EDN

exclusively for designers and design managers in electronics

EEE

Multiplexing: the answer to cabling complexity

A CAHNERS PUBLICATION

APRIL 1, 1972

Look! The world's smallest dual output power supplies.

Mini modules only 2.3" x 1.8" x 1". Tracking ±15V outputs have regulation of ±0.1% and ripple of 1 mv. Model D15-03 has outputs rated at 25 ma and costs only $24.00. Model D15-05 has 50 ma outputs; price $39. Models furnishing other matched voltages and/or higher currents are also available. Some are slightly larger, but all are comfortably priced.

Also available are dual mini modules with electrically independent dissimilar outputs in more than 400 different voltage combinations.

And if two outputs aren't enough, we have triple output mini modules. Plus/minus voltages for linear circuits, and a third output for companion logic. For example, Model 5E25D-D15E05 provides ±15 VDC @ 50 ma, 5V @ 250 ma. Price $88.00.

The world's smallest module for powering Nixie* tubes is the Model NX-25. Only 3.5" x 2.3" x 1". Its 25 ma output will drive up to seven digits. Price $35.00.

Other mini modules with single outputs ranging from 1 to 50 volts. provide up to 500 ma. With regulation as tight as ±.02%. Easily mounted to a printed circuit board. Like all Acopian mini modules, they are ruggedly built and short circuit protected.

For more details, write Acopian Corp., Easton, Penna. 18042 or call 215-258-5441.

For shipping information, just look at our tag . . .

CIRCLE NO. 1

*Registered trademark, Burroughs Corporation

You'll like his drive

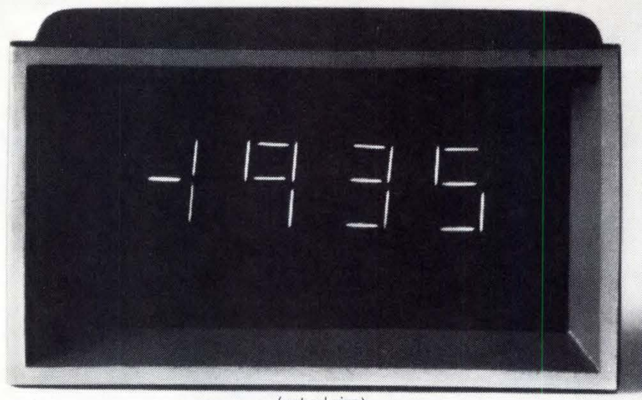
He's a Bodine fhp application engineer. A man determined to give you the service and drive systems needed to meet your design parameters. Fast. A guy you can talk to about speed, torque, windings and power problems. Has thousands of fhp motors, gearmotors, controls and drive systems at his fingertips. And can give you straight answers on modifications, options and special designs. You'll find no better source for ideas, service or results. Write for Catalog S. Bodine Electric Company, 2534 W. Bradley Place, Chicago, Illinois 60618.

. . . the people with the drive to solve your fhp problems

BODINE ELECTRIC COMPANY

BODINE MOTORS/GEARMOTORS
SPEED CONTROLS

CIRCLE NO. 2



(actual size)

If we hadn't made it smaller, simpler and better we wouldn't have made it.

There was no way we could introduce a regular size digital panel meter at a regular size price.

We're the world's largest maker of analog to digital converters. With a little more experience than anyone else in the business.

That's why our AD2001 is the world's smallest and least expensive 3½-digit panel meter. It's just under 8 cubic inches in volume. $89 in 100's. And we're delivering it now.

This is the DPM that's a component.

It's reliable because we made it with fewer parts. Eliminated multi-level power supplies. Used long-life RCA Numitron display tubes. And built in over voltage protection.

It provides 0.05% accuracy. Has a temperature coefficient of ±50ppm/°C. All the interfacing signals are standard. And we make the two critical analog components ourselves.

Each meter is burned-in for 7 days prior to shipment and warranted for one full year. You can send for our complete brochure and order an evaluation sample right now.

Watch for the appearance of our 2½ and 4½ digit DPM's. They'll be smaller, simpler and better with the same performance and reliability as this one. Or we won't make them.

Analog Devices, Inc., Norwood, Mass. 02062. Tel. (617) 329-4700.

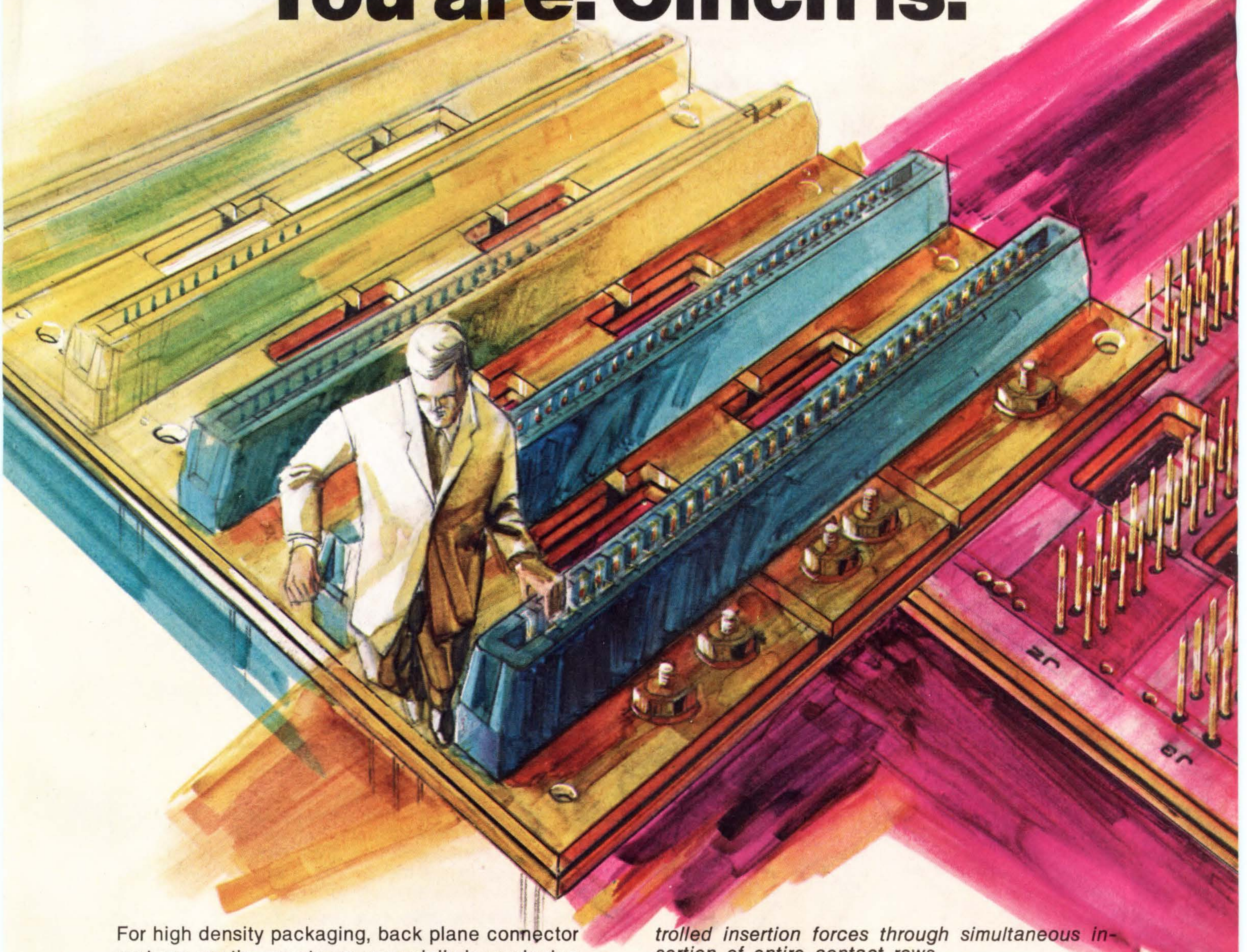
AD2001. $89 in 100's.

ANALOG DEVICES

AD2001 DIGITAL PANEL METER. SIZE: 3″ wide, 1¾″ high, 1½″ deep. Overall volume just under 8 cubic in. DISPLAY: Auto Polarity. Overrange. Out-of-Scale indication. Automatic zero. Programmable decimal points. DATA PROCESSING SIGNALS: External Trigger and External Hold, 3-digit BCD outputs, Overrange, Out-of-Scale, and Polarity signals are all standard. INPUT: Bias Current less than 1nA. Impedance—1000MΩ. Over Voltage Protection. ACCURACY: 0.05% reading. Temperature Range—0°C to 60°C operating. Temperature Coefficient—±50ppm/°C. POWER: Single power source. +5VDC input.

CIRCLE NO. 3

Who's into back planes? You are. Cinch is.



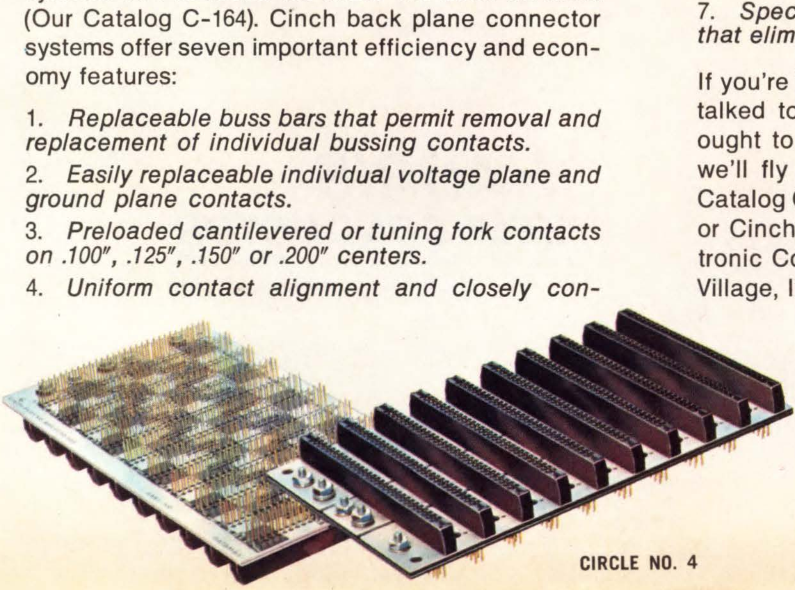
For high density packaging, back plane connector systems are the way to go, especially in producing computers and peripherals.

Cinch can tell you all about back plane connector systems . . . because we wrote the book on them (Our Catalog C-164). Cinch back plane connector systems offer seven important efficiency and economy features:

1. *Replaceable buss bars that permit removal and replacement of individual bussing contacts.*
2. *Easily replaceable individual voltage plane and ground plane contacts.*
3. *Preloaded cantilevered or tuning fork contacts on .100", .125", .150" or .200" centers.*
4. *Uniform contact alignment and closely controlled insertion forces through simultaneous insertion of entire contact rows.*
5. *Selectively gold-plated contacts to reduce costs.*
6. *Precision monoblock or modular connector bodies.*
7. *Specially designed molded styrofoam carriers that eliminate damage in transit.*

If you're into back planes already, you've probably talked to Cinch. If you're not into them yet, you ought to talk to us. Call us at (312) 439-8800, and we'll fly out to see you. Incidentally the book—Catalog C-164—is free, from your Cinch sales office or Cinch Connectors, an Operation of TRW Electronic Components, 1501 Morse Avenue, Elk Grove Village, Illinois 60007.

C-7200



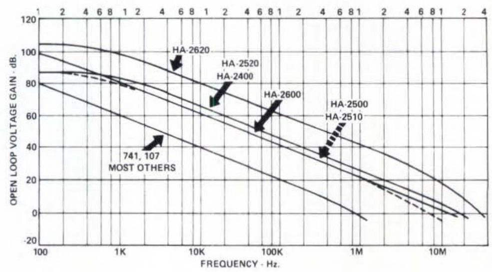
TRW®
CINCH CONNECTORS

CIRCLE NO. 4

Harris' Family of Op Amps. They're a different breed. By design.

Harris op amps have always been a little bit different ever since we introduced the industry's first internally compensated op amp back in 1966.

Today, we still make our op amps a little different. For example, our PNP's, or better put, our P/N/P — are vertical instead of lateral to give you superior AC performance without sacrificing DC characteristics.



Then take our designs. We employ a single gain stage to provide better behaved frequency response. Our bias networks are a bit more complex for uniform performance over a wide range of supply voltages and temperature ranges, and our output stages have better output current capabilities. In testing we're different too—more thorough. In fact, we were guaranteeing slew rates and rise times long before other manufacturers did. Consider just two examples:

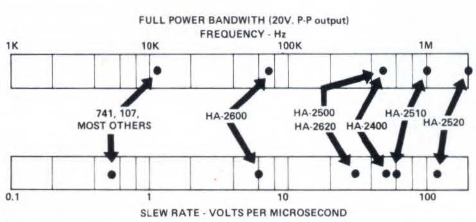
Harris wide band general purpose op amps offer:

■ Close loop bandwidth up to 100 times greater at the same gain or 100 times greater gain capability for the same bandwidth than the common 741 types.

■ Much lower closed loop phase shift, lower gain error, and lower distortion at all frequencies.

■ Superior response at higher gains.

■ Hundreds of times better DC performance (for example, the HA-2600/2620 has a 5nA bias current, 300MΩ input resistance, and 100K minimum open loop gain).



Harris high slew rate series offer:

■ The only monolithic high slew rate amplifiers that are true operational amplifiers. They can be operated inverting, non-inverting, or balanced with fast settling times. In fact, they provide improved performance in virtually any standard hookup.

■ The fastest settling time of any monolithic op amp. (For example, the HA-2520 settles in 250 ns to 0.1%.)

■ Higher output voltage swing at high frequencies. (If you have ever tried to put a 10V peak 1MHz sine wave through a 741 type, you know what we mean.)

In summary, Harris makes a difference . . . our family of proprietary devices and popular alternate source devices can offer you the best price/performance op amp package for your system.

Full military temperature range (−55°C to +125°C):

HA-2101A	HA-2600	HA-2620	HA-2500	HA-2520	HA-2909
HA-2101	HA-2602	HA-2622	HA-2502	HA-2522	HA-2700
HA-2107			HA-2510		HA-2400
HA-2107-3			HA-2512		

Commerical/Industrial (0°C to +70°C):

HA-2301A	HA-2207	HA-2505	HA-2525	HA-2704	HA-2404
HA-2201A	HA-2605	HA-2515	HA-2911	HA-2705	HA-2405
HA-2307					

All in standard 741 pin-compatible configuration. (Except HA-2400/2404/2405 4-channel op amp.) For details see your Harris distributor, representative, or contact us direct.

HARRIS SEMICONDUCTOR

A DIVISION OF HARRIS-INTERTYPE CORPORATION

P.O. Box 883, Melbourne, Florida 32901
(305) 727-5430

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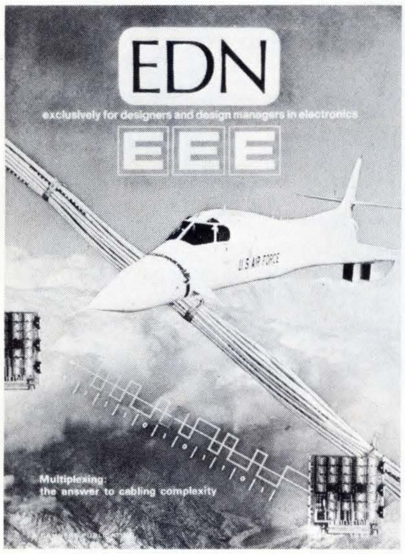
CIRCLE NO. 5

APRIL 1, 1972

VOLUME 17, NUMBER 7

EDN/EEE

EXCLUSIVELY FOR DESIGNERS AND DESIGN MANAGERS IN ELECTRONICS



COVER

Multiplexing of critical control signals, like those of the B-1 Bomber, can often save considerable cabling weight and increase reliability as well. For design details, see p. 18. (Photo courtesy of North American Rockwell Corp.)

DESIGN NEWS

DESIGN FEATURES

PROGRESS IN PRODUCTS

DESIGN PRODUCTS

DESIGN DEPARTMENTS

International Business Press Associates
DESIGN ELECTRONICS
ELECTRONICS WEEKLY
EDN/EEE
ELEKTRONIK
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Everybody wants your components business.

But we're doing 6 things to earn it.

1 Extra reliability. We build extra reliability into our components to let you build extra reliability into your systems.

We offer documented reliability from ER through industrial, from precision through general purpose.

2 Pricing you'll like. For many product styles, our quantity resistor pricing is under 5¢ and often less than 3¢. And that's for CORNING® metal film resistors that significantly outperform other metal films (including glazed), wirewounds and carbon comps.

3 Faster delivery. Our distributors can give you off-the-shelf delivery from an inventory of over 50,000,000 components. And our "ball parks" are firm, real and reliable. This lets you keep expediting and inventory levels to a minimum.

4 Production savings. Our unique product configurations greatly simplify both hand insertion and automatic insertion operations. This saves you money. And our QC is so stringent, many of our customers have totally eliminated their incoming QC testing of our parts. This saves them money.

5 Product innovations. Like our new CORDIP™ Component Networks. With up to 23 discrete resistors/capacitors/diodes in a miniature, pre-tested, plug-in package to save you time, money, and a whole lot of board space.

6 Sharper support. We've hand-picked the 30 most competent distributors in the country and built the industry's largest technically trained field force—then backed everything with a full team of specialists—to give you all the in-depth service you want and then some.

We too want your business. But we're doing 6 extra things to earn it.

Give us a chance to prove it. Write: Corning Glass Works, Electronic Products Division, Corning, New York 14830. Or call: (607) 962-4444, Extension 8381.

CORNING
ELECTRONICS

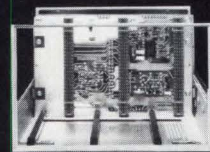
Resistors & Capacitors

for guys who can't stand failures

CIRCLE NO. 6

A low-cost oscilloscope that keeps up with changing applications

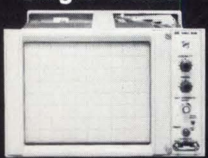
When you shop for a low-frequency oscilloscope, you'll want to know about the measurement capabilities, exclusive cost-saving features and flexibility provided by the new TEKTRONIX 5100 Series.



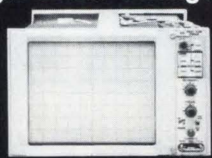
First, you start with the 5103N three plug-in mainframe.

Then, select your display from five interchangeable units with 6½-inch CRT's:

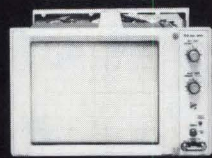
single beam



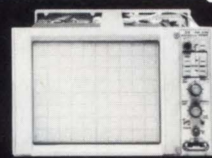
single-beam storage (2)



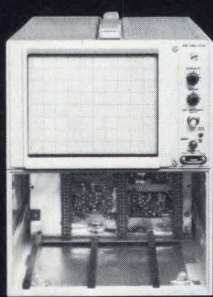
dual beam



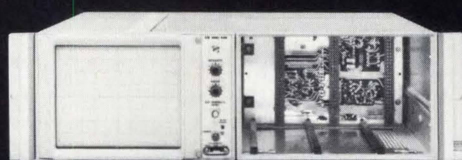
dual-beam storage



Assemble the mainframe and display unit into a cabinet



or rackmount.

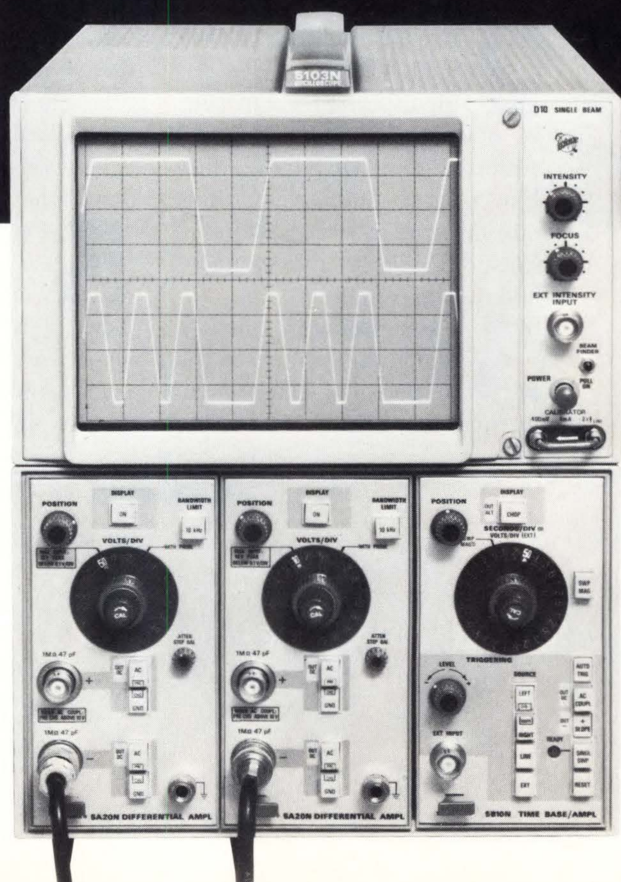


Now, add the low-cost plug-ins of your choice.

There are eleven vertical amplifiers and three time bases to choose from (including a semiconductor curve tracer). Bandwidth is DC to 2 MHz, depending upon the amplifier plug-in.

When your applications change, just buy additional modules instead of a complete oscilloscope. Interchangeable display units let you update to dual beam, or storage, or dual-beam storage by simply buying a module—not a new scope. Here's another way to save. When your applications call for a new configuration, you can change these oscilloscopes from cabinet to 5¼-inch rackmount and back. It takes only a few minutes and a low-cost kit. And with plug-in flexibility you solve many measurement problems in one mainframe.

The most exciting part—low-cost. If you choose a D10 Single Beam Display Unit assembled with the 5103N, 2 ea. 5A20N 50 μV/div 1-MHz Differential Amplifiers and the 5B10N Time Base, here's what you get.→
The cost? Only $1045 in cabinet or rackmount (includes slide assemblies). You can choose an X-Y oscilloscope, cabinet or rackmount, for as little as $590.



U.S. Sales Prices FOB Beaverton, Oregon

TEKTRONIX®
committed to technical excellence

Contact your local Field Engineer for a demonstration and complete details.

CIRCLE NO. 7

The Government sprints ahead . . .

The first hurdle in the establishing of an office of Technology Assessment (OTA) was passed last month when the House of Representatives adopted Bill HR 10243. The bill would set up an 11-man board whose duties would be to appraise technology and its probable impacts on the country and inform and advise Congress accordingly.

With a first-year budget of $5 million and a total staff between 50 and 100, the OTA would have the authority to use the services of the National Academy of Sciences, industrial research and technology organizations, universities, and even private individuals. In effect, OTA would be comparable to the General Accounting Office, providing Congressmen with data on technology much the same as GAO keeps Congress informed of Federal contracting and spending.

With the Senate now in the process of holding hearings on the bill, it may not be too long before the Office of Technology Assessment is a reality.

Strangely enough, we find this both encouraging and discouraging. Discouraging, because it will have taken Washington so long to accomplish this first step in developing a sane policy towards technology. For two years technology-based industries and their employees have suffered acutely from what could only be called a "no policy" on the part of the Federal Government. And to make things worse, during this time technology became the favorite whipping boy of sincere environmentalists and conservationists as well as others whose sincerity could be questioned.

Two years is a long time, as would be attested to by all the companies who went Chapter XI, all the engineers who were layed off, and all the unemployed who relocated to other industries or other areas. And yet, unfortunately, it wasn't long enough for the Government to realize that it has both a stake in and responsibility to the technological community.

So much, though, for the sour grapes. Although "better late than never" may have a hollow sound, we'll support it 100 percent in the case of the Office of Technology Assessment. The OTA won't be a cure-all, and it would be foolish to think that it would be. But it should help eliminate or lessen wasteful hassles like those over the SST or the Safeguard ABM system. It should also help the U.S. develop a world trade posture that takes into consideration the causes and effects between trade and technology.

Most of all, the OTA should be a decisive force for planned technological growth and advancement, since it can and should consider things from a long-term vantage point—something that has been sorely missing in the past.

Frank Egan

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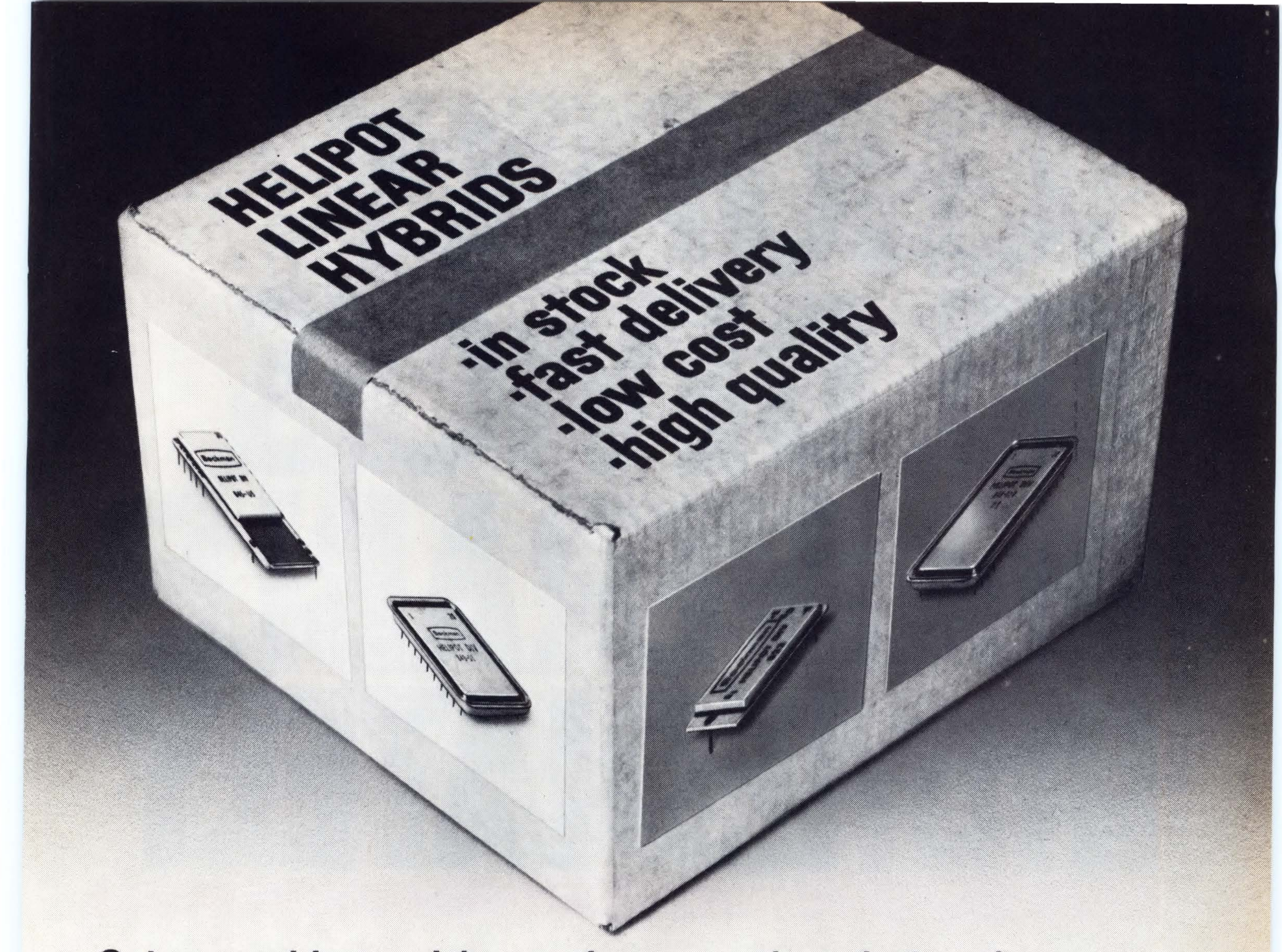


Get our problem-solving package: good products, prices, availability and design assistance—all from one source.

