid manufacturer, General Instruments Corp., of Hicksville, NY, has been able to get up to 13 multiple layers of gold and thick-film pastes using this multi-layer method.

Actually, an optimum number of layers exists for each circuit type. This depends on how many monolithic IC and capacitor chips used, and on the number of interconnections employed and their relative position in the circuit.

One reason why this method is still complicated to use is the fact that the materials used must be chosen carefully and thus certain ground rules must be adhered to in the early design layout stage for maximum connection effectiveness.—*RA*


CONTROL DATA
CYBER 70

Given The Options

You Could Build The Ultimate Phase-Locked Loop System

Any designer looks for the ultimate answer to his system requirements. Sometimes that answer does not exist in the options that are available so he must work out a compromise. Now, Motorola offers the designer a choice of specially designed integrated circuits for the Phase-Locked Loop (PLL) functions of phase detection, frequency division, filtering, and voltage-controlled signal generation. The modular concept, where circuits are optimized as independent building blocks rather than specific systems, increases the designer's flexibility and opens up a broad spectrum of design options.

The new concepts presented are "digital harmonic mixing" and "digital phase detection." Drawing from the extensive building blocks available, the designer can produce optimum systems from the sub-hertz region to over 500 MHz.

The following pages outline Motorola's digital approach which can be applied to frequency synthesis, synchronization of digital signals, and clock recovery from encoded digital data streams.

Frequency Synthesis Options

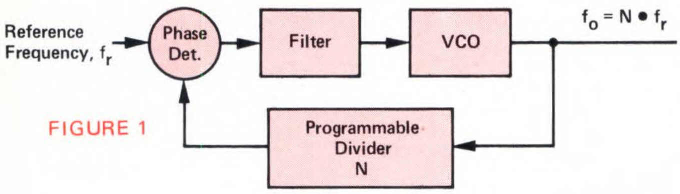


FIGURE 1

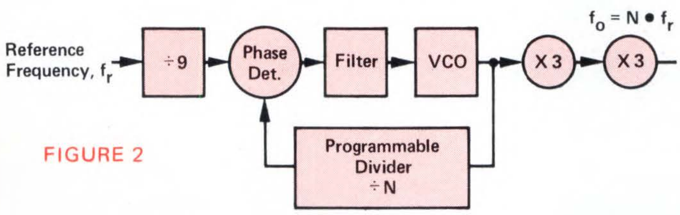


FIGURE 2

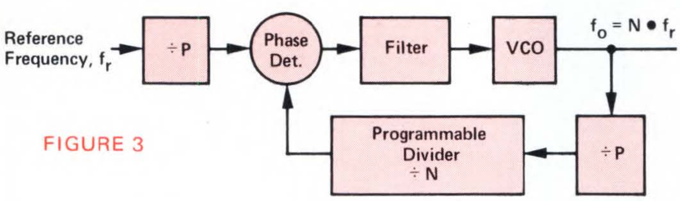


FIGURE 3

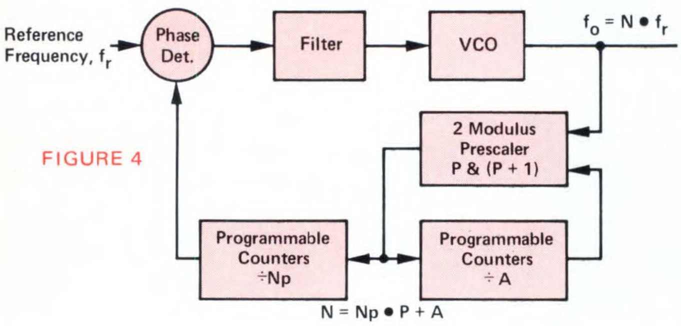


FIGURE 4

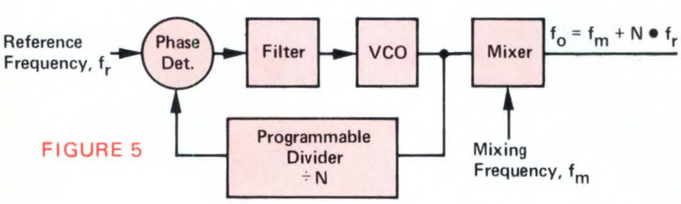


FIGURE 5

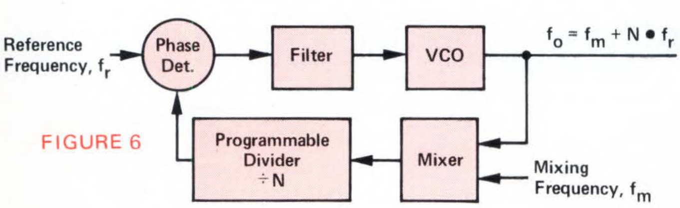


FIGURE 6

The basic PLL technique compares the frequency and phase of the incoming data to the output of a voltage controlled oscillator (VCO). If the two signals differ in frequency and/or phase, an error voltage is generated and applied to the VCO, causing it to correct in the direction required for decreasing the difference. The correction procedure continues until lock is achieved, after which the VCO will continue to track the incoming signal.

In the direct approach (Fig. 1), the VCO must be capable of operating at the output frequency, easily accomplished up to 200 MHz. However, the complex programmable counters would also have to operate at these frequencies, a cost factor since high frequency (>25 MHz) programmable counters are expensive. VHF range applications could benefit by the loop variation of Fig. 2.

Here the input frequency is divided by 9 before phase detection, and the VCO output is multiplied by 9. This method works well for VHF applications at a fixed output frequency, or where a very small change in frequency is required. But the required tank circuits must be tuned and periodic servicing is needed.

The prescaler system in Fig. 3 places the frequency multiplication inside the loop thereby eliminating the tuned multipliers. The input frequency into the divide-by-N is as low as that in Fig. 2, and likewise, loop response is slow.

Two modulus prescaling in Fig. 4 includes a prescaler with provisions for varying the modulus (divisor). Control is by an inexpensive low frequency programmable counter. System cost is slightly greater than the prescaling technique of Fig. 3, but performance is equal to the direct approach in Fig. 1.

In the mixing up option the reference frequency is equal to the channel spacing. This allows a low operating frequency for the VCO and logic, but requires the generation of a fixed frequency (f_m) to mix to the higher frequency. It also requires a tuned output in the mixer, thus restricting the allowable tuning range.

By mixing down the VCO operates at the high output frequency. A mixing frequency must be generated as a heterodyning signal and the mixer must be capable of handling the required input frequencies. Since the mixer is inside the loop, the effect of the mixing oscillator drift on the output frequency is included.

Implementing The Options

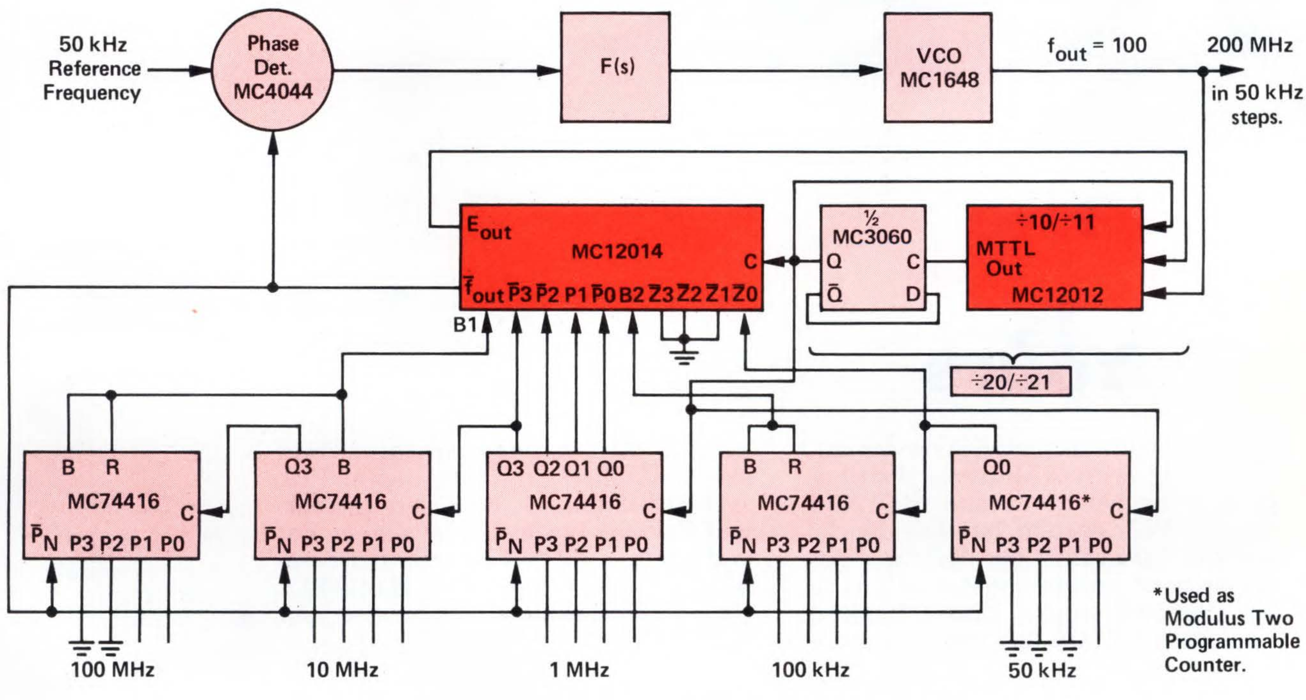
Using the modular, or building block concept, the designer can tailor the PLL to his application and provide optimum performance at minimum cost. Drawing from a full complement of MECL, MTTL, and McMOS loop building blocks; designers can meet design objectives of speed, performance, economy, and power.

Two new PLL developments are now available to implement direct programming by two modulus prescaling (Fig. 4).

- MC12012 Two-Modulus Prescaler. Consists of three functional blocks: A controllable divide by 5/divide by 6 prescaler; a divide by 2 prescaler; and a MECL to MTTL translator. When used with the MC12014 and MC74416, a divide by N programmable counter can be constructed for operation to 200 MHz.
- MC12014 Counter Control Logic. Consists of a zero detector which controls the modulus of the MC12012, and an early decode function controlling the MC74416. The early decode feature also increases the useful frequency range of the MC74416 from 8 MHz to 25 MHz.

The disadvantage of using a fixed modulus (÷ P) for high frequency division (Fig. 3) is that it also requires dividing the desired reference frequency by P (desired reference frequency equals channel spacing). By "variable modulus prescaling," the MECL MC12012 can be controlled by a relatively slow MTTL programmable counter. This technique permits direct high-frequency prescaling without sacrificing resolution since it is no longer necessary to divide the reference frequency by the modulus of the high frequency prescaler.

An example of MC12012 and MC12014 application illustrating one possible counter scheme follows:



Direct Programming 100-200 MHz Synthesizer In 50 kHz Steps.

IC Options Available

FUNCTION	DEVICE NUMBER	LOGIC FAMILY	SPEED (TYP) MHz
Phase-Frequency Detector	MC4044	MTTL	10
Voltage-Controlled Multivibrator	MC4024	MTTL	25
Voltage-Controlled Multivibrator	MC1658	MECL	125
Voltage-Controlled Oscillator	MC1648	MECL	200
Digital Mixer/Translator	MC12000	MECL	250
Two-Modulus Prescaler	MC12012	MECL	200
Counter Control Logic	MC12014	MTTL	25

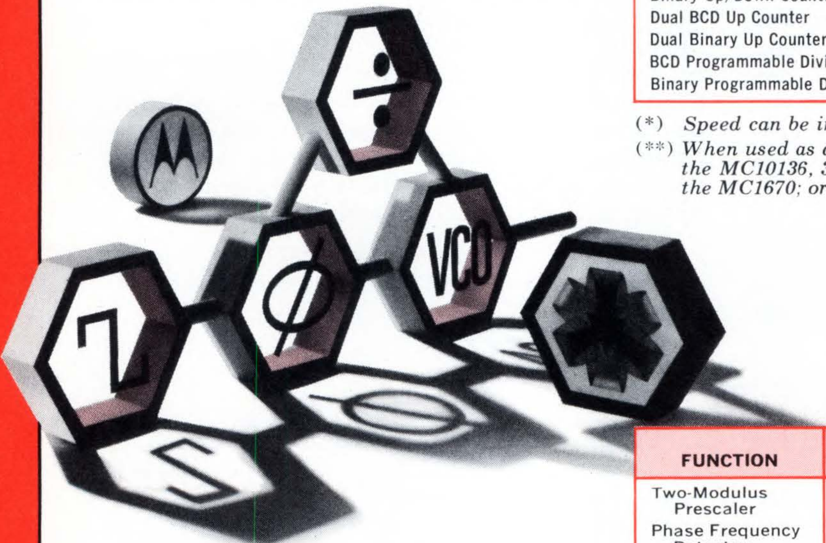
Motorola's digital approach overcomes limitations of linear monolithic PLL systems. Linear systems are harmonic sensitive limiting the capture range, and operation is restricted to an upper limit of 20 MHz. Motorola's digital phase detectors are not harmonic sensitive and capture range is limited only by the tuning range of the VCO. And using the modular building blocks, digital loops can operate at frequencies of approximately 250 MHz. Here are the IC system components now available.

COUNTER OPTIONS

FUNCTION	DEVICE NUMBER	LOGIC FAMILY	SPEED (TYP) MHz	MODULUS
Programmable Modulo-N Counter	MC74416 (MC4016)	MTTL	10*	÷ 0 thru 9
Programmable Modulo-N Hexadecimal Counter	MC74418 (MC4018)	MTTL	10*	÷ 0 thru 15
Universal Counter	MC4023	MTTL	30	÷ 2 thru 12, except 7 and 11
Decade Counter	MC7490	MTTL	20	÷ 2, ÷ 5, ÷ 10
Bi-Quinary Counter	MC1678	MECL	325	÷ 2, ÷ 5, ÷ 10
UHF Prescaler Type D Flip-Flop	MC1690	MECL	500	÷ 2
Universal Hexadecimal Counter	MC10136	MECL	150**	0 to 15
Universal BCD Decade Counter	MC10137	MECL	150**	÷ 10
Decade Counter-Divider	MC14017	McMOS	5	÷ 10
Binary Counter	MC14040	McMOS	10	÷ (2^{12})
BCD Presettable Up/Down Counter	MC14510	McMOS	6	÷ 10
Binary Up/Down Counter	MC14516	McMOS	6	÷ 16
Dual BCD Up Counter	MC14518	McMOS	6	÷ 10 or ÷ 100
Dual Binary Up Counter	MC14520	McMOS	6	÷ 16 or ÷ 256
BCD Programmable Divide By N	MC14522	McMOS	5	÷ 0 thru 9
Binary Programmable Divide By N	MC14526	McMOS	5	÷ 0 thru 15

(*) *Speed can be increased to 25 MHz (typ) when used with MC12014*

(**) *When used as a prescaler, it is possible to extend the input frequency of the MC10136, 37 to over 200 MHz with the MC10231; to 300 MHz with the MC1670; or to over 500 MHz with the MC1690.*

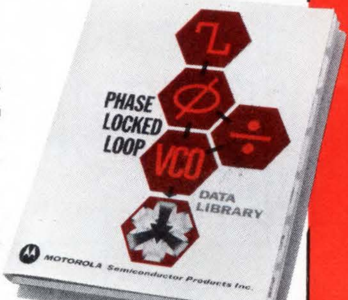


Future Options

FUNCTION	DEVICE NUMBER	LOGIC FAMILY	SPEED (TYP) MHz	CHARACTERISTICS
Two-Modulus Prescaler	MC12013	MECL	350	÷10/11 ÷10/12
Phase Frequency Detector	MC12040	MECL	80	Operation identical to MC4044
Crystal Oscillator	MC12060	MECL	100 kHz to 2MHz	Provide a sine wave output (with ECL thresholds), TTL square wave output and ECL square wave output.
Crystal Oscillator	MC12061	MECL	2MHz to 20MHz	External crystal required (fundamental, series mode).

The Option Is Yours

Evaluate what this digital approach can offer. Your nearby Motorola distributor has the MC12012 and MC12014 plus all PLL system building blocks available for evaluation. And to assist you in your design considerations, a new comprehensive Phase-Locked Loop Data Library has just been published. This library contains data sheets, application notes, digital PLL system techniques and covers the various building blocks now available. For your copy write to Motorola Semiconductor Products Inc., P. O. Box 20912, Phoenix, Arizona 85036. Exercise your option today!



MOTOROLA DIGITAL

— Advanced Concepts In System Design

First we souped-up super beta transistors. Then we closed the gate on FET leakage.

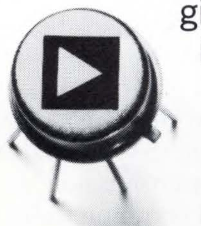
And as if that's not enough, we've come up with the lowest noise, lowest drift dual FET around, too.

These three are just part of the broad line of high performance dual monolithic FETs and transistors we've designed to solve more of your linear circuit problems.

2000β@20V
AD815 NPN

Our AD815 super beta dual monolithic NPN transistor features 2000 beta at a breakdown voltage of 20V. It can reduce your input noise current by a factor of ten. Plus, you get a 0.5mV offset. Price: $5.50 in 100's.

Our AD830 dual monolithic FET gives you an extremely low leakage current — less than 0.1pA. That's as low as they come. Price: $11.10 in 100's.



0.1pA I_g
AD830 FET

And when it comes to super-low noise and drift, our AD840 dual monolithic FET has the lowest noise of any dual FET you can get anywhere: $9nV/\sqrt{Hz}$. It delivers an adjusted drift of $1\mu V/°C$, too. Price: $7.80 in 100's.

These designs are just right for upgrading existing circuits in low-current measurement instruments, preamplifiers, and applications involving high impedance sources. Or build them into brand new circuits; they'll make your design a lot better than anybody else's.

$9nV/\sqrt{Hz}$
$1\mu V/°C$
AD840 FET

We've got samples and comprehensive data sheets. And our 1973 Product Guide. Just ask.

Analog Devices, Inc., Norwood, Mass. 02062.

ANALOG DEVICES

Call 617-329-4700

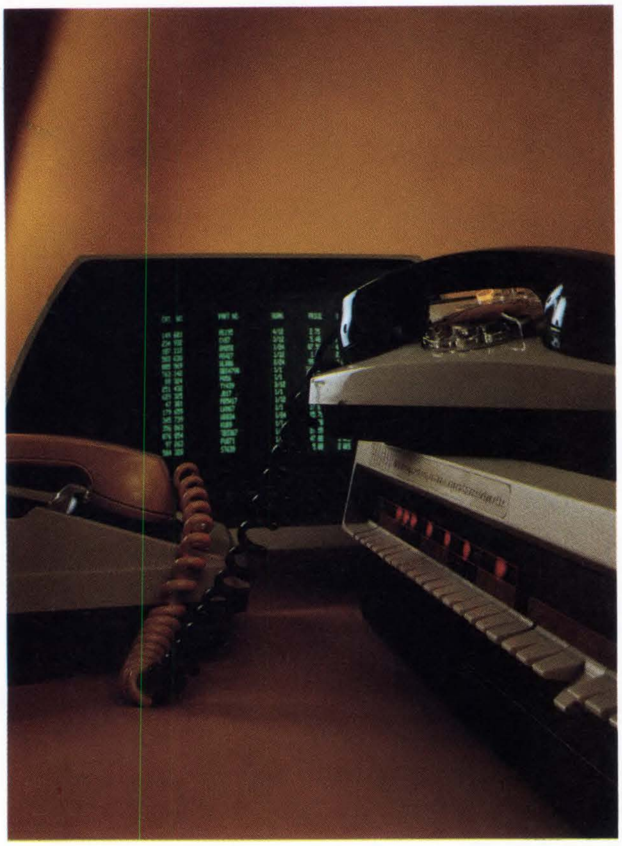
for everything you need to know about dual monolithic transistors and FETs.

Circle No. 23

Minicomputers relieve big brothers of data communication chores

As applications of data communication technology expand, minicomputers are providing low-cost flexibility.

John Bond, Associate Editor



The minicomputer's growing importance in efficient data communications is demonstrated by this DEC minicomputer surrounded by terminals and telephone.

The use of computers is expanding at an ever increasing rate and with it, efficient data communications is becoming a necessity. To satisfy this need for better data communications, minicomputers are being used more frequently because of two important considerations: they are programmable and they have memory. Those two features allow the minicomputer to perform many of the functions that traditionally have been performed by hardwired controllers, other hardware, or by the main computer itself.

The jobs that data-communication systems must perform are data synchronization, line control, code conversion, error control, message concentration and message switching. These functions can be combined in minicomputers acting as front-end processors and remote-data concentrators, to effect savings in hardware and host computer programs. This article will examine these and other uses of minicomputers in data communication.

Since the subject is essentially a hybrid technology derived from communications and EDP, a glossary has been provided at the end of the article to help keep the terminology straight and eliminate confusion.

Common carriers impose constraints

Before minicomputers and other hardware or software can be discussed intelligently, common-carrier facilities must be understood. Telephone and telegraph cables, high-frequency radio and microwave are common-carrier facilities. Because of price and availability, telephone and telegraph lines are most often used. Since telephone voice lines transfer digital data at higher rates than telegraph lines, they are commonly used for data transmission between computers. Much of the technology has evolved to get around the frequency limitations of voice-grade telephone lines which constrain the number of channels available and the transmission speeds. The future will hold increased use of specialized common carriers with networks such as high-speed, wide band microwave systems, specifically designed for data transmission. However, voice-grade lines should continue to be the most important segment of the market into the forseeable future because of lower cost.

Modulation techniques

Communications facilities, in conjunction with appropriate processing equipment, can operate in three basic modes: simplex (one direction only), half-duplex (two way but only one direc-

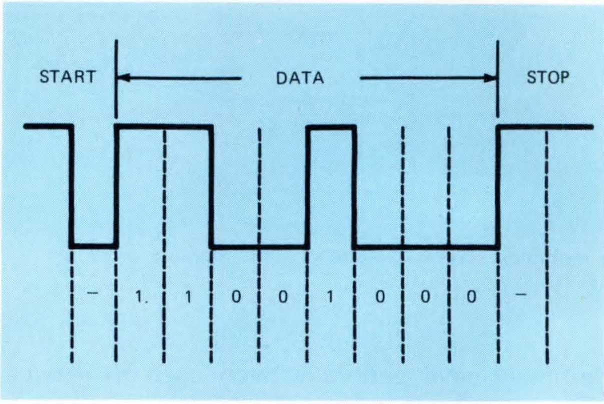


Fig. 1—Asynchronous transmission. Each character consists of a start bit, 8 data bits and a stop bit.

tion at a time), full-duplex (both directions simultaneously). Modulator/demodulators (MODEMS or Data Sets) interface the digital system to the analog communications lines. These modems may use several different modulation techniques, the most popular being frequency shift keying (FSK). FSK is not too efficient in bandwidth utilization so that bandwidth must usually be increased to adopt multilevel coding. Consequently, amplitude shift keying (ASK) and differential phase-shift keying (DPSK), which permit multilevel coding schemes, are used in high-speed systems or for bandwidth efficiency. At any rate, it is not too important from the minicomputer standpoint what particular modulation scheme is used.

More important is the data rate, whether it is synchronous or asynchronous, and the code or codes used in and out of the minicomputer to service modems, multiplexers, main processor (if used in a larger facility) and numerous peripheral devices. Usually transmission is serial but it may be parallel as in the case of a high-speed computer interface.

Data synchronization techniques

Asynchronous-serial transmission **(Fig. 1)** is the technique used by most low-speed (up to 300 baud) electromechanical-serial devices, such as teletypewriters and keyboard printers, which have irregular transmission rates. Unbuffered terminals like paper-tape readers and punches, card readers and line printers use medium-speed (300-500 baud) asynchronous transmission.

In asynchronous transmission, each character consists of 3 parts: a start bit, up to 8 data bits per character and a stop bit. The transmit and receive terminals resynchronize after each stop bit. Because each character has its own synchronizing information, it allows data to be sent at an asynchronous rate.

In synchronous-serial transmission, **(Fig. 2** and **3),** a serial bit-stream is sent over the line in the same manner as an asynchronous-serial bit-stream except that there are no start and stop bits to synchronize each character. Instead, the entire block of data is synchronized with a code which causes the receiver to lock in and count the incoming bits to assemble a character.

Synchronous transmission at medium speeds (300-500 baud) is used for buffered card readers and line printers. High-speed (500 baud and up) synchronous transmission is used for inter-computer communications. A minicomputer data concentrator or front-end processor can service a number of different-speed terminals or lines and execute speed and code conversion to whatever is appropriate for the transmission lines or the main computer facility. Speed and code conversion can also be accomplished with hardwired interfaces but this approach limits the system's ability to react to changing equipment and conditions .

Code conversion

Code conversion is another function that minicomputers may perform. There are a number of codes in use for various purposes. Baudot Code is a 5-level code used for telegraphs, keyboards, printers, punches and readers. The American Standard Code for Information Interchange (ASCII) is a 7-level plus parity code established by the computer industry. Most computers and terminal manufacturers conform to ASCII but minor changes to the code are frequently made to make it more applicable to a particular terminal. A minicomputer has the flexibility to deal with these ASCII variations.

The Four-of-Eight Code is typically used for credit-card verifications and is not important in data communications. Hollerith Code is a 12-level

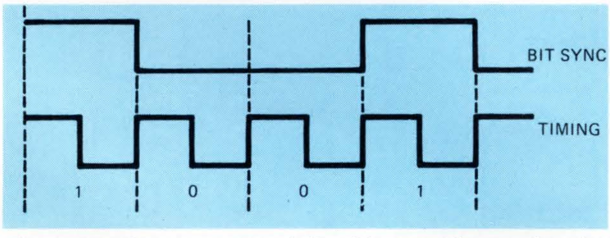


Fig. 2—Synchronous-transmission bit sync. The synchronization code that gets the receiver in sync with the transmitter.

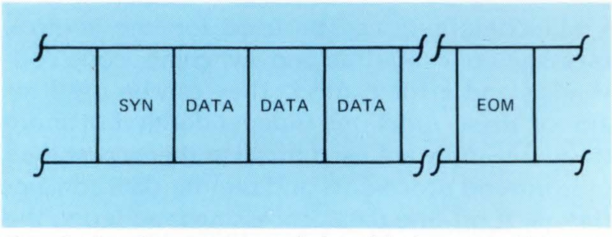


Fig. 3—Synchronous-transmission block sync. After synchronization is achieved, data is sent until end of message.

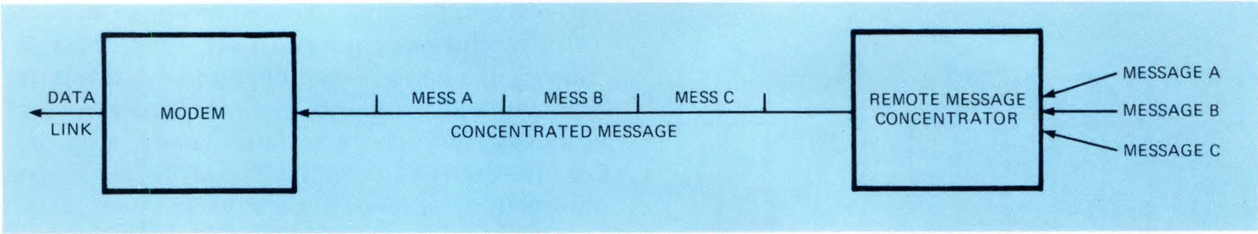


Fig. 4—Message concentration. Remote-message concentrators multiplex several low-speed lines into one or more medium-speed lines.

code used in punched-card applications. Binary Coded Decimal (BCD) is a 6-bit data-processing code mostly used with computers. EBCDIC or Extended Binary Coded Decimal Interchange Code is the BCD code extended to 8 binary bits to allow handling of graphic and control-character codes. It is compatible with BCD oriented data processing.

Generally, Baudot and ASCII are used for low-speed asynchronous applications; ASCII is used for medium- and high-speed asynchronous operations and EBCDIC is used for medium- and high-speed synchronous communications.

Communications processors

A communication processor has to be able to input and output several different codes at different rates, synchronously and asynchronously. It must know what to do with the data, when and where to store it and what commands to send. These are likely functions for a computer. Either the main computer will handle it, with an obvious high-overhead cost, or some external device must be used.

To take some of the load off the main computer, hardwired data-transmission terminals can be used. These are special-purpose devices designed for this type of work. They work well with the equipment for which they were designed but tend to be mainframe dependent. When a computer manufacturer has control over all the peripherals as well as the main computer installed in a facility, hardwired data-communication terminals may be a good choice. If a facility has a mix of equipment from several manufacturers or has very heavy communications requirements, a mini may be a better bet.

Minicomputers in data communications

Minicomputers can be used for line control, message concentration and switching, code conversion and error control. They can be used for any of these functions independently but more frequently they are used for all of them combined in front-end processors and remote-data concentrators. If off-line data processing is added to the functions that minicomputers perform, they are called remote-batch terminals. These remote terminals have generally been used in service bureaus or large corporations for the collection and transmission of data from remote facilities. Considerably more than data communications is involved in remote-batch processing, so that only a small-computer system can perform this function and hardwired terminals cannot be used.

Remote-data concentrators reduce costs

The basic function of a data concentrator is to reduce line costs by concentrating the data-stream without losing information. Traffic smoothing is one technique that can be used to concentrate data. This method smooths the bursts and quiet periods of typical data traffic by buffering. Buffers are storage devices that are used to compensate for rate of data flow or timing differences. Because a mini is well equipped with circuits that can perform these functions, it can provide a moderate amount of buffering quite cheaply without additional hardware costs. Also, mass memory can be used as temporary storage when the total data-input rate is higher than the rated speed of the communication line serviced.

Data compression can be used to reduce traffic load by deleting redundant information such as the start and stop bits in asynchronous transmission. This can improve line utilization by 20% (2 out of 10 bits). Data compression may also be done simply by encoding of multiple-character sequences.

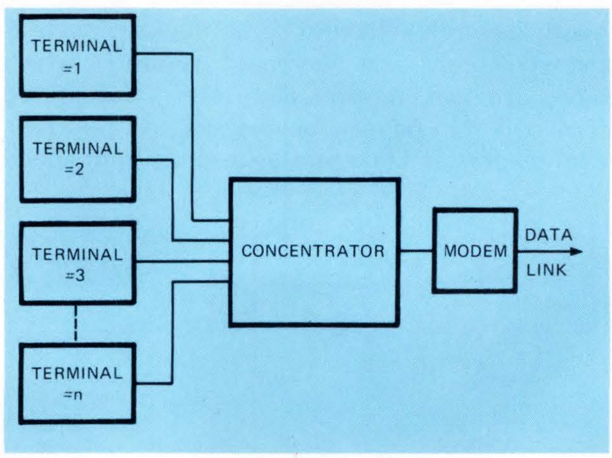


Fig. 5—Line concentration. Remote-line concentrators multiplex medium-speed lines into one high-speed line.

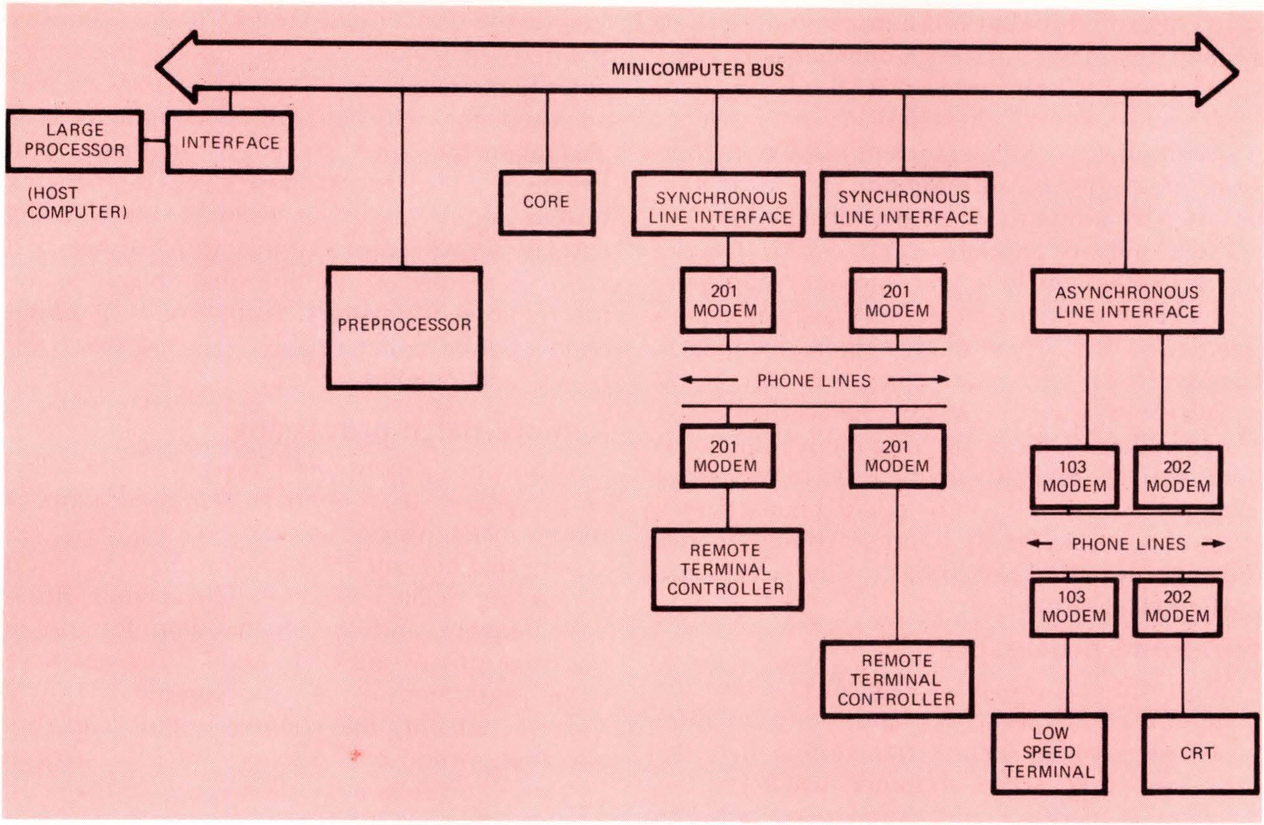


Fig. 6—Front-end processor manages the communications networks and performs pre-processing of data before transferring it to the host computer.

The remote-data concentrator can be used in place of or as controller for time-division (TDM) and frequency-division (FDM) multiplexers. Frequency-division multiplexing is essentially an analog technique, where the communications line is divided into channels separated by guard bands. Digital devices are not suitable for this function but can be used as controllers for FDMs. However, time-division multiplexing assigns each channel to a specific time period, referenced to a synchronizing signal and is well suited to digital techniques. Hardwired FDMs and TDMs cause some communications capability to be wasted because they cannot adapt to temporary under utilization or oversaturation of the communications line. Unlike hardwired multiplexers, a minicomputer can adapt itself to different terminal data rates and can store data that temporarily exceeds the capacity of the line. It can also function as a programmable TDM. Used in this capacity, a minicomputer data concentrator acts as a programmable super TDM, capable of handling many more terminals or lines than conventional multiplexers.

Adaptive-concentrator systems allow terminals of different speeds and codes to service any given port of the computer. Thus, special telephone lines do not have to be designated for each device and maximum use of the communications facilities can be achieved. The flexibility allowed by the use of programmable-adaptive concentrators assures a solid future for minis since it is probably the most economical way to interface terminals of varying characteristics.

Two other important functions that minicomputers can perform are line concentration and remote-message concentration. A line concentrator **(Fig. 5)** is essentially a front-end processor that is not local to the host computer. A line concentrator may be used wherever several communications paths exist over long distance lines. Suppose there are several locations, remote from each other but in the same part of the country. Rather than having dedicated high-speed lines for each location, it is more cost effective to multiplex medium-speed data from these locations into one high-speed line by using a minicomputer line concentrator.

Remote-message concentrators **(Fig. 4)** are similar to line concentrators except that they multiplex several low-speed lines (up to 300 baud) into one or more medium-speed lines. They are always remote to the central processor. Several of them may feed a line concentrator.

Message switches

A message switch may perform line and message concentration but it is a more sophisticated system. The major difference between a message switch and a concentrator is the long term "store-and-forward" characteristics of the switch. A system must include sufficient mass storage to store messages for an indefinite period of time before forwarding them to their destination.

Large military systems such as AUTODYN, which use extremely large computer complexes, have been around for years. Even a very moderate sized switching system might require 100 to 200k characters of core (two characters per 16-bit word) and at least 2.5 million characters of mass storage. That's a bit much for a minicomputer so minis would probably only be used in very small systems. However, a mini could be used as a front-end processor to a larger computer in a message switch. That brings us to a very important class of devices.

Front-end processors

The front-end processor **(Fig. 6)** manages the communications networks and performs preprocessing of data before transferring it to the host computer. The computer used for this function is placed in the data-stream between remote terminals or computers and the host computer. Unlike the line concentrator or remote-message concentrator, the front-end processor is local to the host computer. It interfaces to the main computer by a communication channel or by hardwiring. A high-speed parallel transfer of data is most appropriate for the interface. Most minicomputer manufacturers make standard interfaces for IBM 360 and 370 computers and will make special interfaces for other large computers.

The minicomputer front-end processor establishes line disciplines since not all lines transfer at the same speed or characteristics. It performs handshaking routines which are internal routines executed to acquire and establish a communication link between the front-end processor and the remote station. The mini transmits and receives data to and from remote stations. It assembles data and performs parameter checking, header interpretation and code conversion. It may add information to the messages like origin, destination, time, etc. Finally, the mini transfers messages to or from the host computer on demand or on a pre-established time lapse. If mass storage like a disc system is included, the front-end processor will then have the capability of storing messages until appropriate channels are available, waiting for the computer to finish higher priority jobs before dumping in more data as well as smoothing the flow of data in and out of the system.

Hardwired telecommunications controllers such as the IBM 2701, 2702 and 2703 are expensive and require software support in the host computer to the extent that 10 to 15% of the CPU may be used for telecommunication functions. A programmable front end is not only more cost effective, it also adapts more easily to changing system requirements. It reduces multiplexing costs by allowing direct connection of asymetrical TDMs (time-division multiplexers), thus reducing the number of adapters. Furthermore, it allows connection to noncompatible concentrators, terminals and computers.

Remote-batch processing

As previously mentioned, there is another class of processors used in data communication. A remote-batch processor is a minicomputer based system that decentralizes processing. It is a local computing facility with access to the communication network and the main computer and it performs processing that would otherwise have to be performed in the main computer. Thus it relieves not only the communication load, but also that portion of the processing load that can be carried on remotely, often closer to the point of entry. Remote-batch processing is becoming a highly competitive market with the entry into the field of a number of minicomputer manufacturers who have not been primarily involved with data communications. Since these companies may eventually offer a full line of data communication equipment in competition with those already established in the field, it is to be expected that the competition will become fierce. Even IBM has reluctantly moved into remote-batch processors and programmable-communications controllers to meet the threat of the mini manufacturers. Such competition can only advance the state-of-the-art of minicomputers in data communication. □

EDN would like to thank the many companies who provided the information that made this article possible. Particular thanks go to:

Data General Corp.
Southboro, MA 01722

Digital Equipment Corp.
146 Main St.
Maynard, MA 01754

Interdata Corp
2 Crescent Pl.
Oceanport, NJ 07757

Data Communications Glossary

Asynchronous transmission: Each character contains its own start pulse from which local timing is derived for the interpretation of that character. Synchronizing characters are not required. 1, 1.42 or 2 stop pulses terminate each character, depending on the amount of time required for the equipment to resynchronize.

Auto answer: Capability for the computer to respond automatically to an incoming call initiated by dial equipment.

Auto dial: Capability for the computer to dial calls automatically over the communications network.

Automatic error correction: The detection and correction of errors by the use of special codes and/or automatic retransmission of the message or a portion of the message.

Bandwidth: The difference in Hertz between the highest and lowest frequencies of a band.