Digital-to-Analog Converters

Model 845: Complete 8-bit binary DAC. 4 preset output ranges. Slew rate: 0.2V/μsec min. Settling time: 5.0 μsec/volt + 1 μsec. Price (1-9) $39.75.

Model 846: Complete 8-bit binary DAC. 4 preset output ranges. Slew rate: 4V/μsec min. Settling time: 0.25 μsec/volt + 2 μsec. Price (1-9) $49.75.

Model 848: Complete 11-bit binary DAC. Guaranteed monotonicity and accuracy levels. 4 preset output ratings. Slew rate: 4.0V/ μsec min. Settling time: 0.25 μsec/volt + 2.0 μsec. Hermetically sealed Kovar case. MIL-STD-883. Price (1-9) $95-$155 depending on accuracy code.

Model 849: 13-bit resolution binary DAC. Four quadrant operation (AC reference). Accepts serial data input. MOS compatible (high threshold). Low power dissipation. Price (1-9) $155-$185 depending on accuracy code.

Ladder Networks

Model No.	Standard "R" Values	R_{sw} Compensation	Best Standard Accuracy	Pricing 1-9	
811 (Binary)	5K, 10K, 20K	5Ω Bits 1-4	±122 ppm −55°C to +125°C	811-B12	$40.00
812 (Binary)	50K, 100K	500Ω All Bits	±122 ppm −55°C to +125°C	812-B12	40.00
814 (Binary)	10K	5Ω Bits 1-5	±30 ppm @ +25°C and +61 ppm −20°C to +85°C	814-D14	90.00
815 (Binary)	10K	None	±1952 ppm −55°C to +125°C	815	6.95
862 (BCD)	50K, 100K	500Ω All Bits	±300 ppm −55°C to +125°C	862-B	45.00

Miniature Power Amplifiers

Model	± Supply Range	Output Max. Range	Minimum Load Resistance	Price (1-9)
821	10 — 20V	±16V	100Ω	$30.00
822	10 — 20V	±16V	50Ω	35.00
823	10 — 30V	±26V	$\frac{30\ (E_o\ \text{max.})}{E_{cc} - E_o\ \text{max.} - 1}$	8.95
824	18 — 30V	±27V	140Ω	40.00
866	10 — 20V	±16V	50Ω	40.00

Call your local Helipot Sales Representative today.

Model 841 Ladder Switch

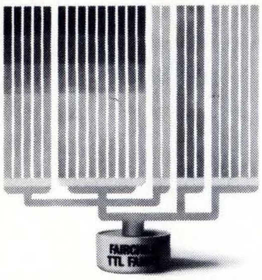
Features: 0 to 2 mV switch offset. 5 (±3) ohms "on" resistance. 200 ns rise and fall time. 0 to 5 mA load range. R_{OFF} and V_{OFFSET} independent of reference voltage used. Model 841-1 Price (1-9) $100.

Beckman®
INSTRUMENTS, INC.
HELIPOT DIVISION
2500 Harbor Blvd., Fullerton, Calif. 92634

CIRCLE NO. 9

SCHOTTKY TTL DEVICES DELIVERABLE IMMEDIATELY

Our TTL Family Tree has a vigorous new Schottky branch: SSI devices now. Proprietary MSI (and more SSI) devices soon.



Our TTL Family Tree continues to grow. Now a new Schottky branch: SSI in volume now. MSI coming up. To give you new ways to solve your very-high-speed digital systems design problems.

Schottky TTL Devices are pin-for-pin replacements for slower, functionally equivalent elements in existing TTL systems. An example of the speed improvement achieved is shown in the table below. These Schottky functions can be used to selectively replace devices in critical speed limiting paths within the system.

TTL SWITCHING TIME COMPARISON
EXAMPLE: HEX INVERTER

	T_{PLH} (turn-off delay) Typ.	Max.	T_{PHL} (turn-on delay) Typ.	Max.
9N04/7404	12.0	22.0	8.0	15.0
9H04/74H04	6.5	10.0	9.0	13.0
9S04/74S04	3.0	4.5	3.0	5.0
9S04A/74S04A	2.5	4.0	2.5	3.5

Note: All speeds listed in nanoseconds.

Important areas where speed limiting occurs are: decoder and multiplexer expansion; memory addressing and selection; general arithmetic and control functions; prescalers and counters; and elimination of skew problems in clock distribution. System speed improvements of 20 to 50% can be expected in these situations without any major redesign. Power requirements, logic levels and noise margins remain compatible with the slower, lower cost standard TTL devices which can be retained when speed is not important.

For your Schottky needs we now have 13 TTL/SSI functions, making us the only major supplier to second source these devices. And we can deliver them immediately. Our 9S and 93S series are completely interchangeable with the 54/74S series.

Just as important, these are but the first of the new Fairchild Schottky TTL family. Soon other SSI elements. Soon also, our first 93S series of proprietary MSI functions.

FAIRCHILD TTL/SSI DEVICES AND AVAILABILITY

Device	Description	Available
9S00/54S00, 74S00	Quad 2-Input NAND Gate	Now
9S03/54S03, 74S03	Quad 2-Input NAND (O.C.) Gate	Now
9S04/54S04, 74S04	Hex Inverter	Now
9S05/54S05, 74S05	Hex Inverter (O.C.)	Now
9S20/54S20, 74S20	Dual 4-Input NAND Gate	Now
9S22/54S22, 74S22	Dual 4-Input NAND (O.C.) Gate	Now
9S40/54S40, 74S40	Dual 4-Input NAND Buffer	Now
9S74/54S74, 74S74	Dual D Flip-Flop	Now
9S04A	Fast Hex Inverter	Now
9S05A	Fast Hex Inverter (O.C.)	Now
9S64/54S64, 74S64	AND-OR-Invert	Now
9S65/54S65, 74S65	AND-OR-Invert (O.C.)	Now
9S140/54S140, 74S140	Dual 4-Input NAND Line Driver	Now
9S109	Dual J-K Flip-Flop	2nd Qtr.
9S112/54S112, 74S112	Dual J-K Flip-Flop	2nd Qtr.
9S113/54S113, 74S113	Dual J-K Flip-Flop	2nd Qtr.
9S114/54S114, 74S114	Dual J-K Flip-Flop	2nd Qtr.

FAIRCHILD TTL/MSI FUNCTIONS AND AVAILABILITY

Device	Description	Available
93S41	4 Bit ALU/Function Generator	2nd Qtr.
93S05	Variable Modulo Counter	2nd Qtr.
93S39	Multiple Port Register	3rd Qtr.
93S10	Synchronous Decade Counter	3rd Qtr.
93S16	Synchronous Hexadecimal Counter	3rd Qtr.
93S12	Eight Input Multiplexer	3rd Qtr.
93S42	Carry Look Ahead Unit	3rd Qtr.
93S00	4 Bit Universal Shift Register	3rd Qtr.

Other MSI functions in development include high speed decoders and parity checkers.

Whatever your High Speed needs we have the answer. Schottky TTL for retrofitting existing systems, or our temperature compensated Easy ECL 9500 family for new high-speed systems.

Your Friendly Fairchild distributor has both our Schottky TTL and Easy ECL devices in stock, deliverable immediately. Or for more information, we have data sheets and application notes on both.

MADE IN FAIRCHILD

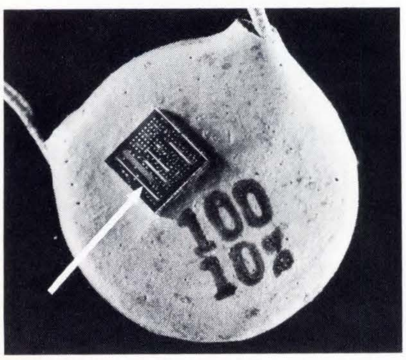
FAIRCHILD SEMICONDUCTOR, A Division of Fairchild Camera & Instrument Corp., 464 Ellis St., Mountain View, Ca. 94040. (415) 962-5011. TWX: 910-379-6435

CIRCLE NO. 10

Charge coupled devices (CCDs) are knocking at the door

To date Amperex Electronics has the only charge coupled device on the market. But this M31 "Bucket Brigade" analog shift register, reported in the Jan. 1, 1972 issue of EDN/EEE, is only the tip of the iceburg. In February IBM, RCA and GE all released reports on digital charge coupled device memories.

IBM's disclosure that a shift register/buffer memory has been built and tested on an IBM system-compatible card has settled any lingering arguments about the viability of CCD memories. IBM's 5760-bit memory is built around 6 dual 480-bit shift register chips, with each 480-bit register consisting of 10 CCD channels in series, and a refresh amplifier at the end of each channel. Although the unit tested used refreshing after each 48 bits of storage, IBM reports that they have achieved operation of the same devices with unrestored lengths of 256 bits.



Basic chip for IBM's CCD memory is a dual 480-bit shift register, shown here on a 100-pF capacitor for size comparison. IBM has achieved packing densities of 3 million bits/inch on some of their CCDs.

The charge storage area on another IBM experimental chip is a scant 0.05 mil^2, and each memory cell is only slightly more than 0.3 mil^2 in surface area. Charge transfer at each stage is 16×10^{-15} coulombs per volt of phase line potential.

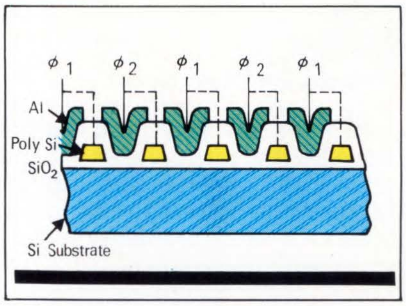
Operating at a data rate of 5 MHz, the average access time for the operational system is 25 μsec.

RCA's announcement was of a 1-MHz, charge-coupled, 128-stage, two-phase experimental shift register having a transfer loss of approximately 0.01 percent per stage. The device was developed by scientists at RCA Laboratories, Princeton, N. J., under a NASA contract. The 99.99 percent efficiency per gate is high enough to permit the use of such devices as building blocks in a low-power, large-capacity, serial semiconductor memory that is projected for operation at 10^7 bits/sec. Packing densities on the order of 1.0 mil^2 per bit (using currently practiced layout rules) and costs in the range of 0.01 to 0.1 cent per bit are forecast by RCA.

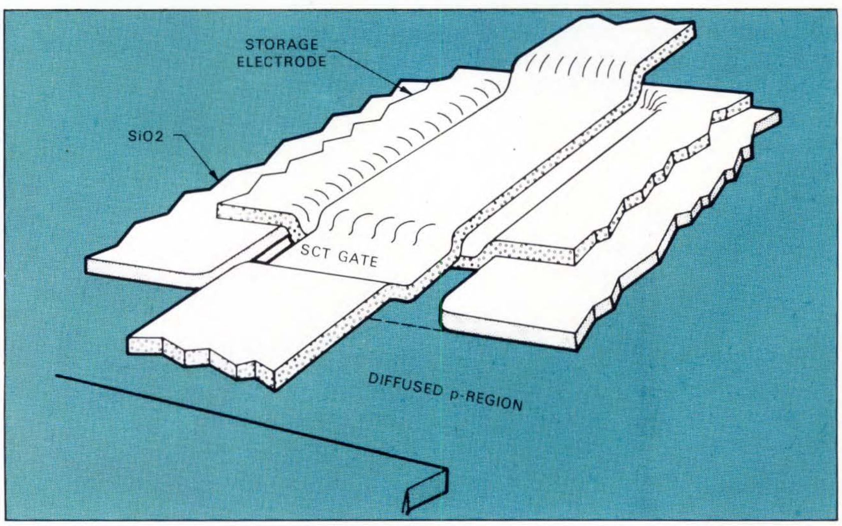
The device, announced by Dr. W. F. Kosonocky is a closely-spaced charge-coupled structure using polysilicon gates overlapped by aluminum gates operating as a two-phase shift register. It is fabricated by standard silicon technology presently being used for fabrication of MOS ICs.

The register operates by transfering charge along a silicon surface between MOS capacitors, or gates, that are powered by a two-phase clock-voltage pulse train.

Other applications forseen by RCA for the charge-coupled device are electronically variable delay times for analog signals and self-scanning photosensor arrays for solid state TV cameras.



RCA's CCD shift register is a 2-phase, 128-stage device using 0.8-mil long polysilicon gate overlapped by 0.2-mil long aluminum gates. The structures are fabricated on <111> oriented N-type silicon substrates.



GE's surface charge transistor memory cell is fabricated by their RMOS (Refractory Metal MOS) process. Some oxide layers are not shown here for clarity. Charge storage area is at the silicon surface under the storage electrode (bit line) and transfer gate (word line) intersection.

Dr. Kosonocky commented that theoretical predictions and experimental results have been in very close agreement, thus far in the NASA research program. He further stated that the present performance levels of CCDs can be significantly improved.

Choosing non-shift-register approaches, GE has revealed two new random access memories. The first, a charge-pumped RAM with cell areas of approximately 15 mil^2, was partially assembled to simulate a 4096-word by 9-bit RAM having a total system read-access time of 60 nsec and comparable write time.

GE's second CCD announcement was a surface-charge-RAM, now in its early development stages, fabricated as a 4- by 8-bit array of 1.2- by 2-mil single transistor cells. Readout is destructive, and provisions are made for refresh and rewrite operations. Present read/write cycle time is approximately 250 nsec. Since the speed of a surface charge RAM is affected by the amount of charge transferred and the capacitance of the bit line, as well as the performance of the sense amplifier, there is considerable room for size-performance tradeoffs.

Miniaturized x-band antenna is not only small but extremely rugged too

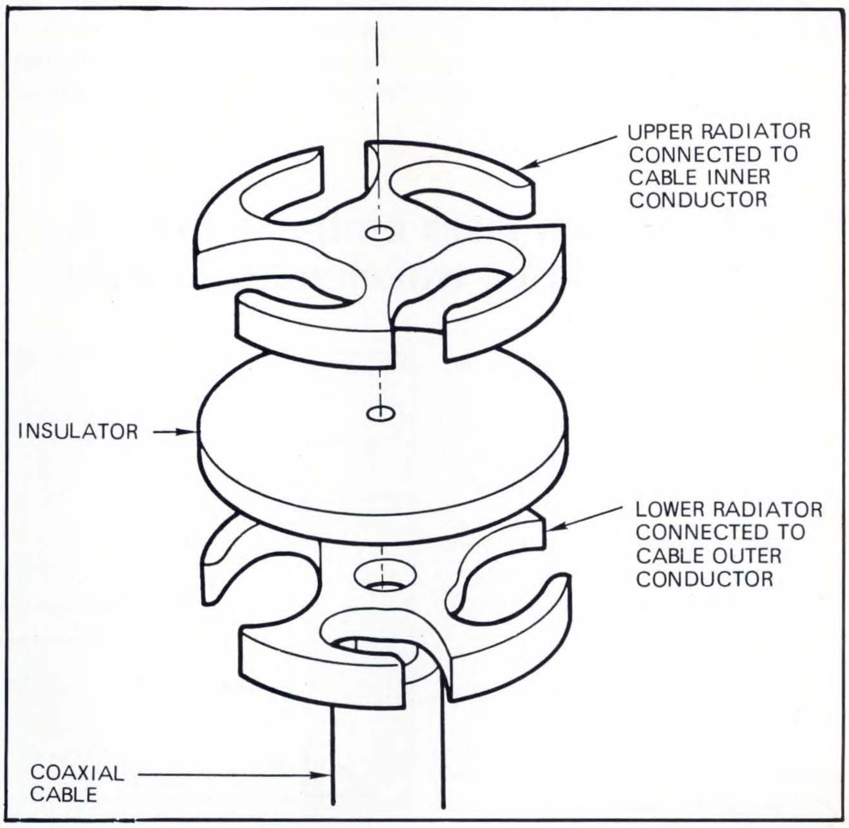
An omnidirectional x-band antenna that measures only one-half inch in diameter has been developed at the Antenna Development Div. of Sandia Laboratories.

The small, rugged unit consists of two radiators separated by an insulating disc. Each radiator consists of discs that have been cut out in swastika form so that four conductive arms remain. Since the radiators are separately connected to a coaxial line, each conductive arm forms a balanced dipole with the corresponding arm on the other side of the insulator.

Each of the conductive arms is of equal geometric length, and has an electrical length of about one-quarter wavelength. Thus each of the four dipoles is about one-half wavelength long.

Undesirable electromagnetic radiation from the radial part of the conductors is minimized by designing them so that they are of equal length and carry equal but opposite currents. This ensures that radiation from one conductor will effectively cancel the radiation from the other.

The new antenna is designed for operation in the 9-10 GHz region.



Each of the four conductive arms on the upper radiator forms a balanced dipole with the corresponding arm on the lower radiator.

Engineering enrollments down sharply at both graduate and undergraduate levels

As a result of a dramatic decline in enrollments last fall, there are 26,000 fewer engineering students now than there were a year ago, according to a study recently completed by the Engineering Manpower Commission of the Engineers Joint Council. The figures are based on a comparison of enrollments for fall 1971 with those at the same time in 1970.

The decline in enrollments was manifested at all levels, from beginning freshmen to doctoral candidates. Half of the total drop occurred in the freshman class, which was 18 percent smaller in 1971 than in 1970 and down by nearly 25 percent from 1967. The sophomore class too was

Table 1. Undergraduate enrollments in engineering

	1st year	2nd year	3rd year	4th year	5th year	Total Full-Time	Total Part-Time
1970	71,661	53,419	49,855	51,983	4812	231,730	18,455
1971	58,566	47,948	48,543	51,377	4391	210,825	18,222
% Change	−18.3	−10.2	−2.6	−1.2	−8.7	−9.0	−1.2

Table 2. Graduate enrollments in engineering

	Master's Degree		Doctor's Degree		Total	
	Full Time	Part Time	Full Time	Part Time	Full Time	Part Time
1970	23216	25853	14802	4949	38018	30802
1971	22405	22692	14100	4610	36505	27203
% Change	−3.5	−12.2	−4.7	−6.8	−4.0	−11.7

hard hit, with a decrease of 10 percent. Junior and senior enrollments were lower by about 2 percent, but it had been anticipated that students would be reluctant to drop engineering at these levels because of the substantial educational commitment already made.

Advanced degree enrollments also decreased substantially, according to the EJC figures. Full-time graduate students were down by 4 percent and part-time enrollees by nearly 12 percent. Complete statistics for all levels are shown in the tables.

According to Dr. Robert J. Raudebaugh, President of the Engineers Joint Council, the decline in engineering enrollments indicates a strong reaction by students to fears of unemployment. The loss of 26,000 students has serious implications for many of the nation's engineering schools as well as for the future supply of technically educated manpower. Despite the reduced levels of engineering recruiting and hiring in 1970 and 1971, new engineers generally fared better than graduates in most other disciplines, Dr. Raudebaugh noted, and long-range projections by the U.S. Department of Labor continue to show needs for large numbers of engineers during the next decade.

New hydrogen laser emits at 1161 Å . . . the shortest laser wavelength to date

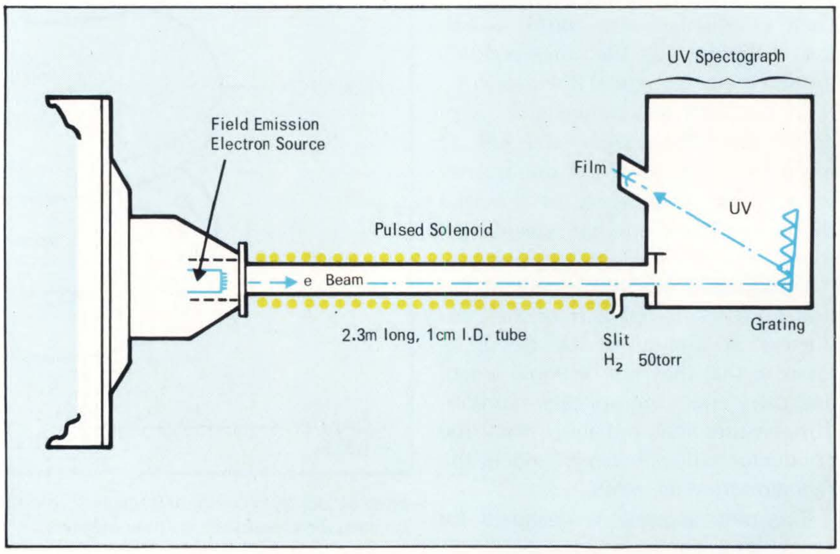
The shortest-wavelength laser yet developed, one that emits at 1161Å in the vacuum ultraviolet, has been developed by scientists at International Business Machines Corp., Yorktown, NY.

Shorter wavelength lasers have higher-energy protons than longer-wavelength types and hold the promise for an ultimate X-ray laser. Such a laser has practical applications as a hologram in medicine, biology and photo-chemistry.

The new laser, according to its developers, Dr. Rodney T. Hodgson and Dr. Russell W. Dreyfus, represents a considerable advance toward shorter wavelengths over the previous record of about 1600-Å achieved by Hodgson in 1970. Both lasers use hydrogen gas as the active medium, but the new laser is pumped by a high-power electron beam rather than by a gas discharge. The electron beam delivers 4 billion watts in a 3-nsec pulse of 400,000V electrons. The beam current of about 10,000A/cm² is generated by a field-emission electron source and is contained along the axis of a 1-cm-inside-diameter tube by an axial magnetic field.

The tube contains hydrogen gas at a pressure of 20 to 100 Torr. Collisions between electrons and hydrogen molecules in the ground electronic state raise the molecules to high-lying electronic states. Stimulated emision occurs from these states to upper vibrational levels of the ground electronic state without the need for mirrors. In conventional molecular spectroscopy, the present 1161Å to 1240Å lines are wavelengths appearing in the well-known Werner bands.

Early experiments with the laser indicate the output power at 1161Å is at least 500 W/cm². Since the electrons in the beam lose only a small fraction of their energy to the hydrogen gas in the laser, it should be possible to increase the power output by merely increasing the length of the laser.



Pumping in the new laser is done by a high-power electron beam rather than by a gas discharge, as is usually the case.

Accuracy to within a few minutes per year is possible with three-piece quartz electronic wristwatch set

Stabilities of 4.32 seconds per day and 26.28 minutes per year for a 0 to 60°C temperature range are achieved with wristwatches made from Motorola's three matched-set timepiece components. These (**Fig. 1**) consist of a 32.768-kHz quartz crystal time base, a monolithic, silicon-gate, CMOS IC containing oscillator, buffer and counter circuits, and a micro-miniature stepper motor. Power can be supplied by either a 1.5V silver-oxide or a 1.3V mercury-oxide battery (not supplied by Motorola) each rated to operate for 12 months.

The crystal timebase was designed for an optimumly large enough frequency and small enough size to be compatible with a practical wristwatch system. Crystals of higher frequencies could have been used with resultant size savings (the larger the frequency, the smaller the crystal size). However, the larger frequencies require more circuitry to divide down to the necessary 1 pulse/sec.

The NT-cut crystal exhibits superior shock-resistance characteristics — it will survive a shock of 3000 gs, which is approximately equivalent to a drop of 1 meter on a hardwood floor. Typical first-year aging is only 2 ppm. Motorola guarantees a maximum 5-ppm aging rate. Combined with the CMOS IC, the total current drain is only 4.5 μA maximum with a 1.3V battery, or 5.0 μA maximum with a 1.5V battery.

The IC is the heart of the electronic wristwatch system. The young CMOS technology has made it possible to pack an oscillator, binary divider, waveshaping and buffering circuitry onto a single 82-X-94-mil die that operates from 1.5V levels at only microwatts of power dissipation. There are 312 active devices on the die in addition to the integrated passive components. The only electronic component not included in the IC (and not available from Motorola) is an external oscillator trimming capacitor.

Fig. 1 — Three Motorola components — an ultra stable quartz crystal, a CMOS IC and a miniature stepper motor make possible the design of electronic wristwatches with stabilities of a few minutes per year. The IC contains all the necessary circuitry to divide down the 32.768-kHz crystal to the single pulse per sec needed to drive the tiny motor. All three parts are available in combination or separately from Motorola's Phoenix, Az, office.