Batch processing: A method of data processing in which a number of similar input items are accumulated and processed together.

Baud: A unit of telegraph signaling speed derived from the duration of the shortest signaling pulse. This pulse is called a "unit pulse". 1 baud = 1 unit pulse/sec telegraph speed.

Baudot code: A 5-bit code widely used for teletypewriter transmission. Thirty-two characters can be represented by the 5 bits. The code consists of a start bit and 5 character impulses, all of equal length, and a stop bit whose length is 1.42 times the start bit. The presence of a bit on a line is called a "mark", while the absence of a bit is called a "space". The start bit is always a space, while the stop bit is always a mark.

Bits per second (bps): The number of information bits in a given time interval. Bits/sec are a measure of information rate as contrasted with baud, which is a transmission-modulation rate. The bit rate and the baud rate are not necessarily identical within a system and should not be interchanged in usage.

Buffer: A storage device used to compensate for a difference in rate of flow of data or time of occurrence of events when transmitting data from one device to another.

Channel, reverse: A communication channel between a slave station and a master station that is used exclusively for control signals.

Contention: An operational condition on a data-communication link in which no station is designated a master station. In contention, each station on the link must monitor the signals on the link and wait for a quiescent condition before initiating a bid for master status.

Continuous operation: A type of message transmission in which the master station need not stop for a reply after transmitting each message or transmission block.

Control characters, data communication: The 10-character subset from the 128-character set of control and data characters of USASCII which are defined for use in controlling a data communication system.

Data set: A circuit-termination device used to provide an interface between a data-communication circuit and a data terminal. A modulation and/or demodulation function is typically performed in a data set. See also Modem.

Dedicated line: A line permanently assigned to specific data terminals not part of switched networks. Also called a private line.

Echo check: A check of accuracy of transmission in which the information which was transmitted to an output device is returned to the information source and compared with the original information to insure accuracy of output.

Full duplex (FDX): A communication channel over which signals may be sent in both directions simultaneously.

Four-wire circuit: A 2-way circuit using two paths so arranged that the signals are transmitted in one direction only by one path and in the other direction only by the other path. The transmission paths may or may not employ four wires.

Half-duplex (HDX): A communication channel over which signals may be sent in either direction but only in one direction at a time.

Heading, message: A sequence of characters that may precede the text of a message to provide the information necessary to route the message to its ultimate destination(s). A heading may information other than routing instructions.

High speed: Wide-band capability. Above 9600 bps.

Identification, station: A sequence of characters used to identify a station.

Leased line: Generally refers to a private full-period line.

Link, multipoint: (1) A data-communication link connecting three or more stations; (2) a data-communication link with the control capability necessary to interconnect three or more stations.

Link, point-to-point: A data-communication link connecting two stations.

Low speed: Up to 200 bps.

Medium speed: Above 300 bps but still voice band.

Message: A group of words, variable in length, transported as a unit. In telegraphic and data communications, a message may be composed of three parts:

(1) A heading that contains a suitable indicator of the beginning of the message together with the source and destination, data and time of filing and routing of other transmission information.

(2) A body comprising the information or advice to be communicated.

(3) An ending containing a suitable indicator of the conclusion of the message.

Message routing: The function (performed at a central-message processor) of selecting the route, or alternate route if required, by which a message will proceed to the next point in reaching its destination.

Modem: Acronym meaning "modulator-demodulator"; now commonly used to describe that piece of equipment which functions at the terminals of a communication system as a link between electronic signals in digital form and audio signals which can be transmitted via the telephone network.

Mode, basic: An operational mode in which the

10 communication-control characters of USASCII may not be used within a message heading or a message text.

Mode, conversational: An operational mode in which message information is used in lieu of , or in addition to, control characters as replies for message information.

Mode, transparent: An operational mode in which all 120 coded combinations of USASCII are allowed as message characters within a text.

Multiplexing: The division of a transmission facility into two or more channels.

Multi-point: A communication channel interconnecting three or more stations.

Narrow band: Communication channels whose maximum speed capability does not exceed 200 bps, primarily private-wire teletype and TWX.

Point-to-point: A communication channel between two stations only.

Polling: A technique for inviting a station to transmit messages at a given time. One station is designated as a control station to invite tributary station(s) to transmit.

Simplex (SPX): A communication channel over which signals may be sent in one direction only.

Store-and-forward switching center: A message-switching center in which the message is accepted from the sender whenever he offers it, held in a physical store and forwarded to the receiver whenever he is able to accept it.

Stunt box: A device to control nonprinting functions of a teleprinter terminal such as carriage return, line feed, ring-signal bell, answer-call directing code, etc.

Synchronization, character: The process by which the transmitting and receiving character frequencies are made the same and are maintained in a phase relationship such that the characters transmitted can be derived by the receiver.

Synchronous transmission: The process by which a block of data is slaved to accurately synchronized clocks at the receiving and transmitting stations. Start and stop pulses are not required with each character. Special synchronizing characters are used to synchronize data.

System, data communication: The aggregate of the data-communication links and link-interface equipment and software required for the communication of coded information between or among discrete physical locations.

Switched network: A multi-point network with circuit-switching capabilities. The telephone network is a switched network, as are Telex and TWX.

Terminal, data: That part of a station that is concerned with the functions of generating data and/or recording or display of data, together with the control equipment and/or software necessary to control these functions.

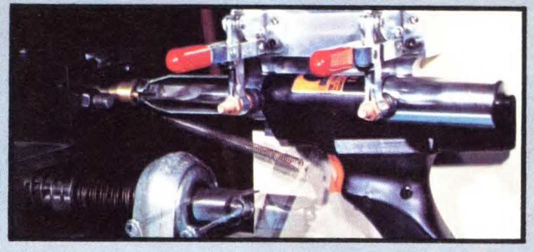
USASCII (U.S.A. Standard Code for Information Interchange): An 8-bit (including parity) code plus 1 start and 2 stop bits to make an 11-unit code. Used in both synchronous and asynchronous transmission.

Voice-grade channels: A communication channel capable of accommodating voice or data transmission with a frequency range of 300 to 3000 Hz.

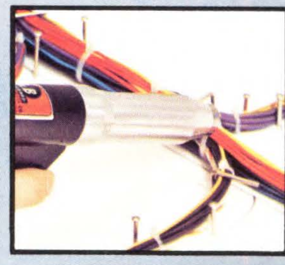
New *TY-RAP*® Tool completes one million ties every month

Triggered 70,000 times each day without a misfire!

As you read this message, the production model of this pneumatic hand tool, TR-225, is continuing its life cycle test... 1,000,000 cycles per month without a falter.



This 20 ounce tool ties wire bundles from 1/16″ to 4″ diameter with just about every regular and "Slim Line" type TY-RAP® cable tie . . . 16 sizes in all. It reduces operator fatigue . . . and is particularly well suited for close-up work, break-out points and tying in confined places in equipment.



Our other new production tool, the high speed TR-300, automatically positions a TY-RAP tie around bundle, cinches to a preset tension, locks tie securely and trims evenly . . . all in 8/10 of a second . . . and on bundle diameters ranging from 1/32″ to 5/8″.

Write for new catalog. The Thomas & Betts Co., Elizabeth, New Jersey 07207, (201) 354-4321. In Canada, Thomas & Betts Ltd., P.W.

Sold Only Through Authorized T&B Distributors

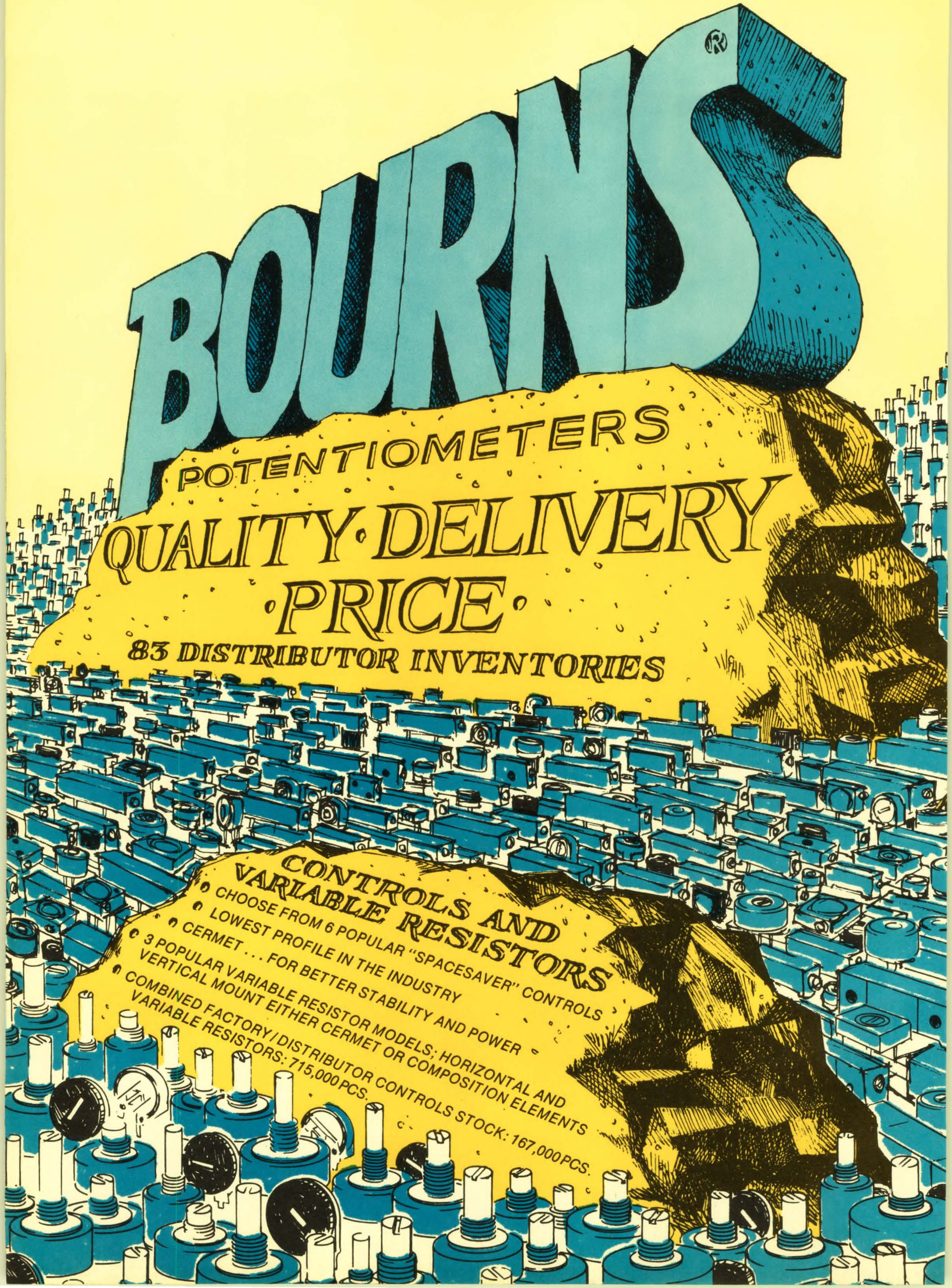
T&B ENGINEERED

THOMAS & BETTS

Division of Thomas & Betts Corporation

Circle No. 28

524


BOURNS®
POTENTIOMETERS
QUALITY·DELIVERY
·PRICE·
83 DISTRIBUTOR INVENTORIES
CONTROLS AND
VARIABLE RESISTORS
CHOOSE FROM 6 POPULAR "SPACESAVER" CONTROLS
LOWEST PROFILE IN THE INDUSTRY
CERMET . . . FOR BETTER STABILITY AND POWER
3 POPULAR VARIABLE RESISTOR MODELS; HORIZONTAL AND
VERTICAL MOUNT EITHER CERMET OR COMPOSITION ELEMENTS
COMBINED FACTORY/DISTRIBUTOR CONTROLS STOCK: 167,000 PCS.
VARIABLE RESISTORS: 715,000 PCS.

TOTAL SOURCE... BUILT ON BASICS!

COMPONENTS FOR LOW-PRICED COMMERCIAL . . . TO MAN-ON-THE-MOON APPLICATIONS!

Circle No. 79

Rectifier Product Matrix

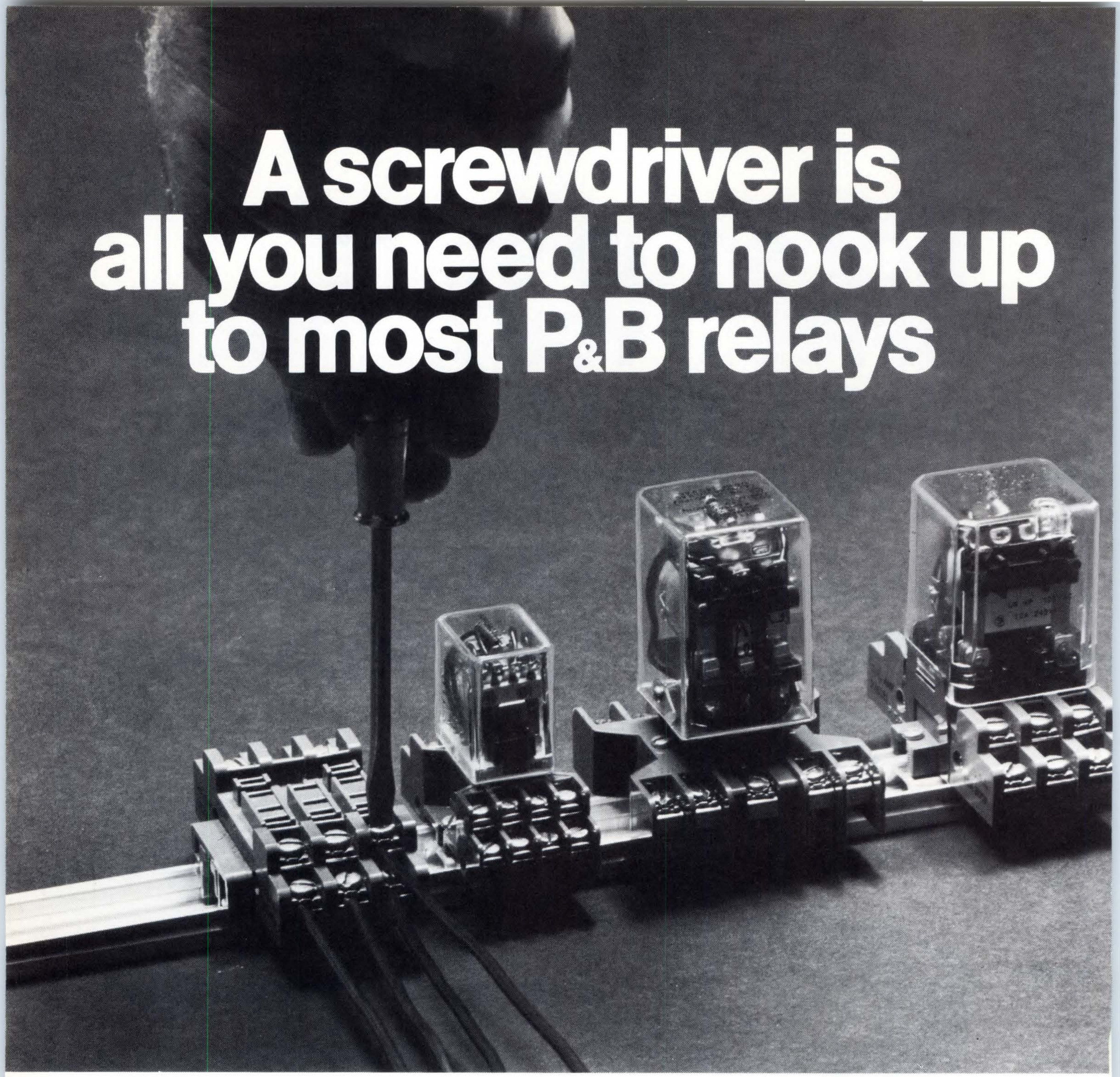
RCA Rectifiers	DO-1 						DO-26 				
I_o	0.125A	0.75A	0.75A	1A	1A	2A	0.5A Ava-lanche	0.75A	0.75A Insulated	1A	1A Insulated
I_{FSM}	30A	15A	15A	35A	35A	35A	35A				
$V_{RRM(V)}$ 50			1N536		1N2858A						
100	1N3754	1N440B	1N537		1N2859A	40266					
200	1N3755	1N441B	1N538		1N2860A	40267		1N3193	1N3253	1N5211	1N5215
300		1N442B	1N539		1N2861A						
400	1N3756	1N443B	1N540	1N1763A	1N2862A			1N3194	1N3254	1N5212	1N5216
500		1N444B	1N1095	1N1764A	1N2863A						
600		1N445B	1N547		1N2864A		40808	1N3195	1N3255	1N5213	1N5217
800							40809	1N3196	1N3256	1N5214	1N5218
1000									1N3563		

RCA Rectifiers	DO-15		DO-4 				DO-5 	
I_o	1A	1.5A	5A	6A	10A	12A	20A	40A
I_{FSM}	30A	50A		160A	140A	240A	350A	800A
$V_{RRM(V)}$ 50	44001	1N5391	1N1612	1N1341B	40108	1N1199A	1N248C	1N1183A
100	44002	1N5392	1N1613	1N1342B	40109	1N1200A	1N249C	1N1184A
200	44003	1N5393	1N1614	1N1344B	40110	1N1202A	1N250C	1N1186A
300		1N5394		1N1345B	40111	1N1203A	1N1195A	1N1187A
400	44004	1N5395	1N1615	1N1346B	40112	1N1204A	1N1196A	1N1188A
500		1N5396		1N1347B	40113	1N1205A	1N1197A	1N1189A
600	44005	1N5397	1N1616	1N1348B	40114	1N1206A	1N1198A	1N1190A
800	44006	1N5398			40115			
1000	44007	1N5399						

Fast Recovery Types

RCA Rectifiers	DO-26 	DO-15	DO-4 		DO-5 	
I_o	1A		6A	12A	20A	40A
I_{FSM}	35A		125A	250A	300A	700A
$V_{RRM(V)}$ 50		44933	43879	43889	43899	40956
100		44934	43880	43890	43900	40957
200	TA7892	44935	43881	43891	43901	40958
300			43982	43892	43902	
400	TA7893	44936	43983	43893	43903	40959
500						
600	TA7894	44937	43984	43894	43904	40960
800	TA7895					
1000						
Reverse Recovery Time trr						
Typ.	200 ns	200 ns	200 ns	200 ns	200 ns	200 ns
Max.	500 ns	250 ns	350 ns	350 ns	350 ns	350 ns

A screwdriver is all you need to hook up to most P&B relays



The new Potter & Brumfield socket system with screw terminals gives you a whole new world of relays to choose from.

How?

By converting octal and quick-disconnect tab termination relays to screw terminals.

Quickly. Simply.

Our system comes complete with mounting channel. Brackets. Retainers. Spacers. And sockets made of virtually indestructible Lexan.

Think of it!

Now you can use newer, more sophisticated relays.

Just as compatible as the ones you've been using. And every bit as reliable.

But they cost less. And take up less space.

(You probably can save as much as 75 percent of the space you're now using.)

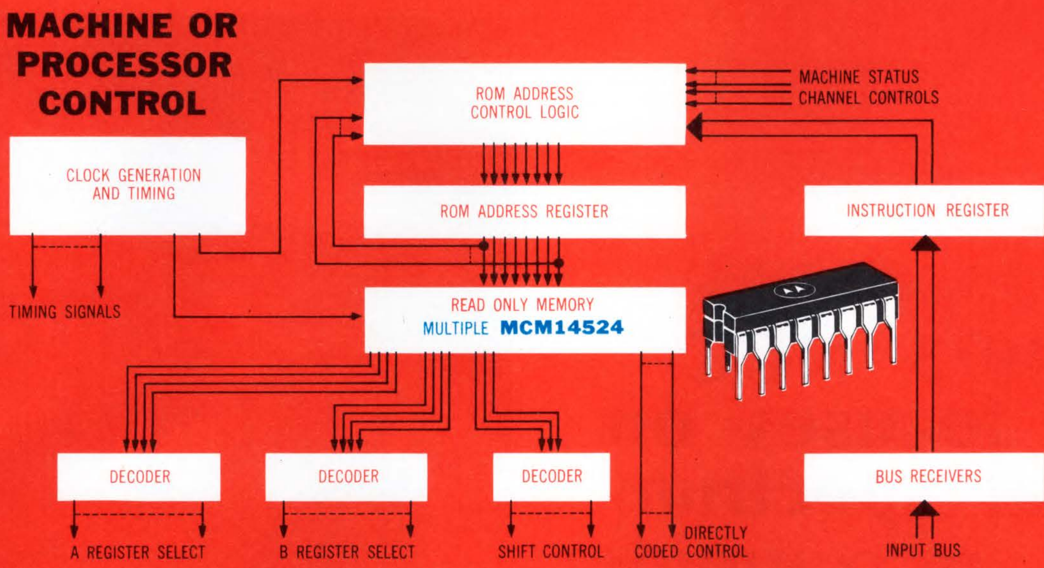
This is just part of what's possible with P&B's new socket system.

To find out more, write or call Potter & Brumfield Division, AMF Incorporated. Princeton, Indiana 47670, (812) 385-5251.

Or talk to your local P&B distributor or representative.

AMF
Potter & Brumfield

Circle No. 26



FIRST 1K CMOS ROM

Creates All-CMOS System Capability–

The interest aroused by Motorola's new MCM-14524 McMOS* ROM was predictable. After all, it's the first 1024-bit CMOS memory. And the interest is much deeper than simple curiosity. The growing ranks of designers with requirements for low power operation and/or high noise immunity have recognized the MCM14524 as the closing link in the solution to many of their problems. The all-CMOS system.

For example, this machine or processor control section using microprogramming techniques can now take full advantage of CMOS. No need to mix in bipolar ROMs. Until the MCM14524 provided an alternative, no matter how the rest of the logic was executed, only relatively power hungry memory options were available for the ROM function. None of them offered any simple approach to noise immunity. With availability of the MCM14524, integrity of low system power use and high system noise immunity may be maintained.

Because it's a mask programmable ROM, the MCM14524 is ordered as a factory special, with the desired unique pattern for the 256 x 4 organization specified on punched computer cards, or if preferable by means of a completed truth table. The memory is expandable by virtue of memory enable on the chip. Output latches provide a storage register, and full address decoding circuitry is on the chip, too.

Somewhat paradoxically, though the McMOS ROM is generally considered in the medium speed category, 70ns data retrieval is possible under certain conditions, i.e., in the chip enable access mode where addressing already has been established.

General McMOS family characteristics serve as a good guide to further definition of the MCM14524. Each of two versions is designed for single supply operation. The AL suffix version operates over a wide supply voltage range of +3 to +18 volts with a −55 to +125°C operating temperature range. The CL version operates over the +3 to +16 V supply range and a −40 to +85°C temperature range.

Mask charges are $1,400.00 on orders to 24, but gradually decline to nothing when order quantities reach 500. 100-999 prices are $24.70 and $13.75 for the AL and CL respectively. Documentation, including programming instructions, is available from Motorola Semiconductor Products Inc., P.O. Box 20912, Phoenix, AZ, 85036. Your Motorola sales office with be pleased to entertain enquiries, too.

*Trademark of Motorola Inc.

MOTOROLA MOS

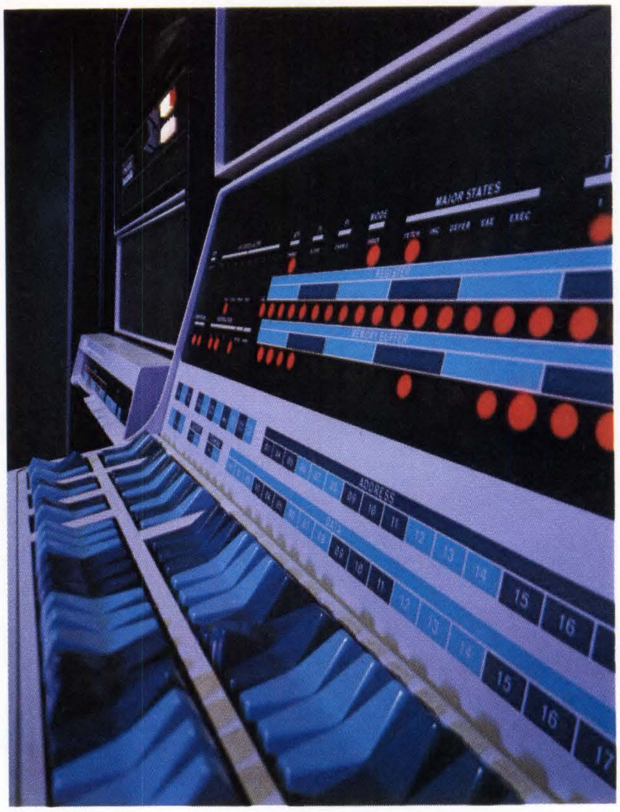
Expanding Dimensions In Digital Design

McMOS

LOGIC OF THE 70's

Circle No. 27

1973 NCC focuses on total spectrum of computer technology



Advances in computer technology can take many different directions as evidenced by this mixed-architecture computer, the PDP-15/76, by Digital Equipment Corp.

From June 4th through 8th, the American Federation of Information Processing Societies (AFIPS) will host "the biggest computer show on earth", the 1973 National Computer Conference and Exposition. The '73 NCC, which will be held at the New York Coliseum, supersedes the traditional Spring and Fall Joint Computer Conferences. AFIPS is committed to creating a major forum for the data-processing community, aimed at fostering dialogue between the computer industry, EDP users, government and the general public. The '73 NCC will present an overall view of computer technology, what it's doing, where it's going and its impact on users and the economy.

"The biggest computer show on earth" is not merely an idle boast. With over 200 exhibitors at approximately 700 booths, it promises to be just that. All segments of computer technology and EDP services will be exhibited and explained by the exhibitors at the conference.

The technical program is divided into three major areas: Methods and Applications, Science and Technology and a Special Program.

The Methods and Application Program will concentrate on the effective use of computers, time and people in a very pragmatic approach to resource utilization. It is divided into sections concerning installation management, government, industry, merchandising and a number of general topics considering the impact of computers on human affairs.

The Science and Technology Program, the largest of the three programs with 56 sessions, will present a review of the state-of-the-art and examine all aspects of developing technology. The areas to be covered in this program include: communications, networking and terminals; computer architecture and hardware; information processing and pattern recognition; management topics including conversion, data bases, data security, forecasting and performance evaluation; displays and graphics; EDP education; simulation and process control; software and areas of concern to the computing community.

Finally, the Special Program presents a number of special sessions and seminars which are of broad general interest. There will be a special seminar on managing the impact of generalized data bases as well as 5 key sessions covering computer technology as a public resource; venture capital for the computer industry; outlook and prospects for marketing abroad; career development for computer professionals and economic future of the data-processing industry.

Sessions in review

The computer industry has come of age and this view is well represented by the mature, thoughtful viewpoints presented at many of the sessions. The thrust of these ideas is that computers must serve the needs of people rather than the other way around, as too often happens. This theme is stressed in the panel session (88) chaired by Gabriel F. Groner of the Rand Corp., "Computers are for people". Or at least they're supposed to be, but it's often hard to prove. The state-of-the-art has reached a point where it is both feasible and mandatory that computers become subservient and palatable to human users. People are scared away by the psychological and physical barriers built into computer usage. The purpose of this session is to learn more about the reasons for success and failure so that better people interfaces can be designed.

Voice answerback

Another session (2) of great interest is "Voice answerback comes of age", chaired by Tom Fisher of IBM. This session will discuss the sharp increase in the use of computer-voice answerback during the last two years, which has occurred because of advances in hardware and applications. The quality of computer speech has gotten better until it is quite acceptable to the human ear. Also, there has been a spectacular growth in vocabulary available to computers equipped with VAB. Existing applications are fascinating but not widely known. Uses of VAB will be demonstrated with emphasis on the increased efficiency of workers who can move around as they hear replies, rather than stay at one fixed work station. Some applications will be demonstrated live and online.

Data-base management

"Trends in data-base management," organized and chaired by Dr. George Dodd of General Motors Research Laboratories, discusses evolutionary trends in data-base technology. The developments shown in this session include specialized processors for data-base management, relational data bases, a technique for data-base sharing and an algorithm for optimal distribution of data within a computer network. Since operating system design will ultimately be influenced by data-base requirements, papers will be presented describing the results of real-time data-base measurements and optimal file-allocation strategies.

Intelligent terminals

There is a trend toward decentralization of computer power as evidenced in the growth of remote-batch processing, remote-data concentration, etc. Along with this trend has come an explosive growth in the use of intelligent terminals. These terminals use built-in logic circuits to perform some processing of data which passes through them to or from the computer to which they are connected.

ira Cotton of the National Bureau of Standards has organized a session on intelligent terminals. The papers and discussion will cover the spectrum of terminals which vary widely in complexity. They range from "dumb" point-of-sale terminals through text oriented terminals up to "bright" graphics terminals.

Processing power raises questions concerning all these different-type terminals and provides a unified theme for the session. For example, what is the proper or most efficient division of labor between the terminals and the central computer? What are the limits, if any, to the power that can be provided in such terminals? After the three invited papers, a panel will address itself to the questions raised.

Hardware advances and their problems

"Advanced hardware", chaired by John Lynch of Burroughs, Corp., will include various hardware developments that reflect on computer architecture. The high-speed capability of the Josephian junction and the optical-interconnection technology will be discussed in relation to whether it will prolong the life of the traditional high-speed processor. Low-cost memory techniques will present the computer designer with new storage management problems. The computer on a chip and the network of chips will force the design of distributed processing systems. Included will be a paper which will tell how special-purpose hardware (firmware) can be tuned to the application via a high-level language.

Computer graphics—a day-long session

Computer graphics continues to play an ever more significant role in every facet of man's environment. "A day with graphics" reports on recent achievements in this field. The 13-1/2 hours that the five sessions encompass spotlights a few of the graphics programming methods applied in enlarging man's creative ability; in producing 3-dimensional drawings, and in employing computer graphics in the various related fields of education, medicine, aerospace, engineering, architecture, art and movies. Ms. Jackie Potts of the Naval Ship Research and Development Center and Dr. Rodney Allen of Flow Research Inc. are the organizers.

Virtual memories

A session entitled "Virtual machines" has been organized by Dr. Ugo O. Gagliardi and Dr. Robert P. Goldberg of Harvard University. This session explores architectural implications of virtual-machine systems. In addition, unique performance aspects and applications of virtual machines will be discussed. Virtual-machine systems provide a powerful and useful tool for debugging operating systems, running multiple-operating systems and isolating the users of the machine from each other. Virtual machines are getting more popular so this should be an important session for anyone involved with them.

Data communication by satellite

For those concerned about high-speed data communications and/or computer and data networks,there are several sessions that examine the techniques of communicating data by satellite. One of these sessions, "Data communication via satellite", will concentrate on examining commercial-data communications by means of satellite established connections. Some of the topics to be discussed are error models, error control, mobile services, and wideband transmission. W.G. Schmidt of COMSAT Laboratories is the chairman.

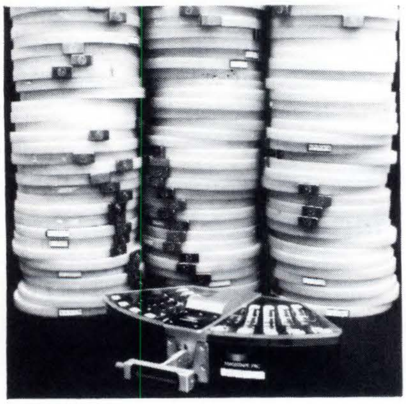
Another session, organized by Dr. Lawrence G. Roberts of ARPA, is "Satellite packet communications". This session looks at the possibility of including communications satellites in data networks. As computer and data networks like ARPANET spread to widely separated areas, communication satellites can play an important role in providing the necessary wideband transmission capacity. Techniques for using a satellite in a multi-access broadcast mode will be considered. (This is accomplished by transmitting addressed data packets from many ground stations, dynamically sharing the capacity of a single wideband satellite channel.) Also, progress toward application of these techniques to international extensions of ARPANET will be covered.

Complete proceedings of the National Computer Conference (Vol. 42) are available for $40 from:

AFIPS Press
210 Summit Ave.
Montvale, NJ 07645

NCC NEW PRODUCTS

Mass memory is expandable to one trillion bits



MASSTAPE™ is the most economical mass on-line storage system available in terms of initial investment, operating cost and space required.

At present, MASSTAPE is designed for 360 and 370 systems running under OS. It is estimated that, in a typical installation with 2 computers, use of this system can realize a savings of up to a half-million dollars a year.

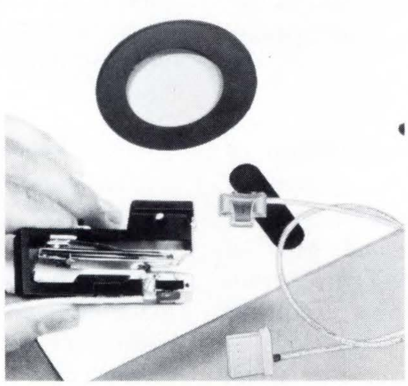
Designed on the modular principle, MASSTAPE units can be added as the demand increases, with a storage capability of up to one trillion bits. Each storage unit holds the equivalent of as many as 5000 conventional tapes. The system speeds information to the computer at data rates up to 1.2 million bytes/sec.

Total purchase price for a basic system, including an interface unit, data buffer unit, system control unit and one storage unit with a capacity of 14 million bytes, is under $356,000. The same system can be rented for approximately $11,800 per month, including prime shift maintenance. Grumman Data Systems Corp., 711 Steward Ave., Garden City, NY 11530. Phone(516)575-3034.

Booth No. 2427 **275**

Long-wear, hard-coat heads designed for floppy disc systems

Originally introduced by IBM, floppy disc systems were created to provide a key-to-disc input system that could increase the speed and accuracy of data entry. One small 8-in. flexible disc element provides significantly more storage capacity than thousands of standard 80-column punched cards. The original concept is now being expanded by the industry to include data-collection and storage devices, key-entry recording, point-of-sale recording, minicomputer-storage and minicomputer-programming applications.



The Series FD long-wear, hard-coat heads that Nortronics is introducing at NCC include read-after-write, wide-write/narrow-read, read only heads and read/write straddle erase heads.

These heads are designed for operation in IBM-compatible, read only, and in 32- and 64-tracks/in. at a density of 1600 bpi, double frequency. Typical disc speeds are 90 and 360 RPM with data transfer rates of 33-133 kbps. Nortronics Co., Inc., 8101 Tenth Ave. N., Minneapolis, MN 55427. Phone(612)545-0401. **Booth 1311** **276**

Data set requires a spectrum of only 965 to 2165 Hz

The Model DS4801, with a data rate of 4800/2400 bps (strap selectable) is designed for multi-drop polled networks and point-to-point systems. It features fast turn-around time, automatic equalization and built-in diagnostic capability.

The DS4801 utilizes 4-level, single sideband, suppressed carrier, amplitude modulation. This technique, coupled with an optimally selected carrier frequency, requires a spectrum of only 965 to 2165 Hz.

The transmit spectrum of the data set occupies only 1200 Hz of a normal 3-kHz voice channel. This narrow spectrum, coupled with the use of an automatic equalizer, provides for operation at 4800/2400 bps over unconditioned, C1 or C2 telephone lines.

The data set may be used in a continuous or a controlled-carrier mode. In polling systems, the data receiver will synchronize and equalize within 50 msec. In the continuous-carrier mode, receiver synchronization may be achieved independent of transmit start-up sequence. $3750. Rixon Inc., 2120 Industrial Parkway, Silver Spring, MD 20904. Phone (301)622-2121.

277

Biplexer provides less than 1 error in 10^6 at 19.2 kbps

The 296 biplexer provides data transmission at 19.2 kbps at lower cost and with better restoral capabilities than wideband service. By combining 2 voice-grade lines in conjunction with Codex 9600 data modems, it will provide full-duplex 19.2 kbps. For present users of Bell 19.2 kbps wideband service, the 296 provides lower monthly costs for distances of approximately 80 miles or more, improved availability, servicing and restoral of lines.

The Codex 296 transmit section splits incoming traffic into two 9600 bps serial streams. Each is transmitted using 960 modems through dedicated voice circuits. The 296 receive section adjusts continuously and adaptively for differential delays of up to 100 msec (optionally, to 800 msec) in the 2 channels, and recombines them into 19.2 kbps output. Initial synchronization is performed automatically after modem training.

Automatic-feedback capability to lower speeds and to single-channel operation is provided, as well as remote and local loopback for system diagnosis. It can also be used at lower speeds for 14.4 kbps transmission over 2 dedicated lines and 9.6 kbps transmission over 4 dial-up lines. $5000. Codex Corp., 15 Riverdale Ave., Newton, MA 02195. Phone(617)969-0600.

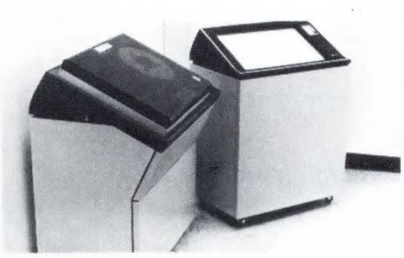
Booths 2339 and 2438 **278**

Off-line matrix print/plot systems

The three systems are designed to operate with the Versatec's 8-1/2 in., 11 in. and new 20 in. line of printers, plotters and combination printer/plotter units which use the advanced matrix electrostatic writing technique (MEWT™).

The matrix print/plot systems (MAPPS™) are designed for use with IBM compatible 37.5 ips magnetic tape; 9 track NRZI; 9 track phase encoded, 1600 bpi; or 7 track NRZI, 200, 556 or 800 bpi.

The MAPPS controller accepts data from the tape and transmits it to the matrix unit after observing appropriate



signal and timing requirements for the raster scan plotting and printing. MAPPS provides eight operational control functions and indicators located on the system control panel, among which are file select, permitting a search and selectivity of any file or file group on the tape; and number of copies, which permits the user to have repetitive printing performed by the matrix unit of any file selected.

Price for the 7-or 9-track NRZI configuration is $8500 and $11,000 for the 9 track phase encoded configuration. Matrix units, which operate with MAPPS, are priced separately, as are individual software packages for use with the different computer systems. Versatec, Inc., 10100 Bubb Rd., Cupertino, CA 95014. Phone(408)257-9900.

Booths 1815 and 1817 **279**

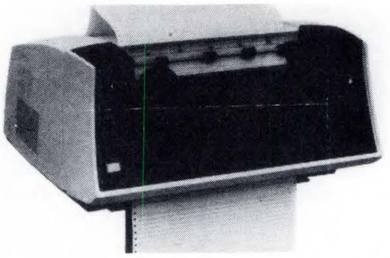
30-cps teleprinter

The 9030 uses matrix-impact printhead with operator selectable speeds of 10, 15 and 30 cps. It offers 132-column print capability; full ASCII upper- and lower-case codes; form-feed tractors that adjust from 2 to 16 in.; half- and full-duplex or local operation; odd, even or no parity error detection; the ability to handle 6-part copy; and an RS232C interface. The terminal includes an integral power supply, electronics,

keyboard and printer assemblies and is shipped from the factory with its desk-top cabinet ready to plug in and use.

Vertical tabulation, numeric keyboards and special interfaces for paper-tape punch/readers are available on both the KSR and ASR versions. A receive only model is also available. Price, $2895 for a single quantity OEM order to $1995 for substantial quantities. Di/An Controls, Inc., 944 Dorchester Ave., Boston, MA 02125. Phone(617)288-7700. **Booth 1338** **280**

Serial impact printer provides 5-fold increase in speed



The PRINTEC-100A full-character serial impact printer uses a 96-character font to provide upper-case and lower-case printout and employs the "multiple split helix" concept.

Model PT-100A is the first true printer, as distinct from typewriters and related mechanisms, to offer upper-case and lower-case printing at high speed and low cost. Key features of the new machines include 70-cps print rate (equivalent to 26 lines/minute at 132 columns/line), ability to print 6-part forms on standard paper, disposable ink roller instead of conventional ribbon, as well as the inclusions of a 2-channel vertical format unit (VFU).

The machine's 70 cps printing rate gives it a 5-fold edge over the IBM Selectric's 10-15 cps rate.

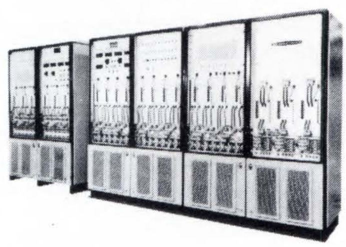
The PT-100A operates on the "print-on-the-fly" principle, whereby electronically timed hammers bang the paper against selected characters on a high-speed print wheel. The high speed is achieved by using multiple-character fonts on a single print wheel. Using separate sets enables the PT-100 series of printers to print several times faster than conventional serial impact machines, which use only one hammer and one character set on the print wheel. $2800. Printer Technology, Inc., Bldg. 3G, Sixth Rd., Woburn, MA 01801. Phone (617)935-4246. **Booths 1206-1208**

281

Fault-clearing inverter for computer uninterruptible power supply

The stepped-wave inverter for battery backed uninterruptible power supply (UPS) systems uses a digitally controlled stepped-wave inverter with subcycle current control. A significant improvement in trouble-free application of UPS systems to critical loads is claimed. This produces unusually precise power in normal operation and the best possible response for overloads, inrush loads and faults.

The Exide all-digital voltage regulator provides 1% voltage balance with phase displacement accuracy of 1° by assigning a particular integer between 1 and 756 for precise-power semiconductor pro-



gramming.

Available in ratings of either 200 kVA or 125 kVA at 0.5 to 1.0 power factor, overload capacity is stated at 125% of rated kVA for 10 minutes, to as high as 250% line to neutral current for 10 cycles. Transient recovery is accomplished within 50 msec for complete recovery to within plus/minus 1% band.

Either multi-tubular lead-acid or pasted-plate lead-acid cells may be used as the battery which backs up the stepped-wave inverter. Exide Power Systems supplies both types in a variety of cell sizes. A matched solid-state Exide charger is also required for the "SuperGuardian" system. Exide Power Systems Div., ESB Inc., Rising Sun & Adams Aves., Philadelphia, PA 19120. Phone(215)342-8000. **Booth 1423**

282

Processor features a user-alterable dynamic control store

The DCS in the Model 85 contains 1024 words of 60-nsec bipolar read-write memory. This allows the user to write and (re-write) his own customized instructions and greatly extend the versatility of an already powerful, general-purpose instruction set. Microprograms in the Model 85 are, typically, 2 to 5 times faster than user-level software programs for the same function.

Interdata will also introduce new versions of their Model 70 and 74 processors featuring 16 kB of core memory on a single 15-in. pc board. Interdata, Inc., 2 Crescent Pl., Oceanport, NJ 07757. Phone(201)229-4040.
Booth 2345 **283**

Interface printer and acoustic coupler

An interface printer for use with Digital Equipment Corp.'s PDP-8 computer and an acoustic coupler compatible with the Bell 103A modem will be exhibited by Terminal Equipment Corp.

The computer interface is a low-cost, plug-to-plug, I/O hard-copy printer, the Holmes Tycom Model CSR-8E, available to users of the PDP-8E/PDP-8M minicomputers. The system uses an IBM Selectric[R] typewriter, the Holmes Tycom baseplate, a power supply and an Omnibus interface. The baseplate is factory installed on the customer supplied typewriter and operates at 15 characters/sec, using the standard DEC Teletype software. All 128 ASCII characters can be generated from the typewriter keyboard.

The Model CSR-8E provides users of the PDP-8 with all the advantages of full upper- and lower-case characters, interchangeable type font, and a high-quality typewriter hard copy for use with the DEC text editor and other business oriented programs.

The Model 920 originate-only acoustic coupler has its own IC regulated power supply. The unit is compatible with the Bell 103A modem and operates at rates from 0 to 300 baud. It can automatically switch between data and acoustic operations and can be used with any terminal having an EIA RS-232 connector. The Model 920 can also switch from full to half duplex. Terminal Equipment Corp., 26 Just Rd., Fairfield, NJ 07006. Phone(201)227-4141. **Booth 1114**

284

Honeywell announces the end.

Our new Honeywell Model Ninety-Six isn't just another high-performance magnetic tape recording system. As far as state-of-the-art will reach…it's **the end**—the ultimate—an instrumentation system that incorporates every feature you have been asking for in a laboratory system.

For example, like previous Honeywell recorders, our Model Ninety-Six has a vacuum-buffered, low-tension tape drive for gentle tape handling, minimum head and tape wear. But unlike all other tape recorders, it will handle 16" reels, through nine tape speeds from 15/16 to 240 ips, and incorporates six other important improvements that together spell **the end** in tape recording:

The end of head wear worries. All of the new Honeywell solid ferrite heads are warranted for 3,000 hours. This alone should help solve one of your biggest headaches.

The end of spectral pollution. Two Honeywell features, FM flutter compensation, and an all new wideband phase lock servo system combine to give you the cleanest reproduce spectrum in tape recording. You'll be happy to know, too, that this servo system offers flutter attenuation at a band-width we believe you simply cannot buy anywhere else.

The end of configuration problems. Tired of trying to match your available electronics to a new task? The 28-channel Model Ninety-Six has omniband electronics. This means you can configure the recorder—at minimum expense—to match your needs as your needs change. Which also means…

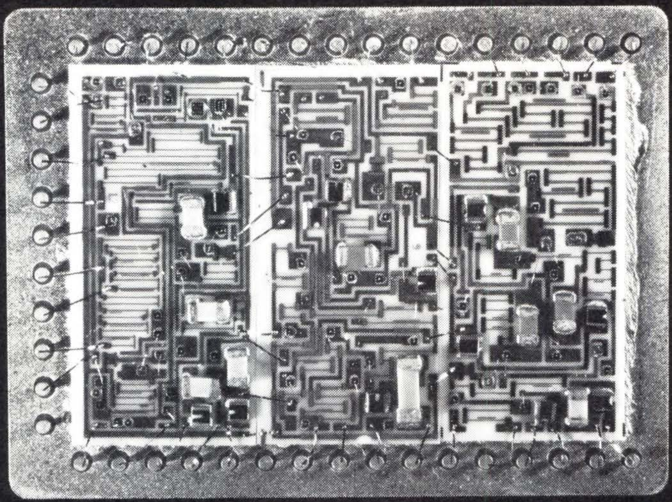
The end of support concerns. Omniband signal electronics require only six basic plug-in assemblies to accommodate **all** record and reproduce functions, including bias oscillator, head drivers and preamps.

The end of maintenance hang-ups. Our new Model Ninety-Six is probably the most thoroughly tested tape system ever offered. We've spent thousands of hours wringing the bugs out…to make sure you don't have to. What's more, the testing, front panel access and built-in transport calibration system all were designed to be simple and reliable…to minimize service requirements.

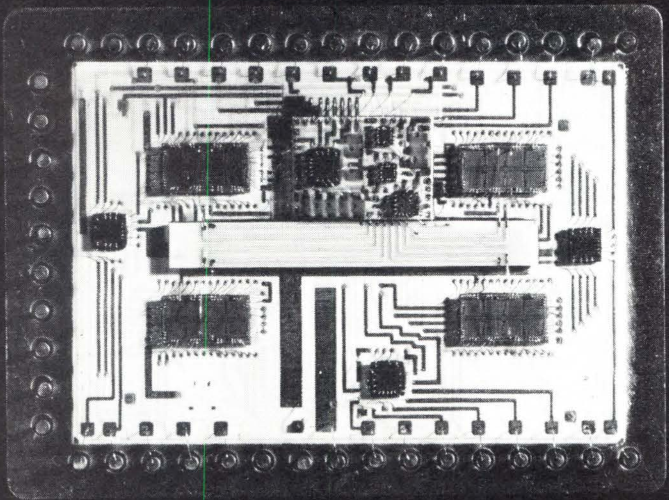
For full details on the new Honeywell Model Ninety-Six, call or write: Charles O. Miller, MS211, Honeywell, Inc., Test Instruments Division, P.O. Box 5227, Denver, Colorado 80217, (303) 771-4700.

Honeywell
The Automation Company

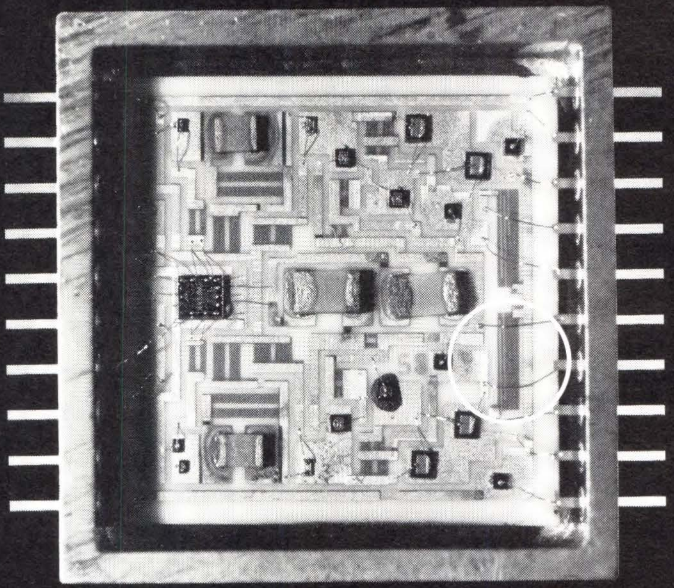
Circle No. 25



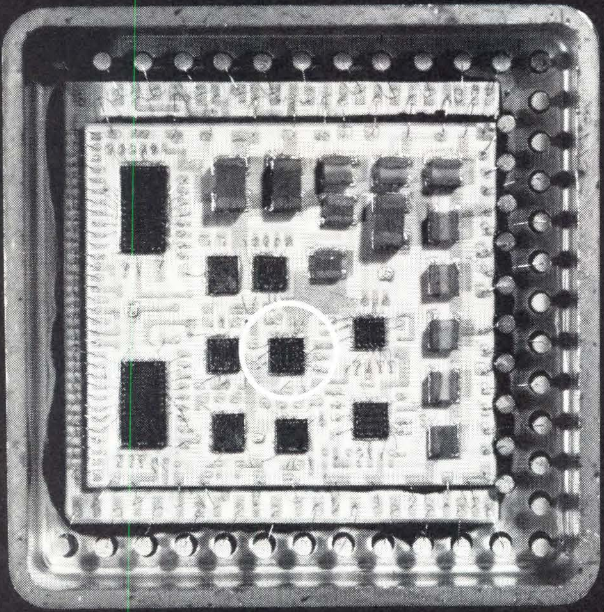
1. Is this circuit a thick film or thin film hybrid?
■ Thick ■ Thin



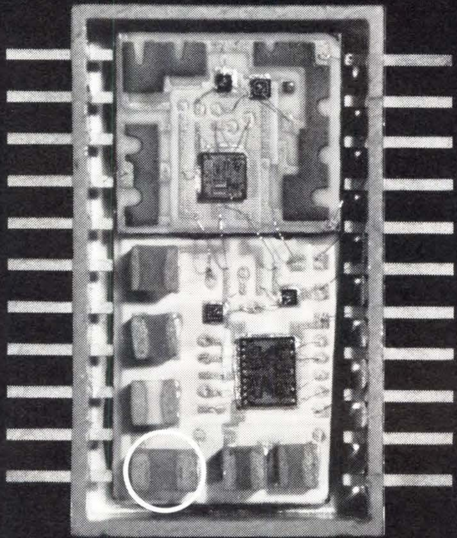
2. Is this hybrid's package designed for a hermetic seal?
■ Yes ■ No



3. Has this resistor been abrasive or laser trimmed?
■ Abrasive ■ Laser



4. Is this semiconductor chip an integrated circuit or transistor chip?
■ IC ■ Transistor



5. Is this passive chip a resistor or capacitor chip?
■ Resistor ■ Capacitor

Test your Hybrid IQ:

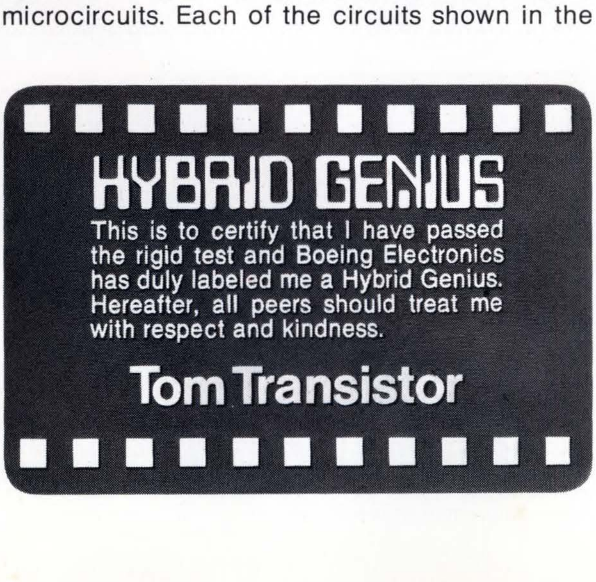
Eight out of ten people in this business can't get 100% on the Boeing Electronics Hybrid IQ test. That's not surprising. It's a highly technical, complicated science.

If you wound up with five right answers, we'd like to give you special recognition. It's a Hybrid Genius identification card, made of metal and stamped with your name.

But you have to be absolutely honest with us. Did you, or did you not, get all five correct, without peeking? Even though you missed one or two, there's still another chance. Just ask for the Second Chance Hybrid IQ test.

This little examination is our way of letting you know Boeing knows quite a lot about hybrid microcircuits. Each of the circuits shown in the test was produced by Boeing for very specialized product requirements.

Boeing is especially adept in supplying the right technical support to the equipment designer. Our engineers know how to design with your unique specifications in mind, and how to keep the price in line. But just as important, they know the importance of keeping your job on schedule. In other words, you'll never get lost in the shuffle at Boeing Electronics. We'd like to tell you more about our abilities.



The right answers:

1. Thin Film. This is a digital logic circuit being used in a military guidance and control system.

2. Yes. This is a 4096 bit random access memory circuit for a digital computer.

3. Laser. This hybrid dual current switch circuit handles .4 amps per switch in an airborne computer.

4. IC. This 16-channel multiplexer hybrid is used in an aircraft on-board maintenance and test system.

5. Capacitor. This circuit is an accelerometer restoring amplifier used with a gyro in a guidance and control system.

P. O. Box 24666
Seattle, Washington 98124

BOEING electronics

The basics of using FETs for analog-signal switching

If you understand the characteristics of the FETs currently available you can make the optimum choice for each particular application.

Arthur D. Evans, Consultant, Santa Clara, CA

The field-effect transistor (FET), when biased in the ON condition, contains a conducting channel of either n- or p-type carriers. Channel conductance can be enhanced or depleted by an appropriate voltage on the control gate. For the n-channel FET a more positive gate voltage (V_G) increases the channel conductance and a more negative gate voltage decreases the channel conductance, as indicated by the curves shown in **Fig. 1a, b, c.**

Depletion type JFET and MOSFET structures contain a channel which connects source and drain, even in the absence of bias voltages. These are normally-ON devices. The channel conductance is a function of its length (L), width (W), thickness (T), mobile carrier concentration (N_c) and carrier mobility (μ), and is expressed as $g_{DS} = K_1 \frac{WT}{L} N_c \mu$

Carrier concentration, carrier mobility and channel thickness are affected by electric fields and temperature. The function of the control gate (G) is to control the electric field in the channel region and thus control the channel conductance g_{DS}. For the normally-ON, n-channel structure a negative voltage applied to the gate introduces electrostatic fields which will decrease the channel conductance. If the gate voltage is made large enough the channel conductance will be reduced to essentially zero. The gate-source voltage at which this occurs is the "pinch-off" voltage (V_P). Typically, V_P is designed to be in the 1 to 10V range.

In an enhancement-type (normally-OFF) device, a positive gate voltage is required to set up a field that "enhances" or creates a conducting channel from source-to-drain. The gate-source voltage at which a channel is just created is called the threshold voltage (V_{TH}). This is typically in the 1 to 5V range.

Channel conductance is approximately a linear function of V_{GS} with the zero-axis off-set by either V_P or V_{TH} as indicated in **Fig. 1** and by the equations:

$g_{DS} \simeq K_2 (V_{GS} - V_P)$ for depletion type;

$g_{DS} \simeq K_2 (V_{GS} - V_{TH})$ for enhancement type.

For n-channel FETs, V_P (depletion types) will be

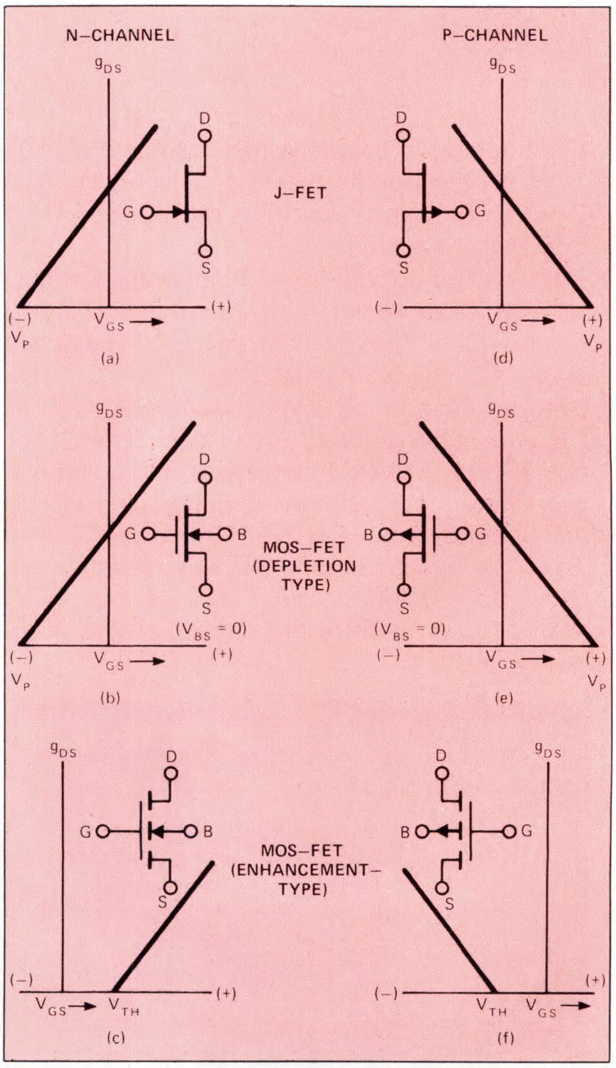


Fig. 1—Comparison of all six types of FETs and the channel-conductance vs gate-source voltage plots for each shows the basic differences in drive and output characteristics.

negative and V_{TH} (enhancement types) will be positive. The slope, K_2, is a function of such parameters as channel-carrier-mobility and W/L ratio. For the MOS types, the thickness of oxide separating gate from channel will also effect the slope. Typically, for a given active area, the JFET type will have higher conductance slope than the MOSFET type.

N-type carriers (electrons) have higher mobility than p-type carriers (holes); thus, other things being equal, n-type FETs will have higher g_{DS} than p-type FETs. Conductance can be increased by increasing the channel width; however, this also increases junction area, and thus capacitance, leakage and cost. Decreasing channel length will increase g_{DS} without much effect on size, capacitance, leakage or cost, but will decrease maximum voltage ratings.

Note in **Fig. 1a, b,** and **c** that for the V_{GS} values equal to or more negative than the pinch-off voltage (V_P), or the threshold-voltage (V_{TH}), the channel conductance is essentially zero; that is, the switch is OFF. Note that the enhancement type (**Fig. 1c**) is normally OFF and a positive gate voltage in excess of V_{TH} is required to create a conducting channel. The depletion types of **Fig. 1a** and **1b** are normally ON; a negative gate voltage is required to turn them OFF. P-channel devices (**Fig. 1d, e, f**) have similar characteristics, except the voltage polarities are reversed with respect to the n-channel devices.

Typically MOSFETs used as analog switches are of the normally-OFF enhancement types; JFETs are normally-ON depletion types. The source terminal is commonly used as the reference terminal when discussing FET characteristics. However, in its use as an analog switch the FET's source and drain terminals are approximately at equal potential when it is ON, and the source-to-drain potential may be of either polarity when it is OFF; thus it makes little difference which end of the channel is used as the reference terminal. Most devices are approximately symmetrical so that the function of the drain and source terminals can be interchanged. There are, however, a few FETs which, by design, have a higher drain-gate than source-gate breakdown voltage. Also, some types have a slightly lower gate-drain than gate-source capacitance.

Junction FETs have some advantages

With JFETs, for the ON state the gate-to-channel voltage should be approximately zero. Although a forward biased gate will produce higher channel conductance, it also may result in excessive current being forced into the channel and hence into the analog signal path. To maintain an OFF state, both the gate-source voltage (V_{GS}) *and* the gate-drain voltage (V_{GD}) must be kept more negative than the pinch-off voltage (V_P). In the OFF state, drain-source voltage may be positive or negative.

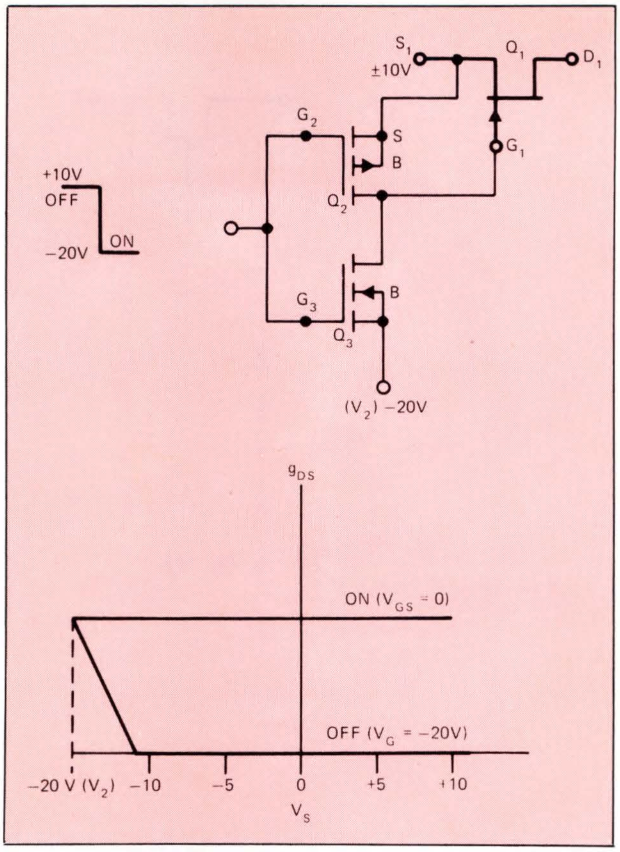


Fig. 2—Basic JFET switch and its drive circuit result in the channel-conductance vs analog-signal voltage plot shown.

A gate-control circuit (driver) which performs the desired functions is shown in **Fig. 2**. With an ON signal applied to the input, the JFET switch gate (G_1) is clamped to its source (S_1) by the MOSFET Q_2. G_1 is free to follow the analog voltage, and thus maintain $V_{GS} = 0$. The drive on the gate of Q_2 should be at least a threshold voltage more negative than the most negative analog voltage so that Q_2 will remain ON throughout the analog-signal range. With an OFF control signal at the input, Q_2 is turned OFF and Q_3 is turned ON; this condition clamps G_1 to the negative supply. It is necessary that the negative supply be at least a pinch-off voltage (V_P) more negative than the analog voltage (V_S); otherwise the switch will turn ON as indicated in the channel-conductance curve in **Fig. 2**. Thus for the ON condition, $V_G = V_S$, and for the OFF condition $V_G < V_S + V_P$.

The switch-control circuit of **Fig. 2** has some desirable features, compared to other types of control circuits, which may not be obvious. In switch-ON condition the gate (G_1) is clamped to the source (S_1) even at high frequencies. The result is that there is practically no modulation of the switch conductance by the analog voltage.

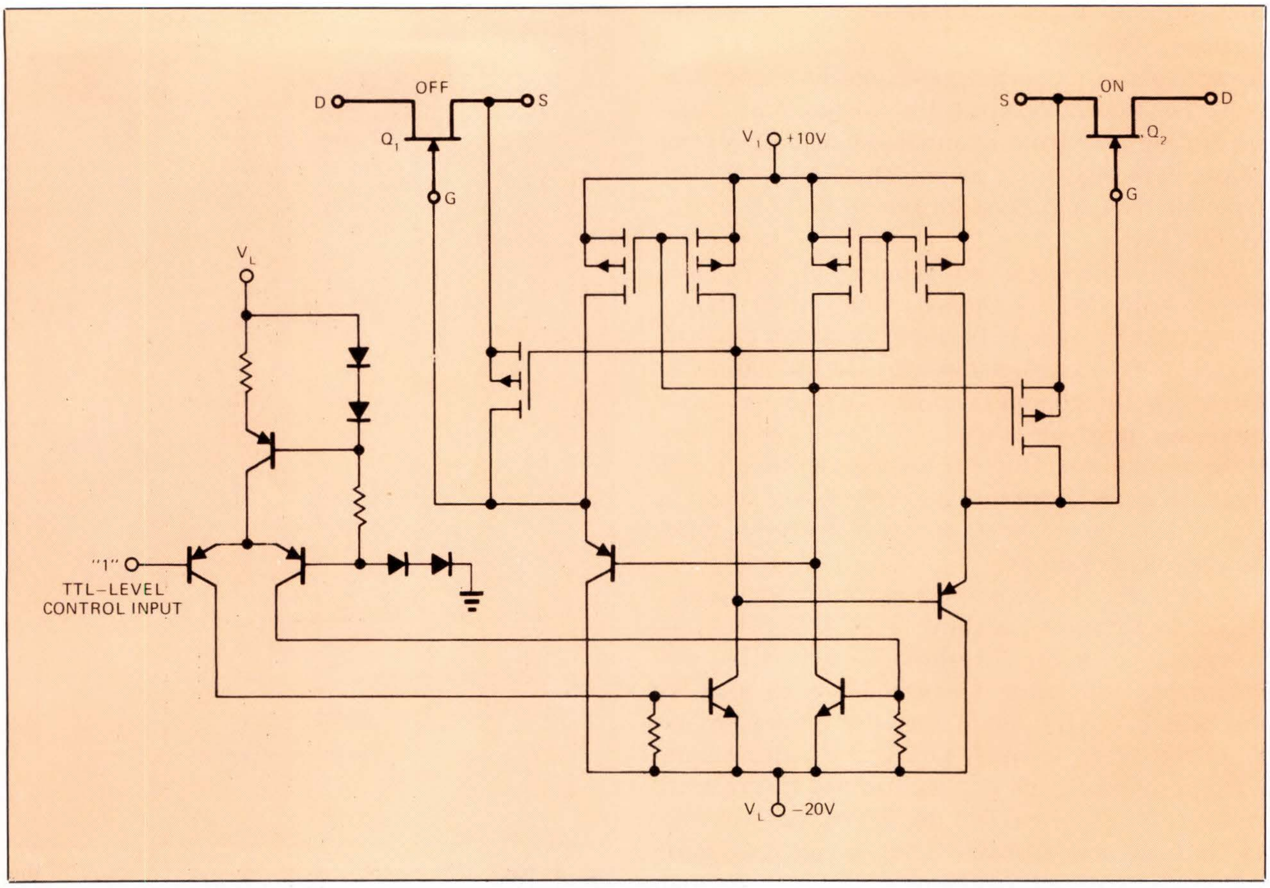


Fig. 3—JFET switches with push-pull driver and TTL compatible level shifter also provide a break-before-make feature.

With some types of diode coupled control circuits, a large-value resistor is used to clamp the gate to the source, with the undesirable result of channel-conductance modulation at high frequency because the gate can't follow the source analog voltage. In some cases, large, high-frequency signals may even cause the switch to turn OFF during positive peaks.

In the switch-OFF condition the gate shown in **Fig. 2** is clamped to the −20V supply via Q_3. The source S_1 (and thus the analog signal) is isolated from ground because Q_2 is OFF. Analog feedthrough via C_{sg} and C_{gd} of Q_1 is minimized because G_1 is ac grounded through the relatively low impedance of Q_3 and the V_2 supply. The ON and OFF channel conductance of Q_1 in the circuit of **Fig. 2** is also shown. Note that if the source voltage becomes more negative than $(V_2 + V_P)$, then the switch is no longer pinched OFF and the channel becomes conductive.

For a p-channel JFET, the schematic of **Fig. 2** could be used by changing Q_2 to an n-channel device, Q_3 to a p-channel device and reversing the polarity of the input drive and the supply voltages. Typically, the n-channel JFET has lower ON resistance than does the p-channel JFET for a given size unit, and is thus more widely used.

For many applications it is necessary or desirable to control the JFET switch with low-level TTL logic signals. Typical values are 0.8V for logic ZERO and 2.4V for logic ONE. The driver which controls the switch must then provide the necessary voltage gain and level control to achieve the gate voltage conditions described above. An integrated driver circuit which provides these functions is shown in **Fig. 3**. In addition to the input being TTL compatible, this circuit provides a break-before-make feature; that is, the turn-OFF is faster than the turn-ON. This feature is important when the switches are used as a single-pole, double-throw application such as in a D/A converter or in a multiplexer.

MOSFETs, too, have their place

The control circuit for a MOSFET switch can be simpler than for a JFET because the MOSFET's gate may be positive *or* negative with respect to the source and drain. With an n-channel JFET, the gate cannot be permitted to become positive with respect to the channel since appreciable current could flow into the channel from the gate-driver circuit.

Currently, the p-channel MOSFET is more common in switching applications than is the n-channel MOSFET; therefore, we will discuss p-channel devices as examples. The same con-

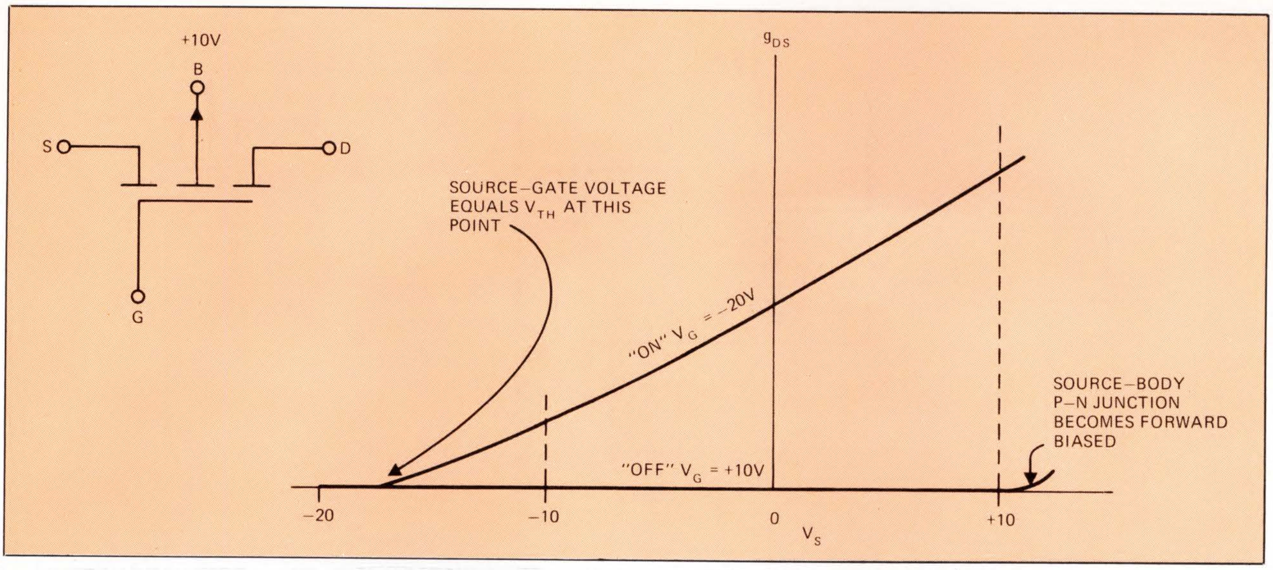


Fig. 4—PMOS enhancement-mode FETs typically display channel-conductance vs source-voltage curves similar to the one shown here.

cepts apply for the n-channel devices.

Typically, the gate of the MOSFET switch is switched between two fixed voltages. To hold the device OFF, the gate-source and gate-drain voltage must not be permitted to exceed (in the turn-ON polarity) the turn-ON threshold voltage, V_{TH}. The turn-ON threshold for most p-channel FETs falls between −2 and −5V. Common practice to keep the switch OFF is to provide a gate-drive voltage that is equal to or more positive than the analog signal. For example, if the analog signal is ±10V, then the gate is held at +10V to keep the switch OFF.

For the ON condition, the gate-source or gate-drain voltage must exceed the threshold voltage, with enough magnitude to achieve a reasonable conductance. The switch source-drain conductance is a function of $V_{GS} - V_{TH}$, as shown in **Fig. 1f**. If the gate voltage (V_G) is fixed, then the channel conductance (g_{DS}) will be a function of the analog voltage, as shown by the "ON" curve in **Fig. 6**.

The MOSFET, in its most common structure, is a tetrode (four elements), having source, drain, gate and body (or substrate) terminals. For the example shown in **Fig. 4**, the body terminal (B) is connected to +10V.

Two typical driver circuits for PMOS switches are shown in **Fig. 5** and **6. Fig. 7** is an all PMOS system. This system has some advantages from a manufacturing standpoint because of the few process steps involved in making it into an integrated circuit. An 8-channel multiplexer which uses this type of circuit is available from several manufacturers. In some cases, a pull-up FET is included at the "Logic In" gate to improve TTL compatibility.

The circuit of **Fig. 6** utilizes both bipolar

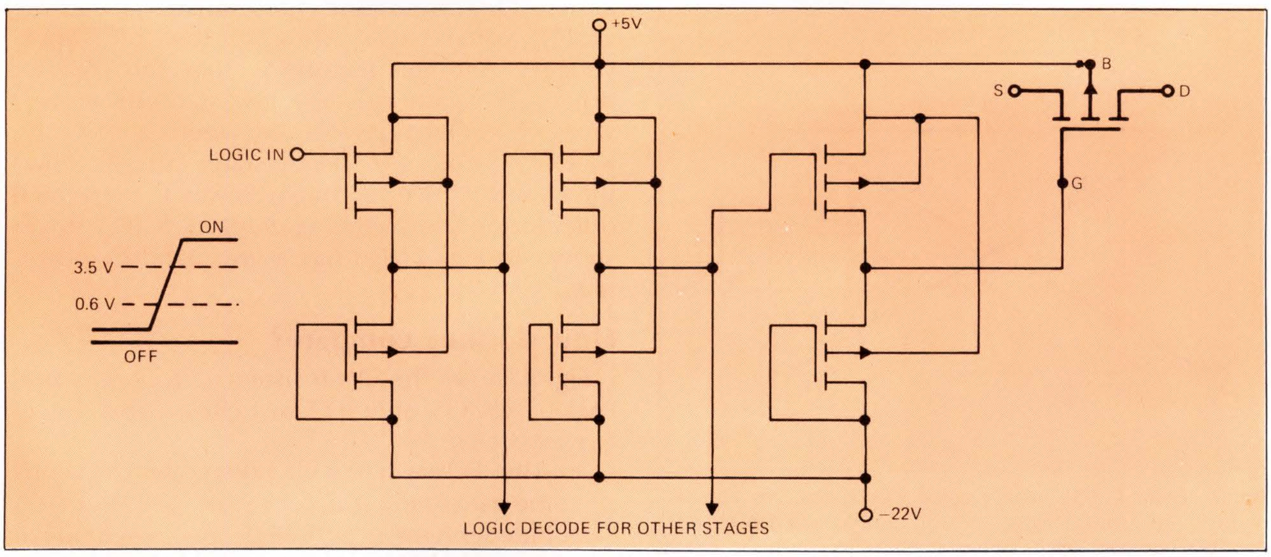


Fig. 5—One channel of a multichannel PMOS switch typifies IC multiplexer designs available from several manufacturers.

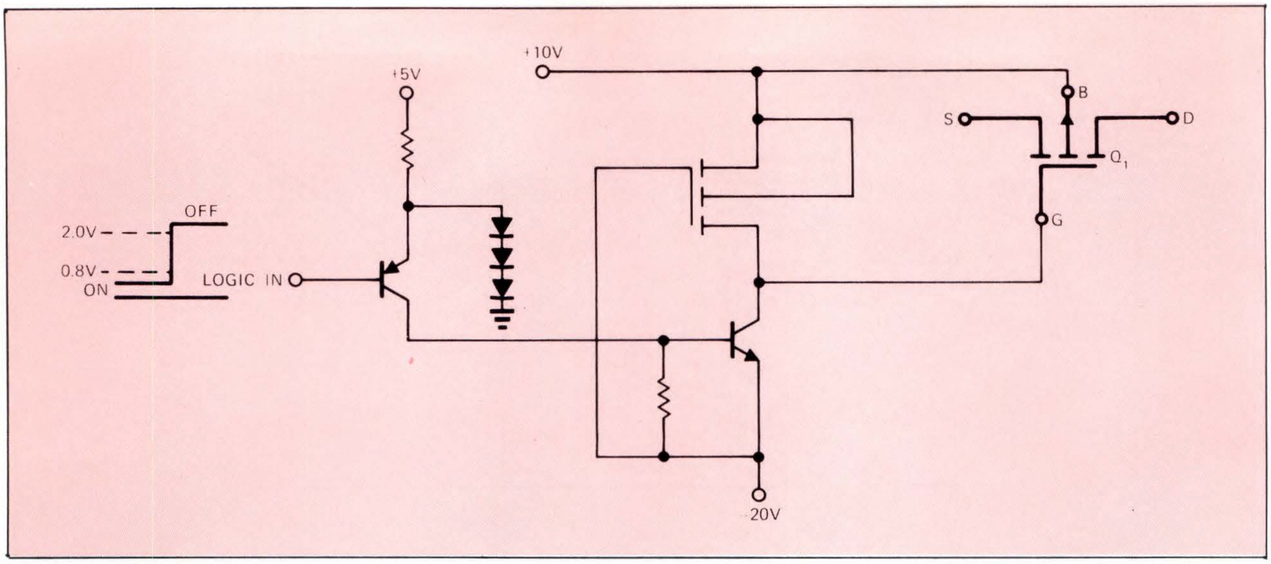


Fig. 6—Combination bipolar/MOS drive circuit offers improved TTL compatibility. Separation of logic bias and analog-switch bias are an important feature.

transistors and MOSFETs. A major advantage of this circuit compared with the all PMOS circuit, is its improved input compatability with TTL logic circuits. Note the similarity of the input to TTL-type input, and the separation of the logic bias from the analog-switch bias.

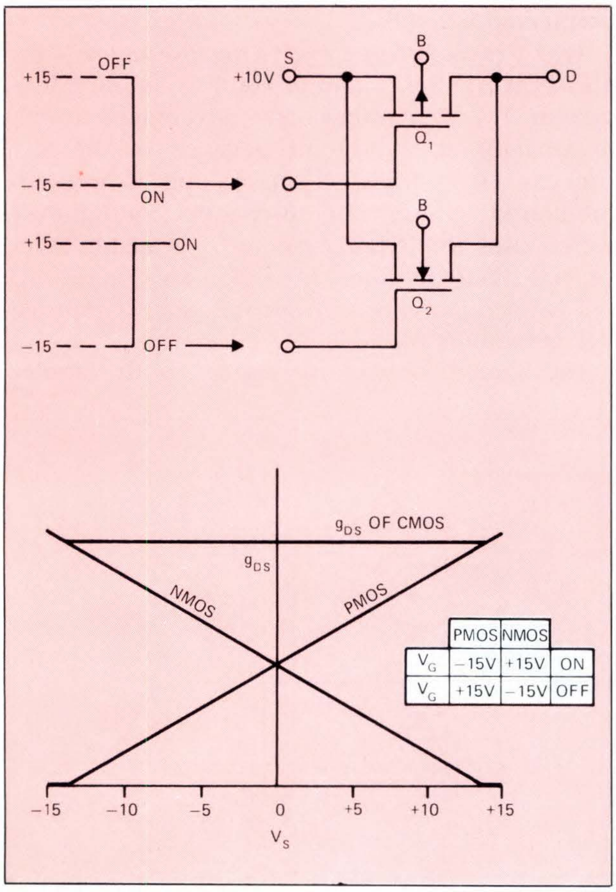


Fig. 7—Basic CMOS analog signal switch requires complement of the control signal. In CMOS, the n- and p-channel conductance variations cancel each other giving a nearly perfect response curve.