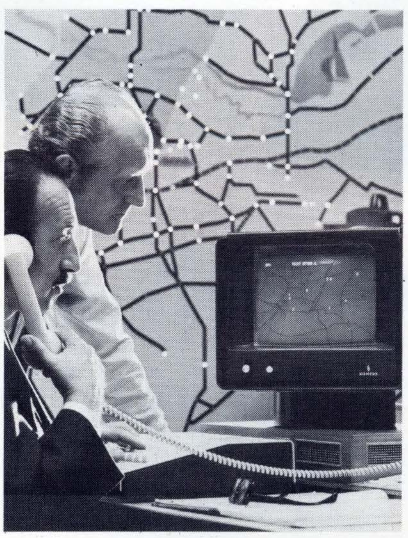
Radio-location techniques and computer locate police cars in metropolitan area

The Nuremberg, Germany city police have recently begun experimenting with a Siemens Corp.-developed hyperbolic navigation system for locating patrol cars. Introduction of this trial system has enabled the dispatcher at police headquarters to continuously monitor the positions of on-duty patrol cars.

Employing radio location techniques to establish the position of patrol cars in a populous city's sea of buildings has until now proved impossible. Obstacles in a builtup area impede the straight-line propagation of radio waves, causing undesirable variations of the measured differences in propagation times.

Siemens engineers were able to program a process-control computer to recognize and discount erroneous propagation-time differences, accepting only correct values in its calculations of patrol car positions.

Patrol cars are equipped with VHF-band radiotelephone equipment which transmits fixed-frequency signals at regular intervals under control of a master station situated at the center of the patrol area. The radio signals are picked up by four receiving stations, demodulated, and routed to police headquarters by way of normal telephone lines. The receiving stations are positioned at the corners of a square with sides measuring 5 kilometers in length.



With only a glance at a TV monitor, police officers in Nuremberg, Germany can see the positions of all on-duty patrol cars. The system, developed by Siemens Corp., uses hyperbolic navigation techniques.

The differences in the radio-signal propagation times arising from the varying distances between the patrol cars and the receiving stations are measured at police headquarters. Several lines of position are derived, whose point of intersection is the location of the given patrol car at that moment. The established position of each car is indicated on a TV screen by the appearance of the car's assigned code number. A chart of the city streets is imposed over the screen. For 100 cars a cycle time of approximately 30 seconds is required.

Multiplexing doesn't have to be limited to communications applications

It's a useful technique for important command and control links, too. But with vital operating signals confined to a single, shared wire, careful design is a must.

J. Ohlhaber, Radiation Systems Div., Harris-Intertype Corp.

Multiplexing is not new. The concept of putting several signals on one path or wire has been used for many years in missile-system telemetry and telephone networks. What is new is using multiplexing for vital command and control links. The NASA manned-space-flight vehicle programs pioneered this "vital" use of multiplexing in the long-distance sense when they used multiplexed telemetry signals to help the Astronauts accomplish their missions. Now the Air Force is pioneering short distance "vital-signal" multiplexing inside vehicles for its next generation bombers.

The multiplexing systems used in the commercial airliners—the Boeing 747, the Douglass DC-10 and the Lockheed L-1011—were forerunners of the use of multiplexing, but these systems could hardly be classified as vital inasmuch as they were only handling passenger-entertainment audio signals.

Why is multiplexing, which has always seemed like an unnecessary, complex, expensive and unreliable way of handling signals, only to be used as a last resort, being used in short-distance critical applications, like inside vehicles? The reason is that as system complexity grows, the point is reached where the complexity and weight of the thousands of separate control lines are more of a liability than the one wire multiplexing system that replaces them. The multiplexing system effectively "cleans up" the system design, reducing complexity and improving reliability.

But to achieve the improvement, the multiplexing system must be designed with great thought.

System layout goals

In the ideal multiplexed system, every signal without exception would be multiplexed directly onto the single common bus, or "party line." Unfortunately, for the proponents of multiplexing, this is only possible in the simplest situations. Part of the restriction on complete multiplexing of all signals comes from the fact that the terminals that put signals on and off the line must of necessity be limited in number, and they must be placed strategically so their hardware economically serves a number of inputs and outputs. If there is a lone signal in a certain area, it may not be feasible to place a terminal at that point just to carry this signal. Therefore, it won't be possible to get that signal onto the common party line.

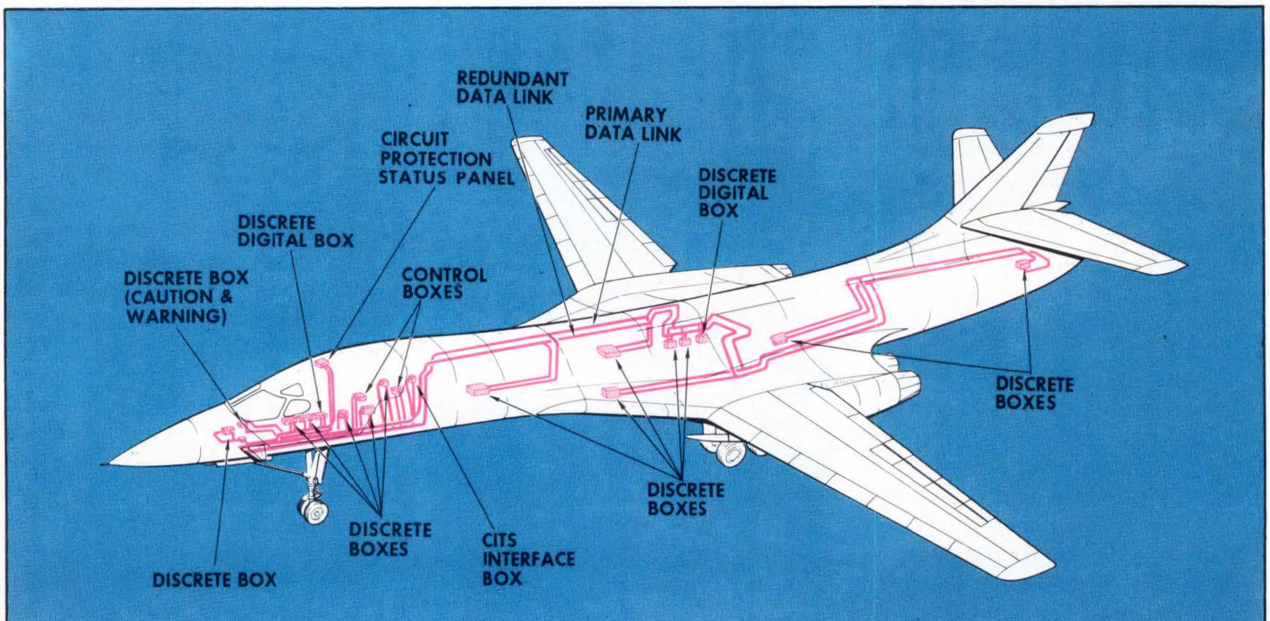


Fig. 1—Vital control signal multiplexing can simplify the control wiring of complex systems such as the aircraft shown here. It also looks promising for submarines and ships. It may also be of considerable interest for industrial processing plants. The port-side multiplexing for the new B-1 strategic bomber, shown here, consists of two redundant "party-lines" running the length of the ship. The control and terminal boxes are spotted along the length of the lines. Each terminal handles a cluster of signals.

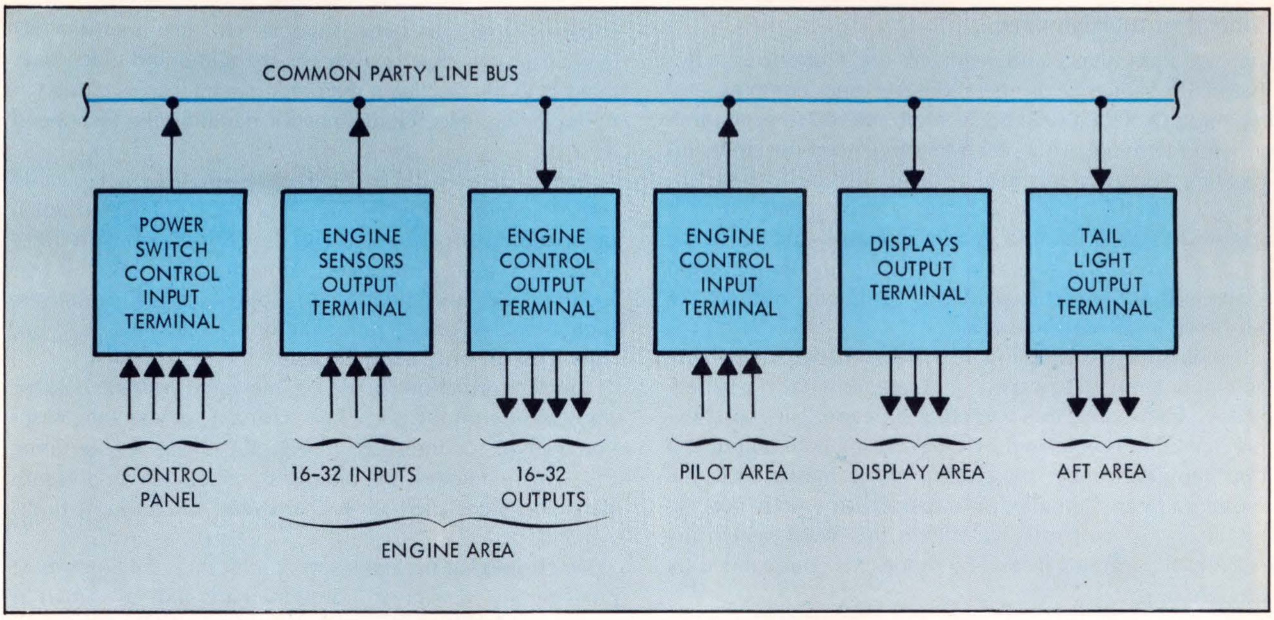


Fig. 2—Ideal, all-inclusive multiplexing system will carry command and feedback signals for a wide "mix" of functions. For the aircraft example, these can be seen to range from engine control to tail light control.

The greatest number of inputs or outputs served by a multiplex terminal varies with each particular signal mix. An analysis conducted by Radiation Systems Div. has indicated that 32 or 64 inputs are about optimum (five or six bits from the control-address standpoint). Since the number of input and output signals in a given area is rarely balanced, separate terminals are often designed for each. In this optimum system, the party line should be capable of accommodating 64 such terminals placed anywhere along its length. **Fig. 2** shows the "mix" of such a system in a rough, pictorial fashion.

Choice of multiplexing scheme.

There are three different ways to transfer multiple channels of information: space division, which is just the old way of using individual hardware channels for each; frequency-division multiplexing (FDM), which means putting the information into different frequency slots and then recovering it by filtering; and time-division multiplexing (TDM), which means putting the information into different time slots then recovering it by timed gating.

Wide bandwidth data such as video and high-speed computer data is typically the most difficult to multiplex. It is usually handled by separate dedicated cables (space division) or by multiple dedicated frequency channels on one cable (FDM). This does not mean that wideband data cannot be handled by TDM, but that these signals would demand inordinately high time-division (or sampling) rates, compared with those adequate for low-speed data.

Of the techniques available to the designer, TDM (or time division multiplexing) is most effectively applied to the handling of low-speed sensor or control data, whether digital or analog, because this type of data needs only low sampling rates. The partial list of signals in a modern bomber aircraft, **Table 1**, points out the large traffic capacities that can be accomodated by a TDM system using PCM (pulse code modulation) coding by interleaving data of various sample rates. But even with this large traffic load, the data rate is less than 1 Mbit/sec, and the state of the art allows data rates up to 10 Mbit/sec.

Table 1.
Typical Signals Accommodated by VIMS Concept

CLASSIFI-CATION	SIGNAL	INFORMATION BANDWIDTH	MULTIPLEXING METHOD
Video	Scan converter	40 MHz	Baseband or FDM
	Television	10 MHz	Baseband or FDM
	Radar	2-40 MHz	Baseband or FDM
	Sonar	20 kHz	Baseband or FDM
Analog	Audio	300-600 Hz	FDM or TDM
	Synchro	400 Hz	FDM or TDM
	High level	DC-100 Hz	TDM Baseband
	Low level	DC-100 Hz	TDM Baseband
Digital	Computer serial digital	to 200 Mbp/s	Baseband or FDM
	Vehicle control	DC-20 bp/s	TDM Baseband

Table 2.
Typical Signal Distribution for Aircraft Multiplexing

SIGNAL QUANTITY		BITS/SECOND
200	Analog, 5 Hz, 1% (250 S/S), 8-Bit Code	400,000
100	Analog, 10 S/S, 8-Bit code	8,000
400	Analog, 1 S/S, 8-Bit code	3,200
2450	Bilevel, 1 S/S, Discretes	2,450
1000	Bilevel, 5 S/S, Discretes	5,000
100	Serial-Digital, 16 Bit, 100 B/S	1,600
		420,250

Control of multiplexing

When transmitters and receivers are themselves time-shared, the sequence of operations becomes complex, and the majority of data on a bus is of no interest to each input or output terminal. Thus, each terminal need not store and maintain a program relating its operation to the total system operation. In this type of situation, a "command" form of operation is most feasible, A central master unit stores the entire program for a system or subsystem and issues coded commands addressed to particular terminals to direct the selected transmit-receive action.

It is possible to command the data exchange from a specific input terminal to a specific output terminal in a variety of ways, each suited to a particular situation. The most flexible operation is achieved by time-sharing both output and input terminals under the control of the master unit. The master unit can then allocate transmission time to specific output and input terminals. Within this TDM system the master unit operates in several modes, as commanded by programming.

In one mode, the master unit will "roll call" by transmitting a serial binary code addressing each input terminal in turn, or as required, directing it to transmit its data onto the common "party line" bus. The master unit itself then receives and processes the data.

In another mode, the master unit addresses output terminals, directing them to accept processed data from the master unit. In addition, the master unit can issue a command containing the addresses of both an input and an output terminal and thus command a block of data to be transmitted directly from the selected input to the selected output.

Data Conditioning

The low-speed data that forms the major portion of the signals handled by today's new multiplexed command and control systems has some characteristics that are quite different from the characteristics of the audio and video data that has in the past been the predominant signals carried in multiplexing links. Guidelines for handling the low-speed data are:

Analog data should be digitized in a PCM format to attain sensor accuracy of better than 5 percent and bilevel signal compatibility, as shown in **Fig. 3a.** EMI immunity in transmission is greatly enhanced and error-detecting and correcting codes become more feasible. (Due to the relatively high signal-to-noise ratio present in lossless systems, three bits of parity are adequate.)

Clock information should be integrated with the data for transmission on the party line. Using a self-clocking Manchester type, as indicated in **Fig. 3b,** is one way of doing this. This eliminates the necessity for separate and redundant clock lines and receiver hardware, and only one bus is needed.

Synchronizing preambles of at least three bit times must precede any transmission onto the party line, as shown in **Fig. 3c**. This allows space for an "invalid Manchester bit" plus a guard bit and guarantees word synchronization no matter what delays occur.

Lossless or lossy . . . which line is best?

The design of the party line itself requires a great deal of thought. The line should be immune to electro-magnetic interference, and it should allow terminals to be added or removed anywhere along its length, without disrupting its characteristics.

Basically, there are two line designs, lossless and lossy, each with its own advantages and disadvantages. The lossless approach uses a transmission line. As shown in **Fig. 4**, the terminals are placed across a line and the ends of the line are terminated in the characteristic impedance. The advantage of this arrangement is that the line will not be

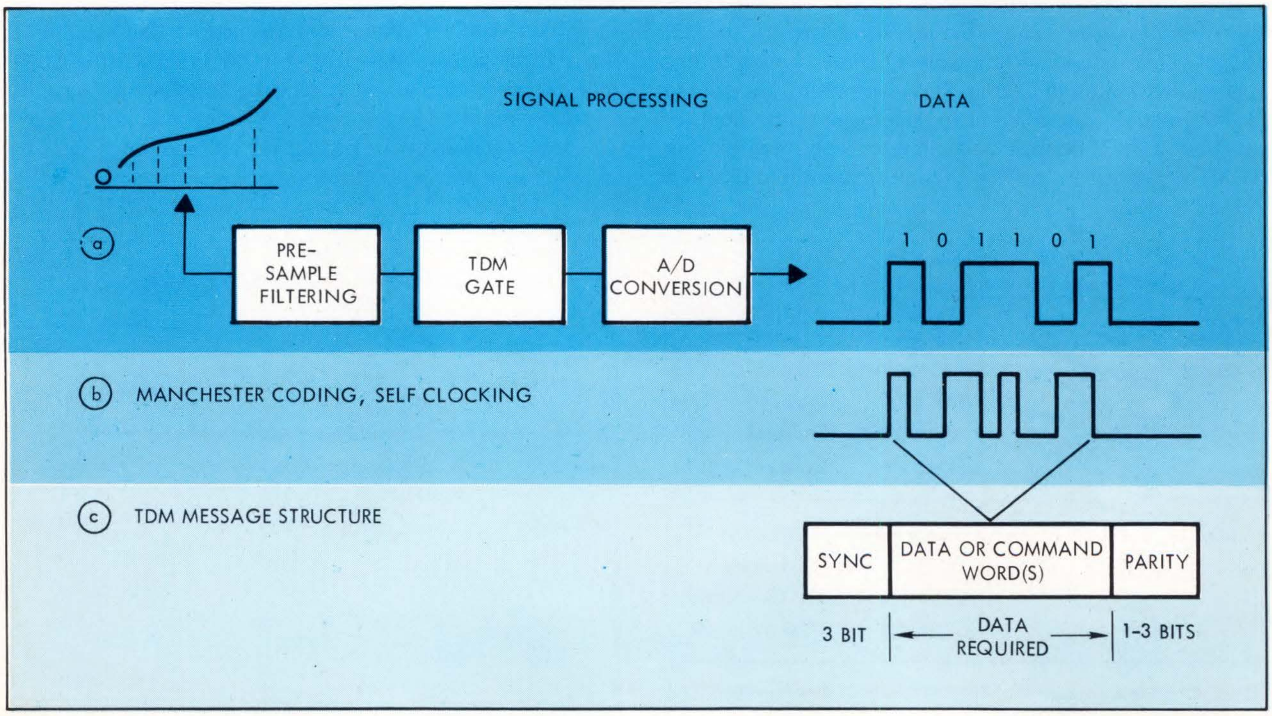


Fig. 3—Data signal conditioning amounts to taking both the digital and analog signals and reducing them to the standard message structure used on the multiplexing line. The signals should include both clocking and parity error checking.

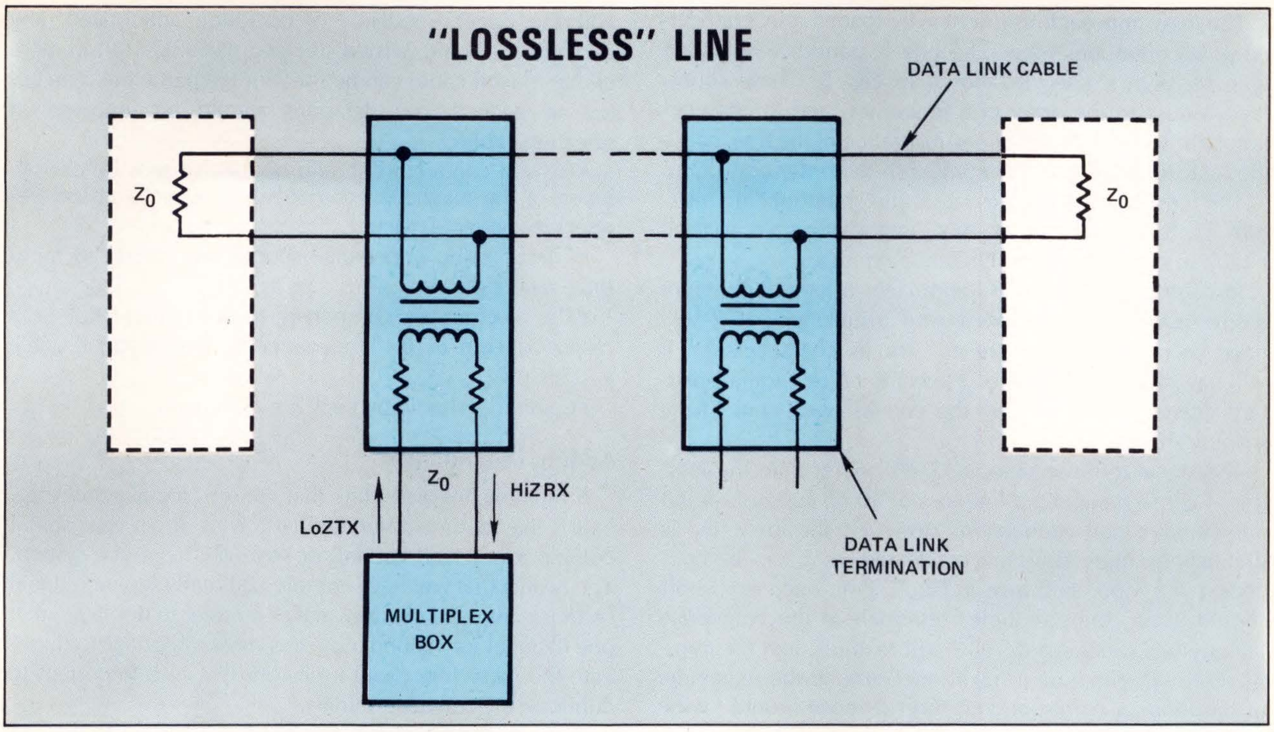


Fig. 4—The lossless line is a transmission line correctly terminated to avoid reflections. Terminals are kept at high impedance when they are in the receiving mode and are commanded to low impedance when they are to transmit a signal onto the line.

frequency sensitive and will have a minimum of pulse reflections. Further, as the losses down the line will be low, the signal-to-noise (s + n/n) can be close to optimum.

The multiplex terminals are kept at relatively high impedance when they are in the receiving mode. Then, when one of the terminals is commanded to transmit, it can do so at a low impedance without disturbing the line's characteristics.

Lossless systems are easily expanded after installation by simply adding cable, and the transmission distance is limited only by the inherent cable distortion at the frequency of operation. Additional FDM signals to accommodate audio and video can be stacked above the TDM baseband. Voice commentary can be superimposed over the basic low-frequency control signals in this manner. The lossless method is generally the most flexible approach for most applications, but it is vulnerable to cable damage.

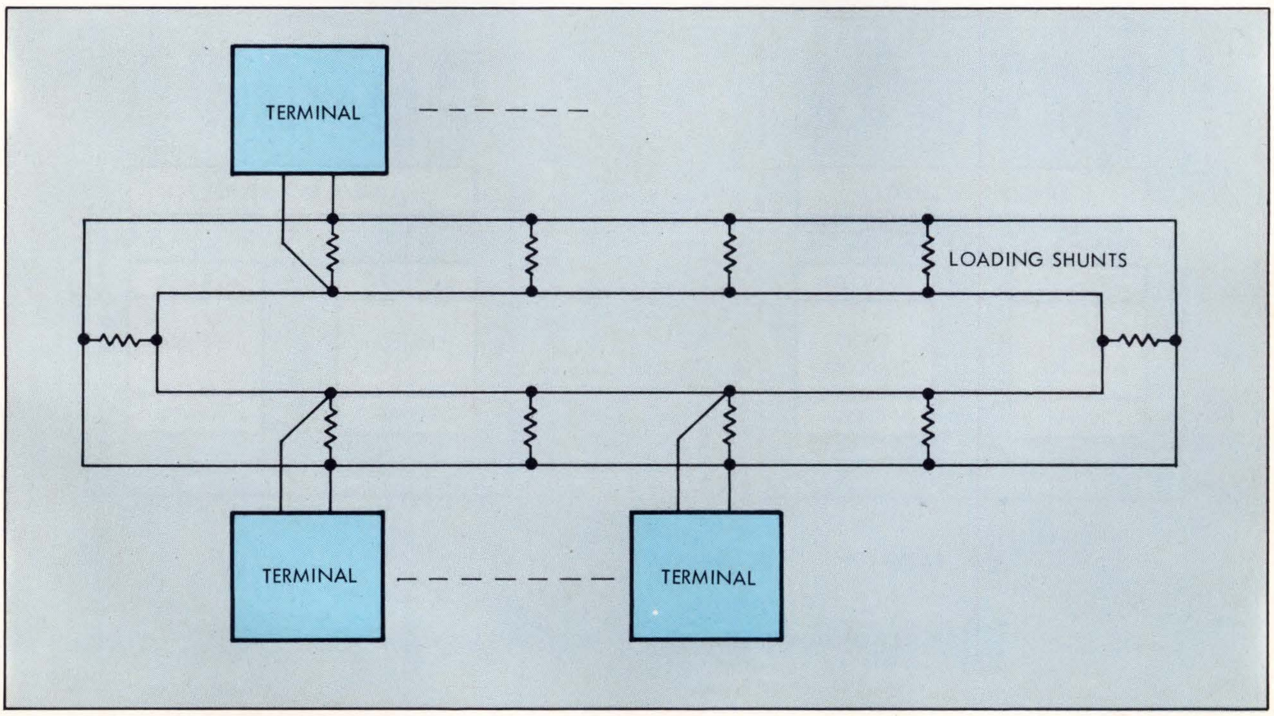


Fig. 5—The lossy line is purposely loaded with low-value resistive shunts so that there is a 40 dB loss down the signal path. It has a much poorer signal-to-noise ratio than the lossless line, but if connected as a loop, as shown, it can survive damage.

The lossy approach uses a heavily-loaded line, connected as a continuous loop. The line is periodically loaded with resistive shunts, as shown in **Fig. 5**. These shunts have values in the order of a few ohms, and in conjunction with the distributed series resistance of the line, cause the total signal path to have a loss in the order of 40 DB.

The terminals are placed across the shunt loading resistors. Each receiver has an AGC (automatic gain control) circuit to compensate for different path losses.

In contrast to the lossless approach, a lossy loop is not easily modified or expanded after installation, as it will have been individually "tuned" for its characteristics. It will have been designed for a specific pulse width, repetition rate and path loss by the careful placement of the loading shunts.