CMOS is a combination

As noted above and shown in **Fig. 4**, the typical PMOS-switch circuit exhibits a variation in ON conductance as the analog voltage is varied. This undesirable variation can be greatly reduced by paralleling p- and n-channel switches, as shown in **Fig. 7**. For the ON state, the n-channel gate is forced positive and the p-channel gate is forced negative. **Fig. 7** also shows the combined conductance of the two switches. The integrated combination of p-channel and n-channel MOS is commonly referred to as complementary MOS (CMOS).

The driver circuit for the CMOS switch requires opposing voltages for the two gates. A common-driver circuit is shown in **Fig. 8**. Note that CMOS devices are utilized in the driver as well as for the switches. This switch system has some advantages over the JFET and PMOS systems discussed above. One important characteristic is that the analog voltage can swing to the full supply voltage. Another feature is that the inverter driving the gate has very low stand-by power; when Q_3 is ON, Q_4 is OFF and when Q_4 is ON, Q_3 is OFF. Thus, no steady-state current flows through this inverter stage. Power is consumed only during the switching mode. The JFET driver shown in **Fig. 2** also has a low stand-by power feature.

How do they compare?

Fig. 9 shows the ON resistance, (r_{DS}), of typical PMOS, CMOS and JFET switches. This set of curves shows:

1. The JFET switch (with a driver which clamps the gate to the source) has an r_{DC} (ON) that is independent of V_A within specified limits of $\pm$10V), and has a lower value than either of

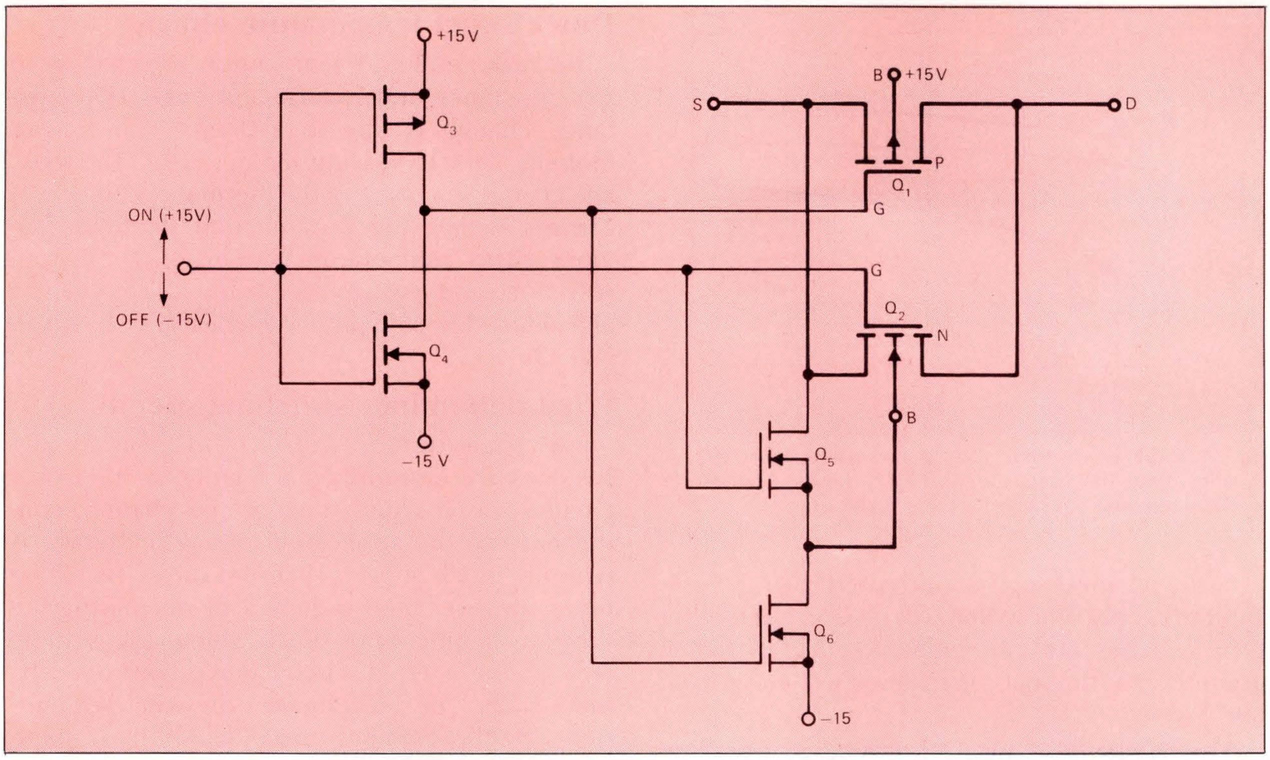


Fig. 8—CMOS switch with CMOS driver. Generating the complement of the control signal internally eases design requirements and is typical of most switches available today.

the other two types.

2. The r_{DS} (ON) of the CMOS switch is relatively independent of V_A for the range shown, but not as flat as the JFET. It may peak slightly more at one end or the other than is indicated in **Fig. 9** because of mismatch in the parallel PMOS and NMOS components of the CMOS. The flat r_{DS} (ON)-vs-V_A characteristic of the CMOS is achieved at the expense of additional active area and more complex processing as compared to the PMOS switch. A major advantage of the CMOS over the other two types is that the peak-to-peak analog voltage V_A can equal the sum of the supply voltages.
3. The r_{DS} of a PMOS switch in the ON state will approach infinity if V_A approaches the negative supply voltage minus the V_{TH} of the switch. The JFET in the OFF state will start to turn ON if V_A reaches the negative supply voltage minus the V_P of the switch.

Shunt capacitance to ground as a function of analog voltage for the ON switch is shown in **Fig. 10**. For the MOS switches a major part of the capacitance is the source, channel, and drain-to-body capacitance. This junction capacitance is voltage sensitive and is the cause of the variation indicated in **Fig. 10**. There is, in addition, the source, channel and drain-to-gate capacitance which is relatively independent of V_A. For the JFET in the ON state the capacitance to ground is principally determined by the driver-output capacitance. The information contained in **Fig. 10** is

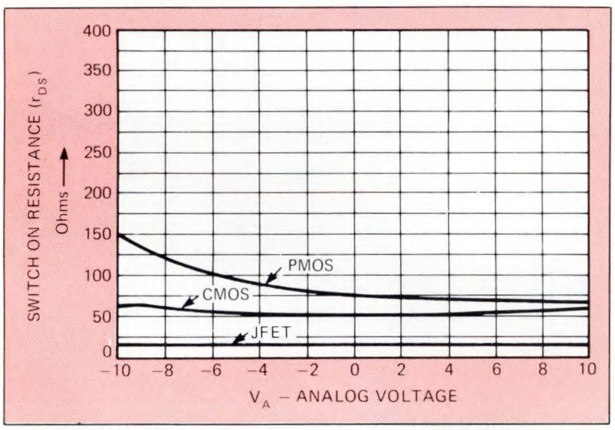


Fig. 9—Comparison of ON-resistance variation with changes in the analog-signal voltage for the three types of switches.

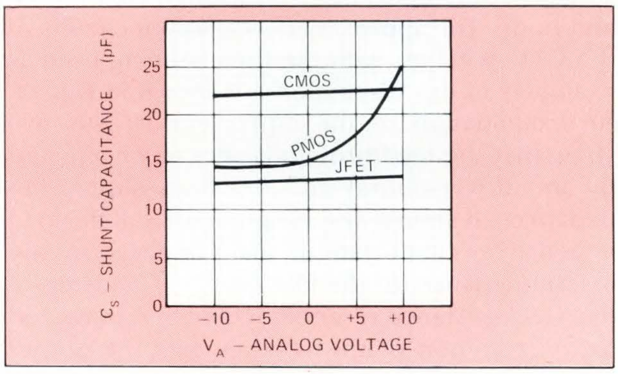


Fig. 10—Effects of analog-signal voltage on shunt capacitance of each of the three switches.

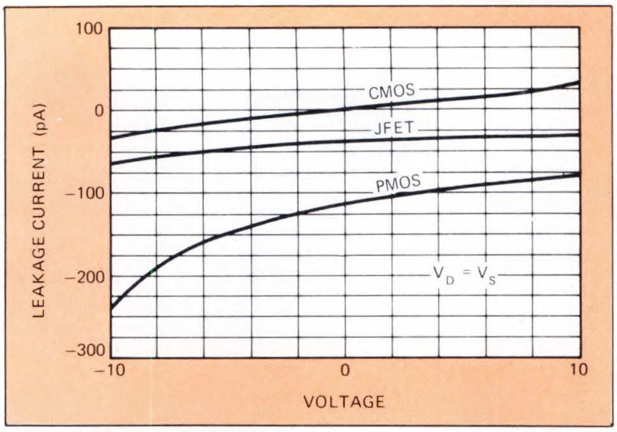


Fig. 11—Leakage currents caused by analog-signal voltage variation. Note that both CMOS and JFET devices have an area of operation where leakages are essentially zero.

for one channel of the indicated switch type. Typically, only one switch will be ON, but if other OFF switches are connected to the ON-switch drain then additional capacitance will make itself felt.

A comparison of the ON leakage of the three types of switches is shown in **Fig. 11**. For the p-channel MOSFET the principal leakage from the switch channel is to the body, which is connected to the positive supply; thus maximum leakage occurs at the most negative analog signal. The CMOS switch has leakage to both the positive and negative supplies. At some specific analog voltage the two opposing leakage currents may cancel, in which case the net leakage will be zero. In a similar manner, JFET leakage may also pass through zero at some analog input voltage.

For all three types of switches, in the OFF condition, the major feedthrough is due to capacitance. The output leakage is not appreciably affected by the input voltage unless the input-to-gate voltage approaches V_P or V_{TH}. The capacitance feedthrough is via the direct source to drain capacitance, C_{sd}, the indirect path via the gate (C_{sg}, C_{gd}) and the indirect path via the body (C_{sb}, C_{bd}) for the MOS types. The driver-output impedance and the body-supply impedance have a major effect upon the feedthrough via the gate and body. The approximate equivalent circuits of the OFF switches, with the drivers being used as examples in this discussion are shown in **Fig. 12**. An examination of the equivalent circuits will show that the feedthrough is very much affected by the driver-output and the body-supply impedances. It should also be apparent that the load impedance is important. In many applications the load impedance for the OFF switch is made up of the ON resistance of another switch (connected to the common drain) in series with the output impedance of the source connected to that switch.

Don't forget temperature effects

The major effects of temperature are changes in ON resistance and leakage currents. The resistance change is due to a decrease in carrier mobility with increasing temperature. The leakage change is a result of the thermal generation of carriers within the p-n junction depletion regions. The temperature coefficients of both resistance and leakage are positive. Temperature characteristics of typical switches are shown in **Fig. 13**.

What determines switching speed?

The actual turn-on and turn-off times for the switches are determined primarily by the driver circuit. The reaction time of the channel conductance to the application of a gate voltage is typically much shorter than the driver switching time; however little is gained by decreasing the driver-switching time much below the settling time of the external circuit being controlled by the switch. The introduction of switching transients by the driver is unavoidable unless some sort of neutralizing technique is used. Turn-on and turn-off transients occur because the switch-control voltage applied to the FET gate terminal is coupled to the signal channel through C_{gd} and C_{gs} of the FET. If source and drain are at a fixed voltage the charge transfer required to turn the switch ON is approximately the same as that required to turn the switch OFF. This does not necessarily mean, though, that the turn-off transient of one switch will cancel the turn-on transient of another switch in a multiplexing system. Typically, the turn-on and turn-off pulses

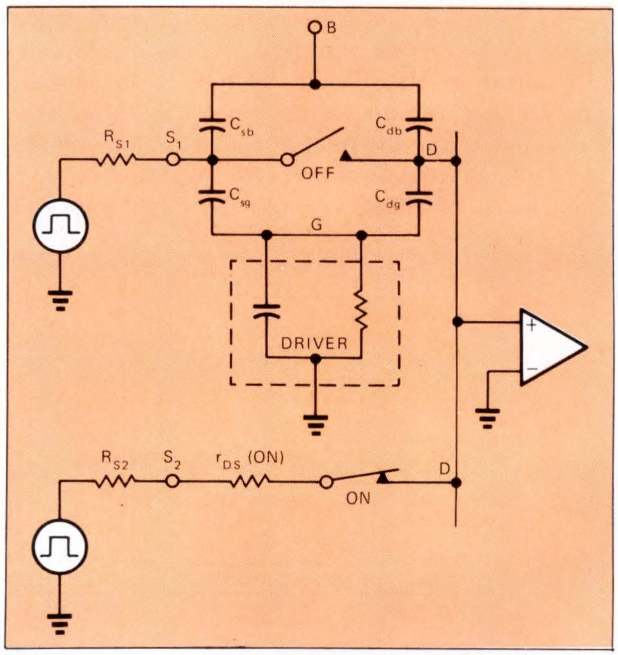


Fig. 12—Equivalent losses are resistive for ON switches and capacitive for OFF switches. Losses through the drivers must be considered, also.

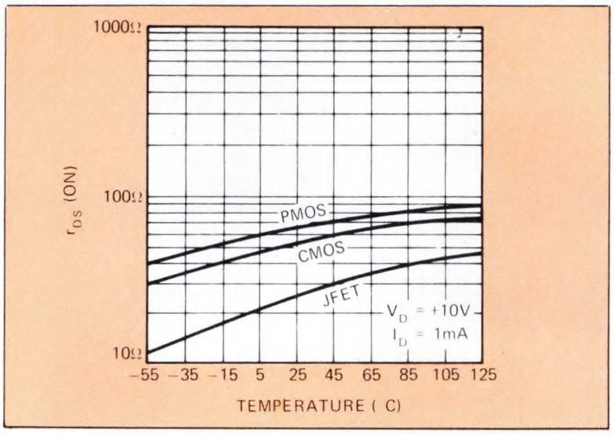


Fig. 13—All FET switches exhibit positive temperature coefficients of ON resistance, though some are more drastic than others.

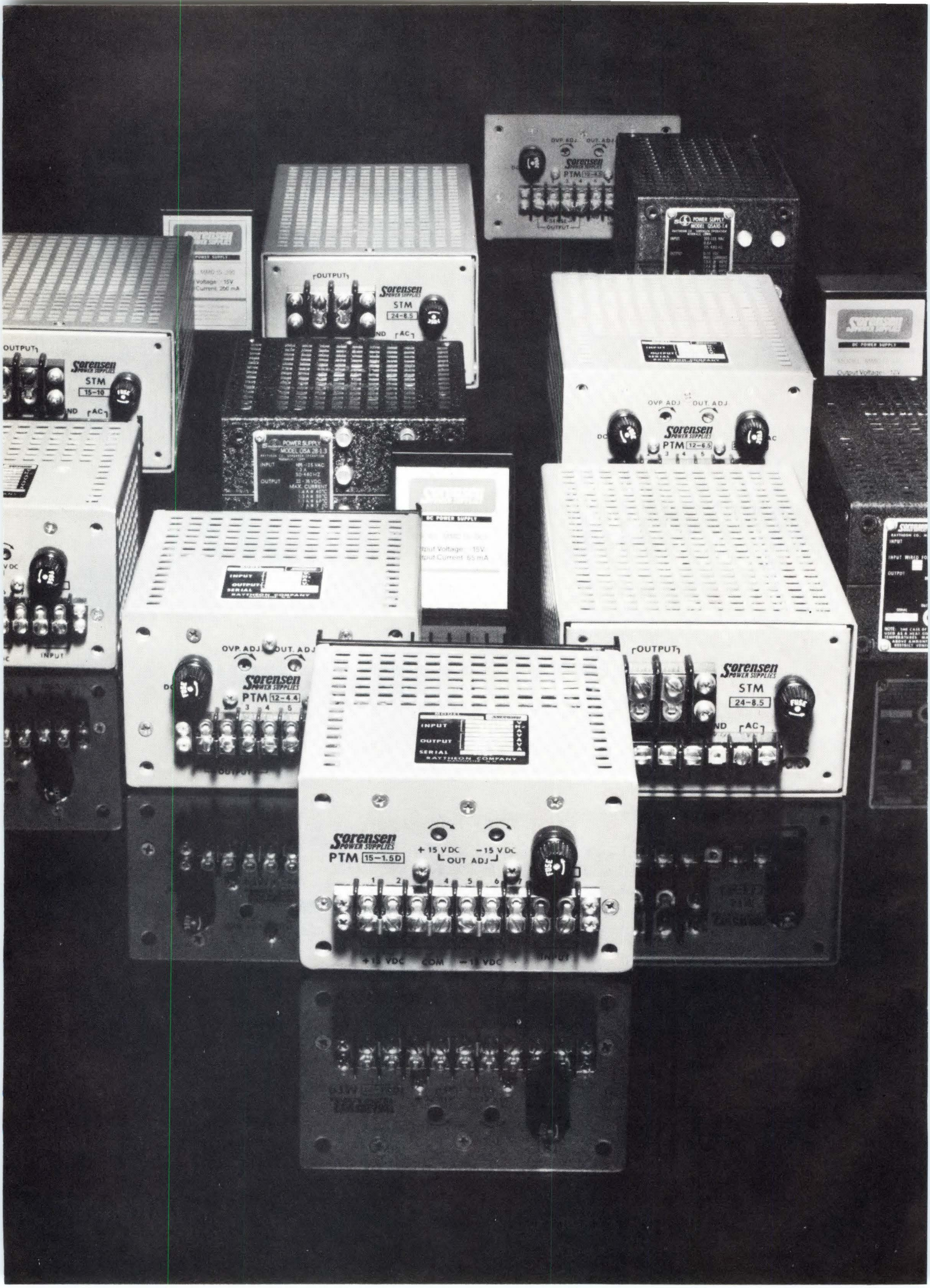
are not matched in either waveform or time. Some drivers are designed to insure that the turn-off delay is shorter than the turn-on delay, to provide a "break-before-make" switch action. Other types have turn-off delay time that exceeds the turn-on delay time. For these, there will be a time during the ON-OFF transition period when both switches are ON. For the break-before-make types, there will be a time when all switches are OFF.

The selection of the best analog switch for a particular application is not necessarily simple. The JFET switch has the lowest value of r_{DS}(ON), and because of the type of driver used, its r_{DS} (ON) is not modulated by the analog voltage. It is, however, the most difficult to integrate on the same chip with a driver and is thus more costly than the MOS or CMOS types.

The all PMOS switch with driver is the least costly to fabricate, but is the poorest in terms of r_{DS} (ON), modulation of r_{DS}(ON) with analog voltage and power-speed characteristics.

The CMOS switch has the advantage of staying ON or OFF with peak-to-peak analog signals equal to the sum of the power supply voltages. Also the CMOS driver typically requires less power for a given switching speed than other types of driver circuits.

You should remember that the device types used as examples are a limited representation of the many analog switches available. One company alone has about 50 standard types listed in their current catalog; in addition, many specials or custom-design types are being made. The use of FETs as analog switches is becoming more widespread, and the manufacturing capability for supplying integrated switches with drivers is growing. In a new system design which will utilize analog switches, it is recommended that the analog-switch manufacturer be contacted for up-to-date information. □


Sorensen POWER SUPPLIES
PTM 15-1.5D
+15 VDC
-15 VDC
OUT ADJ
1 2 4 5 6 7
+15 VDC COM -15 VDC INPUT
INPUT
OUTPUT
SERIAL
RAYTHEON COMPANY
OVP ADJ
OUT. ADJ
PTM 12-4.4
3 4 5
OUTPUT
STM 24-8.5
AC
FUSE
PTM 12-6.5
STM 15-10
DC POWER SUPPLY

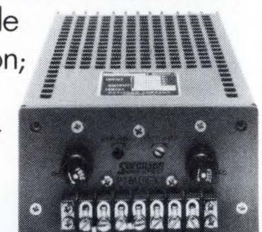
The Sorensen Modulars. A powerful line-up.

Sorensen Modulars give you maximum choice. Plus dependability and efficiency. No matter what your power requirement, count on Sorensen. From the advanced switching-transistor STM series to the miniature encapsulated MMs, there's a Sorensen modular to meet your system specifications and your most rigid performance demands.

Single Output

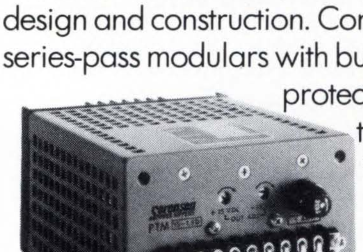
STM Series — 40 models. Switching-transistor modulars that provide twice the efficiency of series-pass competitors in half the space — and eliminate need for external cooling. STMs feature built-in overvoltage protection; computer-optimized filtering; 0.05% voltage regulation; output voltages range from 3.0 (min.) to 56 (max.) Vdc.

PTM Series — 12 models. All solid-state series-pass modulars that achieve state-of-the-art power density; deliver more power per cubic inch than comparable competitive units, at lower cost per watt. Features include built-in overvoltage protection; highest quality components; adjustable automatic current limiting; 0.05% + 5mV voltage regulation; low ripple and noise; six voltage levels to 100 watts.



Dual Output

PTM DUALS Series — 9 models. Dual output versions of PTM series, with the same advanced design and construction. Compact, solid-state series-pass modulars with built-in overvoltage protection; feature tracking accuracy to 0.2%; voltage regulation — .02%; transient response — 50μsec. Series includes +5, −12 volt model for CMOS applications.



Circle No. 42

Miniature

MM Series — MMS (single) MMD (dual) MMT (triple) — 15 models, 4 package sizes. Designed for maximum reliability in microminiature electronic applications. All MM encapsulated modulars feature built-in overvoltage protection; excellent voltage regulation; single outputs from 5 to 28 Vdc; dual outputs of ±12 or ±15 Vdc.

Other dependable Sorensen power supplies

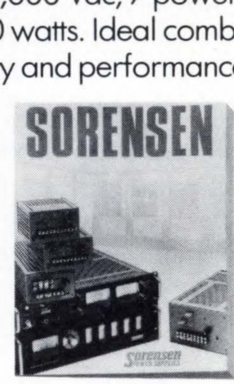
QSA Series — 29 models. Modular, wide range, convection-cooled power supplies feature excellent operating specifications plus a wide range of accessories. Models provide outputs from 3-330 volts and up to 300 watts. Top choice for multi-output systems.

Lab/Systems Power Supplies

SRL Series — 14 models. Low voltage, regulated, solid-state DC power supplies. Rack-mount style featuring excellent stability, fast response time over the full load range, built-in overvoltage protection. Power ranges from 0-60 Vdc and 100 Amps.

DCR Series — 37 models. High performance, all-solid-state power supplies featuring the lowest cost per watt on the market. 10 voltage ranges from 20 Vdc to 30,000 Vdc; 7 power levels from 400 to 20,000 watts. Ideal combination of economy, reliability and performance.

SORENSEN CATALOG/73 provides fully detailed specifications for all models of Sorensen modular and lab/systems power supplies. Write for your copy. Sorensen Company, a unit of the Raytheon Company, 676 Island Pond Road, Manchester, N.H. 03103. Tel. (603) 668-4500. Or TWX 710-220-1339.



Sorensen POWER SUPPLIES

See us at Booth #2010 at the 1973 National Computer Conference.

Have you kept up with sampling scopes?

Their bandwidth, dynamic range and recovery time make them ideal for many high-frequency measurements. And they're easy to use, too.

Russ Harding, Hewlett-Packard

In the past few years the state-of-the-art in sampling oscilloscopes has been extended to 18 GHz, thus making possible the viewing of signals having very fast transitions or very high frequency components. The sensitivity and extended high-frequency response of sampling instruments make them highly suitable for studying fast, repetitive waveforms in high-speed digital circuits (**Fig. 1**).

In addition to offering more bandwidth, the new sampling oscilloscopes have approached real-time instruments in ease of use. This now means that anyone needing the measurement characteristics of a sampling oscilloscope can use it without worrying about special and confusing controls.

In addition to fast, sensitive response, sampling oscilloscopes have other characteristics which will satisfy most high-frequency measurements. One of these characteristics is the ability to display high-frequency Lissajous patterns in MHz and GHz ranges. Sampling oscilloscopes can also magnify waveforms for studying fine detail without loss of fidelity.

All of this capability can provide the engineer with a powerful and versatile design tool. To use this capability fully, though, he must understand the mechanism of sampling (see box), the characteristics of the sampling scope and the variety of applications in which it can be used.

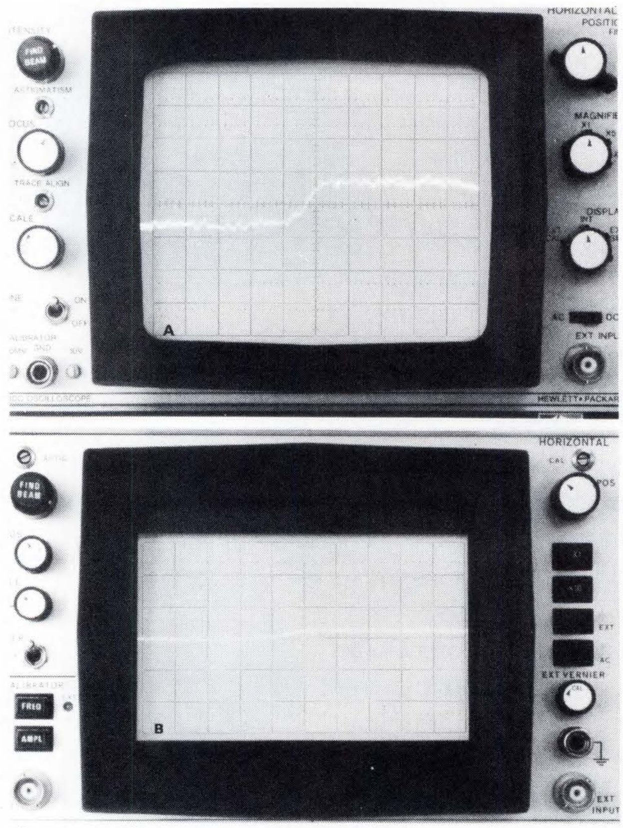


Fig. 1—Oscillograms compare performance of a sampling oscilloscope with that of a real-time oscilloscope. Both photos are of a 2.5-mV, fast risetime pulse, displayed on the left by a 1-GHz sampler (2-mV/div deflection factor, 500-psec/div sweep speed) and on the right by a 250-MHz real-time unit (10-mV/div deflection factor, 1-nsec/div sweep speed).

Sampling units have come a long way

The technological advances in sampling oscilloscopes can be likened to the advances in high-frequency counters and digital voltmeters.

In the early 1960s, a 10-MHz counter weighed over 100 pounds and occupied about 6 cubic feet. Today an equivalent counter weighs about 5 pounds, occupies a fraction of a cubic foot and costs 75% less. In addition, the new counters are available to 18 GHz.

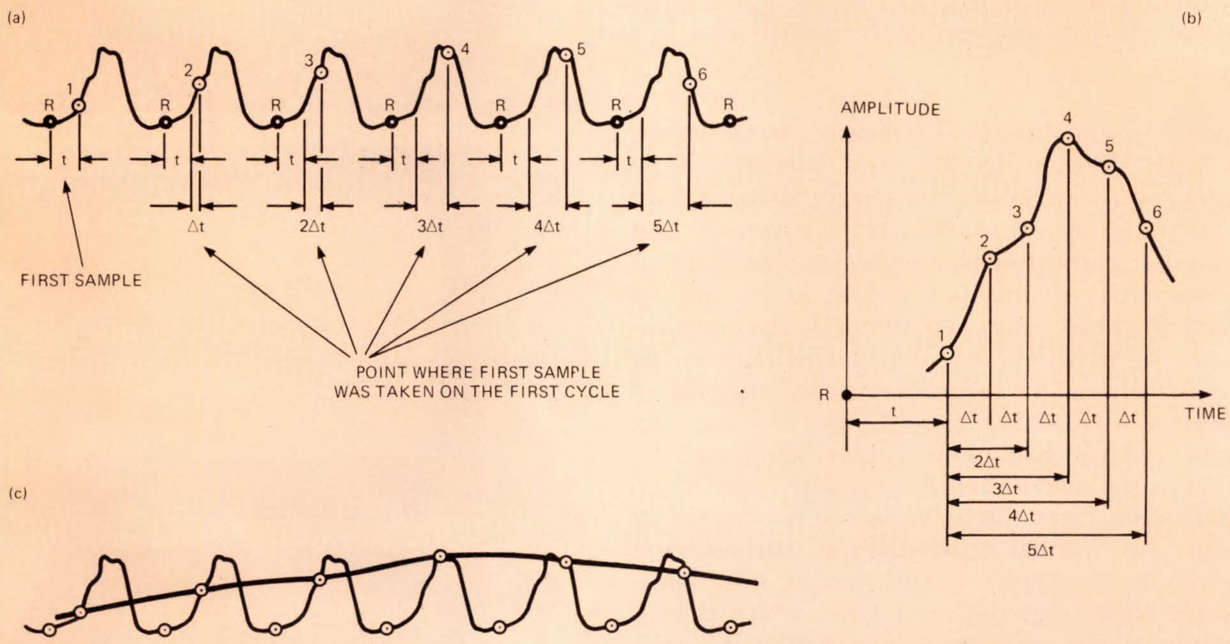
Early 1-GHz sampling oscilloscopes weighed over 70 pounds and occupied over 3 cubic feet. Today, they are equivalent in size and weight to real-time systems and cost much less than their predecessors. Although the cost reduction is not as impressive as for counters, it is worth noting that today's sampling systems are plug-ins for high-frequency mainframes, thus comprising a measurement system of great flexibility. As with

Basic sampling

Sampling is a technique which converts a high-frequency, repetitive signal to a low-frequency signal while maintaining signal fidelity. The low-frequency signal is then amplified and displayed on a cathode-ray tube. For direct reading of the high-frequency signal parameters, the sampling oscilloscope is calibrated in terms of the high-frequency signal rather than the low-frequency displayed signal. The major restriction of a sampling scope is that it requires a repetitive signal—it cannot display a waveform which occurs only once or is asynchronous.

Assume a waveform, like that of **Fig. A,** is in the GHz region and a sampling technique is applied. If each of the repetitions in the waveform is referenced with respect to time, as indicated by points R, and if points 1 through 6 are plotted on an amplitude-versus-time graph using point R as the origin in each plot, the original waveshape can be reconstructed, as shown in **Fig. B.**

The important thing to notice is that now the reconstructed waveform is in a much lower frequency domain than the original wavetrain. Because of this low-frequency characteristic, the waveform can now be processed and displayed on a relatively low-frequency oscilloscope system. This can be seen very clearly if points 1 through 6 are connected with a continuous line, as shown in **Fig. C.**



high-frequency counters, the state-of-the-art has been extended to 18 GHz.

User convenience is another area where substantial improvements have been made. For many years the potential sampling oscilloscope user was plagued with controls like dot response, smoothing adjust and minimum delay. He was also troubled with a complex scan control and multiple-control triggering. In addition, an abundance of seemingly seldom used or not understood functions were placed on the front panel. These included x and y outputs with offset and calibration, sweep output and horizontal input. The density of controls and other panel functions sometimes frightened the potential user so much that he often would not even consider the

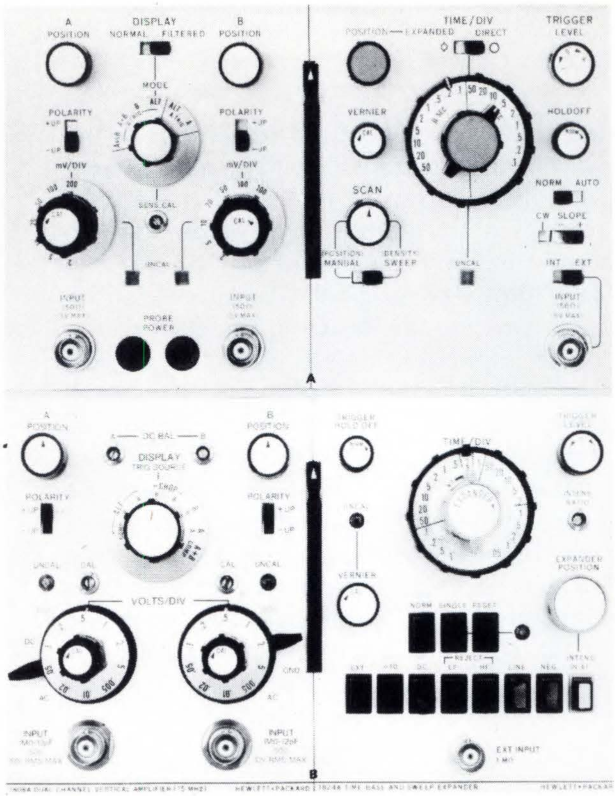


Fig. 2—Front panels of 1-GHz sampling oscilloscope (left) and 75-MHz real-time oscilloscope (right) show the basic similarity between the controls of sampling and real-time units.

sampling scope to solve his measurements needs.

Today this is no longer a problem. New sampling oscilloscopes are as easy to use as their real-time counterparts. The response and smoothing adjustments are gone except as initially necessary to match a system to an external sampling head. This is a result of design improvements in the vertical circuits. The minimum delay adjustment is no longer necessary because of improved time-base circuits, and the complex scan control has been greatly simplified by eliminating seldom used functions, such as record scan, since the function can be duplicated with the manual scan control. Furthermore, advances in trigger circuit design now allow single-knob triggering to 1 GHz, which is very helpful to the user who is only comfortable with real-time oscilloscopes.

In addition to the elimination of many controls and simplification of others, care has been taken to create as many similarities as possible in the panel layouts of sampling and real-time systems. This is illustrated in **Fig. 2,** which shows the front panels of a 1-GHz sampling unit and a 75-MHz real-time system. Comparing the vertical portions of the two systems, there is only one control unique to the sampling system—the normal/filtered display switch. The layout, controls and their usage are nearly identical.

Comparing the sweep portions of the panels, again the controls and functions are quite similar, with the sampling system providing an expanded/direct slide switch and scan controls unique to sampling. Both systems have a single trigger control, with the sampler having fewer trigger selection controls (INT/EXT, Line, ac/dc, etc.) than the real-time system. (Line and ac/dc are not required when making high-frequency measurements.)

With such panel similarities, there is no need to educate the user on how to operate the sampling oscilloscope. He is able to make high-frequency measurements just as easily as he makes low-frequency measurements. In addition, the writing speed problems that exist with real-time oscil-

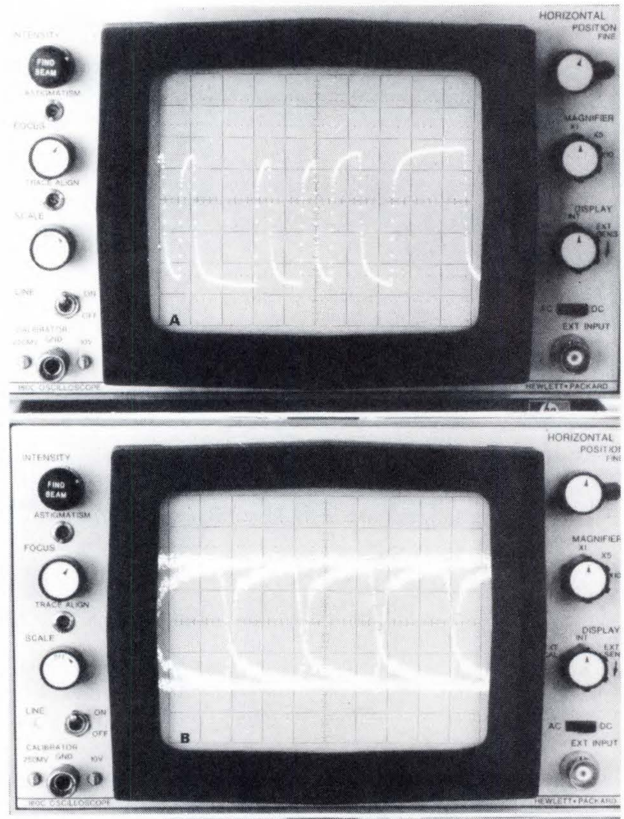


Fig. 3—Eye pattern characteristics possible with a sampling oscilloscope are shown by an 2^5-1 random sequence as seen at the output of a poor transmission line (**a**), an eye pattern generated by a $2^{20}-1$ random sequence (**b**) and an expanded eye pattern showing jitter on the rising and falling edges (**c**).

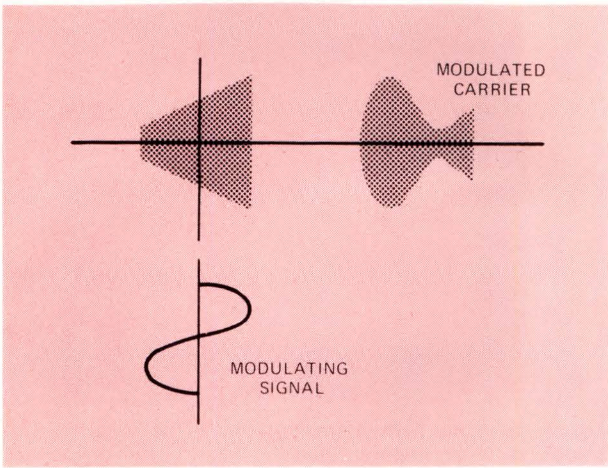


Fig. 4—Trapezoidal waveform is produced with the modulated carrier on the Y axis and the modulating signal on the X axis.

loscopes do not exist with sampling oscilloscopes. Because of the low-frequency display, the display is always bright, even on the fastest signals. The sampling transducer is the only part of the system that sees high-frequency signals.

From the standpoint of cost, sampling oscilloscopes offer twice the bandwidth for about half the cost. Thus, when evaluating high-frequency measurement needs, it is often rewarding to consider the sampling oscilloscope. For example, if you compare the cost of high-frequency real-time systems with the cost of 1-GHz sampling system, you find that 250-MHz to 500-MHz real-time systems are available in the \$4000-to-\$5000 price range while 1-GHz sampling systems are available for less than \$3000.