The signal-to-noise ratio is 17 dB poorer than the lossless system—assuming a line loss of 40 dB because of the intentional signal attenuation. However, the lossy line is significantly more resistant to damage, as it can be connected in a loop, as shown in **Fig. 5**. If an open or a short should occur, only multiplex terminals in the immediate vicinity will be affected. AGC will readjust, and the transmission will continue to take place around the remainder of the loop. A corresponding short or open would "wipe out" a lossless line.

Design details for lines

Depending on the length anticipated for the distribution and the upper frequency of operation anticipated, any cable from simple twisted shielded pair (RG-108) to more exotic triaxial cable can be used for the party line. The following general considerations should be followed in selecting cables.

•Twisted conductors should be used to provide cancellation of the magnetic components of EMI baseband frequencies under 20 MHz.

•Characteristic impedance should be uniform to minimize reflections.

•The electrostatic component of EMI should not be a major concern as the impedance of any practical cable will be low.

•Cable loss should be kept at a minimum.

Adding redundancy

A multiplexing party line that carries critical system signals is like the nerve bundle that travels down your spinal column. Cut it and you kill or seriously maim the system. Yet the fact that you have compressed many separate signal channels into one channel makes it easier to duplicate that one channel for redundancy. It is most important to duplicate the party line cable itself, but it is also important to duplicate the critical terminals.

Because of the weight saving with multiplexing in large complex systems, it is often possible to have four duplicate party lines and still have a lighter, simpler system than with

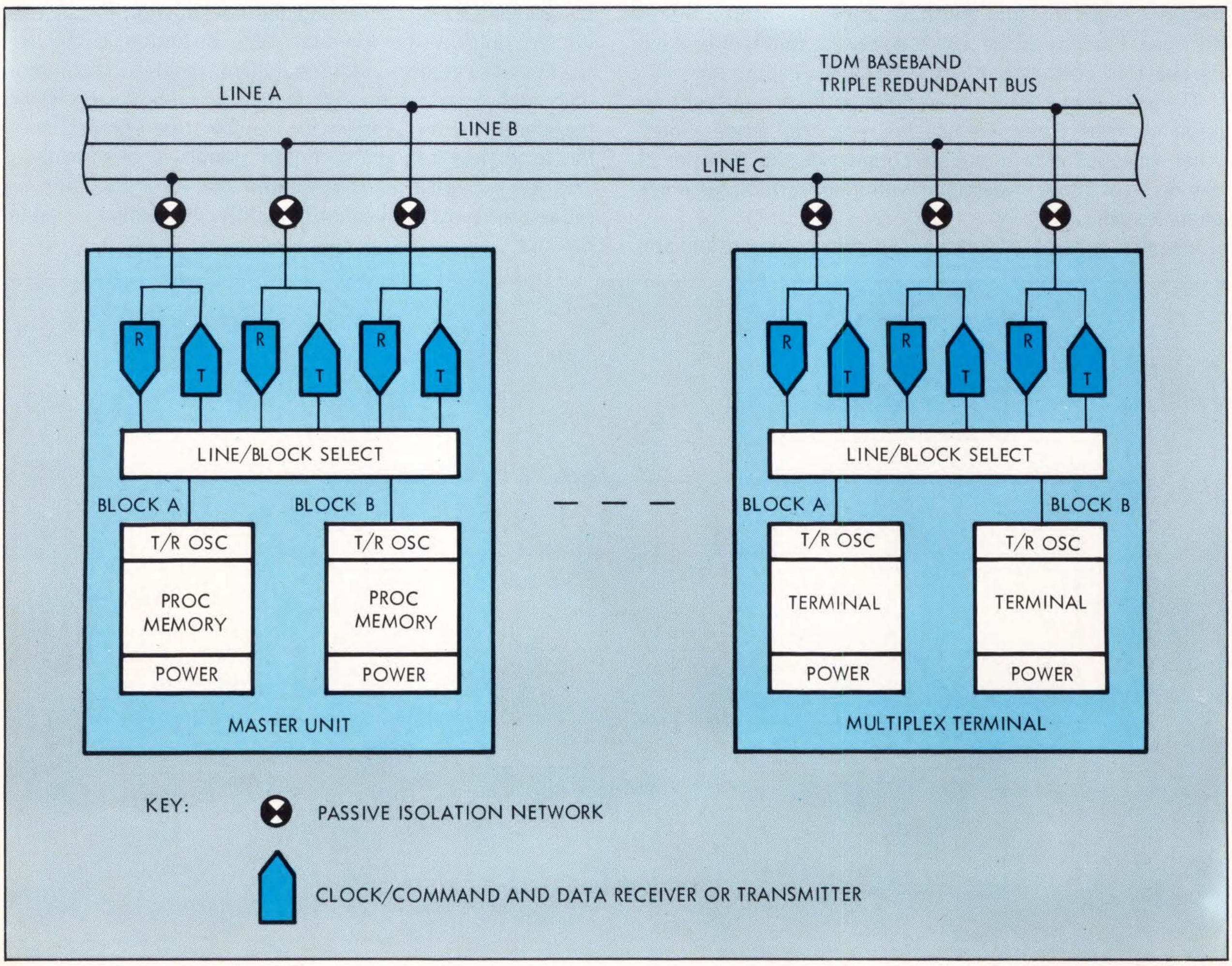


Fig. 6—Redundancy removes much of the risk of entrusting many vital signals to a single multiplexed party line. Here triple redundancy is used on the lines and dual redundancy is used on the terminals.

A First Example

The first application of these "vital-signal" multiplexing principles that the author knows of is on the B-1 strategic bomber being built for the Air Force by North American Rockwell Corp. About one quarter of the B1's primary system controls are multiplexed. The port-side half of the B-1 multiplexing system is shown in **Fig. 1.** The system has the reserve capacity to be expanded to handle 13,000 signals.

The system is a complete data-handling communications network in itself. It has a respectable amount of computing ability. Because much of the system direction is concentrated in master control boxes, it is relatively simple to modify the system after installation. The control is sequenced by a programable-type read-only memory (PROM), and the changes can be implemented by entering new programs into a new set of PROMs and plugging these into the master control boxes.

Computations predict that the following savings will come from this multiplexing:

Weight saved	1550 lbs.
Wire saved	206,000 ft.
Volume saved	15%
Maintenance saved	1/5th frequency of corrective maint.

Because the B1 is a "man-rated" weapon system and ought to have "survivability" despite battle damage, extensive redundancy is used throughout the system. The fault protection is a safeguard against both battle damage and equipment failure. The protection is designed into the system at two levels—overall system, and individual boxes.

Two separate master control boxes are used in each section. Parity is checked on each acting and standby unit on a continuous basis, and any error will bring the standby unit into operation automatically. The two redundant party-line cables used in each side of the system (like the port side shown in **Fig. 1**) are short circuit isolated from the individual terminal boxes, and therefore, either one of them will keep the total system in operation without degradation. The master control boxes and their power supplies are redundant, to be consistent with the party-line redundancy. Part of their programming is to give the system an automatic check every 30 msec.

The individual input and output terminals are not themselves redundant but are isolated so that no component failure can affect another channel. Inputs and outputs can, however, be commanded to operate as parallel redundant channels.

previous individual lines. Usually, however, you don't have to go beyond duplicate lines to gain a sufficient increase in reliability because of the inherent "leverage" of redundancy.

The terminals along the line are less critical because they only affect their particular functions, not the entire system. Therefore, it is usually adequate just to double up on them. However, it may be desirable to have triple redundancy for the master unit, as it can affect the whole system.

Fig. 6 shows triple redundancy on the lines and dual redundancy on the terminals (one of which is the master unit). The redundant elements have been isolated with the passive networks indicated by x'd circles. These isolators prevent the failure of any transmission bus or terminal assembly from spreading through the rest of the system. Each of the transmission lines, A, B, C, carries the same data, and each terminal is allowed to select the best line of the three. If two of the lines are shorted, the terminals will individually seek the remaining line.

With this level of redundancy, the failure rates for a 64-terminal system having the complexity of **Table-2** will be:

- Mean time between single functional failure . . . 3000 hr
- Mean time between total functional failure . . . . . . 10^8 hr
- Mean time between loss of a multiplex terminal . . . . 187,000 hr

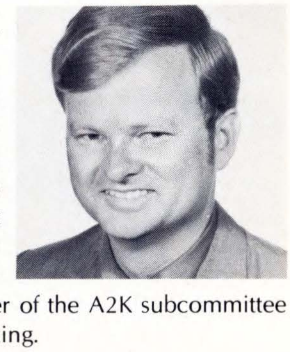
These failure rates assume that system checkout and repair will be made every six hours. Because of the standardized concentrated nature of such a multiplexing system, these regular system checks are easier to make than if maintenance personnel had to individually check all the separate systems in a non-multiplexed system.

The periodic maintenance checks can be augmented by a built-in, self-check capability to validate that proper data transfers are being made. Test data can be sent down the line and back to see if the system alters it. This self-checking will also be on a time-share basis and can be used to control the redundant switching. It can be the basis for isolating faults during regular maintenance periods.

A feature that maintenance technicians will appreciate is that the self checks can point to the access panel behind which the trouble lies. The technicians can thus avoid the time-consuming effort of removing unnecessary access panels.

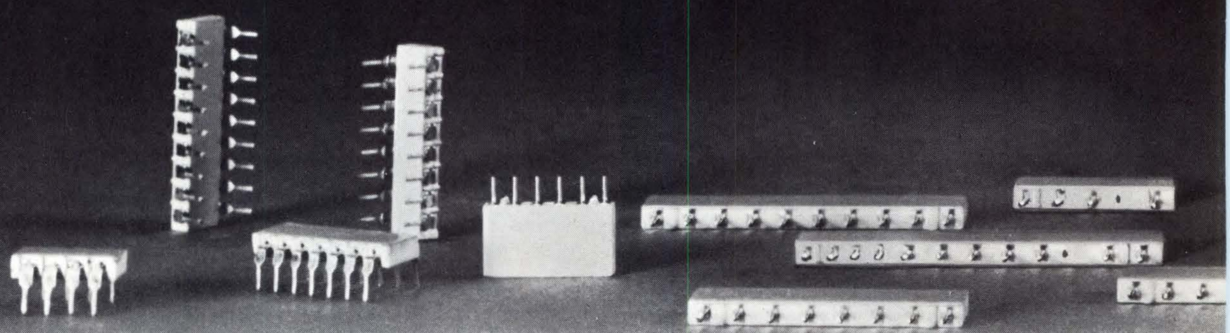
Redundancy can also be a means for reducing vulnerability. The three cables of the system of **Fig. 6** can be spaced at 120-degree intervals around the hull of the ship (or given different routes around an industrial process control plant) so that it is unlikely that enemy firepower (or plant fires) can simultaneously damage all three. ▭

Author's biography



Jack Ohlhaber is with the Systems Management Group of Radiation Systems Division's Aerospace Operations. His background is in circuit design, systems analysis, and program management; and he is the originator of the present VIMS Program. Mr. Ohlhaber holds a BSEE from the University of Florida and is a member of the A2K subcommittee of the SAE on aircraft multiplexing.

CTS *has the answer in*



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DIGITAL CARTRIDGES . . . New steps in many right directions

Digital cassettes spotlighted the need for mini-mass-memories. Now digital cartridges try to solve the need better.

Robert H. Cushman, New York Editor

No one who examines the never-ceasing flood of small data systems being announced for communication, business, retailing, ecology, automation, etc., can fail to see that the weakest link in many of these systems is the mass memory. Progress in minicomputers has produced excellent core and semiconductor "main-frame" memories with capacities at the kilobyte level; what is sorely needed are economical, reasonably high-performance memories approaching the megabyte level.

The digital cassettes surveyed in a previous article (EDN/EEE Feb 1, p. 28), are acceptable answers for the low-performance data-capture and program-entry applications, but they mostly do not have high enough data access and transfer rates to work on-line with modern minicomputers. Large 10-1/2-in. open-reel magtape memories and large discs have more nearly acceptable data rates but they are bulky and typically cost more than most minicomputers, so are sized and priced out of the picture.

It is obvious that some form of mini-mass-memory is needed. It should combine the convenience and low cost of a digital cassette and the performance of a large open-reel drive. This need is inspiring a growing number of design groups to create new cartridge systems.

There is a great deal of rivalry between the developers of Philips cassette systems and the developers of unique cartridge systems (the term cartridge will be arbitrarily used to describe a tape container that is not a Philips cassette). The backers of cartridges say that trying to upgrade the Philips audio cassette (it was only intended for 1-7/8 ips playing speeds) is trying to make a silk purse out of a sow's ear.

About the only thing they all agree upon is that for the foreseeable future only some form of "moving magnetic medium" technology will answer the need. Other schemes such as laser-beam read-writing of optically-sensitive surfaces are still some years off.

We'll examine the features of four of these linear-motion cartridges and then take a brief look at a promising new disc cartridge. We'll cover:

1 – The jumbo cassette proposed by IBM.
2 – The very high-tape-speed cartridge by 3M.
3 – A "practical and conservative" cartridge by Digitronics.
4 – A "one-reel" cartridge by Cogar.
5 – A six inch disc cartridge by Iomec.

Our list isn't complete – there is no example of an endless-loop cartridge – but it is complete enough to permit us to show the diversity of possible approaches.

Before getting to the specific configurations, let's look at what the designers have had to work with. **Fig. 1** shows the four main elements that any moving-magnetic-medium memory must have in one form or another:

A) long track (or tracks) of magnetic memory film properly supported by some stronger film and wound or looped around for manageable, compact storage and handling.

B) mechanics for providing the relative motion between

EXAMPLES IN STORY	A) TAPE STORAGE			B) MECHANICAL MOTION					C) SIGNAL COMMUNICATION				D) UNIT CONTROL
	Tape	Reels		Tape Guidance		Tape Advance			XDCR	Amplifiers(s)		For-mating	Accept External Commands and Sequence Elements to Obey.
		Supply	Take-up	Lateral	To Head	Hubs	Capstan	Motor(s)	Head	Read	Write		
1 -IBM													
2 -3M													
3 -Digitronics													
4 -Cogar													

Shading shows what portion of elements are removable as part of cartridge modules

Fig. 1 – **Where the system is split.** All "moving-magnetic-medium" memory systems have the same basic elements: (A) tape storage, (B) mechanical motion, (C) signal communication and (D) unit control. Where they differ is in the line of demarcation between the elements that come and go with the tapes, and the elements that remain behind with the transport. The shaded bars show what comes and goes with the tapes in the four examples discussed in the text.

the magnetic memory medium and a transducer that permits communication with the main electronic system.

C) transducing, amplification and formating circuits that permits two-way communication between the magnetic medium and the main electronic system.

D) system control that synchronizes the first three elements (A, B and C) with each other, allowing locations of the large-capacity memory to be rapidly and selectively addressed, and read or written upon.

The pivotal question in designing a cartridge system is: How much do you put in the cartridge and how much do you leave behind on the deck or transport? Of course you want to have the tape separable from the cartridge as it is the open-ended modularity that makes this form of memory so very, very attractive. It has infinite add-on capacity and you can store chunks of the memory off the machine for later re-reading on this or another transport if you so desire. At the transport end of the system, you obviously wouldn't want to duplicate the cost and bulk of the master control system (D) on each cartridge, nor the electronic data signal interface (C). While you might want to incorporate some of the motion guidance of (B) into the cassette, it is unlikely that you would want to add the bulk and expense of a drive motor to each cassette.

So it can be seen that the main system-partitioning variations will occur at the juncture of elements (A) and (B). Cogar's transport incorporates the bare minimum into the removable cartridge—just one of the two reels. 3M's transport goes the other way and incorporates enough mechanism and structure in its cartridges that they are practically complete decks in themselves. The different partitioning choices and reasons for them will become more apparent as we discuss each of these examples.

1—IBM proposal

The IBM "suggestion" to the ANSI standards group on cassettes (document X3B1/500 by Jack Heermans of IBM's system development division, Boulder, Colorado) describes a cartridge that looks like a scaled-up version of the Philips cassette (**Fig. 2**). It uses a 1/4-in. wide tape rather than the 0.15-in. wide tape of the Philips. The IBM document proposed that this cartridge be operated at 1,600 bpi density, phase encoded, and at a 50 ips speed. There could be up to four tracks on the 1/4-in. tape which means that, if desired, a full half-byte of ASCII code could be recorded in parallel across the tape. At 50 ips, this would permit data transfer rates of 40,000 characters per second.

The IBM proposal caused quite a stir among the cassette and cartridge manufacturers during 1971 because they feared that it would again be a matter of big, dominant, IBM forcing a "de facto" standard on the data industry. Many reasoned that if IBM followed up this "suggestion" with a product, that cassettes and other cartridges would automatically be frozen out of the upper, computer portion of the market. IBM itself has not said what it intends to do, but rumor has it that IBM is looking instead to small discs.

Meanwhile, one company at least, Wang Computer Products, Inc., Santa Monica, Calif., has taken IBM's suggestion seriously and has announced a cartridge system based on IBM's outline which they showed at the FJCC at Las Vegas. The Wang unit has, at present, one large single track on the 1/4-in. tape and uses the 50-ips speed for read, write and search. The tape length is 350 ft.

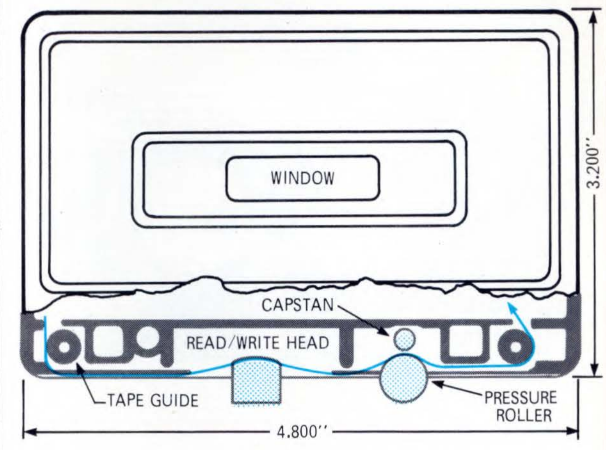


Fig. 2—**The IBM jumbo cassette proposal** that threw the mini-tape industry into a panic for awhile. It looks like a scaled-up Philips cassette that substitutes 1/4-in wide tape for the 0.15-in wide tape used in cassettes. But IBM took pains to specify features that make it more suitable for digital applications.

2—3M's fast cartridge

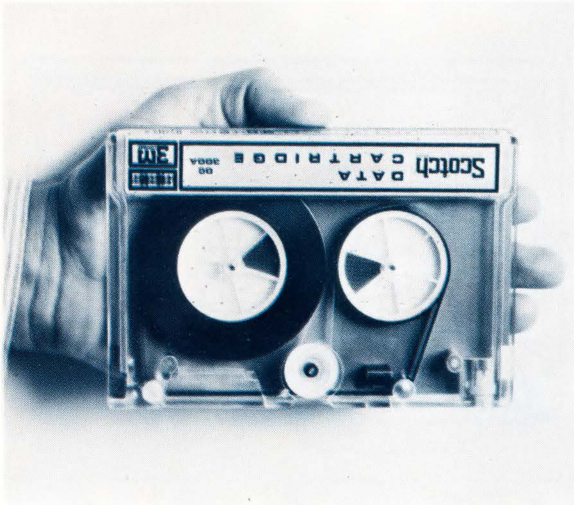
The 3M cartridge looks promising for high performance applications. The cartridge is almost a complete little recorder in itself. It carries everything but the motor, the head and the electronics (**Fig. 3**). 3M says this is possible at reasonable cost because the usual capstan has been replaced with a novel "belt-and-pulley" reel drive. An elastic band inside the cartridge encircles part of the flangless tape reels in such a way that the band moves the tape and also keeps it in tension.

Therefore, it is only necessary to stick in a motor shaft with a rubber friction wheel to move this band and all tape motions will be taken care of. Electronic communication with the tape is achieved by sticking in a tape head through another opening (these openings are provided with flap doors to keep out dust when the cartridge isn't on the transport). The band keeps the tape wrapped in tension across the head face so no pressure pads are needed.

This drive is apparently able to move the tape at very high speeds. 3M is specifying 90 ips for read-write and 180 ips for search. This compares favorably with large open-reel decks. 3M claims it is also very reliable for their life tests have reached 10,000 passes without failure.

3M plans to sell these cartridges under its "Scotch" label and is encouraging others to make suitable transports. 3M itself will be offering a transport for $250. The price of the transport need not be high, 3M says, as only a piece of sheet metal and a motor are needed on the mechanical side. But it would seem that to get the high-speed motion they speak of, with the 20 msec start accelerations they claim, would demand a fairly powerful, high-performance DC servo motor.

The cartridges themselves will sell for between $8 and $10, says 3M. They can't be down at the $4 level of cas-



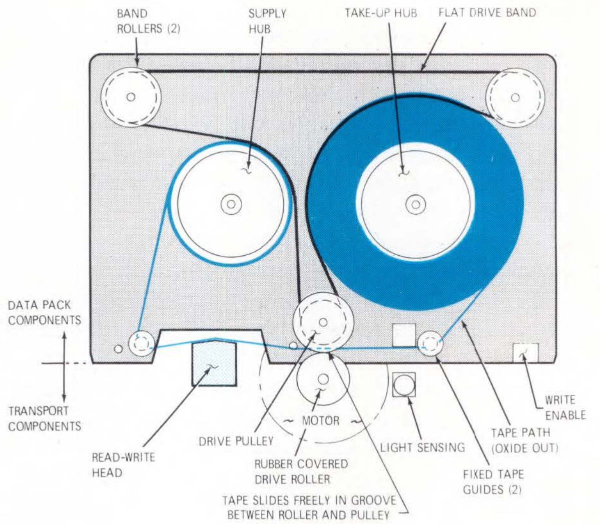


Fig. 3 — **The 3M cartridge** that can really move tape at high speeds. 3M says their unusual drive-band arrangement will permit reliable read/write operation at 90 ips and searching at 180 ips! Note that it is practically a complete mechanical deck

settes because the bottom plate must form a precision chassis to carry the moving parts, and therefore must be of metal. But 3M believes this will be no deterrent because their system with its higher data packing densities — 1,600 bpi phase encoded, and four tracks — will have eight times as much storage capacity as cassettes. It should also, because of its speed, have data transfer rates almost as good as large open-reel systems.

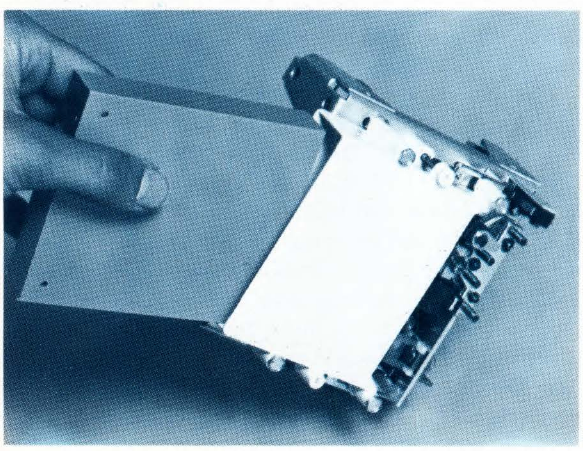
3 — Digitronics' conservative cartridge

Digitronics, Albertson, N.Y., has further perfected a rugged little cartridge that was originally developed by Novar. About 5,000 of these machines have been out in the field in the Novar typewriter terminals. Digitronics has reduced the size and weight of the already compact little units by replacing the single ac motor used by Novar with a tiny dc motor.

It's ironic that Digitronics, which is related to Philips of Holland — the originator of cassettes — by virtue of being part of North American Philips, has chosen to go the cartridge route. But Digitronics believes that the mushrooming "grass- roots" data-entry market needs something that is easier to use than a cassette. "The customer can sock our cartridges in place like he puts a slice of bread into a toaster," brags Digitronics. "Most of the cassettes have to be loaded in two motions. One to slide the cassette into a hinged frame, and another to swing the frame down onto the deck."

The key feature that Digitronics says makes its cartridge so easy to use is the coiled spring between the two co-axially mounted (rather than co-planar as in most other systems) tape reels (**Fig. 4**). This coil pre-loads the reels so they play tug-of-war on the tape and keep it in tension. This tension holds the tape "wrapped" against the head when the cartridge is in place and holds the tape securely in the cartridge when the cartridge is off the transport.

The performance specifications for the Digitronics units are quite conservative as befits their remote terminal appli-



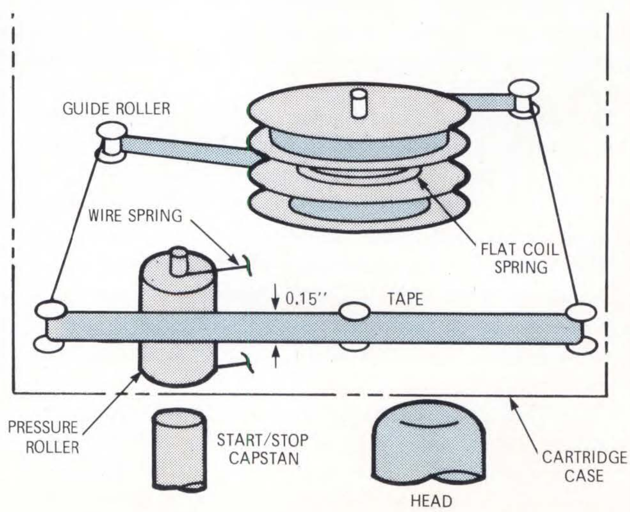
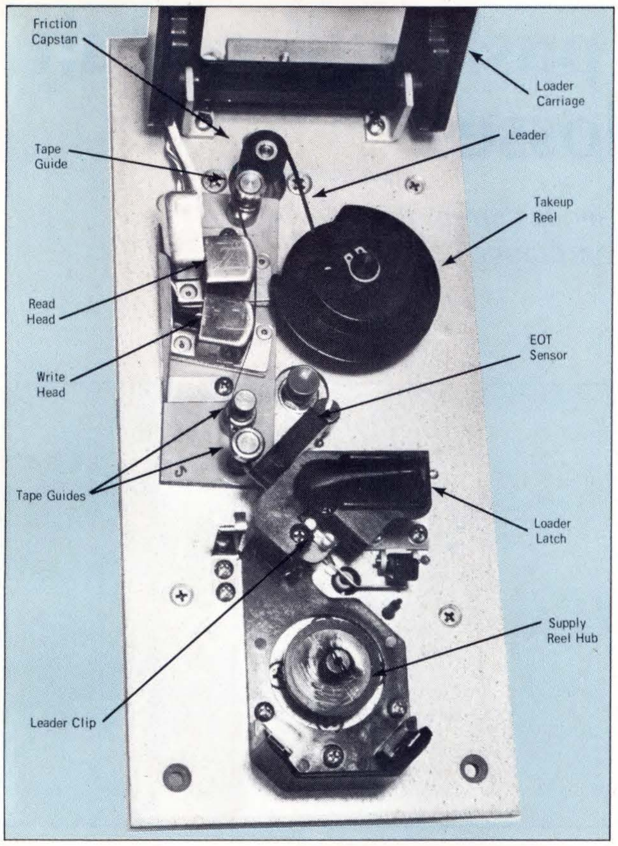


Fig. 4 — **Digitronics' foolproof cartridge.** Loading it is like "popping slices of bread into a toaster." A pre-loaded torsion spring coil between the two co-axial reels keeps the tape in tension.



cations. The forward speed is just 5 ips and the rewind just 10 ips. Data is put down at a modest 400 bpi (phase encoded) on one wide track on the 0.15-in. wide tape. If the user wants tighter packing density Digitronics will supply a more expensive read-after-write head and specify 800 bpi.