Applications are the key

Possible applications are of paramount interest to the engineer considering the use of a sampling oscilloscope. For example, consider digital eye patterns. **Fig. 3a** illustrates a 2^5-1 random sequence as seen at the output of a poor transmission line. **Fig. 3b** shows the eye pattern generated with a $2^{20}-1$ random sequence. The distortion in the pulses (intersymbol interference) caused by the poor transmission line is recognizable in this photograph. If the eye pattern is expanded (**Fig. 3c**), the time jitter that is introduced by the poor transmission line can be measured (horizontal scale is 5 nsec/div). The time jitter at the 50% points is 800 psec on the falling edge and 1 nsec on the rising edge. The jitter is introduced because the pulses do not reach the same 1 or 0 level each time, causing the threshold crossings to be different, as can be seen in **Fig. 3a.**

High-frequency modulation trapezoids are another appropriate application for the sampling oscilloscope. This technique measures modulation index, phase shift and, to some extent, distortion caused by the modulator. The modulation trapezoid is generated by displaying the AM modulated carrier against the modulating signal (**Fig. 4**). When the modulating signal goes positive, the carrier is at its maximum amplitude (right side of CRT). A number of possible displays are illustrated in **Fig. 5.**

Fig. 6b shows a modulation trapezoid of a 1-GHz carrier modulated by a 12-MHz sine wave. The trapezoid indicates about 70% modulation, with some phase shift between the input and output, and distortion. The phase shift is recognized as the two separate paths traversed from the left to right edge of the trapezoid. The distortion shows up as a deviation from an ideal

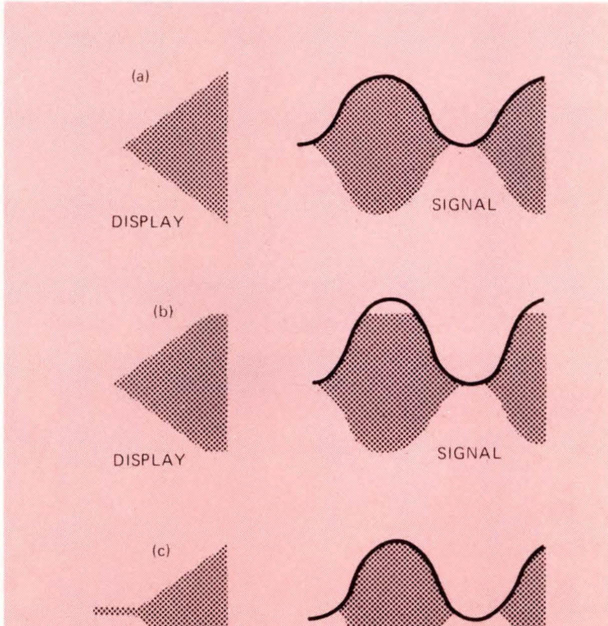


Fig. 5—Modulation condition is indicated by nature of display: 100% modulation (**a**), overmodulation—positive (**b**), overmodulation—negative (**c**), overmodulation—positive and negative (**d**) and undermodulation (**e**).

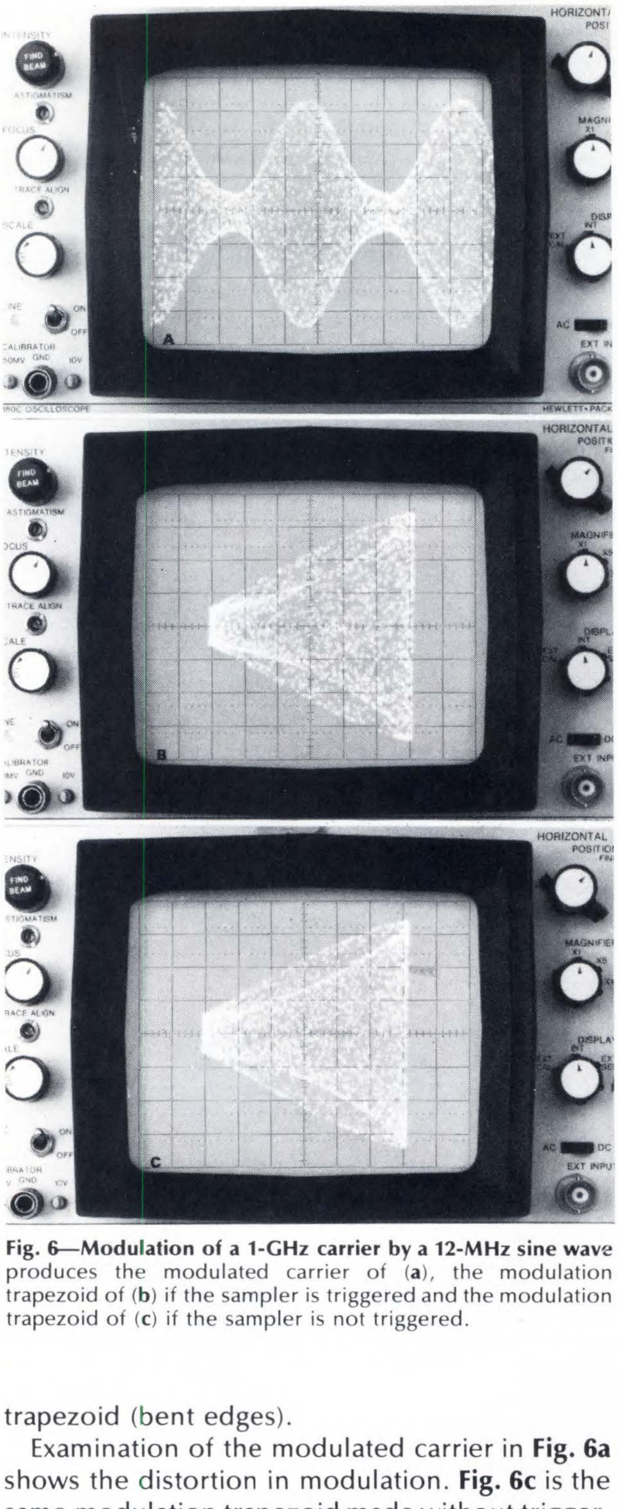


Fig. 6—Modulation of a 1-GHz carrier by a 12-MHz sine wave produces the modulated carrier of (**a**), the modulation trapezoid of (**b**) if the sampler is triggered and the modulation trapezoid of (**c**) if the sampler is not triggered.

trapezoid (bent edges).

Examination of the modulated carrier in **Fig. 6a** shows the distortion in modulation. **Fig. 6c** is the same modulation trapezoid made without triggering the sampler. Design improvements have eliminated the need to trigger the sampling oscilloscope for modulation trapezoids. The advantage is that swept modulation trapezoids can be made without concern for triggering, or modulation trapezoids can be made on live transmission systems where the modulating signal is a complex waveform and triggering is not possible.

The Lissajous pattern has been used for many years in the low-frequency field to determine

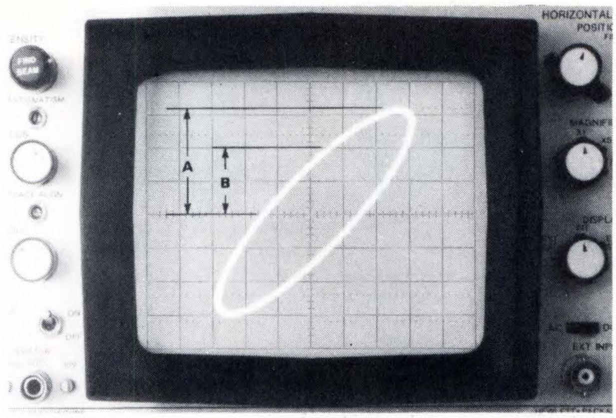


Fig. 7—Lissajous pattern techniques can be used on GHz signals with a sampling oscilloscope. In this phase shift measurement, $\sin \theta = B/A$.

phase relationships, amplitude and distortion between two signals. Sampling oscilloscopes allow this measurement to be made in the GHz region. The phase measurement is made as shown in **Fig. 7.** Although phase measurements in the neighborhood of 90° are difficult to make on a Lissajous pattern, measurement of phase differences in the zero degree phase shift region are quite sensitive. If the characteristics of a narrow-band IF strip need to be checked, a simple phase/amplitude/frequency measurement can be made by sweeping through the bandwidth of the IF strip and extracting the information from the Lissajous pattern as displayed on the CRT (**Fig. 8**).

In addition to the applications previously mentioned, the sampling oscilloscope has been a long-time workhorse in the high-frequency measurement area for both pulse and CW signals. Because of its broader bandwidth, the sampling oscilloscope can more faithfully reproduce complex waveforms, so long as they are repetitive. This is demonstrated by the photographs of **Fig. 9,** which show that a significant amount of information is lost due to the lower bandwidth of a

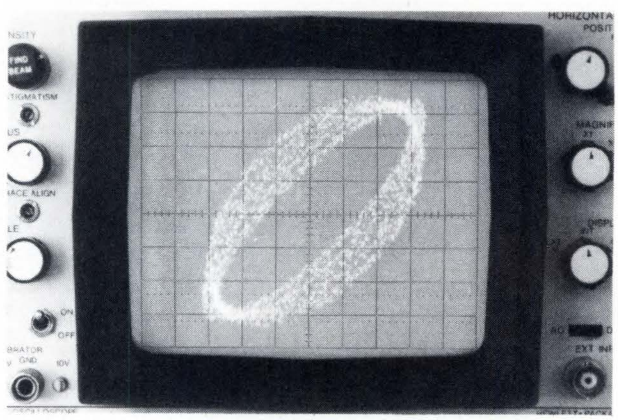


Fig. 8—A typical swept Lissajous pattern shows the results of sweeping a 6-in. piece of coaxial cable to produce phase/amplitude/frequency characteristics. In this case, the center frequency is 640 MHz and f = 20 MHz.

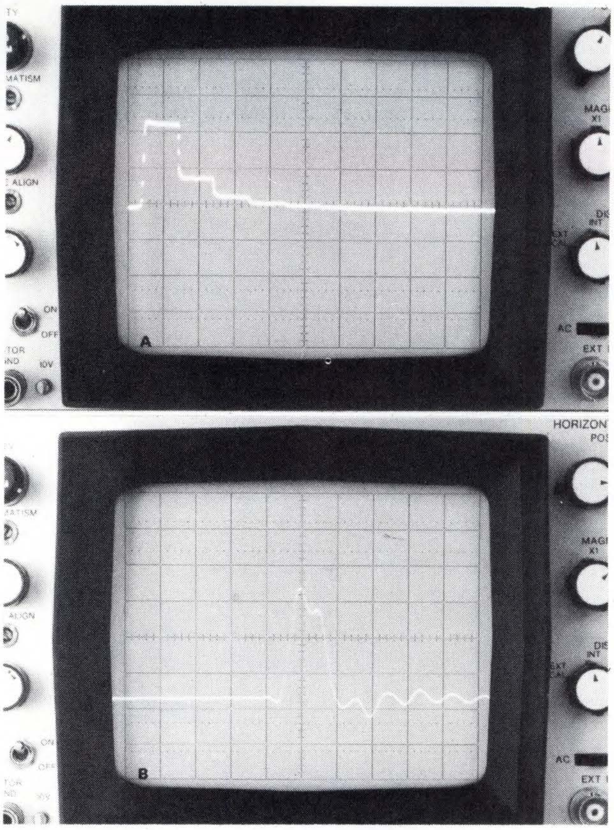


Fig. 9—**Wider bandwidth of sampling oscilloscope** allows better reproduction of waveforms. The same waveform is shown here displayed on a sampling scope having a 1-GHz bandwidth (top photo) and a real-time scope having a 75-MHz bandwidth (bottom photo).

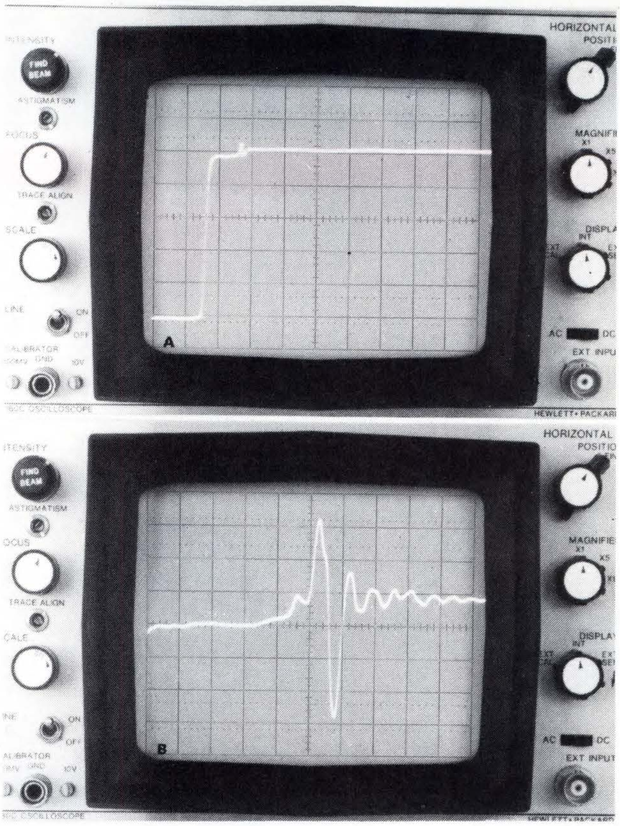


Fig. 10—The perturbation at the leading edge of the waveform in (**a**) is magnified in (**b**) to show the large dynamic range of the sampling oscilloscope.

real-time oscilloscope. Similar benefits can be realized when making sine-wave measurements. Phase, amplitude and distortion can be measured using conventional sine-wave instrumentation, but before these measurements are valid, it is necessary to make a qualitative measurement of the signal to insure that no clipping or other such effects are present. The sampling oscilloscope, with its broadband capabilities, can easily make this measurement at high frequencies.

The large dynamic range and fast recovery time of sampling oscilloscopes are other features that have wide application. Dynamic range might be defined as the ability to see a very small pulse or aberration riding on top of a large pulse. Sampling oscilloscopes accurately reproduce small pulses or aberrations in the presence of large ones, with the ratio of amplitudes being as great as 1000:1. This is demonstrated by time domain reflectometry techniques (TDR), as in **Fig. 10.**

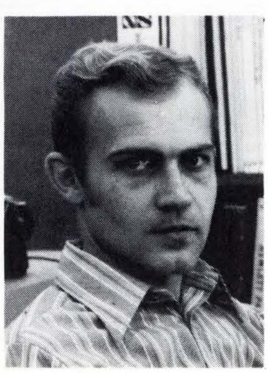
Recovery time is a factor that must be considered when discussing dynamic range. This phenomenon limits the representation of transitions. It can also be demonstrated by trying to view a small pulse preceded by a large pulse —one large enough to saturate the real-time amplifier. The small pulse will be masked in the recovery time of the large pulse if the amplifier has a long recovery time. Sampling oscilloscopes do not have this limitation because of the low-frequency signal path after the sampling transducer and because of the long time (typically 10 μsec) between samples. □

Bibliography

Johnson, Jim, "Sampling Oscilloscope Techniques," *Electro-Technology,* Sept., 1968.

Donaldson, Chuck, "The State of Sampling," *EDN,* Nov. 22, 1967.

Author's biography

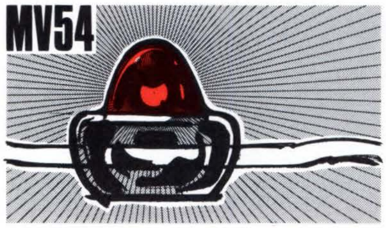


Russ Harding is a project leader at the Colorado Springs Div. of Hewlett-Packard, where he has been employed for five years. Russ is presently involved in circuit design within the X-Y Display Group. He received his BSEE and MSEE from Purdue Univ.

YOU WANT 100,000?

FOR YOU, TEN CENTS!*

*Unit price in 100,000 quantity.



This is the day Monsanto's red LEDs can be sold like jelly beans. TEN CENTS EACH. (100,000's)

Not a low performance unit. Not a special device. Not a compromise on Monsanto quality. This is our popular MV50 package, with a red epoxy lens for high contrast.

We've made and sold more than **ten million** of this type of solid state lamp. Volume production brings the price down. Now you can get into LED's at a new low cost—whether you need one or hundreds of thousands. And you can get them fast; they're on your local distributor's shelves. What's more, besides the built-in quality and integrity you can expect of Monsanto, we give you the backup of people with extensive technical experience on applications just like yours.

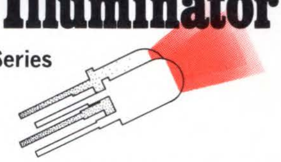
★★★★★★★★★★★★★★★★★★★★★★★★★

Pop-in Panel Lights

13 varieties in our MV5010, MV5020, MV5030 series. Available in red, yellow, green, or bicolor units. Handy snap-in mounting clips are included at no extra cost. New technology has **doubled** the light output of our MV5020. You can choose either wide viewing angle or point source, clear lens or red.

The Illuminator

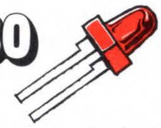
MV5054 Series



Available with 1, 2, and the new 3 millicandela outputs at 10 milliamps. Ideal for backlighting of switches or panels. GaP performance in a GaAsP lamp.

★★★★★★★★★★★★★★★★★★★★★★★★★

MV5080 Series



High intensity and small size make these units great for PC board mounting and arrays. Mount on 85 mil centers for high packing density.

★★★★★★★★★★★★★★★★★★★★★★★★★

NEW

A direct replacement for the TIL209, the **MV5074** has Monsanto quality, round leads, high performance. The **MV5063** is 0.2 inch diameter, with round leads. Easy replacement for the HP4403-4850, both are only 17¢ at 100,000 quantity.

★★★★★★★★★★★★★★★★★★★★★★★★★

THE LED STORE

Monsanto pioneered this technology and its applications. As a result, we can offer you the widest selection of devices, colors, and packages. If you don't have our catalog, get one. Ask any of our distributors:

EASTERN

HAMILTON ELECTRO SALES
Atlanta, GA (404) 448-0800
Baltimore, MD (301) 796-5000
Boston, MA (617) 273-2120
Cedar Grove, NJ (201) 239-0800
Cherry Hill, NJ (609) 662-9337
Long Island, NY (516) 333-5800
Miami, FL (305) 925-5401
Syracuse, NY (315) 437-2642

KIERULFF ELECTRONICS
Gaithersburg, MD (301) 948-0250
Hicksville, NY (516) 433-5530
Rutherford, NJ (201) 935-2120
Paoli, PA (215) 647-2612
Needham Heights, MA (617) 449-3600

SCHWEBER ELECTRONICS
Rockville, MD (301) 881-2970
Hollywood, FL (305) 927-0511
Westbury, NY (516) 334-7474
West Long Branch, NJ (201) 870-1755

EASTERN

HAMMOND ELECTRONICS
Orlando, FL (305) 241-6601

SEMICONDUCTOR SPECIALISTS, INC.
Pittsburgh, PA (412) 781-8120

MIDWEST

HAMILTON ELECTRO SALES
Chicago, IL (312) 678-6310
Dallas, TX (214) 638-2850
Detroit, MI (313) 522-4700
Houston, TX (713) 526-4661
Kansas City, MO (913) 362-3250
Minneapolis, MN (612) 854-4800
St. Louis, MO (314) 731-1144

KIERULFF ELECTRONICS
Garland, TX (214) 271-2471

SEMICONDUCTOR SPECIALISTS, INC.
Dayton, OH (513) 278-9455
Chicago, IL (312) 279-1000
Detroit, MI (313) 255-0300
Indianapolis, IN (317) 243-8271
Minneapolis, MN (612) 854-8842
Kansas City, MO (816) 452-3900
St. Louis, MO (314) 428-6100
Dallas, TX (214) 358-5211

SCHWEBER ELECTRONICS
Elk Grove Village, IL (312) 593-2740
Cedar Rapids, IA (319) 366-0774
Beachwood, OH (216) 464-2970

WESTERN

ALTA ELECTRONICS, INC.
Salt Lake City, UT (801) 486-7227

ELMAR ELECTRONICS
Mountain View, CA (415) 961-3611
Denver, CO (303) 287-9611

HAMILTON ELECTRO SALES
Culver City, CA (213) 870-7171
Denver, CO (303) 534-1212
Mountain View, CA (415) 961-7000
Phoenix, AZ (602) 269-1391
Salt Lake City, UT (801) 262-8451
San Diego, CA (714) 279-2421
Seattle, WA (206) 624-5930

KIERULFF ELECTRONICS
Palo Alto, CA (415) 968-6292
Phoenix, AZ (602) 273-7331
Denver, CO (303) 343-7090
Seattle, WA (206) 763-1550
San Diego, CA (714) 278-2112

LIBERTY ELECTRONICS
Phoenix, AZ (602) 264-4438
Seattle, WA (206) 763-8200
El Segundo, CA (213) 322-8100

WESCO ELECTRONIC
Los Angeles, CA (213) 685-9525

WESTERN RADIO
San Diego, CA (714) 235-6571

CANADA

CANADIAN DYNAMICS, LTD.
Vancouver, B. C. (604) 325-3201
Calgary, ALB. (403) 265-6500

CESCO ELECTRONICS, LTD.
Montreal (504) 735-5511
Ottawa (613) 729-5118
Toronto (416) 638-5250
Quebec (418) 524-4641
Vancouver (604) 433-7834

HAMILTON ELECTRO SALES
Montreal (514) 735-6393
Ottawa (613) 725-3071
Toronto (416) 677-7432

SCHWEBER ELECTRONICS
Toronto (416) 925-2471

SEMICONDUCTOR SPECIALISTS
Ontario (416) 678-1444

And if you need additional information or applications assistance, we're glad to help:

Monsanto Commercial Products Co.
Electronic Special Products
10131 Bubb Road
Cupertino, CA 95014
(408) 257-2140

A unit of Monsanto Company

★★★★★★★★★★★★★★★★★★★★★★★★★

Putting innovation to work.

Monsanto

Circle No. 31

Ease radio-spectrum congestion by bandwidth compression/expansion

Working models with compression ratios of 10:1:10 and 2:1 are demonstrated using real-time substitution of lower frequencies.

James J. Savidge, MS Laboratories

In recent years, congestion of the electromagnetic spectrum has become a major problem for the communications industry. Most of the communication services could expand if more spectrum space were available, or if less of the spectrum were required for each transmission. Pseudo-bandwidth compression techniques, such as single-sideband modulation, have permitted some services to double the number of communication channels available for use by reducing the transmitted bandwidth to that of the modulating signal. True bandwidth compression reduces the bandwidth of the original signal and may be used with any standard modulation or storage method.

Various approaches have been used to reduce the bandwidth of signals. Signal redundancy has been reduced by such techniques as sampling and transmission of only the changes from the last condition. But some signals require more bandwidth to transmit when sampled and time multiplexed with other similar signals than if sent "as is".

The method disclosed in U.S. Patent 3,349,184 accomplishes bandwidth compression by a real-time substitution of lower frequency components for components in the original signal. The resultant reduction in signal bandwidth provides economic advantages by requiring less in the way of facilities for transmission or recording of the signal and reducing the power required for signal reception with a given signal-to-noise ratio.

A graphical picture of the effect of coding can be had by comparing the various methods of sending vocal information. Voice signals are allotted approximately 2700 Hz of bandwidth in the telephone system. The spoken word rate is said to average about three words per sec. At 6 characters per word, this is about 18 characters per sec, or nearly twice the 10 cps (characters per sec) speed of ordinary Teletype, with about 20 times as much bandwidth as Teletype.

Facsimile can be used to transmit typewritten material over telephone channels at a rate of one 8-1/2 x 11-in. page in 3 minutes. Such a sheet will hold approximately 50 lines of 70 characters each, or 3500 characters (and spaces). This is about 19-1/2 cps, or twice as fast as Teletype in 20 times the bandwidth. Voice information rate has been stated to be approximately 50 to 60 bps (bits per sec). Note that Shannon's (Professor Claude Shannon of MIT) bits and binary bits are not the same. A 2000-baud modem will send the 3500 characters over an ordinary telephone line in about 14 sec.

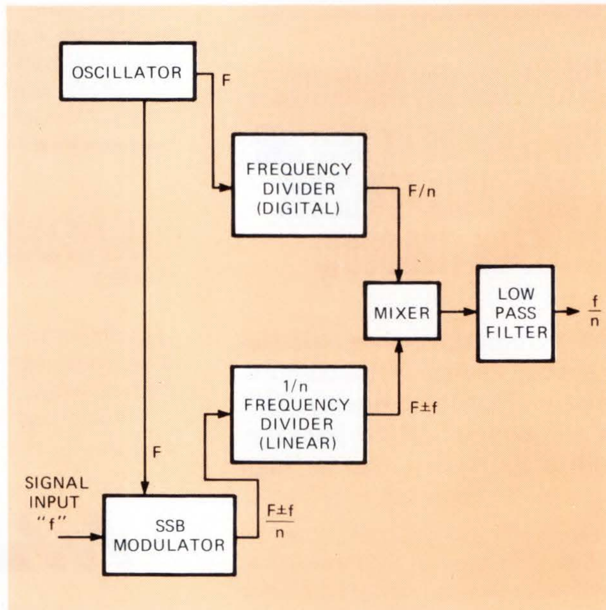


Fig. 1—Bandwidth compression involves modulation of the signal onto a carrier, followed by amplitude-linear frequency division and synchronous demodulation. The f/n component can be separated by a low-pass filter.

Information is carried by amplitude and phase. The relative importance of frequency can be observed by noting that anyone can talk at the same speed at their normal pitch, at a falsetto, or at a bass pitch. Intelligibility may vary with the pitch if it gets too far from the nominal range.

The nature of signals

Probably all signals consist of wavetrains of discrete frequencies (usually overlapping) which exhibit some sort of amplitude variation from start to finish. The wavetrains are fundamental frequencies plus overtones. The duration of the wavetrains varies with the signal source and the information being transmitted. Voice, facsimile and TV signals can be shown to consist of such wavetrains. Digital signals can be shown to be amplitude modulated fundamentals with strings of harmonics, with the information largely carried by subharmonic wavetrains.

According to Shannon, the minimum bandwidth required to transmit a given message in a set length of time is dependent on the information content. We are a long ways from achieving that minimum bandwidth with any means of coding now in widespread use. In addition, "information" is not defined in any useful way.

A TV picture is a good example of the wide discrepancy between the bandwidth occupied and the actual information rate. In the original scene viewed by the camera, the motion of objects viewed with respect to the camera's coordinate system is relatively slow. Considering that relative position, angular orientation and color are the main information parameters, the information spectrum of a TV scene is probably contained within a few hundred Hertz of zero. The 3 to 4-MHz range occupied by the coding in use is a requirement of the equipment used to produce corresponding electrical signals and convert them to an optical representation. The camera tube is compatible with the CRT and produces what the CRT requires to make up a picture. What happens in between is immaterial, as long as the CRT gets what it needs.

The limit of bandwidth compression is determined by the nature of the signal and its information rate. Ten-to-one bandwidth reduction has been accomplished with voice without noticeable loss of information. How much greater a compression ratio could be used is not known, but from observations, a 20:1 compression could probably be feasible, and possibly even 40:1.

The key to application is economics. When it costs less to use bandwidth compression than to build more facilities, then bandwidth compression should be used. When spectrum space is so crowded that reception of transmissions is uncertain, bandwidth compression provides an economic answer. Mobile radio, satellite communications, facsimile and video recording are application areas that can be expected to make greater use of bandwidth compression in the near future.

Bandwidth changing

Bandwidth compression can be accomplished by simultaneously dividing all the frequency components of a signal by some selected factor in real time. If the original signal spectrum extends from f_0 to f_m, the new signal spectrum will extend (at baseband) from f_0/n to f_m/n. The bandwidth will change from $(f_m - f_0)$ to $(f_m - f_0)/n$. The $(f_m - f_0)/n$ signal spectrum can be transmitted through distance or time (stored). But on reception or playback, the coding will not be appropriate for the usual terminal. Bandwidth expansion is required to restore the signal to its original bandwidth and waveform. There are exceptions to this rule that will be pointed out later.

The method of bandwidth compression discussed here involves modulation of the signal onto a carrier, frequency division which is linear in amplitude and synchronous demodulation. **Fig. 1** shows a block diagram for bandwidth compression. Algebraically, the process can be expressed as follows:

$$f(F) = (F + f) + (F - f)$$

where "f" is the signal spectrum and "F" is the carrier.

Selecting a sideband and dividing, gives $(F \pm f)/n$. Mixing $(F \pm f)/n$ with F/n produces:

$$[(F \pm f)/n](F/n) = \frac{F \pm f}{n} + \frac{F}{n} + \frac{F \pm f}{n} - \frac{F}{n}$$

$$= \frac{2F \pm f}{n} + \frac{f}{n}$$

Low-pass filtering separates f/n. **Fig. 2** shows a bandwidth expander.

It is not necessary to return to baseband, and in some cases it is not desirable.

The key to the compression process, other than the SSB (single sideband) modulation, is the amplitude-linear frequency division. There are a

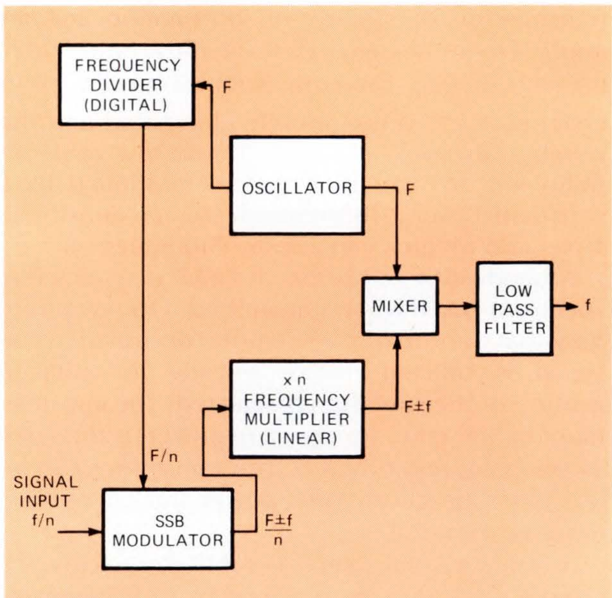


Fig. 2—Expanding the f/n output from a compression circuit involves linear-frequency multiplication of the modulated (SSB) input signal. A low-pass filter may be used to separate the signal spectrum, f.

number of ways it can be done.

The easiest method is to use a phase locked loop to multiply the divided signal back up to serve as a reference for a mixer as in **Fig. 3**. Mixer inputs are (F ± f) and (n ± 1)(F ± f)/n. If a phase locked loop is used, its phase comparator has inputs from the mixer (through a bandpass filter) and from its VCO (voltage controlled oscillator) through a digital-frequency divider.

The VCO is constrained to be any (n ± 1) multiple of the phase comparator inputs by phase-comparator control. The fact that the phase locked loop will operate over an appreciable bandwidth in this manner (not FM) may be a surprise to some people. The phase locked loop can be replaced by a limiting-frequency multiplier chain.

Bandwidth expansion uses similar techniques to restore the signal to its original form. The frequency multiplication required must be linear in amplitude to preserve amplitude information. A phase locked loop can be used for this operation, although in some instances it will be marginal.

Another method is to use a limiting-frequency multiplier to obtain (n ± 1) (F ± f)/n which is mixed with (F ± f)/n to obtain (F ± f). Our 10:1 expander multiplies the first mixer output by 9, then divides digitally by 10 to provide an input to the mixer of 0.9(F − f). Mixed with 0.1(F − f), the mixer output is (F − f) and 0.8(F − f). A bandpass filter eliminates the unwanted lower sideband.

Advantages of compression/expansion

The advantages of bandwidth compression and expansion are the use of less facilities for transmission or storage of information and an improvement in signal-to-noise (S/N) ratio tradeoff with power. The congestion of mobile radio channels can be temporarily eliminated and the number of voice channels through a cable or radio link (or satellite) can be multiplied by a substantial factor. Information storage density on tapes and records can also be multiplied.

A bandwidth-compressed signal occupies less spectrum space when transmitted. On reception, only that portion of the spectrum occupied by the signal is utilized. Noise outside the utilized portion of the spectrum is rejected. The improvement in S/N ratio, for constant power, is the same as the compression ratio. The transmitter can be less costly because of less power and can operate more economically.

In wired systems, such as cable TV systems, the coaxial cable may be replaced by less expensive wire, possibly even present telephone lines.

There are some trivial applications of bandwidth compression and expansion which may

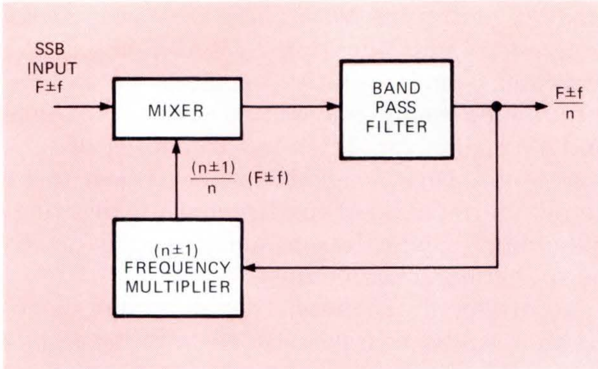


Fig. 3—The frequency divider is a closed-loop system. A phase locked loop may be used as the frequency multiplier.

have economic importance in terms of sales. One such application is a compressor-expander unit which would allow one singer to sound like a barbershop quartet. The singer could change from tenor to bass at the flick of a switch.

A single musical instrument could be made to sound somewhat like a band by mixing up-scale and down-scale translations of the instrument's tones. These things cannot be done in real time without bandwidth compression.

Applications for this technique

Initial emphasis has been placed on voice applications since existing equipment can be used with only minor modifications. In most cases, the only modification required is to place a bandwidth compression and expansion "black box" between the present equipment and the input and output transducers.

As usage increases, new equipment will have the black boxes built-in with facilities to switch the bandwidth compression and expansion components out of the system. This type of equipment will be fully compatible with existing equipment. Conservation of spectrum and security, which is inherent in this method, make it a natural for mobile-radio services such as public-service and industrial-radio systems.

Security is a side effect. At a 5:1 compression ratio, a man's speech is unintelligible when compressed. A woman's voice sounds like a basso, but can be understood. At greater ratios, compressed signal intelligibility would probably be zero even for women's speech. Without the expander equipment, security is complete.

Wider bandwidth systems are being developed and will be applied to facsimile systems in the near future. The ideal compression ratio is not yet known, but a 10:1 or greater ratio is expected. The bandwidth compression will be utilized to speed the transmission through a voice channel rather than multiplexing numerous transmitters through the same channel. This will shorten the time required to transmit a document.

Another broadband application will be voice, multichannel, communication systems such as those of voice common carriers and satellite ground stations. It will be much less expensive to bandwidth compress a group or supergroup than individual voice channels.

The wired cities of the future could be classified as multichannel systems. The cable TV, data systems and telemetry requirements of these cities may be handled completely through ordinary telephone lines after undergoing bandwidth compression.

A long awaited advance in telephone service is the picturephone. A low compression ratio, possibly as low as 10:1, will permit use of present picturephone equipment with existing lines.

Broadband-bandwidth compression will allow recording of video signals on much less exotic equipment than is presently used. It is anticipated that within a couple of years, it will be possible to record TV signals, for later playback, on audio tapes at recorder speeds of 7-1/2 in./sec. A compression ratio of 1000:1 is probably feasible and should not be very expensive.

An obvious application of bandwidth compression is telemetry, particularly from remotely located instruments. The principal advantage in this application is the improvement of the S/N ratio. Returns from telemetry in space, where power is a major factor, will particularly benefit.

Considerable activity has been devoted to educational applications. For several years practical means have been sought for increasing the speech rate without changing the pitch of voice recordings. Bandwidth compression allows frequency division while recording, with playback at a speed greater by the division ratio.

A vocal-book, bandwidth compressed by a factor of two, would be played back at twice speed with normal pitch. Using standard tape recorders and a 2:1 compressor, the recording could be processed several times for speech rate increases in multiples of two. Other ratios could be used but would require recorders with non-standard speeds. One use of this equipment would be in the preparation of talking books for the blind.

The major unknown factor in the use of speeded speech is comprehension. It appears reasonable to expect speech reaction and understanding speed to approach reading rates without extensive training.

A reading rate of 600 to 700 words per minute is not uncommon. This corresponds to a compression ratio of 4:1. Applying this rate to recordings of lectures and conferences would mean that an eight-hour lecture or conference could be reviewed in two hours.

A service based on these principles would find markets in industrial training, continuing education for professionals and general education. For some professionals intensive training could be provided in the use of high-speed recordings. Doctors and lawyers are typical of the group that must keep up with current developments in their fields and in related fields, and would benefit from training to use the recordings.

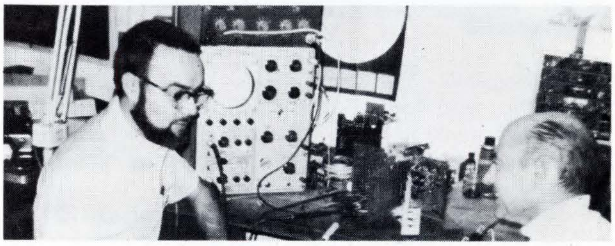
Present developments

The original breadboard was a 5:1:5 voice-bandwidth compressor and expander which was used as the basis for the patent application. That unit was built with discrete components. Two demonstration units, a 2:1 compressor and a 10:1:10 compressor and expander, both with voice bandwidth, are presently in use. Op amps, ICs and some discrete components are used in the demonstration units. These show that the technique has advanced to the point where specific products can be designed and developed rapidly.

Broadband equipment is being developed for high-speed facsimile and similar systems. The 2:1 compressor is being used in initial studies of speeded speech for educational and entertainment use. When used in this application, bandwidth is unchanged, but the word rate of recorded material is increased.

The present 10:1:10 bandwidth-compressor and expander demonstration unit has a probable small-quantity manufacturing cost on the order of \$200 using industrial-quality components. Relatively large-scale manufacture will cut that cost considerably. Engineering improvements can be made to cut price somewhat further. Units with smaller compression ratios will cost even less. Large-compression-ratio units and increased bandwidth add to the cost. ▭

Authors' biographies

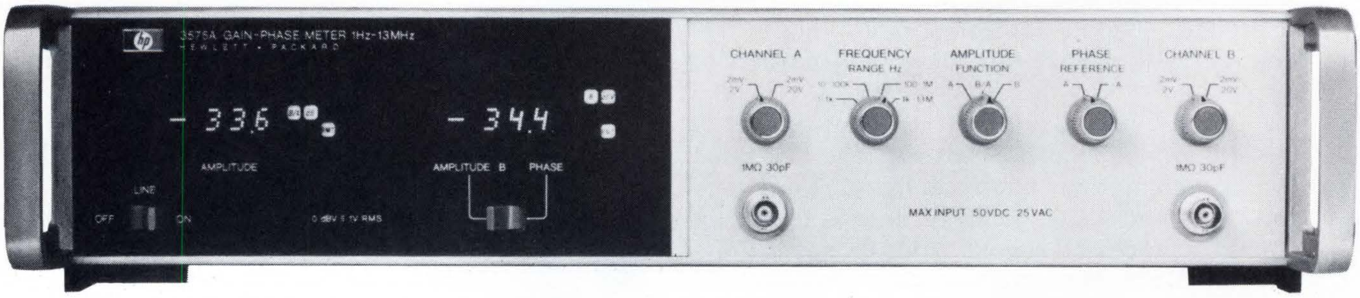


James J. Savidge (left) is a partner and sales manager of MS Laboratories, founded in June, 1972. He holds a BS in physics from the Univ. of Texas at El Paso.

Harvery Morgan (right), MS's co-founder, is the inventor of band-width compression/expansion. MS Laboratories, P.O. Box 28425, Dallas, TX 75228.

Instant Gain and Phase From This Single Instrument

dB & ϕ



Phase measurements. You know they're necessary—even inevitable for the proper design of linear devices. But brother, what a nuisance. When you're faced with the prospect of tweaking a bunch of instruments for a half day, just to get one set of measurements, it's to your credit that you do them at all.

But that's all in the past. Today, you can put our 3575A Gain-Phase Meter on your bench and make those necessary, even critical, measurements in a matter of minutes. One instrument. One set-up. Simply adjust the input signal amplitude and frequency, then read dB and degrees directly on the LED displays.

With a frequency range from 1 Hz to 13 MHz, and levels from 200 μV to 20V, the 3575A has the breadth of coverage you need for most circuit applications: op amps, broadband amplifiers, RCL circuits, filters, etc. Even low-level circuits present no problem since the 3575A has outstanding noise immunity. The starting price of $2450 is low for the capability you get.

Making gain, phase and amplitude measurements the easy way is the subject of our Application Note. No. 157. It covers applications from components through networks. Get your copy by contacting your local HP field engineer. Or, write to Hewlett-Packard, Palo Alto, California 94304. In Europe: HPSA, P.O. Box 85, CH-1217 Meyrin 2, Geneva, Switzerland. In Japan: Yokogawa—Hewlett-Packard, 1-59-1, Yoyogi, Shibuya-Ku, Tokyo 151.

093/44

HEWLETT hp PACKARD

NETWORK ANALYZERS

Circle No. 30

Thinking of additional memory for your mini-computer?