The price for these little transports is $225 in OEM quantities and the price for the cartridges $6. For applications where inexperienced personnel would be handling the tapes often, the Digitronics approach has merit.

4—Cogar's one-reel cartridge

Cogar's transport for 0.15 in wide tape represents the opposite extreme in system partitioning. As little as possible leaves with the tape: only the supply reel. Cogar is able to do this because they have developed an automatic means for coupling the end of the tape to a leader that then pulls the tape onto the take-up reel that is permanently on the transport (**Fig. 5**). There is a small loop in the end of the tape coming out of the cartridge and when the operator pushes down the carriage that lowers the cartridge in place, this loop is lowered over a tiny plastic pin at the end of the leader. The guide path groove ensures that the pin will be in the right "home" position to receive the tape loop and small interlock switches and fingers mechanically ensure that the tape and leader ends won't get misplaced.

The mechanism looks a bit tricky but Cogar has 600 units out in the field, some of which have been operating for 12,000 hours.

One advantage that comes from putting so little in the cartridges is that the price of the cartridge can be lower than other approaches, even cassettes. Cogar can sell these little heart-shaped cartridges for just $2.40. The

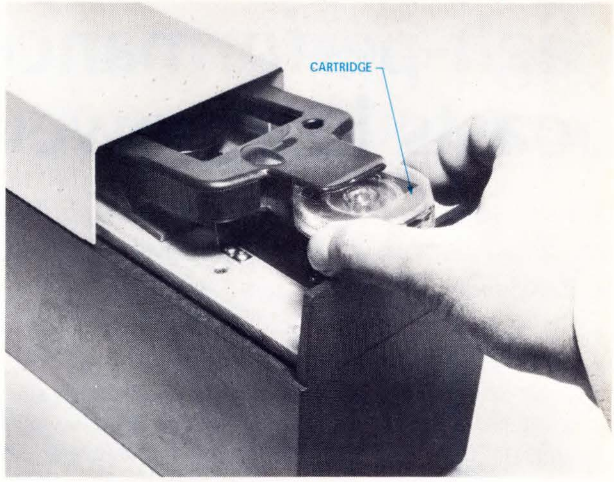


Fig. 5—**Cogar's little heart-shaped cartridge** contains just one of the tape reels. A tricky threading system automatically pulls the tape to the take-up reel that is permanently on the transport. (See photo at left)

decks sell for $290. Both prices are for OEM quantities of course.

But there is another advantage. Because the tape comes all the way out of the cartridge, Cogar is free to use any tape path it desires. They have elected to follow the practice used in many of the large transports where the oxide side of the tape only touches the tape heads and the drive is from a single capstan that contacts the back side of the tape.

The motion specifications are 10 ips for read and write and 40 ips for search. The packing density specifications are 1,600 bpi, phase encoded.

This is just the beginning

The current rate of innovation in both the cassette and cartridge field indicates that we have not yet seen the end of innovation. One exciting new contender for the higher-performance end of this market is a flying disc drive by Iomec. This roughly $1000 transport rotates a 2-mil, 7-in dia., mylar "floppy" disc at 1800 rpm. There are 64 tracks packed at 3,300 bpi NRZI on the outer edge of this disc which are read by one head that rides 80 μin. above the flying disc. Because the head never touches the disc, there is no wear and it never needs to be cleaned.

This disc system does not have quite the capacity of the cassette and cartridge systems but it does have a phenomenal 1.2 Mbit/sec data transfer rate. That's as good as most large IBM-compatible open reel stations! The disc are housed in easily loaded and unloaded cartridges that sell for $12 to $18. ▭

Manufacturers of Digital Cartridges and Transports

Including some additional companies that make cassettes and discs, marked "(Cas)" and "(Disc)."

3M Company (also Cas.)
300 South Lewis Rd.
Camirillo, Calif. 93010

Digitronics Corp.
One Albertson Ave.
Albertson, LI, NY 11507

Cogar Corp.
Cosby Manor Rd.
Utica, NY 13502

Iomec, Inc. (Disc)
345 Mathew St.
Santa Clara, Calif. 95050

Anderson Jacobson (Cas.)
1065 Morse Ave.
Sunnyvale, Calif. 94086

Mobark Instruments Corp. (Cas.)
1080 East Duane Ave. (Suite D)
Sunnyvale, Calif. 94086

Peripheral Dynamics Corp. (Cas.)
2133 West Chapman Ave.
Orange, Calif. 92668

Teac (% Teac Corp. of America) (Cas.)
7733 Telegraph Road
Montebello, Calif. 90640

FOR A FREE COPY OF THIS ARTICLE, **CIRCLE L62**

High-performance push-pull circuit boasts low power-losses

Careful selection of components can eliminate series current flow during the transition period, and reduce power consumption dramatically.

M. P. Xylander, IBM Corporation, N.Y.

This high-performance push-pull circuit is particularly suited to integrated circuit applications. It provides a low output impedance at both the high and low output levels, and automatically prohibits series current flow during voltage transition from one level to the other. Furthermore, it has only one resistor—an important consideration if you are designing it into an IC, and it boasts high performance characteristics, because the "dead" area is much less than that found in other push-pull circuits.

The basic circuit is shown in **Fig. 1**. When Q_1 is saturated, the emitter-to-collector voltage is typically 0.1V, making the collector voltage of Q_1 approximately 0.1V. Similarly, Q_2 also becomes saturated and has a typical emitter-to-collector voltage of 0.1V, making the collector voltage of Q_2 approximately 0.2V (the output voltage).

Since Q_2 and Q_3 have exactly the same base voltage, but Q_3 has an emitter voltage that is about 0.1V higher than that of Q_2, Q_3 is cut-off, or at least has greatly dimin-

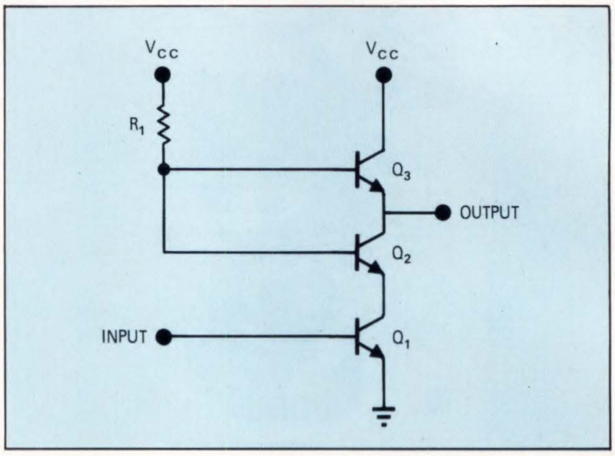


Fig. 1—Q_3 and Q_2 cannot conduct at the same time if they are selected so that VBE_{Q3} is equal to or greater than VBE_{Q2}.

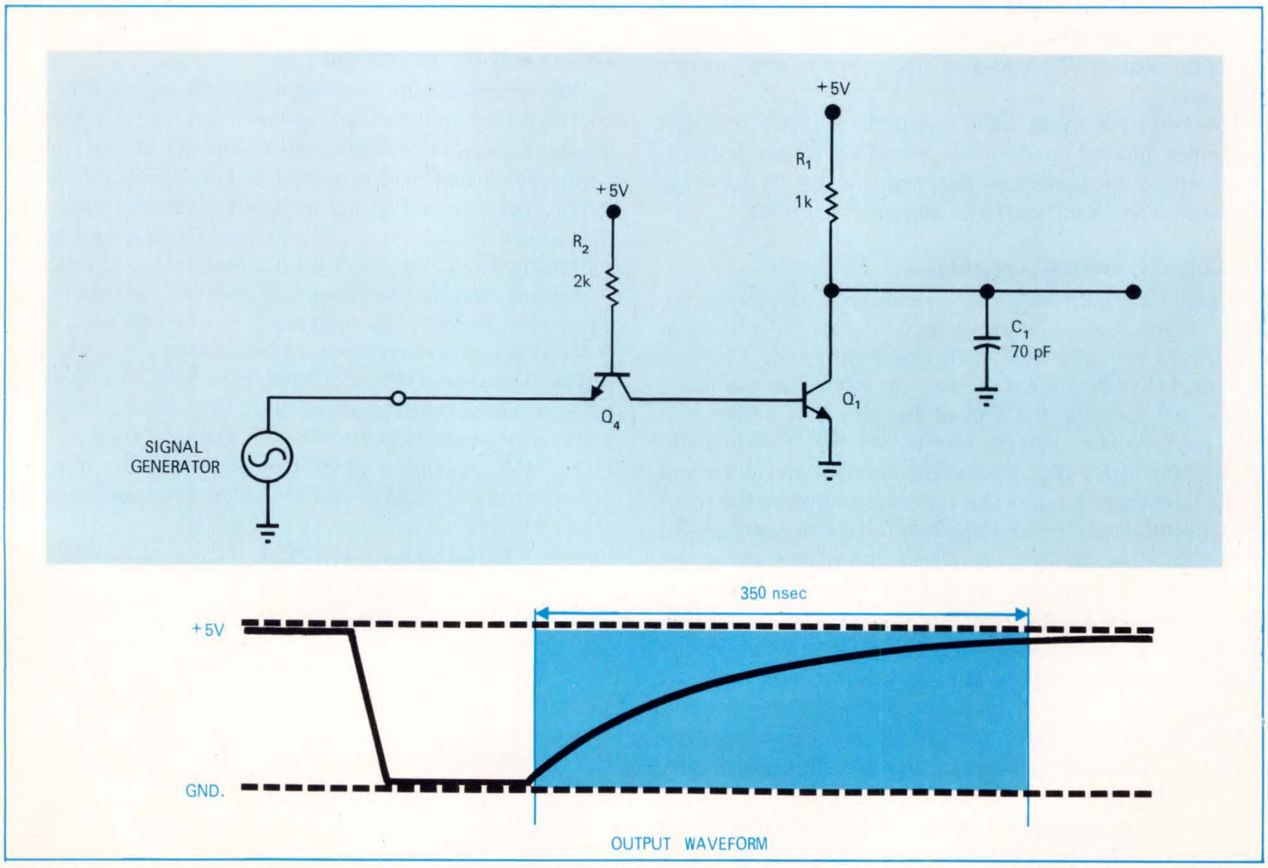


Fig. 2—This inverter circuit, driving a 70-pF, load serves as a standard for performance comparison. Rise time is a function of the R_1C_1 time constant of 70 nsec.

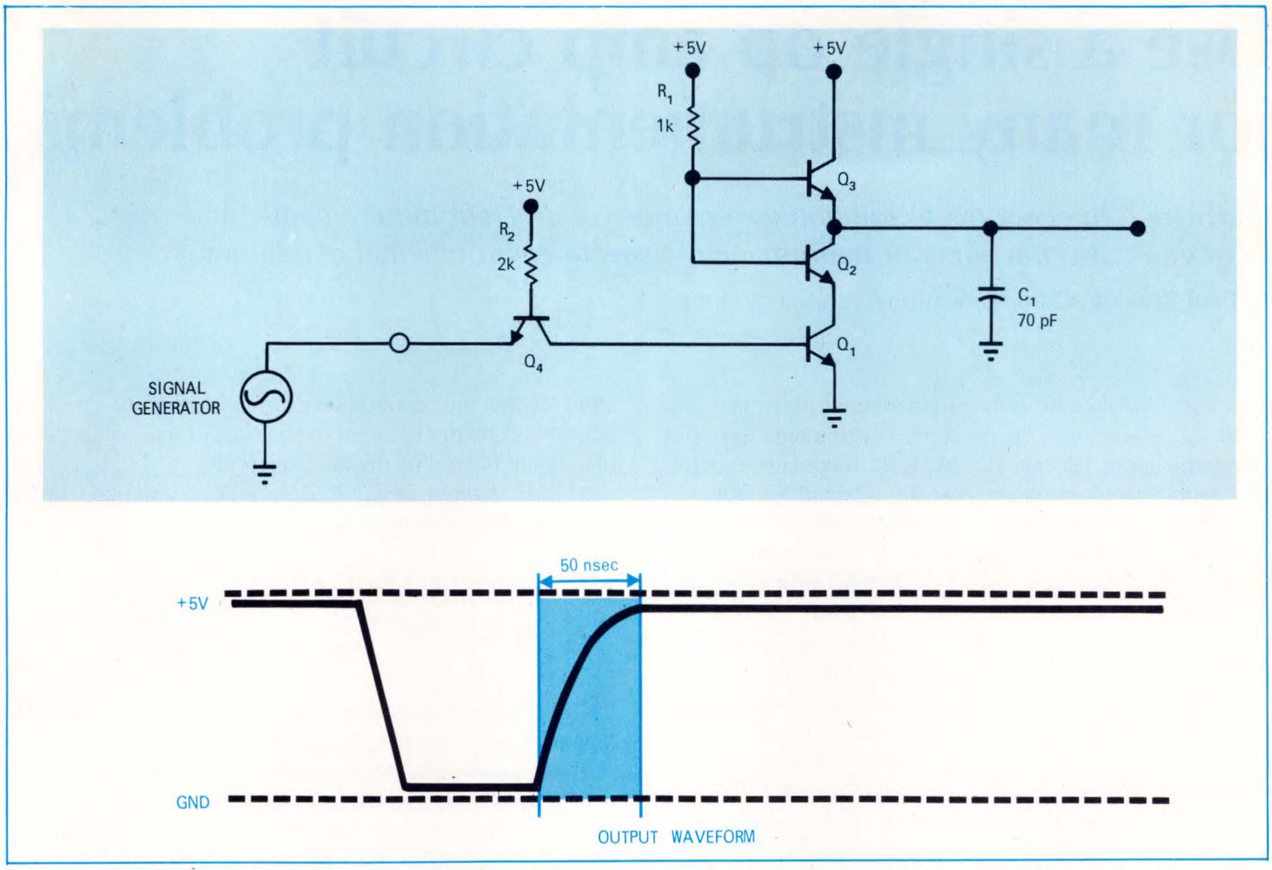


Fig. 3—When the push-pull circuit of Fig. 1 is added to the inverter of **Fig. 2**, rise time is significantly improved since Q_3, not R_1, supplies current to the load capacitance.

ished current flow. This action prevents any significant amount of series current from flowing from V_{cc} through Q_3, Q_2 and Q_1 to ground, because Q_3 cannot support a substantial current as long as there is some voltage drop across Q_2. Either Q_3 or Q_2 conducts, but never both.

When Q_1 is cut-off, it automatically denies current flow through Q_2 because they are in series. Under this condition, R_1 begins to pull the base of Q_3 toward V_{cc} and Q_3 acts as an emitter follower. The output voltage follows the base voltage of Q_3 (offset by V_{be} of Q_3), and provides a low output impedance in the high output level.

During the transition, there is a time called the "dead area," in which neither Q_2 nor Q_3 can conduct. This time occurs when the base of Q_3 goes from its most negative level to the point at which the base-emitter of Q_3 becomes sufficiently forward biased to conduct. This voltage range is only about 0.1V as compared to the 0.7V, typically, of other well-known push-pull circuits. The result is a faster switching time.

Two conditions must be met in order to achieve optimum performance from the circuit: first, in order to prevent significant current from flowing from V_{cc} through Q_3, Q_2 and Q_1 to ground, the base-emitter voltage drop of Q_2 should be equal to or less than that of Q_3. And second, in order to prevent base robbing, the base-collector voltage drop of Q_2 should be kept greater than the base-emitter voltage drop of Q_3. Otherwise, the base current from R_1 that is intended for Q_3 will be robbed by the base-collector of Q_2. A good rule-of-thumb is that Q_2 should not be allowed to rob more than ten percent of the current supplied by R_1.

These conditions can be achieved by choosing the proper device geometry. Monolithic integrated circuits can best take advantage of this circuit because device design is done at the same time as circuit design. The simple inverter shown in **Fig. 2** was modeled to serve as a standard. Transistor Q_4 is merely an input control. A 70-pF lumped capacitance was chosen as a load. As you would expect, the rise time is based on a 70 nsec time constant.

The push-pull circuit in **Fig. 3** was modeled to serve as a comparison. Transistors Q_1 and Q_4 were the same components used in **Fig. 2**, but pull-up transistors (Q_2 and Q_3) were added. Under this condition the fall time and delay times were essentially identical to those from the previous model, but the rise time approximated a 10 nsec time constant—a significant improvement. For proper circuit functioning it is **essential** that transistors Q_2 and Q_3 meet the conditions discussed earlier; that is, that $VBE_{Q2} \leqslant VBE_{Q3} < VBC_{Q2}$. □

Author's biography

Mel Xylander is an advisory engineer at the IBM Components Division in Endicott, New York, where he has been employed for 17 years. He is the author of "Fundamentals of Reliable Circuit Design," published in three volumes by Transatlantic Arts. He has been granted 8 patents.

FOR A FREE COPY OF THIS ARTICLE, **CIRCLE L63**

Use a single op amp circuit for many instrumentation problems

It provides an economical solution to a number of different requirements. And this circuit also has superior performance in severe environmental conditions.

A. Paul Brokaw, Communication Technology, Inc.

Balanced modulation holds a fundamental place in many areas of electronics, particularly instrumentation and communications. A novel balanced modulator circuit, built with a single op amp, is easily adapted for use as a modulator, demodulator, operational rectifier or a lock-in amplifier. In addition to simplicity, it offers a number of other practical features—such as, elimination of errors due to slew rate limiting in operational rectifiers, both inputs and the output are single ended, and the averaged output level range can be increased by internal filtering.

After describing and analyzing the basic circuit, design rules for using the circuit are presented. The design procedure is simple and straightforward, and the resulting values are not critical unless exceptional performance is required. Then several modifications to the basic circuit are discussed as practical solutions to a number of routine instrumentation problems.

The basic circuit

The circuit, shown in generalized form in **Fig. 1** multiplies an input signal by plus or minus one and then by H(s), a frequency selective gain function. The sign is selected by means of a control input. If the sign control input is reversed at each of the zero crossings of the signal input, a full wave rectified version of the input signal is produced.

If the sign control input is driven from a different source, it will modulate or demodulate the input signal. Since the effect of the sign control precedes the effect of H(s), the output will be the rectified or modulated input signal amplified and filtered by the H(s) function.

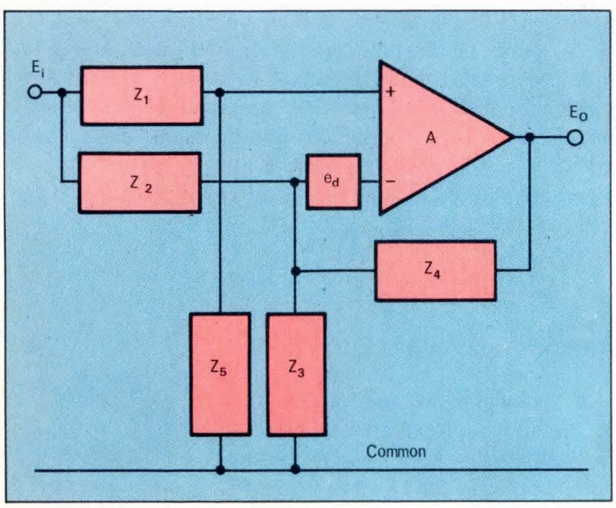


Fig. 1—The basic circuit is easily adapted for use as a modulator, demodulator, operational rectifier or a lock-in amplifier. Normally the transfer function is determined by Z_1, Z_2, Z_3 and Z_4, with the sign determined by a control input Z_5. e_d is the amplifier offset.

With H defined as Z_3, Z_4/Z_3, and Z_2 constrained to be the parallel combination of Z_3 and Z_4, then

$$E_o = \frac{E_i\left(\frac{Z_5}{Z_1 \neq Z_5}(2H) - H\right)}{1 \neq 2HA} - \frac{2H\, e_d}{1 \neq 2H/A}$$

where E is the output signal, E_1 is the input signal, A° is the amplifier gain, and e_d is the amplifier offset voltage.

The second term on the right is a fixed output offset term which is independent of input signal. Neglecting this term and making the "infinite-gain" assumption for A gives

$$\lim_{Z_5} \frac{E_o}{E_1} = +H \text{ and}$$
$$\lim_{Z_5} \frac{E_o}{E_1} = -H.$$

In other words, if Z_5 is replaced by a switch, the circuit becomes an amplifier with gain J or minus H, depending upon whether the switch is opened or closed.

Use a second op amp as a zero crossing detector

The same circuit can be used in variety of applications. **Fig. 2** shows a general purpose circuit built to illustrate a number of uses.

The μA 739C is an inexpensive dual op-amp which makes a simple and compact balanced modulator and zero-crossing detector. Nearly any dual op-amp can be used, however, the μA 739 is particularly well suited for use as a voltage comparator. When used without frequency compensation, it has a very high slew-rate and little delay time, whereas most of the very high performance op-amps are poor in those respects.

The portion of **Fig. 2** above the "common" line is the balanced modulator with the numerical subscripts for the components being the same as the respective generalized impedances in **Fig. 1**. Note that Q_5 is an inverted mode transistor switch replacing Z_5. The other half of the dual op-amp is used as a zero crossing detector which drives Q_5 through resistors R_6 and R_7.

Add a filter

Fig. 2 shows several optional components. Using these components modifies the gain H log approximately

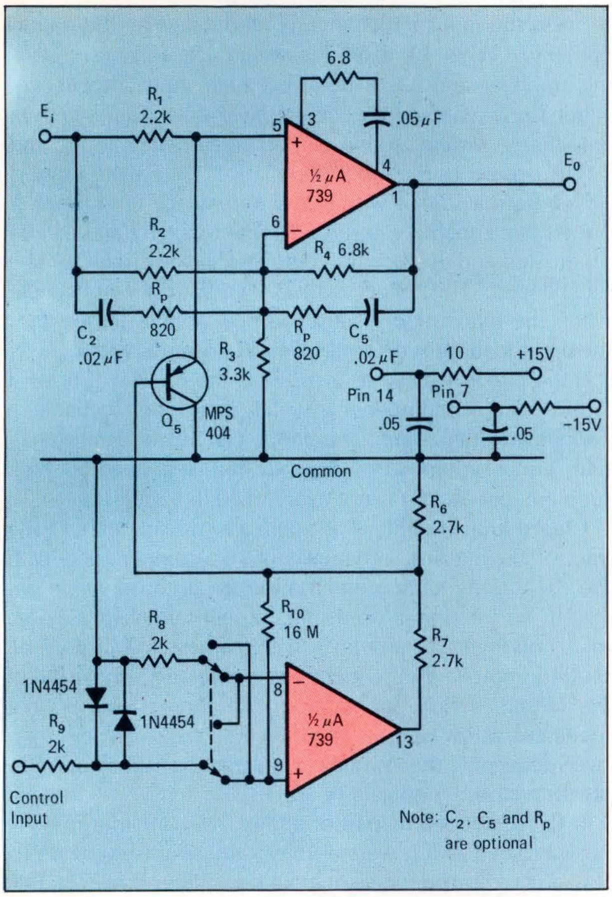


Fig. 2—Using an inexpensive dual IC op-amp makes a simple balanced modulator and zero-crossing detector. Q_5 is an inverted mode transistor replacing Z_5 of Fig. 1 and is driven by the zero-crossing detector (lower op-amp) through resistors R_6 and R_7. The optional components provide additional high-frequency filtering.

$(R_2C_2s + 1)/(R_4\ C_4s + 1)$. The response is a simple pole and zero combination which reduces the high frequency gain to unity.

When the circuit is used as a rectifier, for example, the average output voltage will be about 3 times the average of the full wave rectified input signal. The output ripple, however, is only as large as the input signal peaks. The overall effect is the same as if the input signal had been full-wave rectified, multiplied by three, and filtered to reduce the ripple by a factor of three. It is important to note that the effect of the filtering is in the output signal after rectification rather than on the input signal.

This sort of filtering can always be arranged so that the high frequency gain is reduced to unity. The amount of filtering is proportional to the low frequency gain of the circuit so that the gain should be made as large as practical where filtering is desired.

This filtering can be used to increase the useful output range of the circuit. For example, if the op-amp has a 10V minimum peak output capacity, it can reproduce a full wave rectified output signal of 10V peak which has an average of about 6.4V. By incorportaing the filter in the rectifier, however, signals approaching 10V average can be generated at the output. If the low frequency gain is set to 10, an input signal of 1.47V will produce an average output of 9.4V with a 1.47V peak-to-peak ripple. The overall peaks will be less than 10V. The available output signal level will have been increased by nearly 50 percent.

The resistors R_p have been added to prevent problems due to capacitive loading of the op-amp and of any driving stages. These resistors are small compared to R_2, and as a result their effect on the filter response may usually be neglected.

Using the capacitor values given in **Fig. 2** results in about 10 dB of filtering which occurs between 1.2 and 3 kHz. The amount of filtering is limited by the resistor ratio, but the frequency can be scaled up or down simply by inversely scaling the capacitor values.

The requirement for balanced operation is expressed by the requirement that the impedance of Z_3 and Z_4 in parallel equal the impedance of Z_2. This requirement is satisfied by using equal values for C_2 and C_4. If a capacitor of the same value paralleled R_3 instead of R_4, H would exhibit a high pass characteristic. The gain would rise at 6 dB/ octave from the low frequency level to a limit determined by the open loop gain of the amplifier (if the resistors R_p are omitted). This characteristic could conceivably be useful; however, it requires special care in selecting the op-amp and special closed loop stability compensation, since it introduces an additional pole in the amplifier open loop gain equations.

Design the circuit

Like most "universal" designs, the unit in **Fig. 2** is a compromise arrangement which provides moderate performance across the board without maximizing any parameter. The general configuration can be used by the designer to fit more demanding requirements. All consideration of the basic relationships within the circuit and the application of a few design rules make this a fairly straightforward process.

Off-set voltages

The derivation of the simplified gain equations neglected the amplifier offset voltage. This output error term depends on the amplifier input loading of this configuration; this result is twice the magnitude of the output error usually associated with a non-inverting amplifier with gain H. This error may be eliminated by using the offset trimming provisions available with many op-amps. Remember, however, that the temperature effect on output offset will be twice as large as in ordinary amplifier service.

A general method of correcting input offset is to inject a current into the non-inverting input node of the amplifier. A simple and usually convenient means for injecting this current is to offset R_3 by returning its lower end to a bias voltage instead of circuit common. This arrangement can also be used to produce a desired output offset. Such a controlled offset is frequently desired in lock-in amplifier applications where it is used as zero suppression.

A second source of output offset error is due to i_b, the amplifier input current. The output voltage offset due to input current is affected by the action of the chopper Q_5. Referring again to **Fig. 1**, when $Z_5 = 0$, the current into the non-inverting input does not develop a corresponding offset voltage. When $Z_5 \rightarrow \infty$, however, this current produces an offset which is proportional to R_1. This modulated offset voltage will, of course, be amplified and appear in the output signal. Since this signal alternates between 0 and $i_b\ R_1$ in synchronism with Q_5, the output offset has a low frequency value which is half the peak (if a symmetrical drive is assumed). This offset can be reduced by the same methods used to correct input voltage offset.

A more satisfactory method which will give better temperature performance requires that the input currents to the op-amp be approximately equal. The current into the inverting input will develop an offset voltage. If this current is also i_b, the offset will be $1/2\ i_b\ R_2$. If R_i is made equal to R_2, the average of the modulated offset at the non-inverting input will be equal to that at the inverting input. These two offsets will cancel each other in the output signal. For computational purposes, the input offset voltage due to input offset current will be given by the product of R_1 and the input offset current if $R_1 = R_2$. This result is similar to the usual input offset current error voltage. The difference being that the output signal will contain a small ac component proportional to the absolute input current.

The transistor chopper, Q_5, contributes a small offset voltage which produces an output signal similar to the input current error. This offset may be eliminated by the use of a FET chopper instead of the bipolar unit. The ON resistance of a FET is considerably higher than that obtainable with a bipolar chopper. Therefore, the approximation that $Z_5 = 0$ is poorly satisfied. The circuit of **Fig. 3** illustrates a combination solution which gives the best features of both chopper types. The bipolar chopper Q_5 has a low ON resistance and attenuates the input signal. The FET chopper Q^1_5 works with R^1_1 to reduce the offset due to Q_5. The author has used this combination with a high performance op-amp to build a demodulator with more than 70 Db of dynamic range. This range, including dc stability, was maintained under a wide temperature variation.

Input impedance. This circuit must be driven from a source with a low dynamic impedance at both input and output signal frequencies. The impedance must be low when compared with Z_2 at all signal frequencies. This is because the input impedance is modulated by the operation of Q_5. When Q_5 is off, the circuit acts as a non-inverting amplifier and has a relatively high input impedance. When Q_5 is switched on, the amplifier acts as an inverting amplifier. A virtual ground will be created at its input, and Z_2 will appear as the input impedance. Unless the input is driven from a source with a low impedance (and the output current capability to drive Z_2), the input voltage will be modulated and the resulting output from the circuit will be unbalanced. This effect will be particularly noticeable when the filter option is used, since at high frequencies the input loading is determined by R_p in series with C_2.

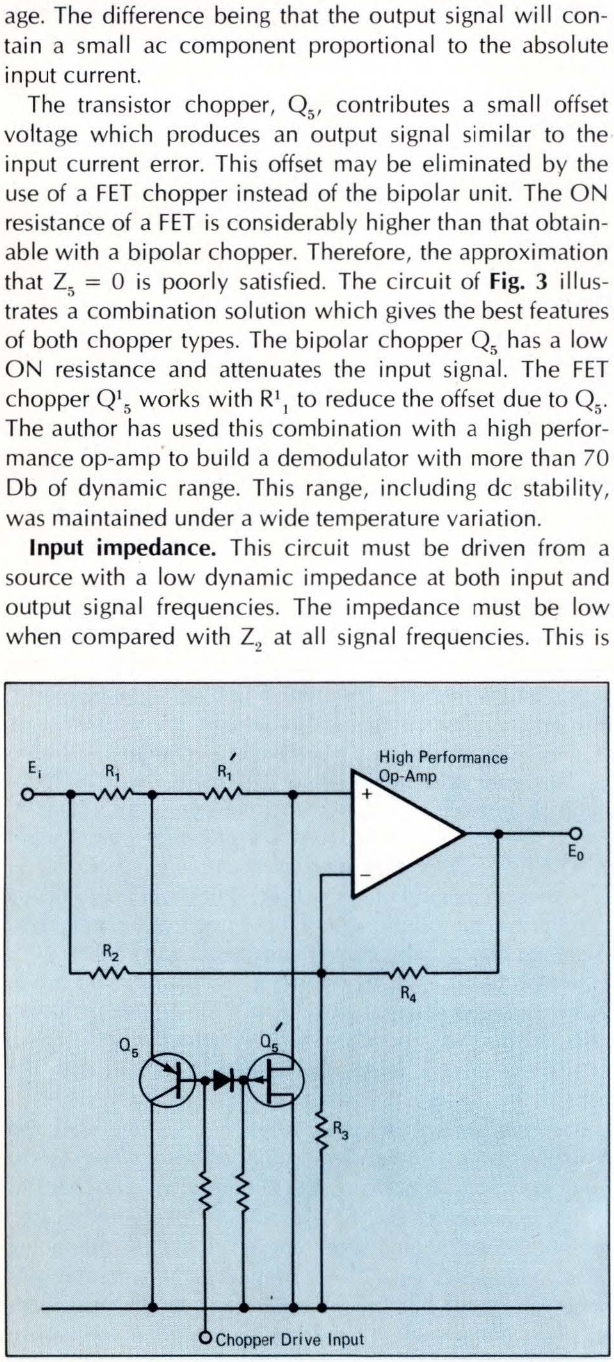


Fig. 3—The small offset voltage produced by Q_5 is eliminated by the use of the FET chopper Q_5' and R_1'. The FET cannot be used in place of the bipolar transistor because of its high ON resistance.

If the circuit is used as a rectifier, the input will draw a direct current component which precludes capacitive coupling at the input. The input can be driven from a transformer or another op amp, so this effect need not be a problem, provided it is not overlooked in the design.

Closed loop stability. For applications using either low-pass or no filtering, op-amps may be compensated with the usual unity gain compensation for a conservative design. If no filtering is used, the compensation appropriate to a non-inverting amplifier with gain H may safely be used to improve the frequency response and bandwidth of the circuit. When, in addition, the input signal source maintains a low output impedance at the amplifier crossover frequency, the compensation may be made appropriate for a closed loop gain of +2H.

If C_2 is included as part of a filter, the amplifier may be compensated as if it were a unity gain inverter, provided a low driving impedance is maintained. Note, however, that the impedance must be low compared to the impedance of R_p and C_2 at the open loop crossover frequency.

Selecting component values

The component values for a specific application can be determined by a method similar to conventional op amp design. The impedance level, Z, for the circuit should generally be selected based on input current offset drift, as in conventional op-amp designs. Usually, the impedance level is chosen to make the offset voltage due to input current offset comparable to the low impedance input offset voltage drift. For example, if an input current offset (initial uncorrected plus drift) of 0.5 μA is anticipated, a 2 kohm input resistance level will correspond to a 1 mV input offset voltage. This is a typical input offset voltage drift for a bipolar transistor input stage in an instrumentation environment.

The low frequency gain factor in the H function is usually dictated by the application. It has upper bounds dictated by the output voltage capabilities of the op-amp at the output signal frequencies and the input voltage drift.

Remember that the drift at the output is twice that normally due to input voltage drift. For example, with 2 mV of input drift (1 mV voltage offset and 1 mV due to current offset) the effect on the output is approximately $2 \times (1 + G) \times 2$ mV, where G is the low frequency gain associated with H.

Once G and Z have been selected, the resistors can be determined from the following relations:

$$R_2 \simeq 2Z$$
$$R_3 = G/(G-1)$$
$$R_4 = (G-1)R_3$$
$$R_1 = R_2$$

Since the exact impedance level is usually somewhat flexible, R_4 is made an approximation in order to allow the use of standard values. Once R_2 is selected, the following equations give values of R_3 and R_4 which satisfy the constraints initially placed on H, R_2, R_3 and R_4. The last equation gives the correct value for R_1 if the amplifier input currents are equal.

The consequences of using a mismatched set of resistors for these values are generally not severe. For example, in an operational rectifier circuit, failing to exactly satisfy the equations will result in unequal half cycles in the output. The filtered average output will nevertheless be directly proportional to a symmetrical input signal over a wide input voltage range. The circuit of **Fig. 2**, for example, uses standard 5 percent values but still gives about 50 Db of dynamic range (with offset trimming) so long as the input signal is relatively free of even harmonics.

If a filtered output is desired, C_4 can be selected based on the value of R_4 to give a simple pole at a frequency of $1/2\pi R_4C_4$. Alternatively, C_2 can be selected to give a simple zero at $1/2\pi R_2C_2$. This will be the frequency at which most (except for 3 dB) of the filtering has taken effect. In either case, C_2 and C_4 should be set equal. In most cases, a small resistance (for example 100 ohms) should be placed in series with each capacitor to prevent capacitive loading problems.

Many analog signal processing systems require the use of operational rectifiers to obtain a precisely rectified signal free of diode voltage drops or offsets. By connecting both the control and signal inputs of **Fig. 2** to the input signal, a full-wave rectified output will be obtained.

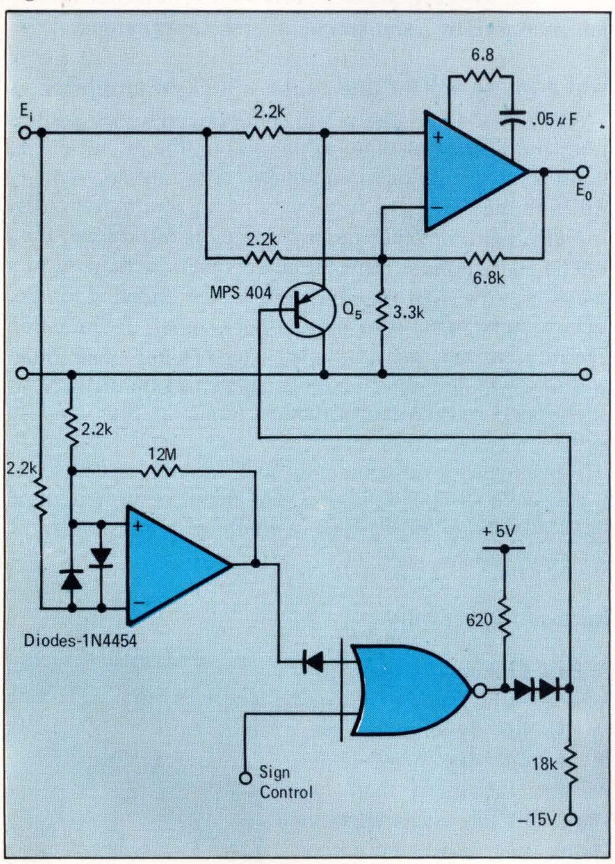


Fig. 4—An exclusive-OR gate provides an alternative to the DPDT switch of Fig. 2 inverting the sign of the rectified output signal.

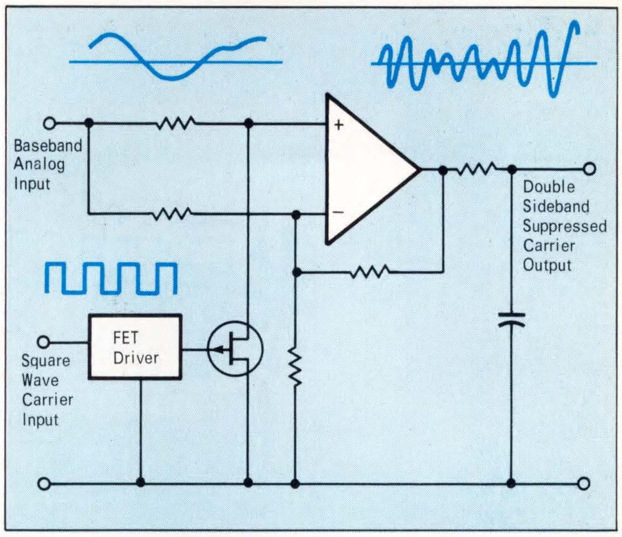


Fig. 5—A high frequency square wave applied to the control input can be modulated by a low frequency analog signal. With output filtering, a double sideband-suppressed carrier signal centered at the square wave frequency is the result.

Whenever the input signal is positive, the comparator half of the op-amp will hold Q_5 off, so that the output signal will be +H times the input signal. Whenever the input signal is negative, the comparator half of the op-amp will switch Q_5 on, and the output signal will be the input signal multiplied by −H. Both these quantities are positive, and the output will consist of a positive full wave rectified version of the input signal multiplied by H. H is simply $(R_3 + R_4)/R_3$ which is approximately 3. Or, if the optional components are included, H is approximately given by:

$$H = \frac{R_3 + R_4}{R_3} \frac{R_2\,C_2\,S+1}{R_4\,C_4\,S+1}$$

if R_p is neglected.

Reversing the DPDT switch in **Fig. 2** reverses the phase of the input to the comparator. As a result, the output will become the negative full-wave rectified signal.

Most other popular operational rectifier circuits involve diodes in the feedback loop of a compensated op-amp. The accuracy and stability of their rectified outputs depends to a large extent on the ability of the op-amp output to slew one or more diode voltage drops in a negligible time. As a result, the performance of these circuits deterioates well below the slew-rate limited frequency for full output of the op-amp used.

The compensated op-amp of **Fig. 2** is not required to slew past a non-linearity. Since the switching occurs at zero input, the amplifier is not required to produce any signals at a rate not included in the desired output. This means that the operational rectifier can be used over the full voltage range right up to the full output frequency of the op-amp. The fast switching is done by an *un*-compensated op-amp, or it can be done by a high speed comparator in combination with a fast op-amp modulator, when wide band width is required.

Fig. 4 shows an alternative method of inverting the output. In this arrangement the comparator output signal is inverted by an exclusive-OR gate under the control of an external logic level.

Double sideband modulation of a sinusoidal carrier

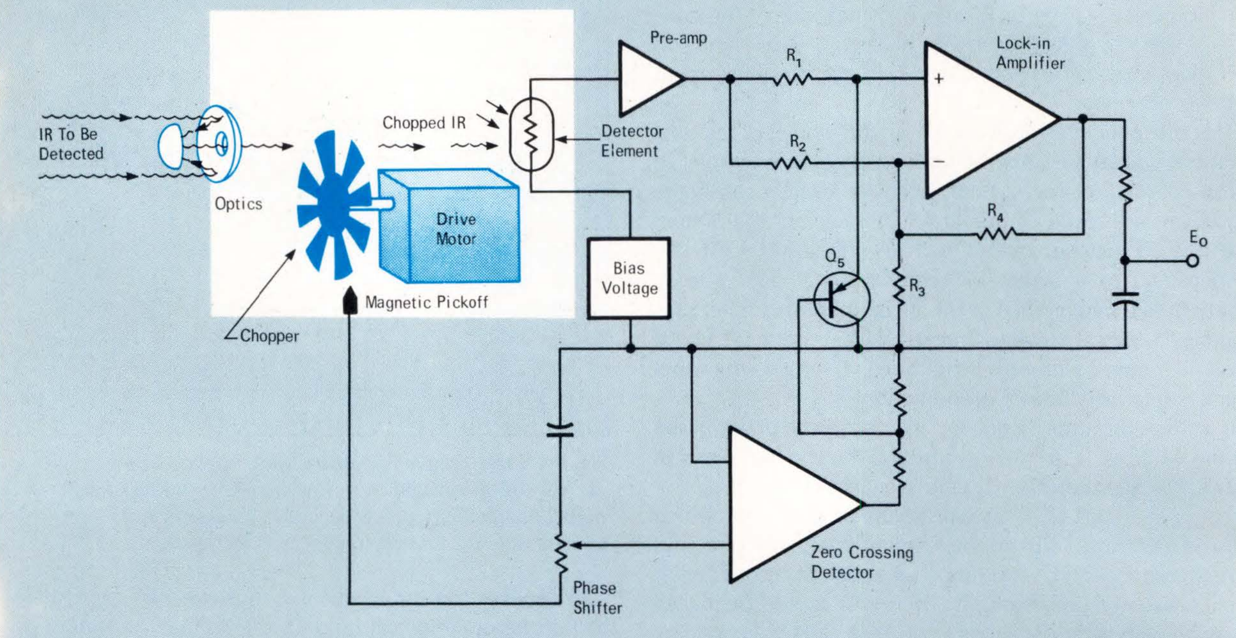


Fig. 6—Lock-in amplifiers improve the signal-to-noise ratio in systems such as this IR detection system, where the background radiation and detector noise levels are high. A phase shifter is required to provide the proper relationship between the input signal and the chopper reference. Output filtering is also necessary.

with a square-wave or digital data signal can be made from the same basic circuit. The carrier signal is applied to the control input. This arrangement can be used to transmit digital information on a carrier signal.

Alternatively, a high frequency square wave applied to the control input can be modulated by a low frequency analog signal applied to the signal input **Fig. 5**. A simple low-pass or band-pass filter will remove the higher order frequency components, and the result is an ideal double sideband suppressed carrier signal centered at the square wave frequency.

When a square wave signal is available, a suitable driver for the switch can be made which will not require a comparator. For high frequency operation, Q_5 can be replaced with a FET chopper. The μA 739C can be replaced with a wideband amplifier to obtain operation to several hundred KHz or even higher.

A particular advantage of this circuit over other modulators is that it requires only a single switch, so that it reduces the expense of drivers and high performance choppers. A second and frequently more significant feature is that both inputs and the output share a common terminal. This eliminates the frequent complication of converting unbalanced signals to balanced signals as required by other methods.

Balanced modulation and demodulation are essentially the same operation; the difference being mainly a manner of semantics. This circuit can be used as a demodulator for data transmission systems.

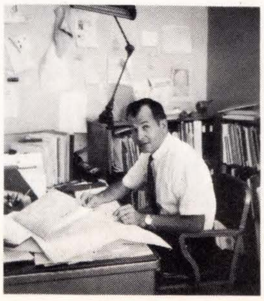
If the double sideband signal of **Fig. 5** is used as the signal input to the circuit and the control input is driven with a square wave in phase with the modulator signal, the resulting output will contain the baseband signal. Again, a simple low-pass filter will reject the image and high order components. In a data transmission system one of these circuits can be used at the receive end to demodulate signals produced by a similar circuit at the transmit end.

Add a phase shifter and make a lock-in amplifier

With the addition of a phase shift network to the control input and a low-pass filter to the output, the circuit of **Fig. 2** can be used as a lock-in amplifier. For example, in many radiation measurement systems, a beam of infrared radiation (IR), light, or other radiant energy is interrupted by a mechanical chopper. This chopped signal is directed to a detector of the appropriate type. By demodulating the detector output signal with the chopper signal, the radiation intensity can be measured. The synchronous demodulation process eliminates spurious detector outputs such as unchopped background radiation, detector bias, and so forth.

Instruments for demodulating such signals are commonly called "Lock-in Amplifiers." **Fig. 6** shows the circuit of **Fig. 2** adapted to form a lock-in amplifier in a simplified IR detection system. ☐

Author's Biography



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CIRCLE NO. 12

Op amps teamed with inductors yield circuits with infinite "Q"

An IC op amp can be used to null the resistive component of an inductor, and "perfect" inductance can be used for some very unusual applications.

by **John C. Freeborn,** Honeywell Marine Systems Center

A lot of work has gone into the development of active filter circuits recently, using op amps to replace inductive components. One of the major reasons for this activity is the bulky size of high quality, large value inductors. The primary methods of reducing the physical size of an inductor are to use smaller wire, which increases resistance, or to use a metal core, which adds core losses. In short, a large inductance in a small package means a lot of unwanted resistance. Almost any inductor can be made to act like a pure inductance by employing a simple op amp circuit in series with the inductor's normally grounded lead. The basic circuit for this resistive cancellation, as illustrated in **Fig. 1**, generates a potential at the inductor lead which is in-phase with the instantaneous current of the inductor and of a polarity which corrects for the IR drop of the inductive winding. The amount of compensation can be adjusted by varying R_3. If the right amount of compensation is used to make up for core losses, as well as the IR drop, the inductor will behave like a theoretically perfect inductance, a detailed proof of this is offered in **Fig. 4**. It should be noted, however, that this circuit can compensate for core losses at only one frequency. For that reason, this technique is especially useful at low frequencies, and with relatively high resistance inductors.

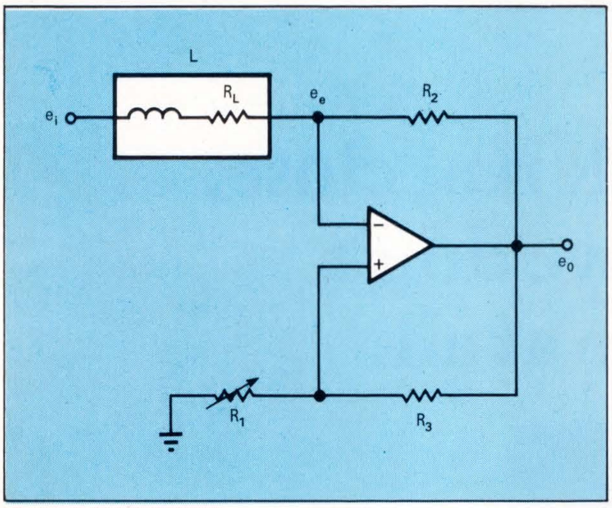


Fig. 1—This simple op amp circuit cancels the high-resistive effects of miniature inductors. For precise cancellation of the coil's IR drop, R_1 should be selected to have the same temperature coefficient as the copper wire of the coil.

In its most basic form, as in **Fig. 1**, the circuit is adjusted so that R_1 is equal to the resistive losses of L (that is, $R_1 = R_L$). The voltage e_e is equal to $I_L R_L$. This relationship holds for instantaneous IR drops and therefore e_o is in phase with the coil current, and proportional to coil-current magnitude. This relationship is particularly useful in circuits that employ square-loop iron core inductors as timing or integrating devices. In these circuits e_i is usually a dc value, and core losses will be negligible. Under these conditions the effects of IR_L are completely and exactly cancelled by R_1 and the entire applied voltage e_i is effective in causing flux change at a rate determined by N $d\phi/dt$; e_o is a continuous readout of inductor current and is an effective saturation indicator.

This circuit also provides all the necessary signals for plotting a hysteresis loop of an inductor core, since e_i is a constant, then $d\phi/dt$ is a constant, and a time based plot of e_o (proportional to I) traces out one side of a hysteresis loop. An input-voltage reversal, such as a low frequency square wave, will reveal both sides of the loop. Changing voltage amplitude of the input can give a family of dc hysteresis loops as a function of flux rate-of-change.

Applications for a pure inductance

As might be expected, the circuit can be made to overcompensate for losses. You will find that if R_1 is made to exceed R_L, regeneration occurs. One application of this characteristic is a very low frequency oscillator where an input dc reversal occurs at saturation. Another could be a

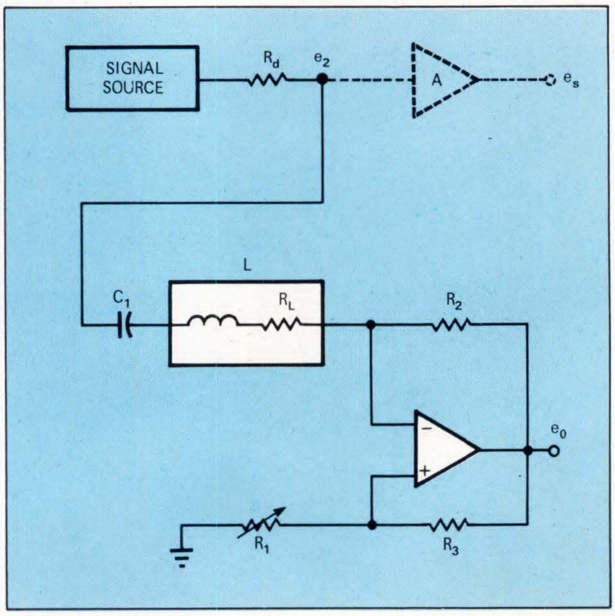


Fig. 2—A series LC circuit, properly nulled, will present zero impedance from e_2 to ground at the resonant frequency. Uses for this circuit include frequency deviation detectors, notch filters, distortion monitors and distortion eliminators.