The best idea is Fabri-Tek's add-on core.

Fabri-Tek's add-on core memories are plug compatible and they're available in 8K word increments to any word size you desire.

So, whatever your needs . . . HP-2100, 2114A/B, DEC-PDP8E, PDP8 I, PDP8M, PDP11, DG NOVA 1200 and others, think first of Fabri-Tek for off-the-shelf delivery. Another Fabri-Tek plus: on-site and factory service by a highly trained professional staff.

For additional information, call or write:

FABRI-TEK INC.

Leader in Memory Technology For over a Decade

5901 South County Road 18 • Minneapolis, Minnesota 55436 • (612) 935-8811

REGIONAL OFFICES:	Boston	Chicago	New Jersey	Phoenix	Long Beach	Sunnyvale
	(617) 969-5077	(312) 437-4116	(201) 964-4770	(602) 266-4448	(213) 420-2493	(408) 739-4780

Circle No. 32

Try any one for 10 days FREE!

Your WESTON distributor is betting you'll never want to give it up.

Weston, the leader in portable test equipment, is willing to bet that once you try one of our digital DMM's, you'll never want to give it up.

So, during April, May and June, you can try any one of these compact, portable, almost indestructible multimeters for 10 days—FREE! Just pick the one that suits your needs best.

Model 4440 Lowest cost, plus high performance. Full 3½-digits. 17 ranges, 200 mV to 1000V, 200 ohms to 2 megohms, plus AC/DC current. Blinking overange indicator. Self-contained, re-chargeable battery gives more than 8 hours continuous operation. Or, use AC line converter.

Model 4442 20 ranges, plus amazing accuracy. ± .05% of reading ± one digit—guaranteed! All solid-state circuitry built around MOS/SLI chip. Automatic blanking of unused digits conserves power. Battery or AC line converter.

Model 4443 Lowest price, most precise, DC-only DMM available. 13 ranges, 200 mV to 1000V (100 uV res.), 200 ohms to 20 megohms (0.1 res.), plus current. ± .05% of reading ± one digit—guaranteed! Battery operated. Comes complete with charger.

Model 4444 The autoranging maximinimulti-meter. Choose VAC, VDC, Ohms or DC current. The 4444 does the rest. Instant automatic range selection. Plus four full digit display including polarity. Ultimate accuracy in a portable, ± .02% of reading ± one digit. No other portable offers more, does more.

So try one today. Just a note on your business letterhead will deliver a Weston Multimeter to you for a 10-day free trial. Weston Instruments, Inc., 614 Frelinghuysen Avenue, Newark, N.J., 07114.

We're either first or best. Or both.

WESTON® WESTON Schlumberger

Circle No. 33

Window detector uses one IC regulator

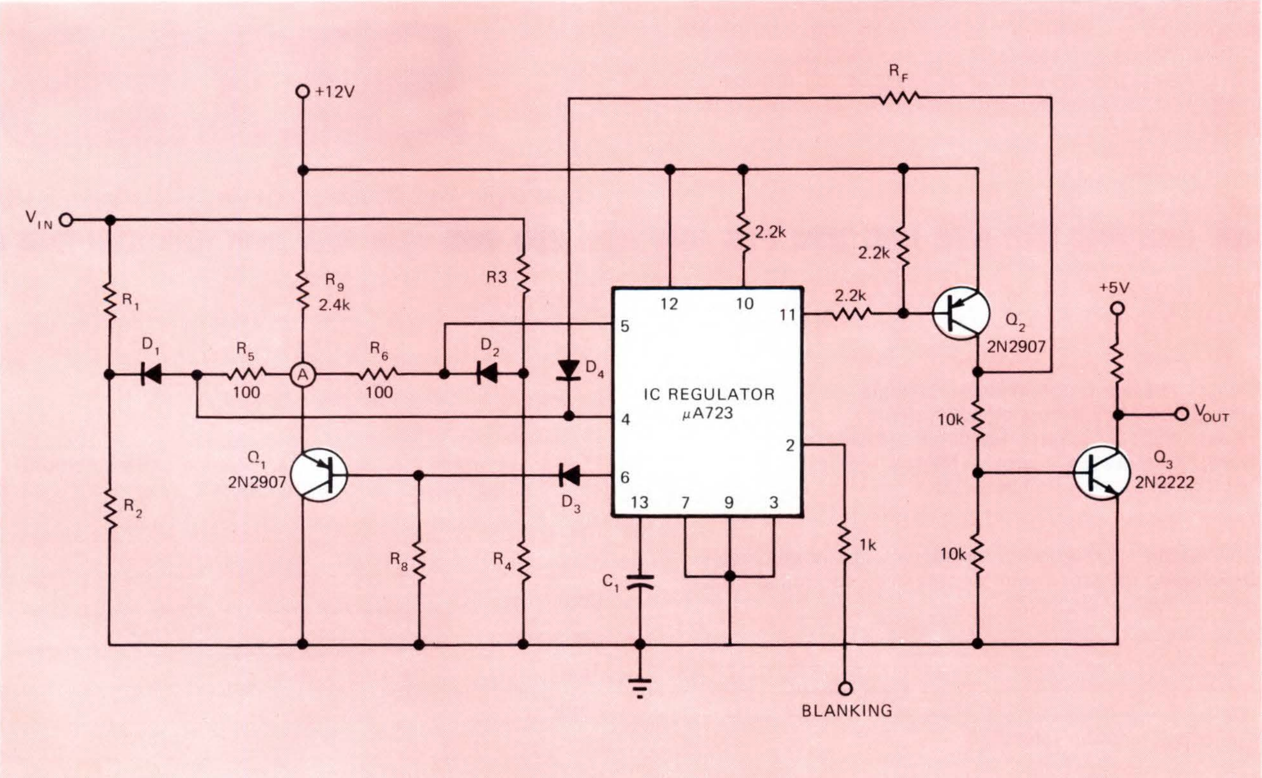
Neal Pritchard
ACDC Electronics Inc., Oceanside, CA

Window detectors typically use two voltage comparators whose outputs are combined to form a single logic output. The unique detector presented here uses only one 723 IC voltage regulator to perform the same function.

The detector circuit compares the output voltage of two separate voltage dividers with a fixed reference voltage. The resultant absolute error signal is amplified and converted to a logic signal which is TTL compatible.

The 723 has an internal reference voltage output which is only capable of sourcing current, not sinking it. Since current sinking is a necessity for proper operation, additional components are required. The reference voltage is applied thru D_3 to the base of Q_1. The emitter of Q_1 is now equal to the reference voltage and is temperature compensated by D_3. If a lower voltage is needed, a resistor may be inserted in series with D_3.

The voltage divider for the lower limit of the detector is R_1 and R_2. This voltage is compared to the reference voltage at point A. During normal operation D_1 is back biased resulting in no error signal. When V_{IN} lowers to a point where D_1 is forward biased, current flows thru R_9, R_5, D_1, and R_2. This produces a negative signal on pin 4 of the IC regulator which turns on Q_2 and Q_3, resulting in a logic ZERO at V_{OUT}. The voltage divider for the upper limit is R_3 and R_4. Similar to the lower limit operation, D_2 is back biased until V_{IN} reaches the upper limit, at which time current flows thru R_3, D_2, R_6, and Q_1. The positive signal developed across R_6 is amplified by the IC regulator and converted to a logic ZERO at V_{OUT}.



IC voltage regulators can also monitor input voltage. When V_{IN} is within predetermined limits, V_{OUT} will be a logic ONE. If V_{IN} is above or below limits, V_{OUT} will be ZERO.

A resistor R_F may be connected between the collector of Q_2 and pin 5 of the regulator. This positive feedback will produce hysteresis in the upper and lower limit settings, thus eliminating noise problems at crossover.

An additional feature of the IC regulator is the internal overload transistor which can be used for blanking. A logic ONE at the blanking terminal will cause V_{OUT} to be logic ONE regardless of the state of V_{IN}. □

To Vote For This Circuit
Circle 160

Low cost charge amplifier

H.C. Carpenter
McDonnell Douglas Research Labs., St. Louis, MO

The charge amplifier shown in **Fig. 1** costs less than $50 to build. Its conversion gain and signal-to-noise ratios are equivalent to charge amplifiers costing many times this amount.

The selection of proper op amps for use in a charge amplifier is critical. I found, after trying many different manufacturer's operational amplifiers, that Teledyne Philbrick's 102601 was one of the best for this application. We are using 132 charge amplifiers to amplify signals from a multiwire ionization hodoscope which is used in our present experiment.

The first stage, called the charge-sensitive stage, converts the input charge pulse to a voltage pulse. The conversion gain of the first stage is expressed in millivolts per picocoulomb (mV/pC), and yields a specific pulse height (in voltage) when a given charge is injected (by a detector) into the input. This charge on C_2 generates an output voltage, $V = q/C_2V$, where q is the charge on the input in coulombs and C_2 is the capacitance in farads. The conversion gain should be high enough to make the signal significantly larger than the noise of the second stage. The lowest noise amplifying devices available make it necessary that C_2 be as small as possible and no more than about 100 pF.

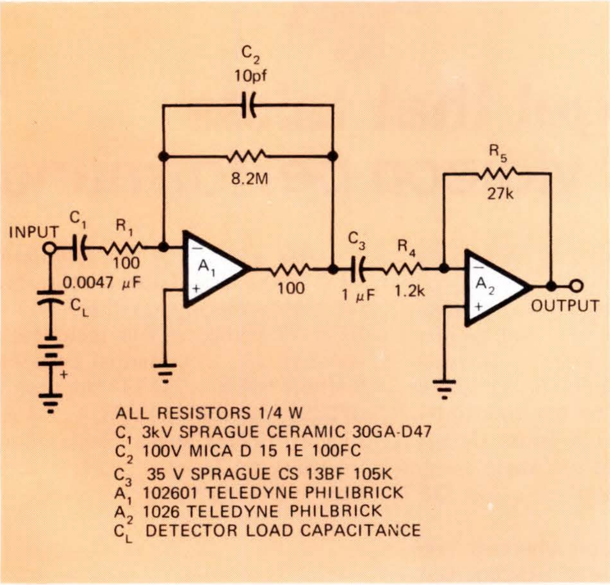


Fig. 1—Charge amplifier circuit costs only $50. Compared to other charge amplifiers presently available, this simple 2-op amp design offers good performance at less than one third the cost.

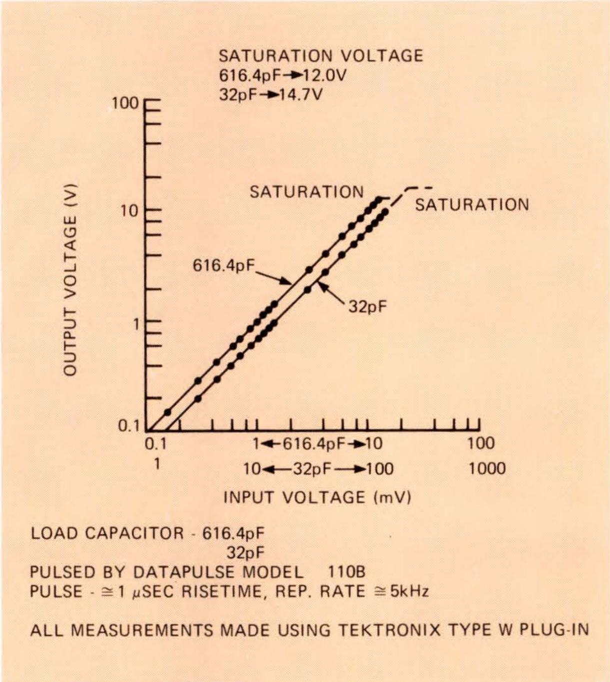
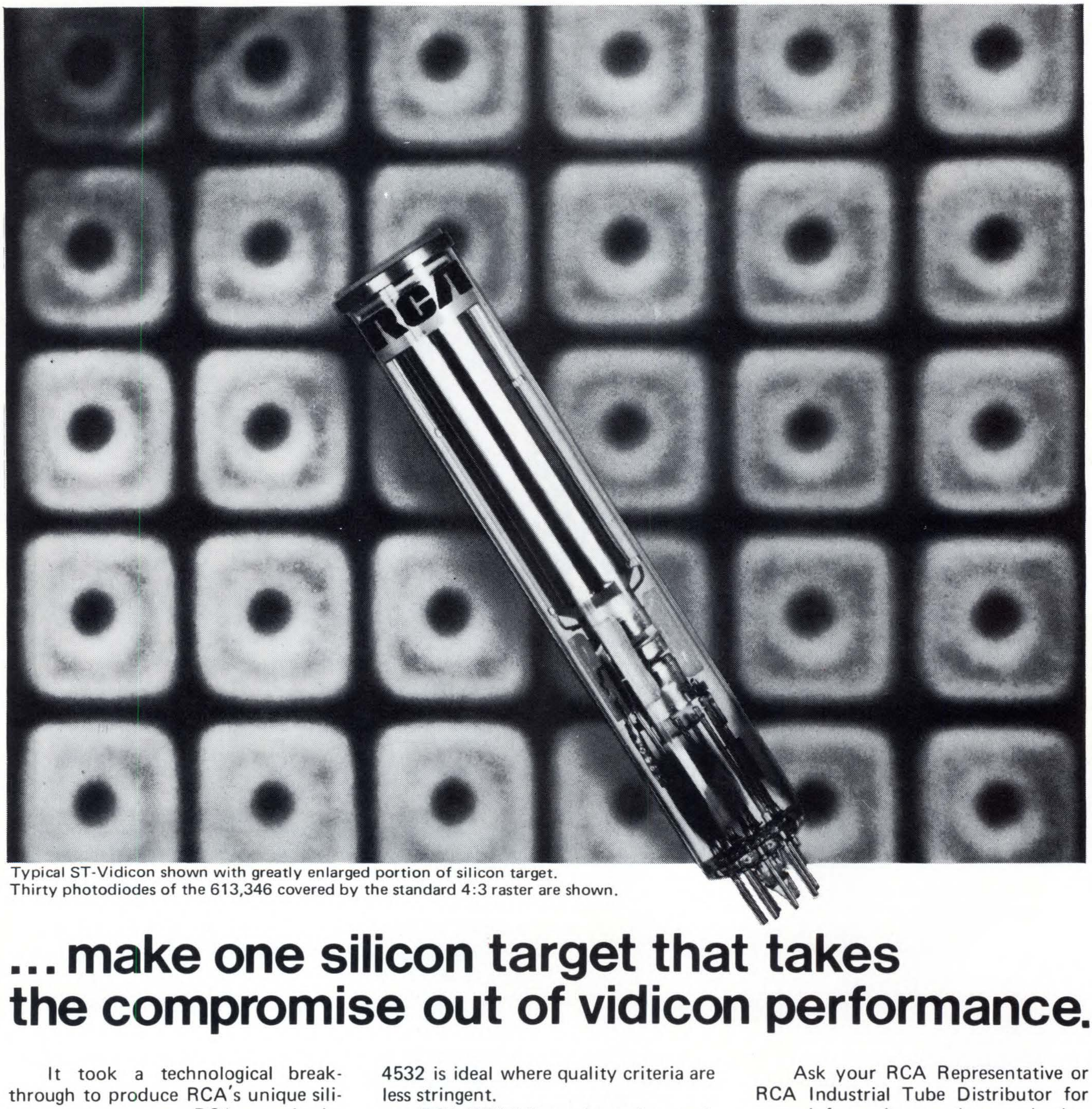


Fig. 2—Input/output response curves of the charge amplifier in **Fig. 1** show that the charge-conversion gain varies as a function of the load capacitance.

An input charge voltage at the summing point of the charge amplification stage is balanced by an equivalent displacement of charge across the feedback capacitor C_2, caused in turn by a change in the output voltage, e_o.

The second stage in **Fig. 1** is a voltage amplifier which provides the desired output signal level, but with low enough gain to prevent continuous saturation of that stage. Both of the op amps used have good thermal stability, which is particularly important in critical applications where the ambient temperature may vary over a wide range.

1,577,703 Photodiodes



Typical ST-Vidicon shown with greatly enlarged portion of silicon target.
Thirty photodiodes of the 613,346 covered by the standard 4:3 raster are shown.

... make one silicon target that takes the compromise out of vidicon performance.

It took a technological breakthrough to produce RCA's unique silicon target structure. RCA conceived a way to achieve the excellent performance of which silicon targets are inherently capable. Then one of the industry's most talented teams went to work. The no-compromise performance was well worth the wait. Now available from stock are silicon target vidicons with outstanding resolution, as well as low dark-current and low lag.

The RCA-4532A is the outstanding example of this unique photodiode target technology and is intended for high-quality TV pickup. The RCA-4532 is ideal where quality criteria are less stringent.

RCA ST-Vidicons have the sensitivity needed for security and surveillance. Quantum efficiency of at least 60% through the visible range provides pictures at as low as 0.1 lux (0.01 footcandle) on the faceplate. Covert systems using infrared are made possible through the ST-Vidicon's 30% QE at 900 nanometers.

Use the ST-Vidicon wherever you now use a conventional vidicon. Get low lag, low dark-current, immunity to highlight burn, and high sensitivity. Use it in broadcasting, education, security, and surveillance.

Ask your RCA Representative or RCA Industrial Tube Distributor for more information on these and other RCA ST-Vidicons. For technical data, write: RCA, Commercial Engineering, Section 50E20 /ZC 13, Harrison, N.J. 07029. International: RCA, 2-4 rue du Lièvre, 1227 Geneva, Switzerland, or Sunbury-on-Thames, U.K., or P.O. Box 112 Hong Kong.

Circle No. 35

RCA Electro Optics

The linear response of the charge amplifier is shown in **Fig. 2**, using load capacitances of 616 pF and 32 pF. Noise measurements, using a HP model 3400 rms to voltmeter with a shielded input, yielded 625 μV rms of noise at the output. To test the charge conversion gain that can be obtained with this amplifier, we have used an ionization chamber with an internal 241Am radioactive source to inject a known amount of charge onto the preamplifier input. This allows a direct determination of the charge conversion gain. The charge conversion gain measured by this technique is 1500mV/pC for a load capacitance of 50pF.□

To Vote For This Circuit
Circle 161

Ramp generator has adjustable nonlinearity

Hank Olson
Stanford Research Institute, Menlo Park, CA

The engineering world has devoted considerable effort to the attainment of a perfectly linear ramp function. However, once the linear sweep has been attained, it is then used to sweep some other device (like a voltage controlled oscillator) which usually has its own type of nonlinearity. The result is that, with a ramp input voltage that is linear with time, the output of the circuit being swept is generally not linear with time.

The ramp generator described here will enable one to pre-distort the sweep with either concavity or convexity to compensate for the nonlinearity of the circuit being driven. The amount of distortion is continuously adjustable by means of a potentiometer.

The ramp generator is shown in **Fig. 1**. Q_1 operates as a constant-current source. The amount of constant current is proportional to the voltage difference between the ±15V supply and the base voltage of Q_1.

$$i \approx \frac{15 - e_b}{R_1} \quad \text{(where } e_b = \text{base voltage of } Q_1\text{)}.$$

If the wiper of the "curvature" pot is set to minimum position (ground), then e_b is equal to twice the voltage on the wiper of the "starting

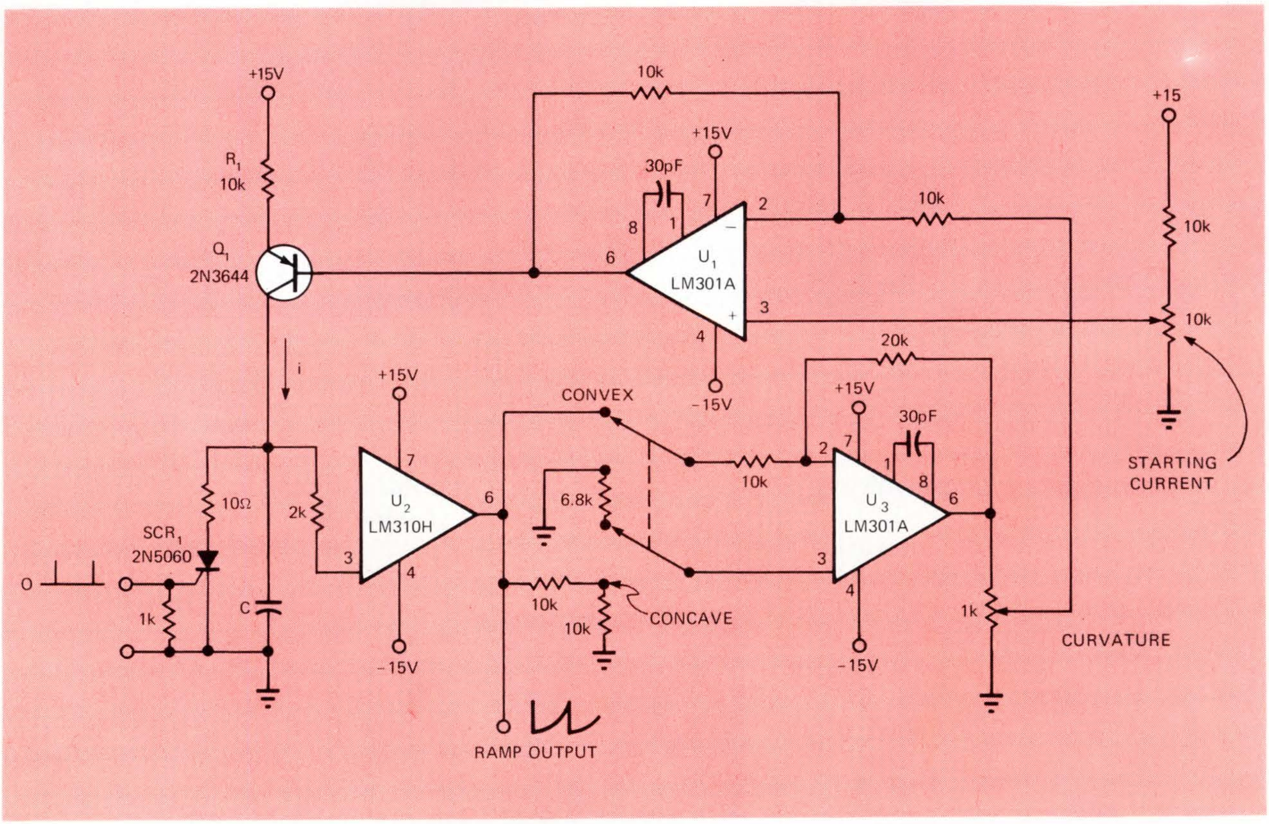
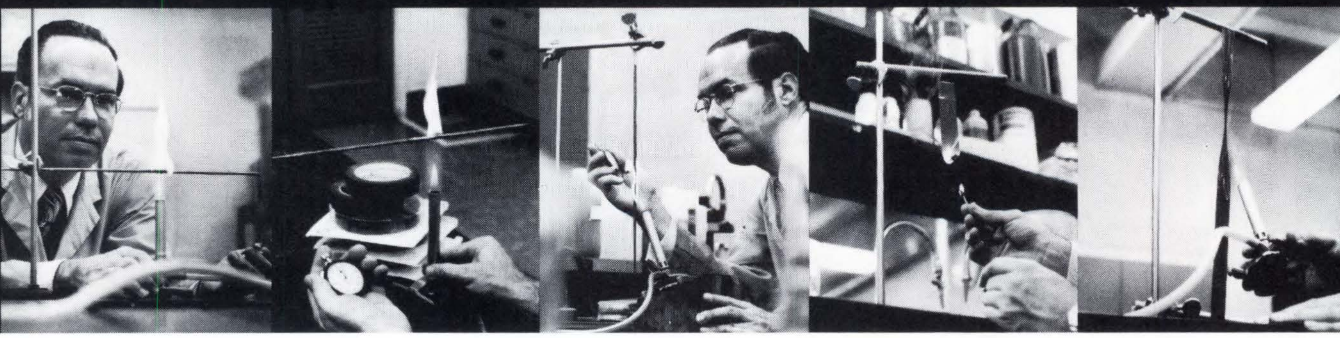


Fig. 1—Adjustable linearity/nonlinearity of this ramp generator makes it ideal for driving circuits which are nonlinear. When the final output must be linear, this circuit can be programmed to cancel the nonlinearity of VCOs and other similar circuits.

"Scotch" X-1284 passed five flame retardant tests.



X-1284 is a pressure-sensitive polyester film tape that handles like "Scotch" 56. However, the color is red, and because of its outstanding self-extinguishing characteristics, it can be used on radio and TV components and wiring involving fire or shock hazards.

It passed the rigid test outlined in U/L Subject No. 492, No. 510 and No. 94 with flying colors. ASTM D-635 was passed. Federal Highway Administration Safety Standard #302. Passed. ASTM D-1000-70a extinguishes in less than 3 seconds. Passed. 3M Cello Fusee extinguishes in less than 3 seconds. Passed.

The reason "Scotch" brand flame retardant X-1284 tape won't support combustion is that the "Scotchpar" polyester film backing and the unique adhesive system are both flame retardant. One of the key technological advantages, included in the "Scotchpar" Type 7300 polyester film backing, is that the flame retardant properties are built in directly. They cannot delaminate or flake off.

X-1284 provides excellent tear resistance. It's ideal for coil holding and coil covering applications, high temperature harness wraps, color TV flyback transformer insuiation and yoke coil assemblies.

For more information write Dielectric Materials & Systems Division, 224-64, 3M Company, 3M Center, St. Paul, Minnesota 55101.

See our product data in EEM.

Circle No. 36

3M COMPANY

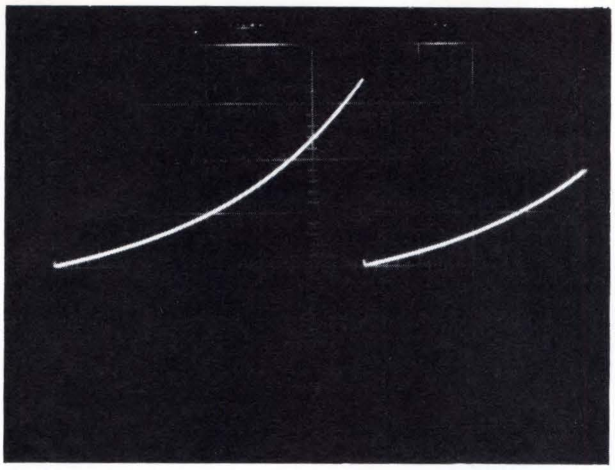


Fig. 2—Scope trace of a concave ramp generated by the circuit in **Fig. 1**. The value of C is 0.22 μF and the period is 6 msec.

current" pot. In this setting, the ramp output is linear. SCR_1 is periodically pulsed ON by the gate trigger impulses shown. The period of the pulses determines the period of the ramp function, because capacitor C is discharged by SCR_1 each time a positive gate trigger pulse is present.

The noninverting follower U_2 assures that the ramp voltage on C is sampled at a high enough impedance ($10^9\Omega$), so as not to cause unintended distortion of the ramp by partially discharging C. The output of U_2 provides a ramp output at reasonably low impedance for operating other circuits.

U_3 is operated as a multiply-by-two amplifier, in either the inverting or non inverting mode—depending on the input switch setting. In the inverting mode (switch in the "convex" position) the output has the effect of decreasing the voltage ($15V - e_b$) as the capacitor charges. Decreasing this voltage decreases the current that charges C and produces a ramp that departs from linear in a convex fashion.

If the switch is in the "concave" position, the rising voltage on C causes the voltage ($15V - e_b$) to increase, which increases the charging current into C. This causes the ramp to be distorted from linear in the direction of concave.

Unlike some earlier circuits which used capacitive coupling of the "bootstrap" feedback, this circuit uses dc coupling. This frees the designer from using huge coupling capacitors which must be considered when any change in the ramp length is made. The photograph in **Fig. 2** is an actual waveform generated by the ramp circuit; the value of C is 0.22 μF and the period is 6 msec. □

To Vote For This Circuit
Circle 162

Data acquisition costs less with DMM/calculator pair

PROGRESS IN TEST EQUIPMENT

Until now, a gap has existed between the simple data-logger type of test set up (typically priced around \$8000 to \$10,000) and fully computerized test setups (priced around \$30,000). Here's a measurement system that spans that gap—the Hewlett-Packard 3050A. It combines a five-digit DMM (HP 3490A), a scanner and a programmable calculator (HP 9820A). This system provides most of the flexibility and capability of a computerized one, but costs only slightly more than a simple data-logger setup.

The new 3050A is well suited for traditional data acquisition, for production testing and for use in R&D labs. Its DMM's 1μV sensitivity and 120 dB effective CMR, combined with better than 50 dB NMR permit meaningful measurements under conditions that would stop less capable instrumentation.

Compact, convenient and ready to use as delivered, the 3050A Data Acquisition System has near-computer capability at a price approaching that of a manual system.

For traditional data acquisition applications—such as environmental or process monitoring—the usual requirements are for multiple low-noise, low-level inputs; high CMR; scan rate of no more than 5 channels per second and both time-of-day information and test pacing. Also called for are transducer linearization, and results in engineering units to cut analysis time. These needs are well served by the 3050A.

Production testing of devices and circuit boards also requires multiple inputs and high CMR. "Hands off" operation is frequently desirable, as is conversational communication with the operator (often unskilled). Generally, ac, dc and ohms measurements are wanted. Again, the 3050A fits the needs.

Calculator control: the key

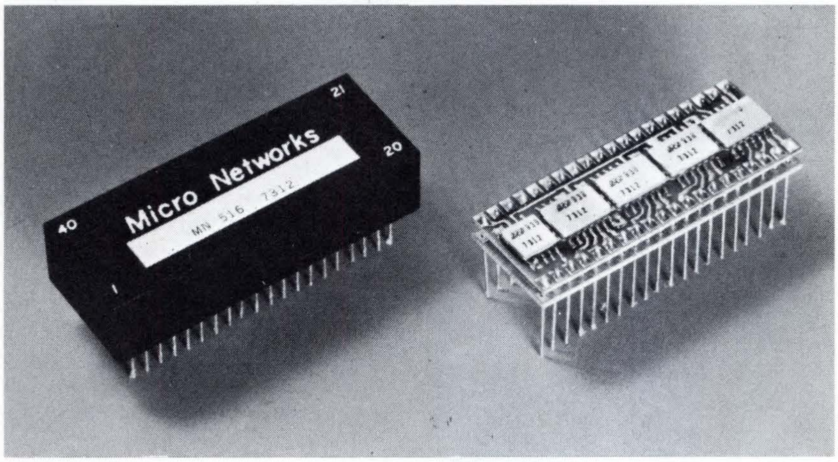
As was true with the first such HP system (the 3042A Automatic Network Analyzer—see Aug. 15 EDN p. 66), the 3050A Data Acquisition System gets much of its power from making measurements under control of the 9820A Programmable Calculator. That's what gives it the capability for automatic control and data analysis.

The computational capability of the calculator not only provides simple decision making, such as Hi/Go/Lo limit testing and relative offset measurements, but also does high-level algebraic manipulations of test data. Data can be stored for a series of tests and manipulated using statistical formulas to obtain the mean and standard deviation. Results can be printed on the calculator's self-contained printer or recorded in other ways for future use.

Price of a complete, ready-to-use 3050A system equipped with 30-channel capability runs $15,500 (Delivery starts in June). This includes DMM, scanner, programmable calculator, rack, all interfacing hard- and software and the Operating, Service and Programming Manuals. All interfacing is done at the factory, so the system is ready to operate as delivered. Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, CA 94304. **285**

Miniature 12-bit D/A and A/Ds are guaranteed stable to ±1/2-LSB linearity over full mil-temp. range

PROGRESS IN PACKAGED CIRCUITS



Guaranteed to remain stable to ±1/2 LSB linearity over −55°**C to** +**125°C,** this miniature 12-bit A/D converter uses nichrome thin-film resistors that have tracking ratios down to only 1 ppm/°C.

A series of 12-bit D/A and A/D converters utilizing ultra-stable thin-film resistive ladder networks is not only rated to operate over the full military temperature range of −55°C to +125°C, but also is guaranteed to hold to ±1/2-LSB linearity over that full temperature range (including extreme points of −55°C and +125°C.

The nichrome ladder networks exhibit TC tracking ratios down to a very low 1 ppm/°C from −55°C to +125°C and absolute maximum TCs of ±50 ppm, which represents a significant advancement in thin-film resistor technology.

An important feature is each D/A and A/D converter's small physical size, 2.2 by 0.825 by 0.5 in., which includes units with or without output storage registers.

In utilizing a precision ladder network, most converter manufacturers purchase the network to a tight absolute tolerance and then mate the complete ladder to individually packaged quad current switches that have slight errors.

In the basic MN415 D/A converter, the quad current switch is mated with a 4-bit ladder, and the unit is functionally trimmed to reduce the error to the smallest possible amount. A high-performance op amp with a nichrome feedback resistor is again trimmed functionally to provide an initial offset error of less than ±1/4 bit. A selected drift-stabilized zener diode reference, driven by a constant-current source, assures excellent stabilities.

Linearity is ±1/2 LSB over −55°C to +125°C, and absolute accuracy is ±1 LSB from −25°C to +85°C, for the MN415H (the MN415 is a commercial version) D/A converter. User options are available for outputs of 0 to +10V, +5V to −5V and +10V to −10V, by external pin strapping. The settling time is 2 μsec to ±0.01% (±1/2 LSB).

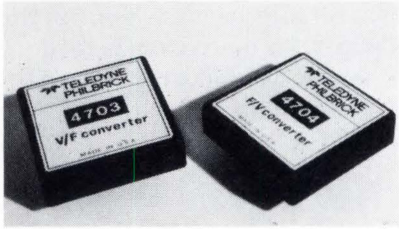
The A/D converter, the MN515H (MN515 is the commercial version), is a successive-approximation unit whose linearity is ±1/2 LSB over −55°C to +125°C, and it has zero error of ±1 LSB for unipolar operation over that same temperature range. User options include selectable input ranges of 0 to +10V, 0 to +20V, −5V to +5V and −10V to +10V.

Parallel and serial outputs are available on both MN515H and MN515 units. Conversion time is 3 μsec per bit.

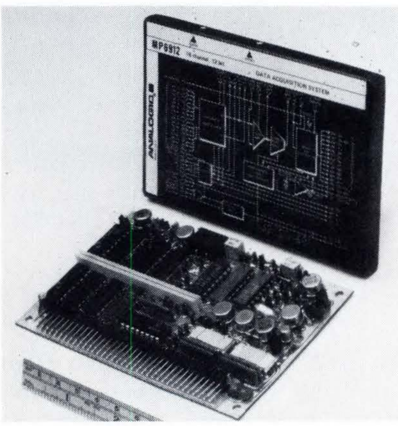
The MN516 is a unit with output storage register. The MN416 is the D/A converter with an output storage register.

Single-unit prices are: MN415, $129; MN416, $169; MN416H, $350; MN515, $199; MN515H, $375; MN516, $244; and MN516H, $425.

Micro Networks Corp., 5 Barbara Lane, Worcester, MA 01604. Phone(617)756-4635. **286**

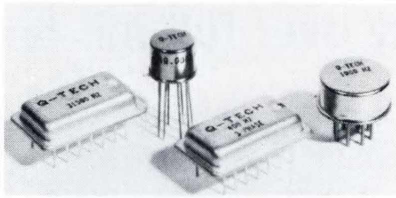


V/F AND F/V CONVERTERS OPERATE TO 100 kHz. Model 4703 voltage-to-frequency converter features 0.015% linearity, 44-ppm/°C stability, a TTL-compatible output, and a price of $69 in 100 quantities. Model 4704 frequency-to-voltage converter features 0.008% linearity, 75ppm/°C stability, and an input stage designed for maximum versatility. Its price is also $69 in 100 quantities. Their serial outputs provide a constant flow of digitized information that requires no synchronized decoding and that is easily isolated to minimize common-mode problems. Teledyne Philbrick, Allied Dr. at Rte 128, Dedham, MA 02026. Phone (617)329-1600. **196**



LOW-COST A/D SYSTEM REPLACES INDIVIDUAL INTERFACE MODULES. A 12-bit data-acquisition subsystem, Model MP6912, provides resolution/throughput combinations that can run as high as 100 kHz (12 bits) or 500 kHz (4 bits). The $695 module is 0.375-in. high, making it compatible with the 0.5-in. card spacing of most minicomputers and instrumentation systems. It can be mounted on a single card or on a small area of a mother card with or without a compatible accessory 5V input-converter power supply. It can also plug directly into a card-cage connector, and is shielded from electromagnetic and electrostatic interference. Analogic Corp., Audubon Rd., Wakefield, MA 01880. Phone (617)246-0300. **197**

SAMPLE/HOLD MODULE HAS 25-nSEC ACQUISITION TIME. Model SHM-UH also features 200-psec aperture time and 25-nsec settling time. It is packaged in a 2 × 2 × 0.4-in. module. Input impedance is 100 MΩ shunted by 20 pF. Output slew rate is 500V/μsec, full-scale output voltage is ±5V at ±30 mA and output impedance is 10Ω. Hold decay rate is 50 μV/sec, feedthrough attenuation is 40 dB at 10 MHz, max. sample rate is 11 MHz and operating temperature coefficient is 50 ppm/°C. Datel Systems, Inc., 1021 Turnpike St., Canton, MA 02021. Phone (617)828-6395. **198**

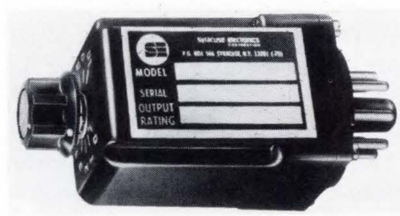


HYBRID CMOS CRYSTAL OSCILLATORS IN TINY PACKAGES. These clock oscillators feature gated outputs and voltage-control capabilities. They are available in TO-5, TO-8, and 14-pin DIP packages (0.2-in. high). Frequency range is 1 Hz to 10 MHz and they can be ordered with multiple output frequencies. A 60-Hz DIP unit consumes only 1.8 mW at 5V. The operating temperature range is −55° to +125°C, with frequency stabilities appropriate to AT cut quartz crystal. From $12 (1000 pieces). Q-Tech Corp., 11529 W. Pico Blvd., Los Angeles, CA 90063. Phone (213)473-1105. **199**

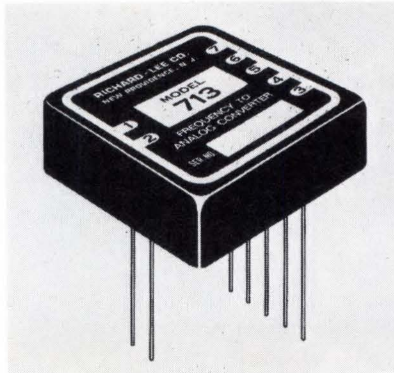
ANALOG MULTIPLEXER DUO CAN HANDLE UP TO 128 DUAL CHANNELS. Models 2204 and 2208 dual 4- and 8-channel multiplexers feature full-scale accuracies of 0.025% max. and 3-μsec typical settling times. Gain for all channels is 0.9995 ±0.0005 and drift is just ±25 μV/°C max. Output frequency for small-signal bandwidth is 5 MHz, and for full output is 150 kHz. Both units can be supplied to operate over 0°C to +70°C or −55°C to +85°C. $175 for the 2204 and $225 for the 2208, in single-unit quantities. Transmagnetics, Inc., 210 Adams Blvd., Farmingdale, NY 11735. Phone (516)293-3100. **200**

10-BIT 4μSEC A/D CONVERTER HAS 2 × 3 × 0.375-IN. SIZE AND $159 PRICE. Model ADC-EH10B has either unipolar (0 to +10V) or bipolar (±5V) voltage inputs by external pin strapping, straight or offset binary or two's complement outputs, and a specified accuracy of ±0.05% of full scale that is maintained over an operating temperature range of 0° to +70°C. TC is ±0.004%/°C and long-term stability is 0.05% per year. Overall linearity is within ±1/2 LSB. The unit uses successive approximation conversion. Datel Systems, Inc., 1020 Turnpike St., Canton, MA 02021. Phone (617)828-6395. **202**

VACUUM-ION PUMP POWER SUPPLIES OPTIMIZE PERFORMANCE. Designed to satisfy the high-voltage requirements of vacuum-ion pumps, this line of power supplies operates from either 115V, 400 Hz ac or 28V dc. They deliver output voltages from 2,500 to 3,500V dc with less than 5% ripple, at loads of 20 μA to 6.5 mA. The power supplies are as small as 3 × 2 × 1-1/4 in. and weigh as little as 10 oz. These units are hermetically sealed in a steel case and will operate over the temperature range of −55 to +100°C. All units are provided with short-circuit protection, overcurrent limiting, and an output current/voltage monitor tap. Capitron Div. of AMP Inc., Elizabethtown, PA 17022. Phone (717)367-1105. **203**



TIME-DELAY RELAY COMES IN AN OCTAL PLUG-IN PACKAGE. Developed for computer and business machine applications, this adjustable, delay-on-energization relay is economically priced in the $8 to $10 range. Only 3-in. high by 1-in. square, Series TCR units have an electrical life of 1 million operations at rated load, and repeat accuracy of ±5%. Their reset time is 100 msec (during and after timing). This spdt device operates at temperatures from −10° to +60°C, and may be knob adjusted or factory preset for delays of 0.5 to 15 sec up to 1.8 to 180 sec. Syracuse Electronics Corp., Box 566, Syracuse, NY 13201. Phone (315)488-4911. **204**



$49 FREQUENCY/ANALOG CONVERTER HAS 0.05% ACCURACY. Model 713 is designed for use in accurate rate-measurement or monitoring instruments and systems. Its input signal may be derived from any source which produces repetitive sine, square or triangular waves or pulses. Signal levers between 5 and 10 mV rms will cause proper operation. The output can drive panel meters directly; produce 0 to 1 mA into external loads; develop 0 to 1V across a load resistor; be read out on digital voltmeters, and drive current-to-pressure converters. Richard Lee Co., Box 724, New Providence, NJ 07974. Phone (201)665-1333. **205**

5 TO 500 MHz DOUBLE BALANCED MIXERS COST FROM $7 IN SINGLES. Model MD-108 unit with an 8-pin relay header style package provides i-f port bandwidth of dc to 500 MHz and has low conversion loss (7.0 dB max. from 5 to 150 MHz and 9.0 dB max. from 150 to 500 MHz). Its low profile (0.312-in. high) and 0.2-in. spacing allow for convenient microstrip or stripline mounting. The unit is housed in an rfi shielded metal case. ANZAC Electronics, 39 Green St., Waltham, MA 02154. Phone (617)899-1900. **206**

MATHEMATICAL MODULE DOES MULTIPLE FUNCTIONS. The A-733 is programmed to multiply, divide, take the square root, square, square a ratio and raise voltage ratios to an arbitrary power. Programming is by 3 pin connections with 2 resistors. With the addition of minimal external circuits, more complex functions such as true rms and vector magnitude can be accomplished. Output error is virtually independent of input signal levels. Input levels from 100 mV to 10V can be processed with a max. output error of less than 0.5% of full scale. Output gain drift at full scale is ±1 mV/°C max. and output offset drift at zero scale is ±1 mV/°C max. Intech, Inc., 1220 Coleman Ave., Santa Clara, CA 95050. Phone (408)244-0500. **207**

The FET set! Everything you need in FET op amps

The Burr-Brown family of TO-99 FET op amps offers you a one-stop source for the exact FET units you need, regardless of your requirements. The three units highlighted below are representative of the performance and price advantages available from Burr-Brown's new 14 unit series. They are pin compatible with 741 types and are 100% tested to all min/max specifications.

Hybrid/thin-film techniques and a monolithic FET input stage provide excellent drift characteristics for source impedances to 1 MΩ. Active laser trimming of proprietary Burr-Brown high-stability, thin-film resistors contributes to outstanding performance at reasonable prices. Both output short circuit and input-to-supply-voltage protection are provided. Units are also available with MIL temperature ratings and MIL-883 screening.

MODEL NO.	3521L	3522L	3542J
Input Offset Voltage			
vs Temperature, Max.	±1µV/°C	±25µV/°C	±50µV/°C
Initial Offset, 25°C, Max.	250µV	±500µV	±20mV
Input Bias Current, Max.	−10pA	±1pA	−25pA
Price, 100 up	$28.00	$12.50	$4.50

FOR COMPLETE INFORMATION, use this publication's reader service card or call Burr-Brown.

BURR-BROWN
RESEARCH CORPORATION
International Airport Industrial Park • Tucson, Arizona 85706
TEL: 602-294-1431 • TWX: 910-952-1111 • CABLE: BBRCORP
CHICAGO OFFICE (312) 832-6520
UNITED KINGDOM OFFICE: Watford WD1 8BY PHONE 33080/30336

Burr-Brown amplifiers deliver what they promise!

Circle No. 41

Dialight sees a need:

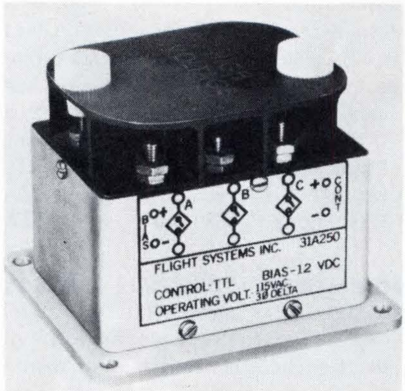
(**Need:** Single source supply for all indicator lights.)

See Dialight.

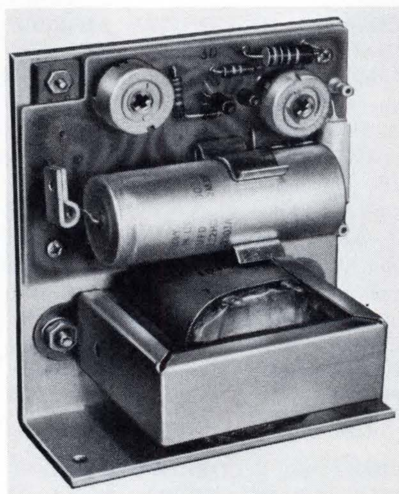
Dialight has so many kinds of indicator lights—approximately 1,500,000 on our shelves—that we have set up a special magic eye seek-out system to help you find the one you need in a wink. Whether it's a flasher, placard, press to test, oil tight, water tight, dust tight, dimmer, or nondimmer, we have them all, some with incandescent, neon or LED lamps, from 1.35 to 220 volts. Sizes vary from small indicators (mount in 0.120″ clearance holes) to large indicators (mount in 1$\frac{3}{16}$″ clearance

holes), and are available in a variety of terminations and finishes, lens-cap shapes and colors with or without hot-stamped, engraved or film legends. We've developed a 14-digit code number that tells any of our 120 stocking distributors in the U.S. and Canada just what indicator you want for off-the-shelf prompt delivery. If you would like to see for yourself how our code works, just write for your free copy. At Dialight it's a designer's choice because we see your need.

CIRCUITS



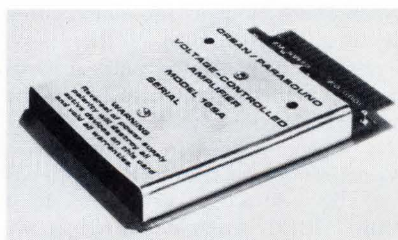
THREE-POLE SOLID-STATE RELAY HANDLES 25A LOADS. Model 31A250-1, with a 3PST N.O. configuration rated at 230V rms, is fully potted in an aluminum housing to withstand harsh industrial environments. The unit can be actuated directly from TTL circuitry, or by 12V dc at 150 mA. False turn-on is said to be eliminated by proprietary circuitry that maintains the triac dv/dt greater than the dv/dt of the impressed voltage. Actuating time is 50 μsec. The mounting flange is 3-1/4 × 3-3/4 in., and the unit is 3-in. high. $145. Flight Systems, Inc., Box 25, Mechanicsburg, PA 17055. Phone (717)697-0333. **208**



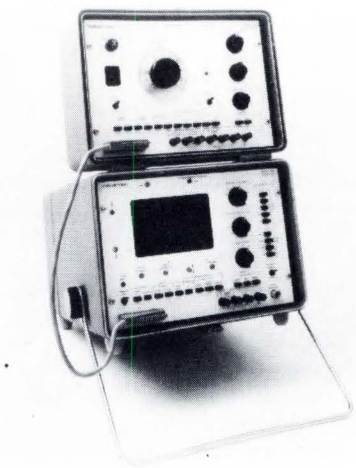
OEM POWER SUPPLIES HAVE U.L. LISTING. Designed for application in "consumer" equipments that range from data terminals to office dictating and transcription machines, these 20W dc supplies are available in 3 models: DPS-1 which output of 5/6V at 3/2.5A; DPS-2 with output of 12/15V at 1.5/1.2A; and DPS-3 with output of 24V at 0.8A. The DPS Series features ±1% regulation, 0.3% rms filtering and overload protection. Supplies are available from stock: $25.60 (1-9), $24.30 (10-24), $23.05 (25-49), and $21.75 (50-99). Tele-Dynamics/Wanlass, Div. of AMBAC Industries, Inc., 525 Virginia Dr., Ft. Washington, PA 19034. Phone (251)643-6161. **209**

SOLID-STATE rf AMPLIFIERS SPAN 1 MHz TO 2 GHz. Series PAM1300 amplifiers are divided into 4 categories, each emphasizing one of the following: low-noise figure ranging from 2.5 to 6.5 dB max.; a spurious-free high-dynamic range; wideband amplification with flat gain response and low-noise figure; or high-output capability with low noise and low intermodulation distortion. These ruggedized amplifiers can withstand environments of most surface and airborne military specifications. American Electronic Laboratories, Inc., Box 552, Lansdale, PA 19446. Phone (215)822-2929. **210**

RF RELAY FEATURES LONG LIFE. A pneumatically operated rf relay that has successfully performed more than 2-million tests operations, Model RF20B1586 allows a peak rf voltage of 15 kV to be applied across its open contacts. Current capability is typically 400A rms at 400kHz, 225A at 4 MHz, and 160A at 16 MHz. Switching time is less than 200 msec. Price is $473 each in quantities of 4 to 9. ITT Jennings, 970 McLaughlin Ave., San Jose, CA 95116. Phone (408)292-4025. **211**

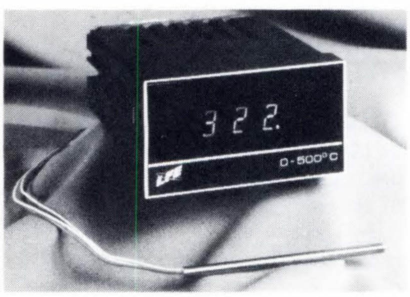


AUDIO AMP WITH VOLTAGE-CONTROLLED GAIN HAS 0.05% THD (total harmonic distortion). Model 169A features an overload-to-noise ratio of 92 dB and can provide up to 25 dB of gain. The encapsulated module has pre-drilled holes for two resistors which can be added to adjust the gain for specific requirements. While the 169A includes 4 independent control voltage inputs, a current input is also provided to allow the customer to add almost any number of voltage inputs simply by adding resistors. The gain reduction in decibal units is 10 times the sum of all control voltages. This relationship can be changed by the customer, however. $59 (100 quantities). Parasound, Inc., 680 Beach St., San Francisco, CA 94109. Phone (415)776-2808. **212**



TRANSMISSION LEVEL TEST SET WEIGHS ONLY 35 POUNDS. Wavetek Model 420 measures return loss (2-wire), attenuation (4-wire), impedance, frequency response and noise. Test results are displayed on a built-in oscilloscope. Features include swept or single frequencies from 50 Hz to 15 kHz, stepped attenuation control on both the transmitter and receiver, lighted display grid, automatic scale selection and simplified, pushbutton operation including calibration check. Price is $1995 (Battery power option, $300 extra). Wavetek, 9045 Balboa Ave., San Diego, CA 92123. Phone(714)279-2200. **170**

TDM-MODEM TEST SET WITH LED MONITOR can test and analyze all digital data communication systems containing low-speed asynchronous or high-speed synchronous modems and time-division or frequency-division multiplexers. Model 1310 generates and analyzes pseudorandom data sequences in the form of start-stop asynchronous characters. Each unit can operate full duplex. Asynchronous bit rates of 75 to 9600 bps may be selected; synchronous to 3 Mbps. $2150. International Data Sciences, Inc., 100 Nashua St., Providence, RI 02904. Phone(401)274-5100. **171**



LOW-COST DIGITAL TEMPERATURE INDICATOR GIVES 1° RESOLUTION. Model 4354 provides digital display for RTD (resistance temperature detector) probes and costs less than $200. It is designed for use with LFE's Type 1 (100Ω at 0°C, 3850 ppm) platinum RTD probe for temperature measurements in the ranges -80 to +229 or 0 to +499 in °F or °C. The display flashes at the reading rate to indicate an overrange condition. LFE Corp., 1601 Trapelo Rd., Waltham, MA 02154. Phone(617)890-2000. **172**

MINIATURE PCM DECOM FEATURES 2's COMPLEMENT CONVERSION. Model ECO-3 PCM (pulse code modulation) encoder checkout unit is a miniature stored format frame and subframe demultiplexer and word selector that operates directly from a PCM encoder or from a bit synchronizer. Features include 4 switchable formats, and data rates from 1 bps to 5 Mbps. $3700. Coded Communication Corp., 1620 Linda Vista Dr., San Marcos, CA 92609. Phone(714)744-3710. **173**

MIDGET 5-Hz TO 220-MHz FREQUENCY COUNTER HAS DISPLAY STORAGE. Crystal controlled Model 151A uses a 7-digit LED display with built-in self check. Measurement ranges are 5 Hz to 20 MHz, and 1 MHz to 220 MHz. Gate times of 100 msec and 1 sec are available. The unit operates from ac line or a dc supply without adjustments. Size is 4.5 in. wide, 2 in. high, 8.5 in. deep, and weight is 3.5 lbs. $795 (plus $200 for optional 10-hr. NiCad battery pack with charger and case). United Systems Corp., (a subsidiary of Monsanto), 918 Woodley Rd., Dayton, OH 45403. Phone(513)254-6251. **174**

VIDEO DISC RECORDER OFFERS VARIABLE-SPEED RECORD/PLAY. Speeds are from 1 to 60 frames/sec offering fast/slow-motion/stop action of 570 frames. Model 9108 is housed in a table-top or rack mounted chassis that contains a constant-contact recording/playback head, high fidelity recording disc and solid-state electronics. Front panel controls select same speed recording and playback, as well as fast recording and slow playback or vice versa, enabling a wide range of effects. $18,000. MOXON INC./CTS DIV. 2272 Michelson Dr., Irvine, CA 92664. Phone(714)833-2000. **175**

MORE POWERFUL TESTER FOR DIGITAL ICs. Model 3200 is designed primarily for incoming inspection and evaluation of semiconductor devices used by electronic equipment manufacturers. Its new techniques and test pattern allow fast, thorough exercising of very complex digital ICs. Test frequency is 200 kHz. The instrument performs both parametric and functional tests on DTL, TTL, ECL, MOS, CMOS, ROMs, RAMs, SSI, MSI and LSI. It accepts devices with up to 24 pins (expandable to 34 pins). Tests include power consumption, fan in, fan out, function and threshold. $4250. Sitek, Inc., 1078 W. Evelyn Ave., Sunnyvale, CA 94086. Phone(408)735-9800. **176**

LOW-COST DIGITAL COUNTER WITH LED DISPLAY sells for less than $400. Model CM50 measures frequency, frequency ratio and single and multiple periods. It also can be used as an event totalizer. Sensitivity (1-MΩ input) is 50 mV over the entire 5-Hz to 50-MHz frequency range. The instrument's 6 gate times (100 msec to 10 sec) are derived from either the standard 10.000 MHz crystal oscillator or an optional high-stability TCXO. Operation is from either 115V ac (±10%) or an external 12V dc source. $399. Analog Digital Research Inc., 1051 Clinton St., Buffalo, NY 14206. **177**

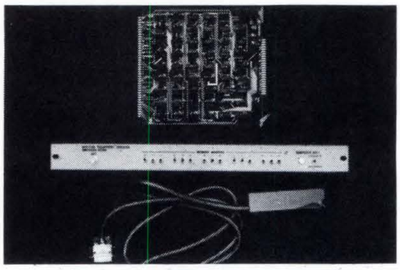
HIGH DYNAMIC RANGE LOCK-IN AMPLIFIER HAS 100 nV SENSITIVITY. A synchronous heterodyning technique permits the Model 186 to measure amplitude and phase angle of signals obscured by noise. It handles transient noise overloads as great as 300,000 times full scale and will track drifting signals. Features include built-in low-noise preamp with choice of single-end or differential input and built-in low-pass filter. Princeton Applied Research Corp., Box 2565, Princeton, NJ 08540. Phone(609)452-2111. **178**

CONTINUOUSLY-TUNABLE SIGNAL GENERATOR offers AM, FM and pulse modulation over the range from 4.5 to 520 MHz. Frequency readout is on a 5-digit LED display. Model 750A features accuracy of ±0.0001% to 0.005% of frequency. The FM, which can be used independently or with the AM or pulse modulation, has a range of 0 to 300 kHz. Rf output is 1V, automatically leveled to within 0.5 dB. RFI and leakage meet or exceed the provisions of Mil-I-6161D. Weight is only 27 lbs. $3100. Logimetrics, 100 Forest Dr., Greenvale, NY 11548. Phone(516)484-2222. **179**

RF POWER AMPLIFIER FEEDS ANY LOAD. All solid-state Model 240L supplies up to 40W of linear RF power or up to 150W of saturated power. It covers 20 kHz to 10 MHz without tuning and will supply its rated output to any load regardless of impedance. (A unique feedback circuit instantaneously protects the output stages from damaging transients.) Gain is 50 dB (50Ω input and output impedances). $1450. Electronic Navigation Industries Inc., 3000 Winton Rd. South, Rochester, NY 14623. Phone(716)473-6900. **180**

MULTI-CHANNEL ANALOG FILTER SYSTEM IS PROGRAMMABLE. System 816 provides up to 16 filter channels, each mounted on a plug-in pc board. Cutoff frequencies from 10 Hz to 150 kHz with 48 dB/octave rolloff may be programmed remotely (or locally by front panel switches). Remote programming is accomplished by TTL levels, and filters may be programmed individually or in common. Programming delay is less than 3 msec. Price is $750 for the basic cabinet, plus $650 per filter card. Rockland Systems Corp., 230 W. Nyack Rd., W. Nyack, NY 10994. Phone(914)623-6666. **181**

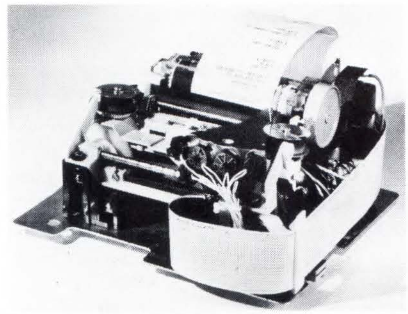
DATA SET FEATURES FAST TURNAROUND TIME. Model DS4801 has a data rate of 4800/2400 bps (strap selectable) for multi-drop polled networks and point-to-point systems. It provides automatic equalization and has built-in diagnostic capability. The set uses 4-level, single-sideband, suppressed-carrier amplitude modulation. The desk top version measures 10 in. H. x 20 in. W. x 25 in. D., and the rack mount 7 in. H x 19 in. W. x 22 in. D. Rixon Inc., 2120 Industrial Pkwy., Silver Spring, MD 20904. Phone(301)622-2121. **182**



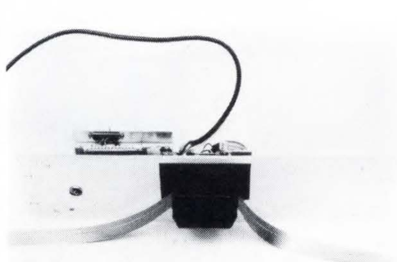
BREAKPOINT REGISTER REDUCES DEBUGGING TIME 50-80%. The BPR 2100 is designed for use with the Hewlett-Packard 2100A computer. It may be used for software debugging where one may breakpoint on an instruction or operand and is an invaluable aid to deriving software timing measurements or hardware-software debugging where a unique BNC output is used. The assembly includes a replacement CPU board, cable and rack-mountable switch panel. $1500. American-Asian Computer Services, Inc., Box 5225, San Francisco, CA 94101. Phone(415)346-1340 **261**

VIDEO TERMINAL OFFERS UPPER/LOWER CASE CHARACTERS. Clearer, sharper characters are offered in the 5000 Series display terminals. Characters are formed on screen by a 7 × 9 matrix with green-phosphor dots. This large format makes characters seem almost like solid strokes instead of individual dots. The matrix also permits the terminals to display the full repertoire of A/N characters with ascenders and descenders, thus helping to eliminate many common recognition errors. $3000 and up. Delta Data Systems Corp., Woodhaven Industrial Park, Cornwelle Heights, PA 19020. Phone (215)639-9400. **262**

MULTIPLE-ACCESS COUPLER DIRECTS 4 DATA TERMINALS to 1 or 2 modems. The TE-795 has 4 RS-232 terminal input ports that can direct any 1 of 4 inputs to either of 2 RS-232 modems. Up to 6 4-wire-audio circuits can be terminated at a front-panel selector to allow switching of a modem to any 1 of the standard audio circuits. The unit has plug-in pc boards and all inputs and outputs are fully buffered (i.e., 1 output amplifier serves only 1 terminal). Collins Radio Co., 4311 Jamboree Rd., Newport Beach, CA 92663. Phone(714)833-0600. **263**



LOW-COST MATRIX PRINTER ENTERS OUTPUT MARKET. The device was designed for point-of-sale systems, various types of instrumentation, data logging, terminals and business systems. The IPM 130 prints at a rate of 110 cps and can be made to print any character in any language. Capacity is 34 characters/line and 6 lines/in. The 130 accommodates, adjustably, many standard adding-machine tapes from 2-9/32 through 3-3/4 in. wide and prints in 2 colors. $275 with OEM and quantity discounts. Victor Comptometer Corp., 3900 N. Rockwell St., Chicago, IL 60618. Phone(312)539-8200. **264**



PUNCHED-TAPE READER SPECIALIZES IN DATA LOADING. The Data Loader is designed for OEM punch-tape reader applications requiring reliable reading for sequential block-data loading only. Data Loader operates synchronously at up to 150 cps. It is TTL/DTL/RTL compatible. The self-cleaning LED/photoelectric read head can read any standard punch tape with 50% or more opacity. Electronic Engineering Co. of California, 1441 East Chestnut Ave., Santa Ana, CA 92701. Phone(714)547-5651. **265**

Compact...reversible...synchronous. These low-cost motors are real workhorses.

When your constant speed applications call for high torque, low power or reversibility, consider these miniature permanent magnet synchronous motors. They not only conserve space but they'll save you money. Low rotor speeds and permanently lubricated bearings assure quiet operation and extended life, as well.

Torque at the rotor shaft is .75 oz-in. @ 300 rpm for the 81300 series (in the hand). Input power is 1.5 watts nominal. Gearing gives a choice of 92 different speed combinations to 1/360 rpm.

Series 81400 gives you 2 oz-in. @ 300 rpm at the rotor shaft. Input power is 3 watts nominal. Gear trains available to lower output speed to 1 rpm.

Send for information now!

A. W. HAYDON CO. PRODUCTS

NORTH AMERICAN PHILIPS CONTROLS CORP.

A NORTH AMERICAN PHILIPS COMPANY
Cheshire, Conn. 06410 • (203) 272-0301

Circle No. 47

Monitor events-track time -conserve space!

Mini events or time indicators for important billing or maintenance functions.

Although they measure only 37/64" square x 1 1/4" long, these precision indicators have a clearly visible 4-digit readout. They're easy to see, yet occupy only a minimum of space. They're non-resettable and tamper-proof — the perfect way to monitor elapsed time or events in peripherals, business machines, production machinery or similar electrical/electronic equipment.

The Elapsed Time Indicator is furnished with either front or side readout, for surface or through-panel mounting. Available for 50 or 60 Hz operation.

The Events Counter comes with the flange-type mount only. Count rate is 1200 cpm. It can be supplied for DC or 50, 60 or 400 Hz operation at various voltages. Power consumption is 2.5 watts nominal.

Send for information now!

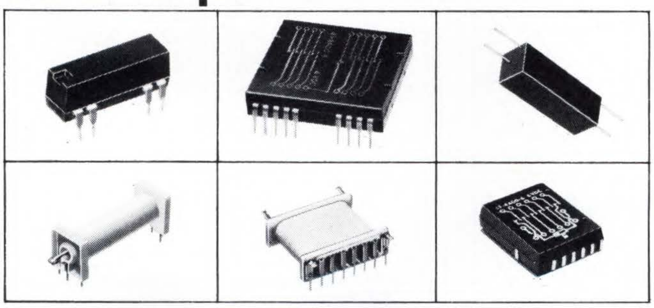
A. W. HAYDON CO. PRODUCTS

NORTH AMERICAN PHILIPS CONTROLS CORP.

A NORTH AMERICAN PHILIPS COMPANY
Cheshire, Conn. 06410 • (203) 272-0301

Circle No. 48

Reed Relays from dry circuit to 1.5 amps



Check into one of the broadest reed relay lines available.

You can meet virtually any reed relay requirement from NAPCC's extensive selection of dry and mercury wetted types. Styles range from low cost, rugged open styles to an exclusive, high density memory reed with six Form A contacts that can save up to 45% or more in mounting space. Miniature types are available to interface directly with RTL, NNIL, DTL or TTL logics, compatible with 14-terminal dual in-line ICs. You have a choice at NAPCC from a related family of reeds, one of the broadest lines available, and at competitive prices or below.

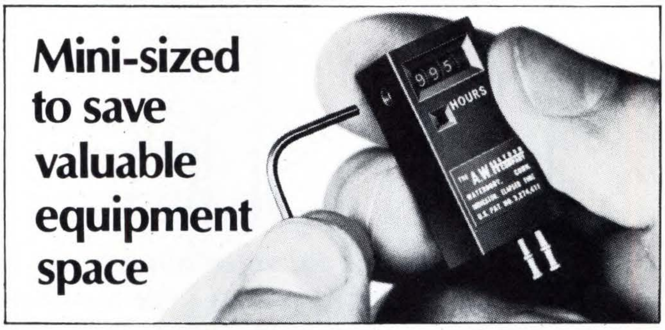
Write for literature. Today.

PRICE ELECTRIC RELAYS

NORTH AMERICAN PHILIPS CONTROLS CORP.

A NORTH AMERICAN PHILIPS COMPANY
E. Church & 2nd St. • Frederick, Md. 21701 • (301) 663-5141

Circle No. 49



Record "run time" with these resettable microminiature elapsed time indicators.

The only thing big about our Series LM49200 Microminiature Resettable Elapsed Time Indicator is the easily readable 3-digit hourly display. All else has been miniaturized including the precision hobbed gearing and the aspirin-sized synchronous drive motor used to insure maximum accuracy and long life. Measuring a scant 37/64" sq. x 1-1/4" , the indicator is as small as a resettable ETI could ever hope to be. It weighs a mere .75 oz. and takes less than .500 cu. in. of equipment space, leaving plenty of room for other needed components. Resetting? All you need is a standard Allen wrench. Operates on 115 V, 60 hz; 1.0 watt maximum power input. Accuracy is ± 1% or ± 1 hour, whichever is greater. Also available with end readout and a variety of mounting configurations.

Send for information now!

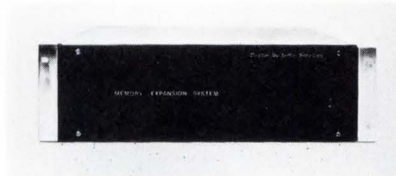
A. W. HAYDON CO. PRODUCTS

NORTH AMERICAN PHILIPS CONTROLS CORP.

A NORTH AMERICAN PHILIPS COMPANY
Cheshire, Conn. 06410 • (203) 272-0301

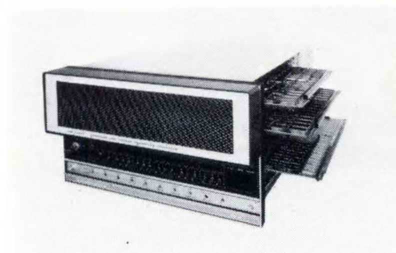
Circle No. 50

COMPUTER PRODUCTS



ADD-ON CORE EXPANDS HP COMPUTER MEMORIES. Model 72001 Series of add-on core memory is available in 7 sizes with the capability of expanding the HP2100, HP2114, HP2115 and HP2116 memory capacities to 32,536 words. The Model 72001 Series are priced as low as 2¢/bit and are available in 4, 8, 12, 16, 20 and 28k, permitting combinations of HP and DSS memory totaling 32k words. This extension memory is completely hardware and software transparent to HP computers. Digital Systems Services, P. O. Box 1239, Mt. View, CA 94040. Phone(415)968-4257. **266**

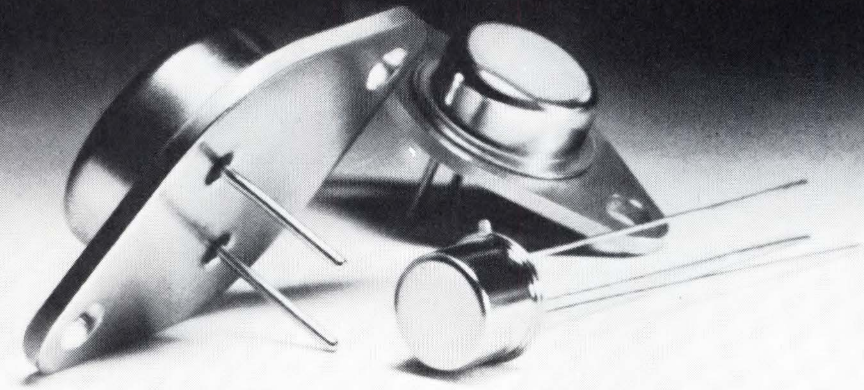
MOVING-HEAD DISC FOR OEM MARKET. Designed as a PDP-11 add-on, the Data Miser^{TM} 110 includes all digital interface electronics (disc is sealed in dustproof enclosure), 1.25 million words of storage with an average access time of 75 msec and a data transfer rate of 10 μsec/word. It requires less than 100W of power and has an operating temperature of 50 to 100°F. At 5-1/4 in. high, it fits into a 19-in. rack and weighs less than 50 lbs. $1950 in single quantity. International Memory Systems, 14609 Scottsdale Rd., Scottsdale, AZ 85260. Phone(602)948-2120. **267**



FFT PLUGS IN. The plug-in hardware Fast Fourier Transform processor Model 306/HFFT Code 1 plugs into the Nova 800 Jumbo computer or other Data General computers on request. It is capable of performing the forward or inverse FFT of 16 to 16,384 real points with a full 16-bit processing accuracy. Typically, the basic complex Fourier transform of 512 complex points takes 9.5 msec when the 306/HFFT Code 1 is used with the Nova 800 computer. $15,-200. Elsytec, Inc., 212 Michael Dr., Syosset, NY 11791. Phone(516)364-0560. **268**

₵-LINE POWER SWITCHING TRANSISTORS

100 WAYS TO GET MORE INDUSTRIAL SWITCHING PERFORMANCE FOR YOUR MONEY



Unitrode's UPT Power Switching Transistor series offers the optimum combinations of price and performance from 0.5A to 20A, and up to 400V in 3 package types. Choose from 100 different transistor types for more efficient and simplified circuit design in power supplies, switching regulators, inverters, converters, solenoids, stepper motors and other inductive load driving applications. They're available off-the-shelf from your local Unitrode distributor or representative. For the one closest to you, dial (800) 645-9200 toll free, or in N.Y. State (516) 294-0990 collect.

For immediate action on any specific problem, call Sales Engineering collect at (617) 926-0404, Unitrode Corporation, Department10Z, 580 Pleasant Street, Watertown, Massachusetts 02172.

For specific data sheets containing full characterization of devices check the table/coupon below.

Unitrode Corporation Dept. 10 Z, 580 Pleasant St., Watertown, Mass. 02172
Please send data sheets on specific ₵-Line Power Switching Transistor series checked below.

Check Here	I_C	V_{CER}	SERIES/ PACKAGE	t_{on}	t_{off}	100 Qty prices each
☐	0.5ADC	up to 400V	UPT011 -TO5 UPT021 -TO66	50ns	400ns	$1.02 to 2.30
☐	1ADC	up to 150V	UPT111 -TO5 UPT121 -TO66	100ns	250ns	0.83 to 1.86
☐	2ADC	up to 150V	UPT211 -TO5 UPT221 -TO66	130ns	300ns	1.08 to 2.42
☐		up to 400V	UPT311 -TO5 UPT321 -TO66	200ns	800ns	1.25 to 2.73
☐	3ADC	up to 400V	UPT521 -TO66 UPT531 -TO3	200ns	900ns	2.30 to 3.80

Check Here	I_C	V_{CER}	SERIES/ PACKAGE	t_{on}	t_{off}	100 Qty prices each
☐	5ADC	up to 150V	UPT611 -TO5 UPT621 -TO66	250ns	550ns	$1.25 to 2.72
☐		up to 400V	UPT721 -TO66 UPT731 -TO3	250ns	800ns	3.38 to 5.43
☐	10ADC	up to 150V	UPT821 -TO66 UPT831 -TO3	250ns	550ns	3.14 to 5.05
☐		up to 400V	UPT931 -TO3	500ns	1200ns	7.67 to 13.92
☐	15ADC	up to 150V	UPT1021-TO66 UPT1031-TO3	450ns	350ns	3.69 to 5.93
☐	20ADC	up to 150V	UPT1131-TO3	300ns	600ns	4.52 to 6.91

Name: ____________ Title: ____________

Co.: ____________ Address: ____________

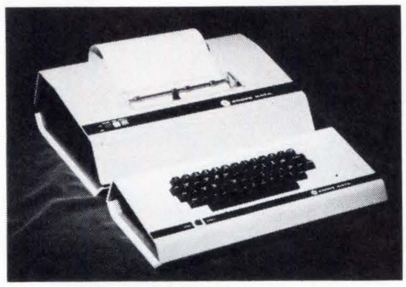
City: ____________ State: ____________ Zip: ____________

Telephone: ____________

See EEM Section 4800 and EBG Semiconductors Section for more complete product listing.

UNITRODE quality takes the worry out of paying less.

COMPUTER PRODUCTS



PRINTER FEATURES BUILT-IN MODULAR DESIGN. The Series 200 printer allows plug-in options to be added as required. Maintenance is as simple as unplugging a malfunctioning module and plugging in its replacement. The printer operates asynchronously at speeds up to 240 cps. Printer speeds are switch selectable with rates beginning at 75 baud. Character recognition includes 128 standard ASCII characters. The printing of 96 upper- and lower-case characters is accomplished through the use of a 7 × 9 dot matrix. SCOPE DATA Inc., 5870 S. Tampa Ave., Orlando, FL 32809. Phone(305)859-1410. **269**

PRINTERS INTERFACE WITH INTELLIGENT TERMINALS. The Model 3486 printer can print 300 lines/min. for a full 132-character line or 600 lines/min for a 72-character line. The contents of 2 cassette tapes resident in the Model 340 intelligent terminal (400,000 characters) can be printed in less than 10 min. on pin-fed, 18-in. wide forms. The 80 cps Model 3481 printer is designed to handle medium-speed print applications. Both models are capable of printing 1 original and 5 copies. Sycor, Inc., 100 Phoenix Dr., Ann Arbor, MI 48104. Phone(313)971-0900. **270**

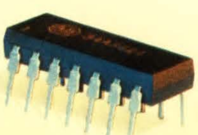
HAND-HELD UNIT TESTS MODEMS. A number of tests can be implemented by the 7914A data-set tester to isolate equipment failures or evaluate system performance. It can be operated in synchronous or nonsynchronous systems and in the simplex, half-duplex, or full-duplex modes. Data rates may be 150, 300, 1200 or 1800 bps in nonsynchronous applications; up to 9600 bps for synchronous applications. The 7914A provides a WECO 914B-compatible 63-bit pseudorandom pattern and mark-hold, space-hold or dotting patterns for performance-evaluation applications. Handshaking functions can also be exercised. $495. Tele-Dynamics, Div. of AMBAC Industries, 525 Virginia Dr., Ft. Washington, PA 19034. Phone(215)643-6161. **271**

Quality resistor networks now available off-the-shelf.

Pull ups or terminators, in popular values.

If you're really serious about cost, be serious about quality.

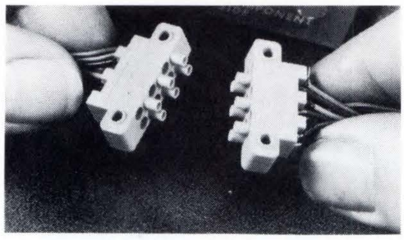
Now our most popular thick-film resistor networks are ready and waiting, in quantity, at your A-B electronics distributor. Pull-up networks and terminator networks with tolerances of ±2% in popular values from 68 ohms to 22K ohms. All in compatible 14 lead .300 series DIP's. Or if you need something special we'll quickly custom design any circuit that'll fit into a 14 or 16 lead DIP. And we mean quickly. Overall specs include: absolute tolerances to ±.5%. Tracking ±50 ppm/°C (and lower). TCR to ±100 ppm/°C. Write for free technical publications 5850 and 5851. Allen-Bradley Electronics Division, 1201 S. Second St., Milwaukee, WI 53204. Export: Bloomfield, NJ 07003. Canada: Cambridge, Ontario. United Kingdom: Jarrow, Co. Durham NE32 3EN.