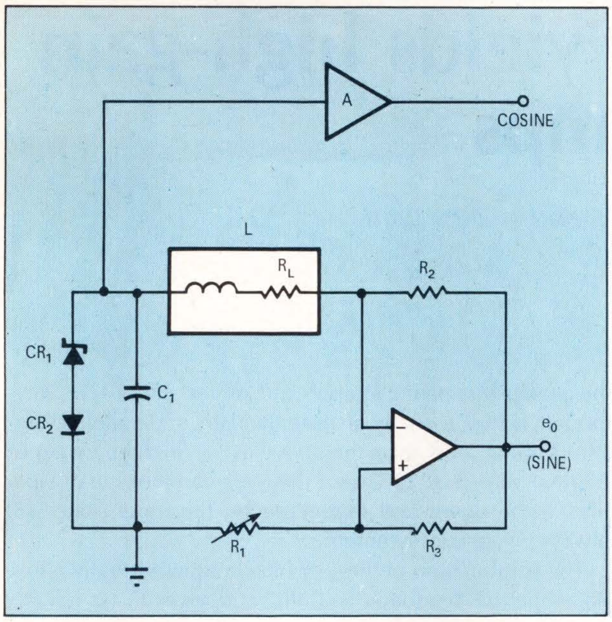


Fig. 3—Core and op amp saturation, and its attendant distortion are overcome by the addition of a zener diode. Avoiding saturation and using limited regeneration produces a reliable low frequency sine/cosine oscillator with less than 1% distortion.

sensing circuit to sense R_1 maximum where R_1 is the parameter of interest.

The circuit shown in **Fig. 2** presents a zero impedance from e_2 to ground at the resonant frequency of C and L if R_1 is adjusted to exactly equal the IR plus the core losses of the inductor. If the signal source and the series LC resonance are set to the same frequency, e_2 becomes zero because of the drop across R_d. The circuit thus becomes a frequency-deviation sensor producing an output at e_2 only when the LC resonance and signal-source frequencies do not match. This configuration is also a form of very narrow-band notch filter. In one such notch-filter tested by the author, the signal at point e_2 was −52dB at the resonant frequency when compared to signal amplitude at frequencies 2 percent higher and lower. By adding a high gain output amplifier (A) and with a precise setting of R_1 for loss cancellation you will find that e_s is proportional to the distortion present on the source waveform. This suggests a possible sinewave distortion eliminator by using the output of amplifier (A) and summing it at the appropriate phase and amplitude with the source signal.

As noted previously, when R_1 exceeds R_L, the circuit becomes regenerative. This condition causes e_0 to progressively increase in amplitude until the core or the amplifier saturates. The addition of Zener diode CR_1 to the circuit in **Fig. 3** limits the signal amplitude within the linear range of both the core and the amplifier, and produces a very high-purity sinewave output at e_0. Frequency of the output equals the LC_1 resonant frequency. This circuit is self starting and has proven to be very dependable. Voltage at the junction of capacitor C_1 and inductor L follows the cosine curve of the output voltage at e_0. Some distortion (flat-topped) occurs at this cosine point. The degree of distortion is proportional to the degree of regeneration employed, which is in turn proportional to the amount by which R_1 exceeds R_L. This distortion can be reduced to less than 1% by limiting the regeneration induced by R_1, while still maintaining reliable oscillation. Using another op amp (A) to amplify this cosine signal gives a reliable 90° shifted sine-cosine generator.

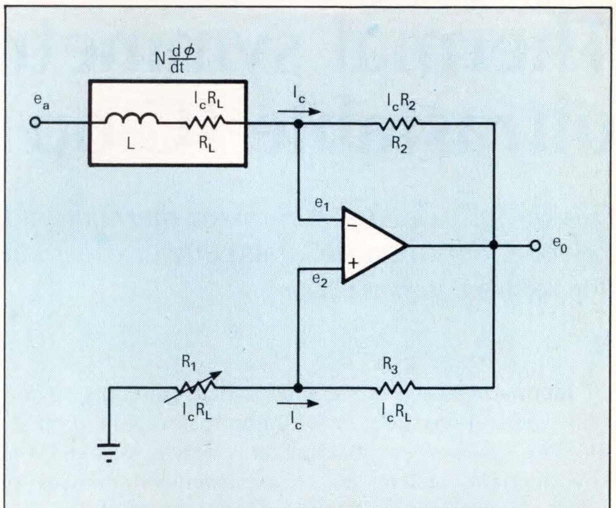


Fig. 4.—Proof of IR drop cancellation:

(1.) $e_2 = 1/2\ e_0$ (when $R_1 = R_3$)

(2.) $e_1 = e_0 + I_c R_2$ (assuming negligible input I to op amp)

(3.) $e_2 = e_1$ (assuming hi-gain op amp)

(4.) $e_a - e_0 = N\ d\phi/dt + I_c R_L + I_c R_2$ (sum of voltage drops)

Combining 1, 2, 3 to solve for e_0 gives:

$1/2\ e_0 = e_0 + I_c R_2$

$-1/2\ e_0 = I_c R_2$

(5.) $e_0 = -2\ I_c R_2$

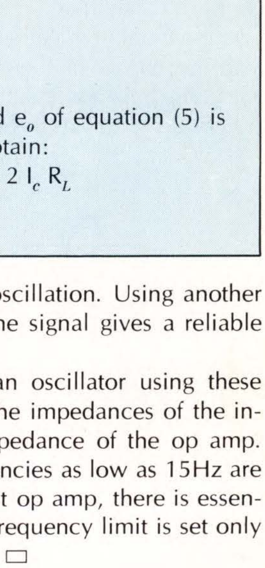
If R_2 is made equal to R_L and e_0 of equation (5) is substituted into (4.) we obtain:

$e_a + 2\ I_c R_L = N\ d\phi/dt + 2\ I_c R_L$

(6.) and $e_a = N\ d\phi/dt$

The low frequency limit of an oscillator using these techniques is not reached until the impedances of the inductor approaches the input impedance of the op amp. Using a 741-type op amp, frequencies as low as 15Hz are easily achieved. With a FET-input op amp, there is essentially no lower limit. The upper frequency limit is set only by the response of the op amp. ☐

Author's biography



John Freeborn is a senior principal development engineer at the Honeywell Marine System Center, in West Covina, Calif, where he has been employed for 19 years. He is responsible for design of solid-state circuits and CRT displays. He graduated from Michigan Technological University with a BSEE, and has done graduate work at California State College at Los Angeles. Mr. Freeborn is a member of Tau Beta Pi, and has been granted 11 patents.

Thermal symmetry yields high-gain ultrastable IC op amps

This design concept minimizes thermal gradients and makes gain independent of output-stage power dissipation.

Roy Forsberg, Boston Editor

If thermal gradients are ignored in high-gain op amp designs, gains in the order of 5 million may rapidly drop to 100,000 or less when the amplifier is heavily loaded. Even when thermal gradients are closely examined, the way to design around them isn't always readily apparent.

It took the combined talents of Analog Devices' IC processing, circuit design, and circuit layout staff to come up with a solution, called thermal symmetry. This means that all power dissipating elements are placed symmetrically around the chip centerline. As easy as it sounds, it becomes difficult to achieve when dealing with devices that alternately switch on and off. The successful implementation of this concept on an IC output stage is shown in **Fig. 1** and will result in a patent being granted to the circuit's designer, Dr. M. A. Maidique.

At the input, it is a different story. Here we are concerned with the effects of thermal gradients on the differential pairs. The apparent solution is simply to split the pairs on either side of an axis passing through the thermal center of the power-dissipating output and driver stages. The key, though, is to diagonally dispose the pairs of paralleled transistors about a point on the above axis called the center of thermal mass (**Fig. 2**). Thus if there are variations in dissipation in the driver and output stages, the input stage will always be affected symmetrically.

The combination of these two techniques virtually eliminates thermal feedback and allows devices to be reliably produced with dc gains of 5 to 10 million at 5-10 mA output current. Gain will remain constant at +10V as well as at −10V and even stay above 1 million with 20 mA load at room temperature. Further, the long term (time) stability of 5 μV/month is an order of magnitude better than that of comparable devices.

Application of such design techniques has resulted in the AD504 series of ultrastable op amps being marketed by Analog Devices and manufactured and designed by Analog's subsidiary, Nova Devices. The AD504 series is packaged in a TO-99 can. ▭

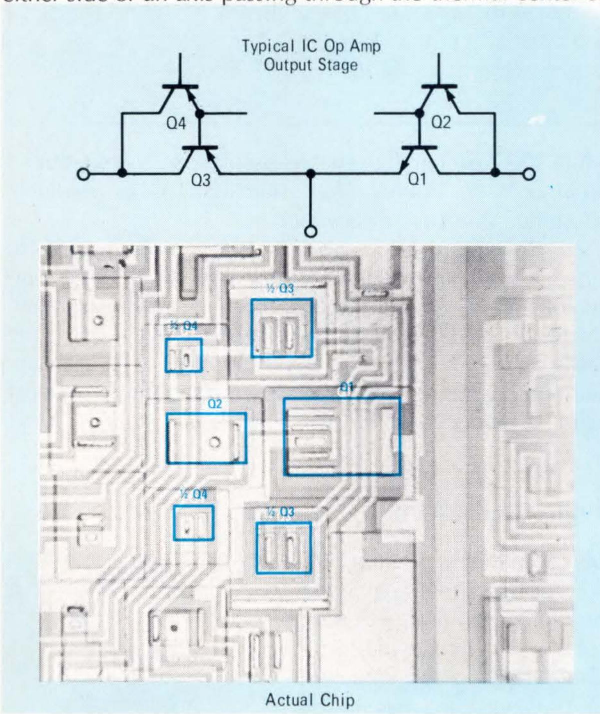


Fig. 1 — Application of thermal symmetry to an output stage. The plus output transistor Q1 and its driver Q2 are placed on the chip centerline, the axis of symmetry. The other driver and the output vertical pnp (Q4 and Q3) are split into two sections each and placed around the same axis. Here it is important to have precise geometries to minimize any series resistance in the paralleling metallization. This design makes the thermal gradient constellation independent of output polarity.

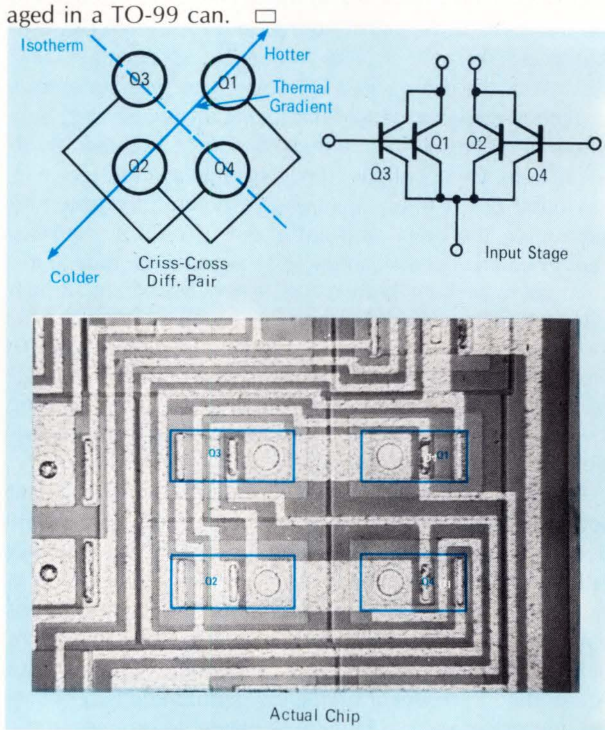


Fig. 2 — Input stage differential pair also follows the thermal symmetry concept. The four transistors are connected in a criss-cross diagonal pattern around the thermal center so that worst-case gradients pass through that center. Thus if the gradient was at a 45 degree angle passing through Q1 and Q2, Q1 would be hot, Q2 cool, and their average value would be at the thermal center. Q3 and Q4 would be at the same temperature and their average value would also be on the thermal center.

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hp MEASUREMENT NEWS

information for better measurement

in this issue

RF signal generator keyed for the future

An RF signal generator with synthesizer stability and spectral purity plus keyboard entry for frequency commands.

Unprecedented operator control is one of the new dimensions in RF signal generators provided by the keyboard-entry HP 8660B synthesized signal generator. All frequency commands are directly entered—not only CW, but also incremental frequency stepping and digital sweeping. Synthesized "continuous tuning" can also be achieved.

Whether you are stepping, sweeping, or tuning, the RF signal retains its synthesizer qualities: high stability, low residual FM, and low spurious content. The 8660 system also has advanced modulation capabilities (AM and FM) plus precise output level calibration and control.

(continued on page 43)

Meet HP's powerful new pocket calculator

The HP-35 is a revolutionary approach to personal computation. Our new pocket calculator has the portability of a slide rule, the ease of an adding machine, and the problem-solving power of a small computer.

This innovative "answer machine" is helpful to anyone who uses advanced math whether in science, engineering, statistics, mathematics, education or finance. The 9 oz. wonder does far more than ordinary four functions; it handles logarithms, exponents, and trigonometric functions each with one keystroke.

Enter values in either floating-point or scientific notation. The operational stack of four registers plus a solid-state memory holds intermediate solutions to problems, then later automatically brings them back for further processing. You do not have to input recurring figures over and over.

The calculating range extends from 10^{-99} to 10^{99}. And the price is within your range—only $395.

To find out how to get one, check the HP Reply Card.

This handful of solutions displays answers to ten significant digits, plus sign and two-digit exponents of 10. The decimal point is automatically positioned.

Collision avoidance role for cesium beam clock

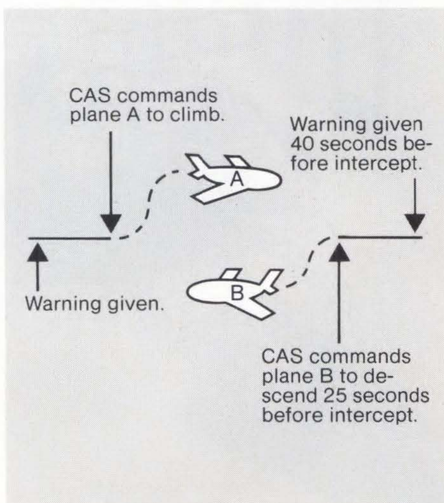
HP's atomic frequency standards play a major role in new air collision avoidance system (CAS) successfully tested by the Air Transport Association and a commercial airline. In CAS each aircraft sends a coded message every three seconds. Time-synchronized equipment in other listening aircraft computes (a) the distance to the transmitting aircraft, (b) the closing rate, and (c) altitude difference to determine collision threat and indicate proper evasive maneuvers.

For ultra-precise CAS time-keeping, HP developed a rugged miniaturized cesium beam atomic frequency source for aircraft use. This HP 5062B "clock" is only 5 by 8 by 19½ in. (123 by 194 by 495 mm) and makes CAS independent of ground stations.

Because CAS is a navigation system, the small CAS cesium beam standard is creating interest among people involved in navigation, tracking and communication systems of other types.

The HP 5061A cesium beam standard, a larger version, has been available for eight years. Absolute accuracy is $1x10^{-11}$ ($7x10^{-12}$ optional). Price: $15,500.

For more about precision frequency sources, check the HP Reply Card.



COLLISION AVOIDANCE SYSTEM
Evasive Action Sequence

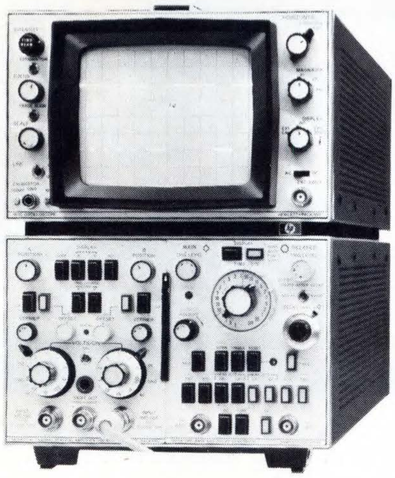
Wide dynamic range for the sight of sound

The 8064A has complete programmability built in for easy computer interface.

Displaying the frequency spectra of sounds as they occur, the 8064A audio spectrum analyzer operates independently or as part of an automatic data acquisition, processing or recording system. Active filters divide the spectrum into 24 third-octave channels in the 2 Hz to 40 KHz frequency range. Dynamic range is outstanding: 84 dB with 60 dB displayed. The price is $9,950.

To learn more, check the HP Reply Card.

Powerful plug-in with selectable impedance



The 1805A (lower left panel) has dc offset that eliminates dc reference on logic and noise pulses yet maintains low deflection factors for maximum amplitude displays.

A new 100-MHz vertical amplifier plug-in for 180-series oscilloscopes packs more measurement capability into one plug-in than any previous unit. The dual-channel 1805A has selectable 1 megohm/50 ohm inputs, 5 mV/div deflection factors from dc to 100 MHz, up to ± 200 divisions of offset, and a vertical signal output that allows cascaded operation to 250 μV/division.

Use 1 megohm input for general purpose probing or the 50-ohm impedance for transmission-line measurements. The low capacitance doubles the frequency range over which probing can be performed without serious loading of the circuits. Price: $1400.

Check the HP Reply Card for details.

continued from page 41

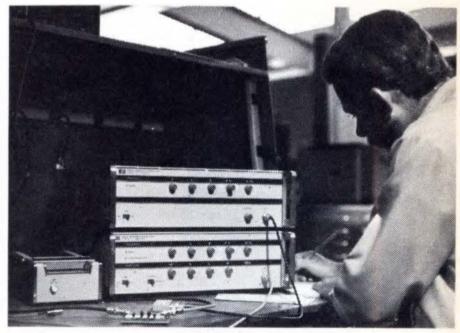
The 8660B is ideally suited for the most demanding measurements; e.g., narrow-band receiver testing and crystal filter tests. In addition to keyboard control, it features 10 digit LED readout of frequency, TTL programmability and computer compatibility. And there is plug-in RF coverage, 0.01–110 MHz and 1–1300 MHz.

Prices of the 8660 systems start at less than $6000; the 8660B keyboard mainframe costs $6000.

Synthesizer for precise amplitude and frequency control

The ideal signal source should have excellent frequency accuracy and stability, precise amplitude control, a reasonable price tag, and the ability to interface easily with systems. The HP 3320 A/B frequency synthesizers have all these features, plus spectral purity of a quality RC oscillator and low signal-to-phase noise.

The 3320A adds synthesizer quality to production and design work yet does not distort your budget. The 3320B is a precision bench instrument as well as a quality programmable signal source. With amplitude accuracy, resolution and frequency response measured in a few hundredths dB over a 100 dB attenuation range, the 3320B is both a frequency standard and a very precise level generator. It is the standard low frequency source in HP's 9500 automatic test systems.



Synthesizer options include remote control, two lower frequency ranges, 75-ohm output, crystal oven, and marked card programmer.

The 3320 has the widest frequency range of any test oscillator, programmable oscillator or low cost frequency synthesizer on today's market—0.01 Hz to 13 MHz.

Prices: 3320A, $1900; 3320B, $2400.

For details, send the HP Reply Card.

How to achieve low-cost data reduction

You can interface a 9100, 9810 or 9820 calculator to the highly-diverse coupler/controller system.

Many people who could benefit by automating data collection and testing shy away from it because they believe it would be too complicated and expensive.

Not any more. HP has developed a calculator-based instrumentation system—low cost and easy to use—for on-line data acquisition and automatic testing. You can program from the keyboard within a few hours; there are no special languages to learn.

It's basically a computing system (in the form of a powerful calculator) attached to a measurement system through a versatile coupler/controller. The calculator interfaces with up to seven devices—DVMs, scanners, teletypewriters, tape punches and readers, recorders, etc. —through cards plugged into the coupler/controller. The calculator serves as the system program source and data processor. Results can be plotted simultaneously with printed, tabulated reports.

Automate your lab experiments and production testing at a fraction of the "computer price." Calculators begin at $2975; coupler/controllers start at $1275.

For all the details, send the HP Reply Card.

A first: do-it-yourself microprogramming

No extra cables or power supplies—the single Writable Control Store cards contains 256 24-bit words and all required address and read/write circuitry.

Now you can have a computer with Writable Control Store capability. You can test and debug preliminary microprograms, alter or extend the instruction set—under actual run conditions, and just as fast as operating from read-only memory.

Program execution in the 2100A is controlled by a computer within a computer. The internal computer, or microprocessor, executes microcode stored in its extendable read-only memory. With WCS, you can check this microcode before committing it permanently to ROM. You can also output, debug and alter microcode subroutines dynamically, during run time.

Specially developed software—including a micro-assembler, utility and I/O routines, drivers, and diagnostics—automatically puts your microprogram into the required form. And an optional PROM Writer commits the debugged microprograms permanently to read-only memory.

Prices: 12908A Writable Control Store, $3500; 12909 PROM Writer, $500.

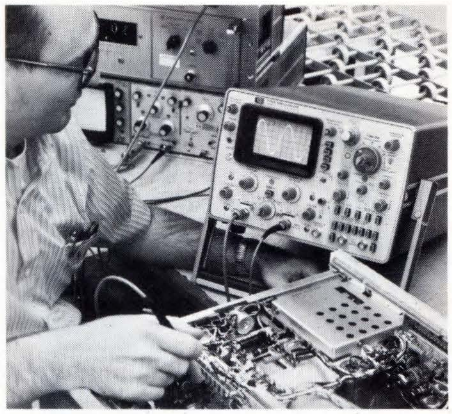
For WCS information and a copy of our "Microprogramming Guide," use the HP Reply Card.

New persistence/storage scopes that work wherever you do

Only our new 35-MHz portable oscilloscopes give you variable persistence/storage *anywhere* and *everywhere*. They are battery-powered and smaller than a suitcase. The 1703A scope has a burn-resistant CRT, along with main and delayed time base sweep speeds to 10 ns/div and a 10 mV/div deflection factor. Model 1702A is identical, but without delayed sweep.

Variable persistence lets you preserve low rep-rate signals and read the CRT display without clutter from old traces. Trace retention time is adjustable, from less than 1 second to over an hour. Use variable persistence as a pseudo-normal write mode when you need extra brilliance, or use it anytime a low sweep speed causes annoying flickering.

The storage holds single-shot phenomena or other infrequent events for over an hour. Writing speed is 100 div/ms; push the Max Write button, and the speed is 1000 div/ms.



The 1703A CRT is burn-resistant and uses P31 phosphor for excellent resolution and sharp spot size.

Both scopes operate on 11.5 to 36 Vdc, any ac outlet, or from a battery pack that fits snugly inside.

The 1703A costs $2725; the 1702A (nondelayed), $2375.

Interested? Check the HP Reply Card.

New high-speed x-y recorder especially for OEMs

Pulmonary testing is just one application for the new high-speed OEM 7041A recorder. Original equipment manufacturers also use it in correlators, Fourier analyzers, pulse-height analyzers, wave analyzers, and calculator plotters. By high-speed, we mean a minimum slewing speed of 30 in/sec and acceleration of 3000 in/sec^2 on the Y axis, 2000 in/sec^2 on the X axis.

The 7041A writing area is 10 by 15 in. (25 by 38 cm) with an autogrip for 11 by 17 in. or international A3 size paper.

This recorder is designed for OEMs who need speed and precision, but don't want costly features irrelevant to end-use. The one-piece aluminum mainframe is rugged, yet shock-resistant. The circuitry contains only ten hand-soldered connections; no expensive maintenance or special calibration is required. A new motor design lets the recorder pen be driven offscale for an indefinite period of time without noise or damage.

You select only what you need from almost 40 available options. The 7041A recorder costs $1050. OEM discounts are available.

To learn more, check the HP Reply Card.

Nifty new options for HP strip chart recorder

HP's 7123 linear motor recorder, enhanced by three new options, now writes without ink, quantifies peak areas, and has four-speed transmission.

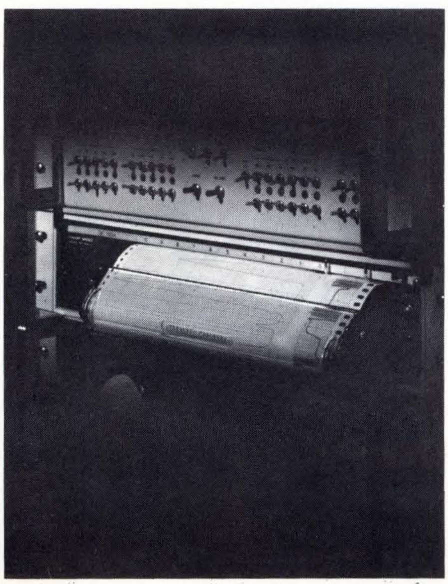
Electric Writing (Option 036) is a low voltage system that provides a clear, permanent trace on electrosensitive paper.

The Electronic Chart Integrator (Option 035) computes complex peak area measurements and averaging. Integration is continuous; there is no lag time between main pen and integrator pen responses. Compare this with the time it takes you to read the chart, calculate mathematically, and write the results—not to mention eliminating human error, too.

Our own version of "four on the floor" is an Incremental Chart Drive (Option 045) which provides four speeds (selectable from the front panel) and an external input. Match the chart speed with other recorders, correlate it with computer output, or synchronize it with pulse output from flow meters. The 7123A costs $750. For electric writing, add $35; the integrator, $750; and the chart drive, $155.

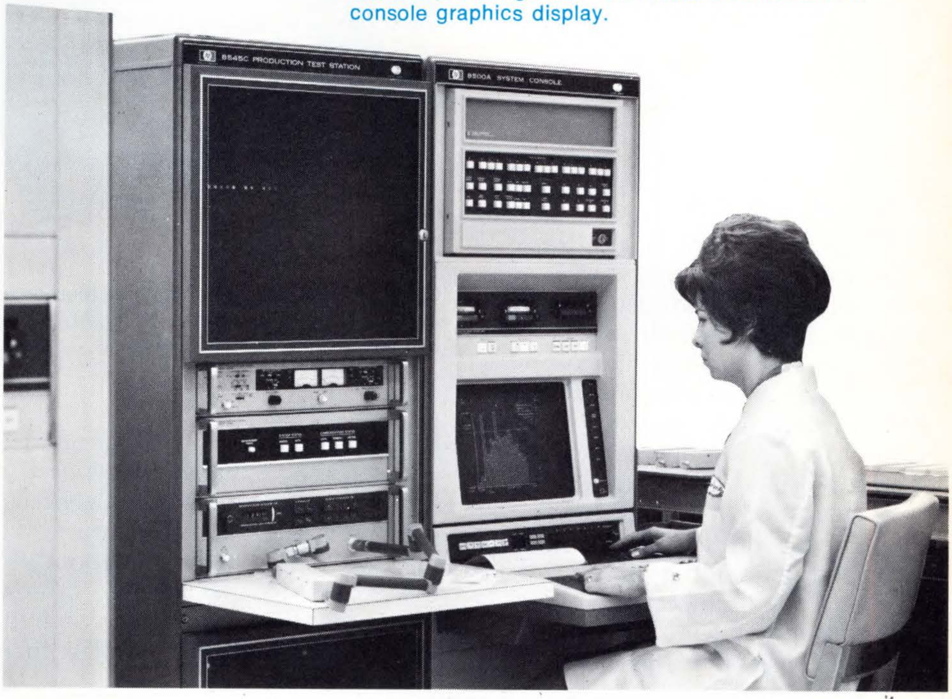
For more details, send the HP Reply Card.