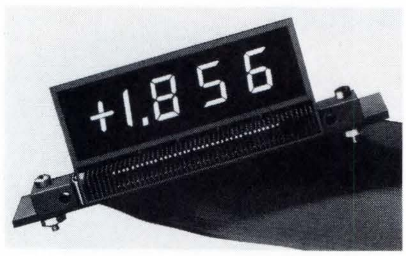
Actual Size

Allen-Bradley
Milwaukee, Wisconsin 53204

Circle No. 77



HERMAPHRODITIC CONNECTORS MATE WITH EACH OTHER. A 6-contact bisexual connector, the first in a family of stackable, snap-together interconnect packages has been developed for prototype design and limited production runs. The connector's unique design consists of a single connector that houses both 3 male and 3 female contacts. The individual units can be mated with each other face-to-face. The 233 Series connector can be used as a single connector or can be stacked with as many modules as needed. Amphenol Industrial Div., 1830 S. 54th Ave., Chicago, IL 60650. Phone (312)652-1220 **213**

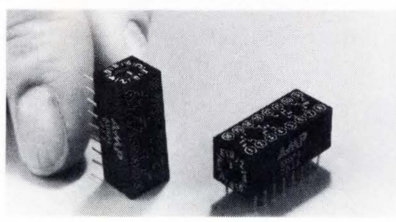


REFLECTIVE LIQUID-CRYSTAL DISPLAYS REQUIRE NO BACKLIGHTING. The Series 1603-02 is a 3-1/2 decade liquid-crystal display with 4 floating decimal points and an overflow (±0.1) (0.0-9) (:0-9) (0.0-0.9). A colon is incorporated in the display for additional application advantages such as clocks. Rated voltage is 24V p-p (15-40V range) at 20 μW per segment. Contrast ratio is at least 15:1 with a minimum life of 10, 000 hrs at rated voltage. $21.50 in single quantity; $8.50 each in 1000 quantity. Industrial Electronic Engineers, Inc., 7720 Lemona Ave., Van Nuys, CA 91405. Phone (213)787-0311. **214**

LED DISPLAY UTILIZES ELD. With the encapsulated light diffusion (ELD) process the Data-Lit 700 Series uses 85% less gallium-arsenide phosphide (GaAsP) material than standard 7-segment displays while improving visibility. The ELD technique allows use of only a single LED per segment to reduce cost and lower power dissipation. ELD is distinguished from present "light pipe" techniques in that a single molding process produces an array of 8 integrated light-diffusing channels and substrate encapsulation. 100-999 price: $3.25. Litronix Inc., 19000 Homestead Rd., Cupertino, CA Phone (408)257-7910. **215**

TRANSFORMERS TRIGGER SCR/TRIACS. Four primary functions are performed by the Series 7330 transformer group. At a specified voltage level, they supply the required current to activate an SCR. In addition to providing isolation between circuits and 180° phase reversal in full-wave circuits, their leakage inductance capability minimizes potentially damaging switching spikes. $2. The Potter Co., a Div. of Pemcor, Inc., 10441 Roselle St., San Diego, CA 92121. Phone (714)453-6610. **216**

DIP TRIMMER FOR AUTOMATIC INSERTION. The Model 86P DIP cermet trimming potentiometer offers total resistance and setting stability with typical change less than 0.5% during the first thousand hours of operation. Change is progressively less, per thousand hours, thereafter. The cermet element permits settings to within 0.05% of a desired voltage. $1.61 each (1000-1999 quantities). Helipot Div., Beckman Instruments, Inc., 2500 Harbor Blvd., Fullerton, CA 92634. Phone (714)871-4848. **217**

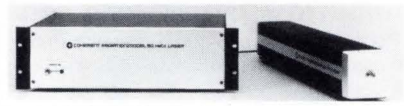


DIP-TYPE ROTARY SWITCH HAS 16 PINS and houses 4 cam operated form "C" switches. The cam itself is binary encoded and can be rotated to the desired setting in either direction. The fully enclosed design provides environmental protection for the gold plated phosphor bronze contacts. Contact resistance is less than 50 mΩ pin-to-pin and with a 100 mA resistive load. Contacts are rated at 28V dc. Life expectancy exceed 2000 cam revolutions. The 16-step bidirectional cam provides BCD and BCD complement outputs. AMP Inc., Harrisburg, PA 17105. Phone (717)564-0101. **218**

TEST SOCKETS FOR DIPs. This design can be used for testing 14- thru 40-lead standard dual-in-lines and the new side brazed packages, without carriers. Unlike some "zero insertion force" sockets, the LMC #2748 Series incorporates excellent contact wiping action, with durable spring quality, to maintain easy insertion and withdrawal of the device. Contacts are easily replaced, thereby extending socket life. Temperature range is from −65°C to +300°C continuous operation. Lorangor Mfg. Corp., P.O. Box 948, Warren, PA 16365. Phone (814)723-8600. **219**

PUSHBUTTONS FEATURE RIGID CONSTRUCTION. Some of the pertinent features of the P01-042 (4-pole) and the P01-062 (6-pole) pushbutton switches are no shaft wobble, perfect shaft alignment and rugged tank-like construction. There are 5 different terminal types available such as solder lug, pc, wire-wrap or space-saver terminals. Both dry-circuit and power-type terminals are available up to 4A, 125V ac. Also, both momentary and push-push actuation is offered. UID Electronics Corp., 4105 Pembroke Rd., Hollywood, FL 33021. Phone (305)981-1211. **241**

COMPONENTS/MATERIALS



SIMPLIFIED He-Cd LASER OUTPUTS 10 mW of power at the 441.6 nm wavelength (visible blue). The Model 90 uses a cadmium ring implanted in the bore as the metal-vapor source. The dc discharge vaporizes and excites the cadmium which is cataphoretically transported from the anode to the cathode region. The integral mirrors are mounted directly on the resonator. A quartz resonator-support structure provides long-term power stability. Lasing action is obtained within 2 min. after turn-on and full power is obtained within 8 min. Coherent Radiation, 3210 Porter Dr., Palo Alto, CA 94304. Phone (415)493-2111. **242**

TORQUE MOTOR DESIGNED FOR FLIGHT CONTROL. The small size and high response of the dc torque Model 431-07 particularly suits it for use in remotely piloted vehicles. The motor produces 160 oz-in. of torque, yet weighs only 17 ozs. Torque-to-power ratio requires only 130W at peak torque. Just 2.812 in. in diameter and 1 in. long, the large I.D. of the pancake shaped motor can be applied directly to, or around, hubs and shafts attached directly to the load, thereby eliminating gear trains and associated backlash problems. Magnedyne, Inc., 5580 El Camino Real, Carlsbad, CA 92008. Phone (714)729-7191. **243**

FERRITE BEADS AVAILABLE ON TAPE. A Ceramag^R ferrite bead for the suppression of transient noise signals in electronic circuitry is now available on lead tape. The same equipment which can handle automatic insertion of axial-lead components can handle this ferrite bead. The bead is 0.138 in. ±0.008 O.D. and 0.175 in. ±0.010 long. Ferrite beads offer a simple way to obtain RF decoupling, shielding and parasitic suppression without sacrificing low-frequency power or signal level. Stackpole Carbon Co., Electronic Components Div., St. Marys, PA 15857. Phone (814)781-1234 **244**

MAGNETIC SWITCH HANDLES HIGH INRUSH LOADS without contact protection. The axial travel switch is a hermetically sealed, magnetically actuated device featuring semi-precious metal contacts and snap-in fuse-clip mounting. The ATS-6000 is available in SPST - N.O. and N.C. versions capable of speeds up to 60 Hz. The N.C. version of the axial switch does not require a biasing magnet thus eliminating fine magnetic adjustment. Total switch resistance is 0.6Ω max. at just operate. Operate time is 4.0 msec including coil lag time. Gordos Corp., 250 Glenwood Ave., Bloomfield, NJ 07003. Phone (201)743-6800. **245**

PHOTOMULTIPLIER TUBE DETECTS LASERS. The 10-stage photomultiplier tube with S-20R (extended red) spectral response has a useful photocathode diameter of 32 mm and is intended for use in the red and near IR regions, especially in detection systems for He-Ne and ruby lasers. The PM2007 has a gain of 10^6 at 1600V, with typical radiant sensitivity of 25 mA/W at 700 nm and 8 mA/W at 850 nm. The spectral response peaks at 580 nm with a typical radiant sensitivity of 30 mA/W. Amperex Electronic Corp., Scientific and Research Products, Hicksville Div., Hicksville, NY 11802. Phone (516)931-6200. **246**

TINY FILTERS OFFER HIGH INSERTION LOSS. These low-pass Button EMI/RFI filters are available in 2 series: the 2050 Series for reduction of RF interference over the entire temperature range (−55°C to +125°C); the 1050 Series for use where variations in performance with temperature change are not critical. Insertion loss of up to 70 dB at 1 GHz is standard in 50, 100, 200 and 300V dc and 115V ac ratings. All units are rated at 15A dc max. The case is less than 0.500 in. long with a 1/4-28 UNF-2A threaded end. $4 in production quantities. USCC/CENTRALAB, 2151 N. Lincoln St., Burbank, CA 91504. Phone (213)843-4222. **247**

MINI CRT FOR DATA DISPLAYS. The 1.5-in. CRT data-display device, the "nimo 64", has 64 independent guns which display an alphanumeric character up to 0.6 in. high or complete message of up to 3 lines of 6 characters. The nimo requires only a half dozen TTL packages for simple and inexpensive interfacing to complete the display package. 1000 qty. price is $38.50. Industrial Electronic Engineers, Inc., 7720 Lemona Ave., Van Nuys, CA 91405. Phone (213)787-0311. **248**

Delay Lines
You name it. We've got it.

Catalog Number	Impedance Z_0 (ohms $\pm 10\%$)	Total Delay (ns $\pm 5\%$)	No. of Taps	Delay Per Tap	Rise Time (ns max)
9822	50	100	10	10	17
9823	50	125	10	12.5	21
9825	100	100	10	10	17
9826	100	125	10	12.5	21
9827	100	150	10	15	25
9828	100	200	10	20	34
9829	100	250	10	25	42
20410	100	10	4	2.5	4
20411	100	20	4	5.0	7
20412	100	30	4	7.5	10

Now you can choose from the broadest selection of DIP Delay Lines ever.

Available today from quantity stock at any PULSE ENGINEERING regional office in the United States and Europe. Featuring:

- Fast rise time and low distortion
- Total delay 10 ns to 250 ns
- Delay per tap 2.5 ns to 25 ns

Order today and send for our free product line catalog.

Pulse Engineering Inc.

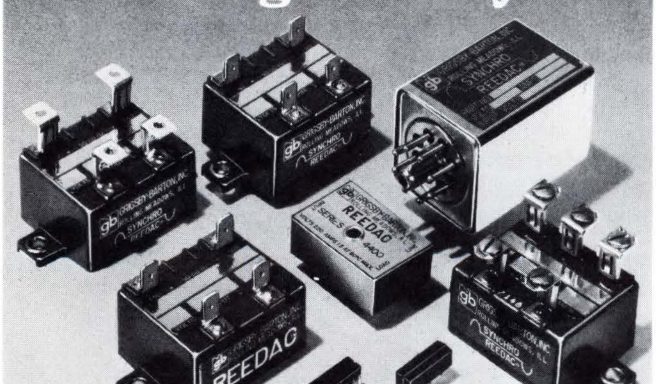
A Varian Subsidiary

Pulse Engineering, Inc.

P.O. Box 12235 • San Diego, Calif. 92112
Phone 714-279-5900 • TWX 910-335-1527

Circle No. 29

The triacs in Reedacs® won't bug out on you.



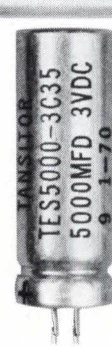
Reedacs are the triac switching devices that conquered the "bug" of permature triac failures. Offered in a wide selection of sizes and types. Octal plug-in to DIP. Hybrid or Photo-coupled input. Synchronous or random turn-on output. Switch to 240 VAC and 40 amps. For complete technical specifications, write or call us. Or see your Grigsby-Barton representative.

gb **GRIGSBY-BARTON INC.**

3800 Industrial Dr., Rolling Meadows, Ill. 60008
Phone (312) 392-5900 TWX 910-687-3789

Circle No. 56

Tansitor
means Tantalum Capacitors.



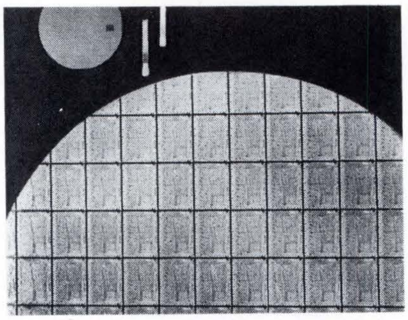
We're the specialists. The firm that offers you a full line of wet, foil and miniature solid tantalum capacitors. The right capacitors for your specifications . . . at the right price for your budget . . . and the right delivery schedule. For tantalum capacitors that meet your expectations . . . count on your first choice. Tansitor.

For more information call your Tansitor Representative or contact:

Tansitor
ELECTRONICS
DIVISION OF AEROTRON, INC

West Rd., Bennington, Vt. 05201 • Phone: (802) 442-5473 • TWX: (710) 360-1782

Circle No. 54

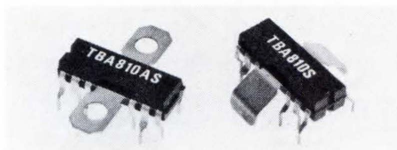


MOS/LSI PARALLEL-PROCESSING SYSTEM OFFERS FLEXIBILITY. Rockwell's PPS performs the arithmetic and logic functions of a 4-bit parallel microprocessor. It is based on a 1-chip CPU controlled by ROM microprogramming and possesses its own I/O capabilities. Predesigned, compatible MOS/LSI circuits—ROM/RAM, ROM, RAM, I/O and a crystal controlled clock generator circuit—enable equipment designers to implement unique systems. Parallel bus design (dual 8-bit data bus; expandable 12-bit address bus), time shared multiplexing and unique 4-phase techniques achieve a PPS instruction and execution cycle time of 5 μsec. North American Rockwell Microelectronics Co., P.O. Box 3669, 3430 Miraloma Ave., Anaheim, CA 92803. Phone(714)632-2321. **184**

DUAL-TRACKING REGULATORS HAVE LOW DRIFT. RC4195 units deliver ±15V outputs that track within 50 mV. Line regulation is 2 mV, load regulation is 5 mV and drift is only 0.005%/°C. The new circuit will source 100 mA at each output and requires only two bypass capacitors. It also provides thermal shutdown that inhibits the regulator's operation at junction temperatures excedding 175°C. The 4195 circuit is available in a mini-DIP that dissipates 600 mW, the TO-5 900 mW, and the TO-66 2.4W (9W with a heat sink at 25°C). Raytheon Semiconductor, 350 Ellis St., Mountain View, CA 94040. Phone(415)968-9211. **185**

IC CONVERTS TTL LEVELS TO MOS. The SN75365 accepts standard TTL/DTL input signals and provides output levels suitable for driving address, control and timing of the 1103, the 4062 and other MOS RAMs. Features include high-speed switching and low standby power dissipation. There are two common enable inputs per gate pair. This driver operates from a 5V TTL power supply and from two MOS supplies, a nominal 20V V_{SS} and 24V V_{BB}. Maximum voltages are 22V for V_{SS} and 27V for V_{BB}. Texas Instruments Inc., P.O. Box 5012, Dallas, TX 75222. Phone(214)238-3741. **186**

64-BIT ECL MEMORY HAS 14-nSEC ACCESS TIME. The 95400 is a RAM organized as 16 words of 4 bits. It features fully decoded 4-bit address capability, 50-line drive capacity, and provision for wired-OR output connections. Price of the memory in a 16-pin ceramic DIP package in 100 to 999 quantities is $20. Fairchild Corp., Semiconductor Components, 464 Ellis St., Mountain View, CA 94040. Phone(415)962-3816. **187**

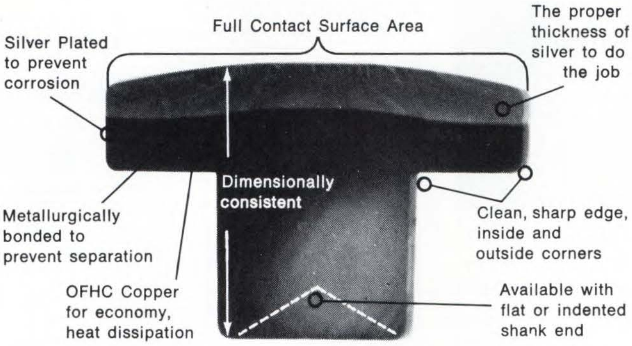


AUDIO AMPS ARE FULLY PROTECTED. TBA810S, when powered by 14.4 V, delivers 6W into a 4Ω load. At this voltage there is total protection against short circuit and accidental overload. Complete thermal protection automatically limits output power in the event of an undesirable rise in junction temperature. The TBA810S is supplied in a 12-lead quad in-line plastic package with external cooling tabs designed to fit a pc board. A version with flat, pierced tabs for the attachment of external heatsink is designated TBA810AS. Price (for 100-999) is $3.00 ea. SGS-ATES Semiconductor Corp., 435 Newtonville Ave., Newtonville, MA 02160. Phone (617)969-1610. **188**

SCHOTTKY MULTIPLEXER ADDED TO TTL PRODUCT LINE. A high-speed Schottky version of the 9312 TTL 8-input multiplexer is similar in operation, but typical address-to-output delay time is reduced to 12 nsec, compared to 25 nsec for the standard unit. Either multiplexer provides in one package the ability to select one bit of data from up to 8 sources. Pricing (for commercial temperature range devices in a 16-pin ceramic DIP package) is $6.50 in 100 to 999 quantities. Fairchild Corp., Semiconductor Components, 464 Ellis St., Mountain View, CA 94040. Phone(415)962-3816. **189**

HERE'S THE INSIDE STORY of ATOMICLAD® II

Gibson Electric's "Silver Saver" COMPOSITE CONTACT RIVETS



The new, improved second generation of Gibson Electric ATOMICLAD II composite electrical contact rivets are available in standard and custom sizes and various materials to solve your contact problem economically without sacrificing dependable performance.

SEND FOR FREE CATALOG AND SAMPLE OF ATOMICLAD II's

Gibson
ELECTRIC INC.
A Subsidiary of GTE Sylvania
DELMONT, PA. 15626

Circle No. 66

---

the best digital... does cost less

Model 2540A1 still the best buy at $1295

5½-DIGIT TRI-PHASIC™ MULTIMETER 2540A1 Autoranging.
1 μV to 1000 VDC. 1 μV to 500 VAC. 1 milliohm to 12 megohms. DC/DC ratio. AC/DC ratio. Isolated BCD output. Remote Control.

Data Precision Corporation
Audubon Road, Wakefield, Mass. 01880
(617) 246-1600

DATA PRECISION
...years ahead

CALL YOUR LOCAL OFFICE FOR A DEMONSTRATION

AL	(205) 883-2530
AZ	(602) 946-7252
CA N	(415) 321-7323
CA S	(714) 540-7160
CO	(303) 449-5294
CT	(203) 527-1245
FL S	(305) 563-8056
FL N	(305) 241-4445
GA	(404) 457-7117
IL	(312) 286-6824
IN	(317) 253-2087
MA	(617) 273-0198
MD	(301) 588-7790
MI	(313) 482-1229
MN	(612) 781-1611
MO W	(913) 236-6600
MO E	(314) 426-2331
NC	(919) 787-5818
NJ	(215) 925-8711
NM	(505) 265-6471
NY N	(315) 446-0220
NY S	(516) 482-3500
OH N	(216) 243-7430
OH S	(513) 298-3033
TX N	(214) 234-4137
TX S	(713) 461-4487
WA	(206) 767-4330

Circle No. 67

Introducing the expensive dual-trace scope that doesn't cost a lot.

The B&K Precision Model 1470.

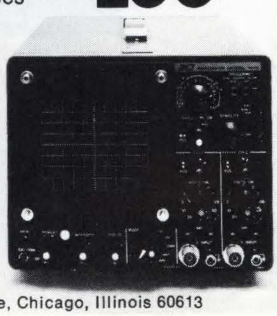
The compact 5-inch solid-state 1470 is specially designed to meet 80% of all your scope applications.

It has DC to 10 MHz bandwidth with 10 mV/cm sensitivity. Sixteen triggered-sweep speeds range from 1 μsec/cm to 0.2 sec/cm. Triggers on input signals as low as 5mV.

$499.95

Sound good? Our prices become even more remarkable once you see our specs.

Call your B&K distributor. Or write Dynascan Corporation.



Very good equipment at a very good price.

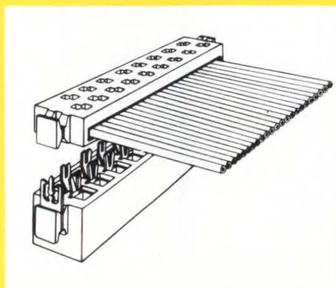
B&K

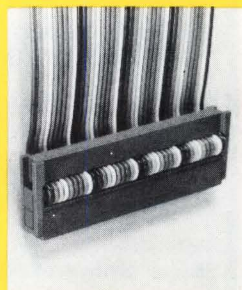
Product of Dynascan Corporation
1801 West Belle Plaine Avenue, Chicago, Illinois 60613

Circle No. 68

QUICKIE* CONNECTOR . . .

FOR THE RAPID, RELIABLE TERMINATION OF FLAT FLEXIBLE CABLE.





The Berg QUICKIE, a female connector, simultaneously terminates multi-lead flexible round cable *without* pre-stripping. The askewed tines of the contact effect a stripping action which terminates virtually any brand of cable, regardless of insulation material, in about 10 seconds. Design assures redundant electrical contact, and allows for visual inspection *before* assembly. QUICKIE can be used to interface cable on .050" centers to .025" square wire-wrapping posts on .100" sq. grid. Write for Catalog 125 or call:

*Berg Electronics Trademark

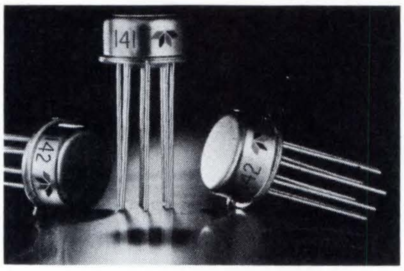
DU PONT
REG. U.S. PAT OFF

BERG ELECTRONICS
Division, E. I. du Pont de Nemours & Co. (INCORPORATED)

New Cumberland, Pa. 17070 Phone: (717) 938-6711

Circle No. 69

SEMICONDUCTORS



OP AMPS FILL PERFORMANCE GAP. A general purpose series of op amp units exhibits performance between that of 741-and 108-type op amps. Improved characteristics of the LM 141/142 series include increased slew rate of 2V/μsec providing full output-voltage swing through the audio frequency range. Input bias current is reduced to 30 mA maximum and input offset current to 5 mA max. The LM 141 series is internally compensated and is compatible with existing designs that use 741, 107 or 1556. The uncompensated version, LM 142 is a replacement for 101A, 748 and 777 applications. Teledyne Semiconductor, 1300 Terra Bella Ave., Mountain View, CA 94040. Phone(415)329-0810. **190**

6 SOLID-STATE RECTIFIER REPLACEMENTS FOR TUBES in certain television applications have been added to the ECG semiconductor line. Types ECG508/R-3A3, ECG509/R-3AT2, and ECG510/R-3DB3 are high voltage rectifiers. ECG511/R-2AV2 is a focus rectifier; ECG512/R-DW4 is a damper diode, and ECG513 is a 45 kV stick rectifier used in high-voltage applications. The devices are packaged individually with a data sheet giving mechanical and electrical ratings and a list of tube types they replace. GTE Sylvania Inc., 730 Third Ave., New York, NY 10017. Phone(617)890-9200. **191**

VOLTAGE REGULATOR SERIES IN PLASTIC POWER PACKAGES. The MC7805/24 series positive voltage regulators can supply in excess of 1.0A at nominal voltages of 5, 6, 8, 12, 15, 18 or 24V, as designated by the last two digits of the device number. These devices have only 3 terminals: Input, output and ground. They require no external components. Maximum input voltage is 35V on all types except for the MC7824 which is spec'd at 40V. All 7 are available at $1.75 ea in 100-up lots. Motorola Inc., Semiconductor Products Div., P.O. Box 20912. Phoenix, AZ 85036. Phone(602)244-3466. **192**

ULTRONIX • ULTRONIX

Five Reasons Why It Makes Sense to Specify Ultronix Power Resistors:

PRICE: Available for under 20c in large quantity lots.

ON-TIME-DELIVERY: Two to four weeks standard.

WATTS: .5 to 12 watt range.

ENCAPSULATION: Coated Silicone

RESISTANCE: .1Ω to 275kΩ.

Meets and exceeds MIL-R 26 requirements.

ULTRONIX INC.

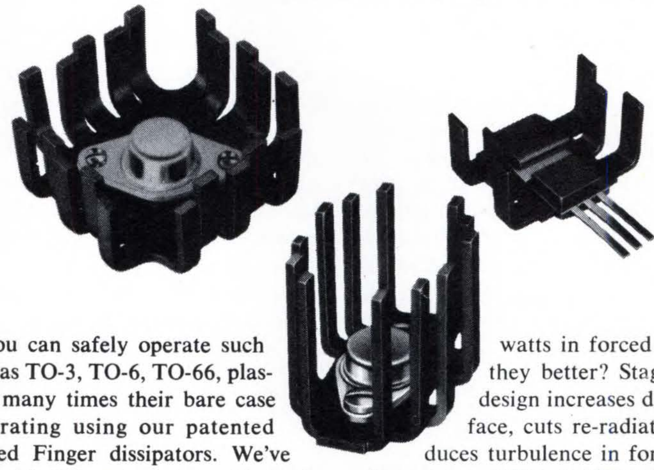
TECHNOLOGICAL LEADERSHIP IN PASSIVE COMPONENTS

461 North 22nd St.,
Grand Junction, Colo. 81501
(303) 242-0810

Dept. EDN

Circle No. 37

Staggered fingers let case-mounted semi's work harder in less space



Now you can safely operate such devices as TO-3, TO-6, TO-66, plastics, at many times their bare case power rating using our patented Staggered Finger dissipators. We've got over 70 different models with dissipation capabilities ranging from 3 to 35 watts in natural convection, up to 125 watts in forced air. Why are they better? Staggered Finger design increases dissipating surface, cuts re-radiation, and produces turbulence in forced air. Send for catalog. IERC, 135 W. Magnolia Blvd., Burbank, Calif. 91502, a subsidiary of Dynamics Corporation of America.

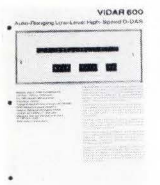
IERC Heat Sinks

Circle No. 64

The only resistor catalog with a built-in expeditor.

SKT electronics, inc.
208 S. LaSalle Street
Chicago, Illinois 60604
312 • 372 - 1465

Circle No. 65



DIGITAL DATA ACQUISITION SYSTEM. Data sheet 186A describes a high-speed, low-level multiplexer/A/D converter, the VIDAR 600. This multiplexes up to 1024 differential-input analog signals at rates to 20,000 channels/sec. It accepts input signals from ±15 mV to ±8V full scale and automatically switches gain ranges. VIDAR, 265 N. Whisman Rd., Mt. View, CA 94040. **249**

BROADBAND POWER AMPLIFIERS. An-6118, "10-, 16-, 30-, and 60-W Broadband (620-to 960-MHz) Power Amplifiers Using the RCA-2N62666 and 2N6267 Microwave Power Transistors," describes basic broadband circuit design. Photographs of assembled modules, schematic diagrams and performance characteristics are included for all circuits discussed RCA Solid State Div., Box 3200, Somerville, NJ 08876. **250**

MULTIPLE-PROCESSOR SYSTEM. The 24-pg. brochure, describing 3 multiprocessing hardware options for the PDP-11 family of computers, contains detailed descriptions of the 3 hardware devices, the Unibus switch, the Unibus window and the Unibus link. The comprehensive brochure also highlights the benefits of multiprocessing and the architecture of the PDP-11 family that permits integration of PDP-11 central processors. Digital Equipment Corp., Maynard, MA 01754. **251**

RATIO TRANSFORMERS. An 8-pg. brochure describes "Ratio-Trans" precision variable ac voltage dividers. These are provided with certificates of accuracy showing traceability to NBS standards. They are used for checking servos, calibrating voltmeters, testing computers and for measuring transformer turns ratios and the arms of sensitive bridges. Singer Instrumentation, Los Angeles Operation, 3211 S. La Cienega Blvd., Los Angeles, CA 90016. **252**

RFI POWER-LINE FILTERS are described in a 12-pg. catalog. It covers 6 series of filters with current ratings from 1 to 60A, and with a wide variety of case styles and termination arrangements. Complete electrical and mechanical information is included along with insertion-loss graphs and an application/selection chart. CORCOM, Inc., 2857 N. Halsted St., Chicago, IL 60657. **253**

MANUAL SWITCH CATALOG. The 84-pg. edition "C" of Catalog 51, *Manual Switches* covers the Series 3 and 4 pushbutton lines and modifications in the rotary selector lines. The catalog also highlights additions to traditional MICRO SWITCH industrial- and commercial-grade lighted and unlighted pushbuttons. MICRO SWITCH, Div. of Honeywell Inc., 11 W. Spring St., Freeport, IL 61032. **254**

80% NICKEL-IRON SHIELDING Mu Guard 80, a high-permeability shielding strip and foil provides excellent shielding protection for sensitive circuit elements against stray magnetic fields. Typical uses are found in transformers, reed relays, vacuum and cathode ray tubes, microphones, loudspeakers, recording heads, amplifiers and other instruments. Bulletin SMA-2R, Magnetics, Specialty Metals Div., Butler, PA 16001. **255**

APP NOTE DESCRIBES USE OF STATIC-CARD READERS. Static-card readers are electro-mechanical devices used to translate information from punched cards into electrical signals. They have applications as programming devices, data input devices and as economical memories. This 8-pg. app note explains it all. The Hickok Electrical Instrument Co., 10514 Dupont Ave., Cleveland, OH 44108. **256**

SOLID-STATE kW AMPLIFIERS. Free technical memos on linear- and switching-type kW amplifiers are available. Topics such as voltage- and current-source amplifiers, output-load selection, dissipation, distortion and efficiency are thoroughly covered. Instruments Inc., 3432 Midway Dr., San Diego, CA 92110. **257**

DIGITAL CLOCK/CALENDARS. Series 70,000 units which feature LED displays are described in this bulletin. It includes a discussion of the time ranges and calendars and the various time bases, such as line frequency or internal oscillators. The units' LED displays are 4 × 7 dot-array shaped character readouts which can be "frozen" for photographing without affecting the time-keeping circuits. Chrono-Log Corp., 2583 W. Chester Pike, Broomall, PA 19008. **258**

SUBHARMONIC FREQUENCY CONVERTERS for PBX and PABX are described in this bulletin. Shown are 18 new SFC Series units for low-frequency ringing power. The Series uses all-magnetic frequency conversion to derive submultiples of the primary frequency at high power levels, with a resulting substantial cost saving. All models are self-starting and feature overload and short-circuit protection. Tele-Dynamics/Wanlass, Div. of AMBAC Industries, Inc., 525 Virginia Dr., Fort Washington, PA 19034. **259**

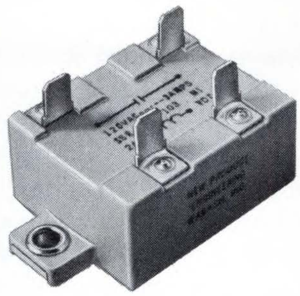
MICROWAVE SOLID-STATE DEVICES. A catalog containing reference data on RCA microwave devices, a 6-pg. booklet, MWD-104F "RCA Microwave Solid-State Catalog", includes information on gallium-arsenide transferred electron oscillator (TEO) diodes, fixed and mechanically tuned TEOs, voltage controlled oscillators (VCOs) and multi-octave oscillators and subsystems. RCA Commercial Engineering, 415 South Fifth St., Harrison, NJ 07029. **260**

For price, delivery, quality

look to wabash

For SSR modules

look to wabash



930 series semi-solid state on-off relay in low profile package. Provides complete isolation between low control power input, high power load. Exceptional switching reliability. TTL logic-compatible. Use to switch inductive, capacitive, tungsten or resistive loads in wide range of equipment. For fast delivery, call today.

SPECIFICATIONS			
		Load Current (maximum)	10 amps A.C.
Control Voltage (nominal)	5-48v D.C.	Life	up to 500 × 10^6 Operation
Load Voltage (maximum)	200 or 400v (peak)	Size	2.63" L × 1.52" W × .850" H

For all relay types

look to wabash

NPE/New Product Engineering, Inc.
a subsidiary of Wabash Magnetics, Inc.
First and Webster Streets, Wabash, Indiana 46992
Phone 219/563-2191 TWX 810-290-2722

■ RF SWITCHING & MERCURY WETTED RELAYS ■ SUBMINIATURE REED SWITCHES
■ DIP REED RELAYS ■ SSR MODULES ■ STANDARD & MINIATURE REED RELAYS

Circle No. 59

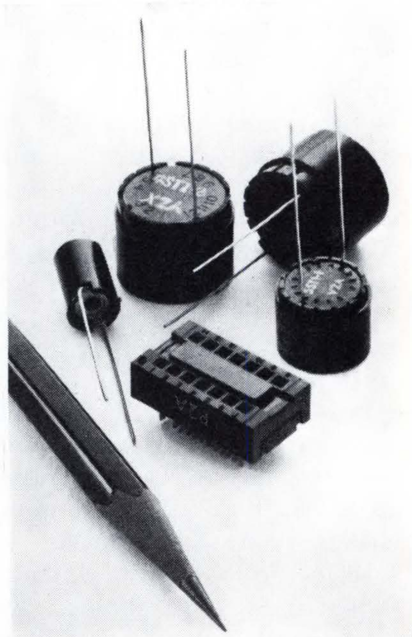
A NEW LINE...

electrocube ...new series of metallized polycarbonate capacitors are offered in a miniature package, smaller than conventional units, with excellent performance characteristics over a wide temperature range. ☐ Choose from more than 1100 different Series 650 models, in six case styles, with capacitances from 0.0010 to 50.0 mfd. and 50, 100, 200, 400 and 600 VDC ratings. Order small quantities from stock, with only a short 4-5 week wait for production runs. ☐ Get more information today from Electrocube, 1710 So. Del Mar Ave., San Gabriel, Calif. 91776, or call (213) 283-0511; TWX: 910-589-1609.

OF METALLIZED POLYCABONATE CAPACITORS

Circle No. 60

5 Remarkable Little Ovens from Texas Instruments, $15.



These self-regulating solid-state component temperature stabilizers provide a low cost means of controlling the environment of a wide variety of transistors, diodes, and ICs. Application of these component ovens permits the use of less expensive semiconductor devices by improving their thermal characteristics as much as 30:1. See how much less you get for your money.

Less Bulk. Typically 1/10th the size of conventional ovens.
Less Headaches. Solid state ovens have no moving parts—are more reliable—aren't handicapped by a limited cycle life.
Less RFI. In fact, there's no RFI since the ovens eliminate the need for thermostats and SCR's which create undesirable radio frequency interference.
Less Money. Costs $3 to $5 instead of the $5 to $250 you're paying now.

Send $15 for your 5-piece Oven Sampler to Commercial Controls Marketing, MS 12-33, Attleboro, Mass. 02703. Or write for the literature.

TEXAS INSTRUMENTS
INCORPORATED

Circle No. 61

signals and noise

Dial Direct---

The response of readers inquiring about the "Phase Locked Loop Handbook" mentioned in the March 5, 1973, issue of EDN has been overwhelming. Many of you thought that we had erroneously omitted the reader service number, so let's set the record straight. Both Signetics (the PLL handbook publisher) and National Semiconductor have requested that we refrain from assigning reader-service numbers to their product announcements. Both will still respond, but only to letterhead, phone or TWX inquirires. This explains the occassional "missing" reader-service numbers that you'll notice in thumbing through the new products.

EDN still hasn't decided whether this is a good or bad trend, or for that matter whether it's a trend at all. Obviously, the processing of thousands of reader service cards costs us a lot of money. On the other hand, one of our main objectives is to make your life a little easier, and writing letters isn't as easy as circling a bingo number. If you have anything to say on this subject, we would like to hear it. Meanwhile, if you need info from either of those companies—phone, TWX or write—to them, not us, please. *Ed.*

Innovations are not inventions

Dear Sir:

You seem to marvel over the patent record of a G.E. engineer and use the word innovate in your text at the same time. (Editorial, EDN Feb. 5, 1973) A patent is to cover an invention, not an innovation. The G.E. engineer may well have made one invention, but the resources of the company are large enough to "cover up" all the possible applications around the area of invention.

Something you did not mention was the cost to G.E. of some \$80,000+, based on \$2000 per for the legal fees, etc. to obtain the patents. It better be something good or G.E. will never recover the cost. It is this cost that keeps the average company/individual to a few patents in a life time.

Stockholders, investors and a few others such as attorneys seem to think that a patent is something. A few are, such as the basic patents on the Xerox and Dr. Land's film process. The remainder are a joke, like the human drive tank I saw in the gazette in the early 1960s. During that period I was at Grumman Aircraft, and the company would route the gazette across my desk. I considered the gazette, a record of U.S. inventions, like *Joe Millers Joke Book.* The area of digital electronics at that time was going from tubes to transistors. The number of ways to "speed up," or increase the "fan-in/out" patented was unbelievable. Also, methods to count/shift used to fill the book. These are "text book" items with a little innovation, not inventions, and they do not deserve a patent.

You might feel that I am down on patents, I am. I do not feel that 99.999% of patents issued by the U.S. Patent Office are worth anything other than trading material for the large corporations. Of the millions issued during my engineering life of 20 years I would be willing to bet that not more than a few thousand are basic inventions of commercial value. Just try to think of 100 basic inventions in the area of electronics during that period (of commercial value). There has been many innovations and applications which are not inventions.

Yours truly,
Charles R. Conkling, Jr.
President
Logos Design, Inc.
Rocky Point, NY 11778

Yes, you can get action

With great interest I read the article entitled "How Users Look At Bench Test Equipment and Manufactures"; and I agree 100% on the viewpoints of the speakers and especially on the point that equipment is used in production facilities. Not too long ago, I worked for a firm that was manufacturing consumer products, and there was approximately \$20.00 per second of finished product going thru it. You can imagine the "Panic" when a piece of equipment broke down.

Perhaps because of our experience of having been on "the receiving end", and also because our products are aimed at "Automatic Production Control", we at Microtronics Corp. include in our warranty that "We Will Ship A Duplicate Within 24 Hours Of Notice" free of charge for as long as the original is in for repairs. We realize that this policy costs money, but let us not forget that service is what counts.

O.P. Fest, President
Microtronics Corp.
203 Gateway Road
Bensenville, Ill. 60106

"WHAT'S THE MATTER WITH YOU GUYS?.... EVERYTIME YOU HAVE A PROBLEM... HERE YOU COME!"

ADVERTISERS INDEX

SALES OFFICES

Foreign

GERMANY
Mr. G. Stelmaszyk
IPC Business Press(West German Off.
Wiesenstrasse, 7,
7146 Tamm/Ludwigeburg, Germany
Telephone: Tamm 7141 3 23 78
Telex: 7 264 780

FRANCE
Mr. D. Soubeyran
Compagnie Francaise d'Editions
Division Internationale
40 Rue de Colisee
Paris 8e, France
Telephone: Paris 225 7750
Telex: France 28274 F

ITALY
Mr. F. A. Corti
ETAS-Kompass SpA
Servizio Estero
Via Mantegna 6
20154 Milano, Italy
Telephon: Milan 347 051
Telex: 33152 Kompass

HOLLAND
Mr. D. Anema
C. Misset NV
Ijsselkade 32
Doetinchem, The Netherlands
Telephone:Doetinchem 8340 25151
Telex: 45481

SWITZERLAND
Mr. H. P. Iff
Agentur Iff AG
Neustadt 57
8201 Schaffhausen, Switzerland
Telephone: Schaffhausen 53 54983
Telex: 76388

JAPAN
Mr. K. Utsumi
Asia Magazines Ltd. (IBP Division)
Akiyama Building
25 Akefune-cho
Shiba Nishikubo
Minato-ku
Tokyo, Japan
Telephone: Tokyo 03 (403) 5623
Telex: J28245 IBP JPN

UNITED KINGDOM
Mr. Douglas Jens Smith
IPC Business Press (Overseas) Ltd.
161-166 Fleet St.
London, EC4P 4AA, England
Telephone: London 01-353-5011
Telex: 267449

INTERNATIONAL COORDIN.
Mr. John Hitch, General Manager
IPC Business Press (Overseas) Ltd.
33/39 Bowling Green Lane
London, EC1R ONE, England
Telephone: 837-1277
Telex: 23839

Domestic

Hugh R. Roome
Publisher
221 Columbus Ave.
Boston, Mass 02116
(617) 536-7780

NEW YORK CITY 10017
H Mason Fackert, Regional Manager
205 E. 42nd St.
(212) 689-3250

BOSTON 02116
Richard Parker, District Manager
Hal Short, District Manager
221 Columbus Ave.
(617) 536-7780

PHILADELPHIA 19103
Steve Farkas, District Manager
Penn Towers
1819 John F. Kennedy Blvd.
(215) 569-2424

ATLANTA 30328
Steve Farkas
District Manager
6065 Roswell Rd.
(404) 252-7753

CHICAGO 60521
Terry McDermott, District Manager
Frank Sibley, District Manager
15 Spinning Wheel Rd.
(312) 654-2390

DENVER 80206
John Huff, Regional Manager
270 St. Paul St.
(303) 388-4511

SAN FRANCISCO 94103
William J. Healey, District Manager
1111 Hearst Building
(415) 362-8547

LOS ANGELES 90036
Ed Schrader, Regional Manager
5670 Wilshire Blvd.
(213) 933-9525

INDEX TO ADS, PRODUCTS AND LITERATURE

Use card for free product information