The 7123 10-in. strip chart recorder with integrator and incremental chart drive fits neatly in a spectrum analyzer.



Automatic microwave test system costs much less than you'd expect

The 8545A has the speed, accuracy and versatility you need to solve measurement problems in production test and the design lab—with visual answers on the console graphics display.



Let us surprise you with the low price and high cost-effectiveness of our new 8545A Automatic Network Analyzer. Modular in concept, a basic system can be linked to your existing timeshare facilities—for less than $50K.

Extend its frequency coverage and measurement capabilities incrementally and expand to an independent dedicated system with BASIC language software control. You can then add the high-speed interactive graphics display and enhanced operator control capability of the system console. You buy only the capability you need now, and add to the system as your needs increase.

The system measures amplitude and phase-related parameters of one- or two-port devices under automatic control in single or multiple frequency bands from 100 MHz to 12.4 GHz. Measurement accuracy difficult to achieve with manual methods is provided by system calibration and error correction techniques. The computer handles data conversions ranging from the s-h-y and z parameters of active devices to gain, loss, VSWR and impedance.

Test fixtures and adapters let you measure active and passive components: transistors, amplifiers, antennas, cables, waveguide and stripline components.

For production testing, the timeshare system provides a low-cost solution to automating those difficult tests even with small variable test runs. Timeshare allows you to store many different user-written programs that the operator can call by typing a name. These same advantages apply to your design lab. Each engineer can develop his own program series to suit his particular measurement needs.

The dedicated system gives you high-speed measurements for large test runs and built-in programming capability with HP BASIC software, together with a flexible operator interface through the use of a magnetic tape cassette unit, high-speed printing and interactive graphics display.

Interested? Send the HP Reply Card.

New capabilities in AM, FM measurements

The 5257A transfer oscillator plug-in that gives HP counters direct readout of CW or pulsed frequencies from 50 MHz to 18 GHz is the key to some more difficult measurements too; e.g., incidental FM, rms incidental FM, FM deviation, percentage AM and distortion from 50 MHz to 18 GHz. Here, the 5257A serves as an ideal down-converter since it preserves the input signal's noise, AM and FM characteristics and, in pulsed RF signals, the pulse width and repetition rate.

A wide-band sampler gives the 5257A its unique wide range, constant sensitivity, and one-dial tuning. Use it with HP's well-known 5245, 5246 and 5248 electronic counters. They accept any of 12 frequency or function-extending plug-in accessories for almost any frequency or time interval measurement you are likely to need. Their outstanding reliability is documented by 40 million hours of operating data.

Prices: $2450 for the 5257A; the counters start at $2000.

For more information on AM and FM measurements, check the HP Reply Card.

5257A Transfer Oscillator

New desktop calculator that converses in algebra

Design your own calculator. Three read-only-memory function blocks plug into the left side of the Model 20 keyboard.

Program ten times faster in algebra with a machine that speaks *your* language—the new 9820A algebraic programmable calculator. You merely enter algebraic equations at the keyboard just as they are written on paper; check expressions on the exclusive alphanumeric display; then press another key to store or execute the program.

Full editing capability lets you press a key to delete, change or insert characters, lines or statements. When a line is added or deleted, the program automatically adjusts to occupy minimum memory.

The basic 173 registers can solve 17 simultaneous linear equations with 17 unknowns. Or, expanded to 429 registers, it is capable of 36 linear equations with 36 unknowns. An optional mathematics plug-in block adds log and trig functions; a user-definable block lets you "personalize" up to 25 keys; and a peripheral control block interfaces with plotters, typewriters, and card readers.

Price: $5475, including thermal printer and magnetic card reader. Functional plug-ins cost $485 each.

For more information, check the HP Reply Card.

Now you can digitize low frequency waveforms

Two new 3480 DVM options, Sample-and- Hold and Data Storage, store up to 50 readings made on a changing input voltage. Sample-and-Hold freezes a changing input voltage at one instant in time; storage enables use of Sample-and-Hold at high speeds (1000 readings/sec) yet lets the data be printed economically on a low speed printer.

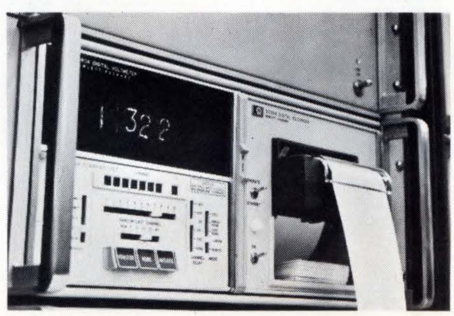
This pair of options opens up new applications including vibration analysis, servo system analysis, and ramp linearity tests. Repetitive wave shapes can be digitized or peak readings can be made. Entire wave shapes up to 410 Hz may be digitized with four-digit resolution.

Both options fit into the 3480 mainframe. Three signal conditioning plug-ins are available for the 3480, including the new 3485A scanning unit with up to 50 input channels. The 2070A Data Logger puts it all together in the form of a self-contained data acquisition system complete with printer.

The 3480A costs $800; the 3480B, $900. For Sample-and-Hold, add $500; Data Storage, $1000. The 2070A starts at $2870.

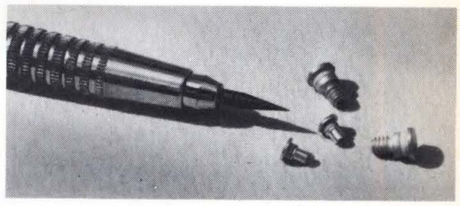
For details, check the HP Reply Card.

Add a few options and the 3480A DVM becomes a handy data logging system.



COMPONENT NEWS

New IMPATTs simplify microwave design



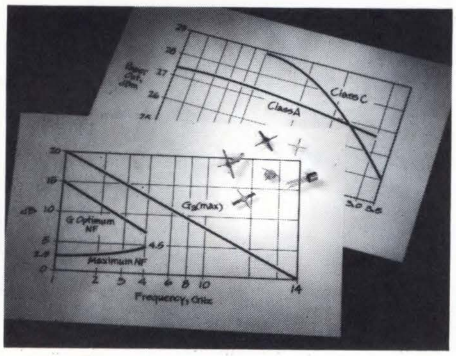
The 5082-0420 series silicon IMPATTs

HP's 5082-0420 series diodes are the first silicon IMPATTs to achieve microwave power levels of 1.5 W at 7 GHz and 1 W at 13.5 GHz. These silicon devices simplify the design of telecommunication repeaters, telemetry transmitters, and doppler navigational radars. Instead of costly gallium-arsenide devices or frequency multiplier chains, these silicon IMPATTs can be used as the active element in oscillators and amplifiers from C through K_μ band, when power, efficiency and reliability are critical. HP IMPATT diodes are rugged and reliable devices that meet MIL-S-19500.

Prices are $150 each (1–9), $110 each (10–99), and $75 each (100).

For complete information on our IMPATTs, check the HP Reply Card.

Microwave transistors: the best cost less



The sturdy HP 21, noise-quashing HP 22, and powerful HP 11 belong in your amplifier design.

Three new high frequency transistors mean you don't have to trade performance for low cost in amplifier and oscillator design. The HP 22 offers a typical noise figure of 4.0 dB at 4 GHz (with a guaranteed maximum of 4.5 dB) without relinquishing gain. At the optimum noise bias (10V, 5 mA), gain at 4 GHz is 6.5 dB. When matched for gain, this 14 GHz f_{max} device has 14.5 dB gain at 2 GHz and 9.3 dB gain at 4 GHz. Price: $75.

The HP 21 gives low cost gain with no mid-stage amplifier noise penalties. This 12 GHz f_{max} device gives a gain of 12 dB at 2 GHz with 4.2 dB NF. Characteristic of all HP transistors, it is reliable; the HP 21 has demonstrated a 10 million hour MTBF. Price: $19.

More Class A and C power per dollar is the strength of the HP 11. It features 27.5 dBm saturated, and 27.0 dBm linear power out at 2 GHz. Price: $19.

Check the HP Reply Card for complete technical information.

Small, new, low-powered LED display

Hewlett-Packard has developed a nifty five-digit LED display for designs where space and power are limited. This 5082–7405 solid-state numeric display package is 0.75 inch wide and requires only 7 mW per digit. Its compact size and low power requirements are ideal for battery-powered or hand-held multimeters, probes and miniature calculators.

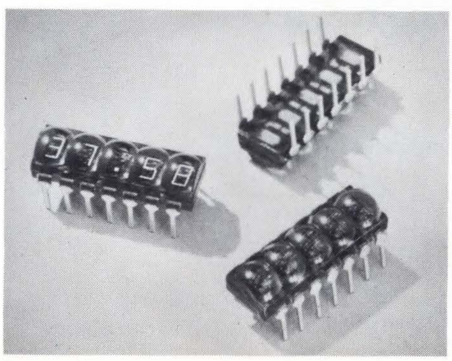
This is one miniature display that is easy to read. Bright red numbers contrast against the dark lead frame. A self-magnifier enlarges each digit to 0.112 in. high, and one digit is dedicated to the decimal point for excellent display legibility.

Installation is quick. Simply plug the display into a standard DIP socket or a printed circuit board.

Prices: $32.50 each (1–19), $22.50 (20–99), $17.50 (100–199) and $16 (200).

To learn more, send the HP Reply Card.

The 5082–7405 LED numeric display



Counter options for high stability, sensitivity

Already they are probably the most versatile medium-priced, general-purpose counters available, but now HP's 5326/5327 universal counter-timers can have higher input sensitivity and stability. Option H60 increases sensitivity to 25 mV rms, 0° to 50°C (10–15 mV rms typical at 25°C). Long term stability becomes 3×10^{-9}/day with Option H49 and 5×10^{-10}/day with Option H50. Temperature effect is $<1 \times 10^{-8}$ total, $-20°$ to $+65°C$.

Option prices: H60—$125; H49—$300; and H50—$450.

Check the HP Reply Card for details.

Now, get HP performance and reliability from 44 new modular power supplies

Three of HP's 44 new 62000-series modular power supplies.

You've undoubtedly heard of HP laboratory power supplies; now you can get the same HP quality in **modular** power supplies. Hewlett-Packard has introduced 44 new competitively-priced models for use wherever a dedicated source of dc power is required.

The 62000-series covers eleven popular voltage ratings from 3 to 48Vdc, with four output current ratings at each voltage rating. For example, at 5V there are 2.0, 4.0, 8.0, and 16.0A supplies. Intermediate output voltage ratings are also available on a special handling basis.

The units are packaged in three uniform height and depth cases which are fractions of standard 19-inch rack width: $\frac{1}{8}$-width, $\frac{1}{4}$-width, and $\frac{1}{2}$-width. Combinations of the three packages can be mounted in an accessory rack tray, or the supplies can be mounted individually on various sides.

These series-regulated supplies provide 0.01% line and load regulation, with ripple and noise of less than 1mV rms and 2mV p-p (up to 20MHz).

What makes these power supplies different? For one, they're thoroughly protected, which means you are too, even if you misapply them. If high ambient temperatures overheat the supply, a thermostat opens the fused ac line automatically. Critical loads are protected from receiving excessive output voltage if a remote sensing terminal is accidentally disconnected. Reverse voltage and current protection is also built in. Should something short the power supply output, adjustable cutback current limiting will restrict current to approximately 10% of rated output. Overvoltage protection (an internal, adjustable, overvoltage crowbar) is also available as a separate option.

This unique combination of protection features helps make HP modular supplies an exceptional value. Excellent reliability, achieved through a trouble-free design utilizing conservatively rated, high-quality components, adds even more value. And should you run into a tough applications problem, every one of HP's 172 field offices stand ready to assist you or provide service support.

Prices range from $89 to $195, depending on power output and package size. OEM and quantity discounts are available.

For full details, return the HP Reply Card.

HEWLETT hp PACKARD

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Japan—Ohashi Building, 59-1, Yoyogi 1-chrome, Shibuya-ku, Tokyo 151, Japan, Ph. 03-370-2281/92.

00242

CIRCUIT DESIGN AWARDS

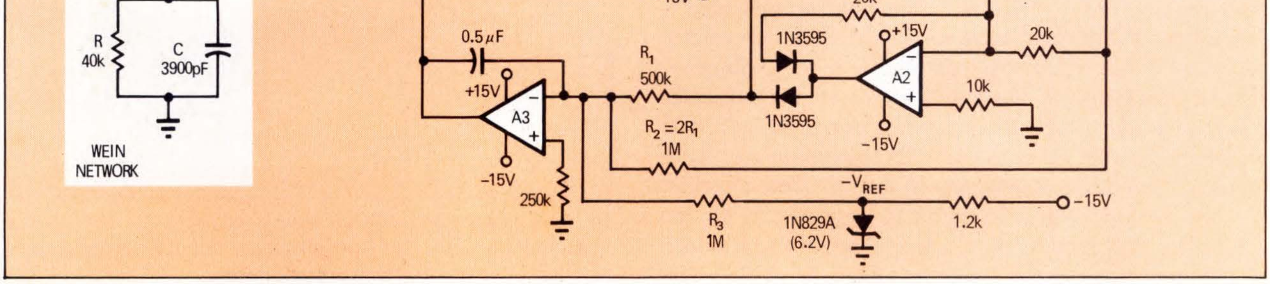
Precision oscillator is versatile

Leonard Accardi, Kollsman Instrument Corp.,
Elmhurst, New York

This design features a low-distortion amplitude-stable oscillator. It does not require the usual trimmers or trial-and-error selection of components to determine the output level. Also of interest are the psuedo full-wave rectification by a single op amp, and the use of an op amp in the "pure" integrator configuration. Usually "pure" integrators can not be built since bias current would cause the amplifier to drift into saturation. The circuit incorporates a Wein Network as the basic resonator.

Normally, response time and linear operation are mutually exclusive properties, and therefore, lamps or similar devices, which introduce a time constant of their own and require circuit trimming are used as gain control elements in order to achieve linearity. A good rule of thumb for the distortion introduced by a FET in the voltage controlled resistance mode is that a drain-source voltage of 1% of pinchoff results in 1% distortion. Knowing that the A_1 circuit gain must be exactly three, this circuit is designed so that the FET resistance merely provides a correction term to the nominal gain, thus minimizing the (drain-source) voltage across the FET and at the same time producing a high level, low distortion output. For a 20V pk-pk output, V_{ds} is nominally 8 mV peak or 1/6% of the minimum pinch-off voltage of Q_1 indicating a distortion of about 1/6%. A_1 is in the non-inverting configuration, therefore its gain is $1 + R_F/R_{in}$. The 40 kΩ feedback resistor and 20 kΩ input resistor set this gain at 3. To maintain the gain of three, the 100Ω resistor forces the FET to operate at a drain source resistance of 50Ω, a highly linear region near the R_{ds} ON maximum of 30Ω for this FET. Distortion over the temperature range is kept to a minimum by specifying tracking of the 20 kΩ and 40 kΩ resistors and using a silicon resistor for the 100Ω resistor so that its temperature coefficient matches that of the drain-source resistance of the FET. Frequency and frequency stability are determined solely by quality of the RC components used in the Wein network, if the closed loop amplifier A_1 introduces no phase shift or no changes in phase shift at the oscillation frequency. Most general purpose op amps are adequate for oscillation frequencies up to 1 kHz.

The remainder of the circuit is for amplitude determination and control. A_2 is connected as a standard precision half-wave rectifier; however, the addition of Resistor R_2 effectively provides a full wave rectified current input to the inverting input of A_3. In the steady state, the dc value of the full wave rectified current is equal and opposite to the current in R_3 which is precisely determined by a reference zener diode. A_3 is designed to give a dc gain equal to the open loop gain of the op amp (3×10^5, typical) and a low ac gain so that ac components of the current input are sufficiently attenuated. A_3 is thus connected as a "pure" integrator (no dc feedback path) which, in open loop circuitry, is forbidden. In this closed loop configuration, however, dc offsets introduce only small errors in the output amplitude of oscillation. Only the values of the integrating capacitor and input resistors to A_3 determine the bandwidth of the regulating loop and thus the transient response of the system, since there is no time constant



associated with the FET. Unlike a lamp, the FET's response is essentially instantaneous and thus entirely predictable.

The high dc gain of the integrator essentially means that its dc output can adjust itself to whatever control voltage is required by the FET to produce the drain-source resistance necessary to maintain the gain of A_1. The voltage output remains constant at 20V peak-to-peak despite variations of the gate-source voltage requirement of the FET.

To Vote For This Circuit
Circle 150

JFET switched resistor controls gain of op amps

Kenneth C. Bower, ESL Inc.
Sunnyvale, California

Often it is desirable to remotely change the gain of a dc amplifier by logic-level signals without causing a dc shift at the output. The circuit shown in **Fig. 1** switches the gain of the op amp in discrete steps, using a TTL control input. When a logic ONE is applied at the switch input of the control circuit, JFET Q_3 is turned OFF, and R_3 is removed from the circuit. The gain of the op amp is then, simply: $A = (R_1 + R_2) \div (R_2)$.

When the logic level input is changed to a logic ZERO, R_3 is in series with the ON resistance of the JFET and these parallel R_2. The gain then becomes: $A = (R_1 + R_f) \div (R_f)$, where R_f is the parallel value of $R_3 + R_d$ and R_2. R_d will not exceed 40Ω for a 2N4869 JFET. If R_3 is kept in the range of 4KΩ, then R_d will not noticeably effect the circuit, and gain calculations are made, as above, on the basis of R_1, R_2 and R_3. This method can be used with several JFET switches paralleled to obtain as many discrete step changes in amplifier gain as may be required for your design.

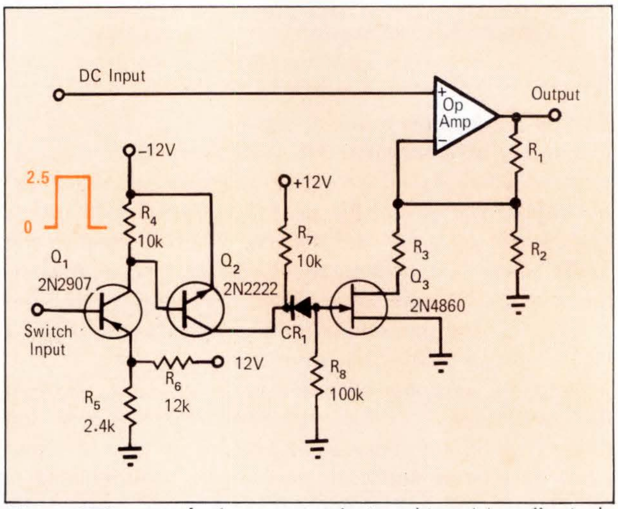


Fig. 1—TTL control of op amp gain is achieved by effectively varying the value of R_2. JFET Q_3 switches R_3 in and out of the circuit in parallel with R_2 to achieve differing feedback ratios.

To Vote For This Circuit
Circle 151

Triangle wave circuit has wide range controls

Jerry Graeme, Burr-Brown Research Corporation
Tucson, Arizona

With only two op amps, a precise triangle wave generator can be formed which has wide range controls for every characteristic of the waveform. Precision is provided by high gain feedback and buffered control loading of the op amps. Although there is some control interaction, the characteristics set by the controls are accurately predictable and highly stable.

The triangle wave generator, as shown in **Fig. 1**, is basically an integrator with a feedback comparator that switches the reference voltage to be integrated. Forming the integrator are A_1, R_f, and C. The voltage integrated is the difference between those supplied by the comparator output and the symmetry control, of $e_1 - V_S$. Since e_1 switches polarities, V_S alternately increases and decreases the voltage integrated. This increases one integration rate and decreases the other to make the triangle wave asymmetrical. Symmetry is affected by control potentiometer R_S. The accuracy of this control is primarily set by the accuracies of R_S and its biases, while the errors produced by the input bias current and offset voltage of A_1 are negli-

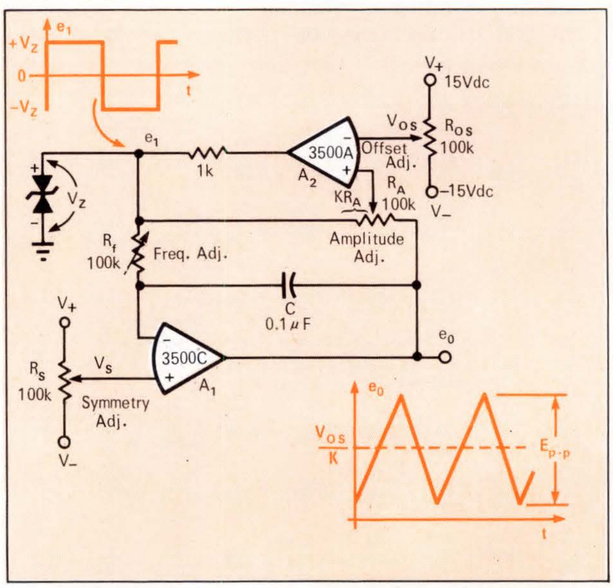


Fig. 1—Comparator feedback around an integrator produces a linear triangle wave. The input characteristics of the two op amps permit accurate control with potentiometers.

gible in most cases. Control range is limited by the maximum integration rate set by either the op amp slew rate or the charging rate limit of C by the output current of A_1.

As the output of A_1 traces out the triangle wave, the waveform peaks are set by the trip points of the comparator, composed of amplifier A_2, the zener diode output limiter and hysteresis feedback through R_A. The amplitude is controlled by the setting of amplitude control R_A. Both the accuracy and the stability of the amplitude are set by those of R_A and V_Z. The range of amplitudes attainable is limited below the output swing limits of A_1 and above the comparator input offset voltage.

Depending on the actual components used, this circuit can provide linear triangle waves from 0.1 Hz to 10 kHz with amplitudes of 10 mV to 20V and with varying degrees of offset and symmetry. Excellent linearity is provided by the op amp integrator with only 0.01% nonlinearity at low frequencies. Control errors will typically be 0.1% to 1% as determined by the potentiometer and supply voltage accuracies.

To Vote For This Circuit
Circle 152

Buffer/filter extracts WWV time codes

Ernest F. Wilson, E.G. and G, Inc.
San Ramon, California

This circuit is capable of extracting the 100 Hz sub-carrier of the modified IRIG-H time code now being transmitted continuously by the National Bureau of Standards radio stations WWV and WWVH. It consists of a dual-op amp with one section operating as a unity gain voltage follower to allow the signal to be extracted from high impedance circuits, such as the second detector of the radio receiver. The other section is a low pass filter to remove all higher frequency components (400, 500, 600, 1000, 1200, and 1500 Hz) without unacceptable distortion of the step modulation of the 100 Hz sub-carrier.

The voltage follower, op amp A in **Fig. 1**, has a very high input impedance, so the circuit from which the signal is tapped sees only the value of R_1. This stage must have sufficient amplitude range to accept the total audio signal, although the 100 Hz component is only a small percentage of the total signal amplitude. It delivers the signal at the low output impedance required by the active filter.

The second section is a 3-pole low-pass Chebyshev active filter with 1 dB ripple and f_0 = 130 Hz. This is a reasonable compromise between simplicity and effectiveness.

With an average signal extracted from the second detector of a Specific Products SR-7 receiver, and with a ±15V op amp power supply, a pk-pk mark-output amplitude of about 3V is obtained. The amplitude stability is dependent on the rf signal stability of the signal, modified by the AGC action of the receiver, and the amount of low frequency noise components present.

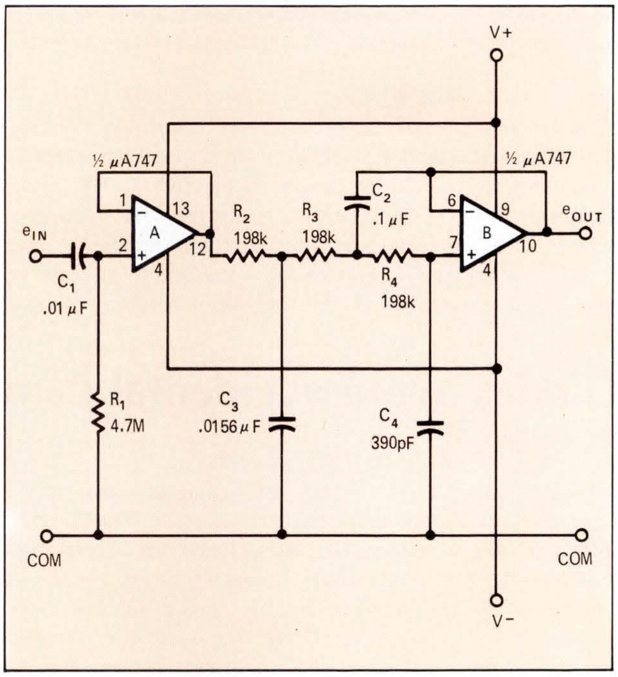


Fig. 1—WWV 100 Hz time signals can be extracted from receiver detector circuits with this simple dual-op amp module. Op amp A is a unity-gain voltage follower, and op amp B is a 3-pole, low-pass 1 dB Chebyshev filter.

To Vote For This Circuit
Circle 153

SCR's form electronic combination lock

Edwin R. DeLoach, Astro-Dynamics Electronics,
New Orleans, Louisiana.

This circuit may be employed the next time your design calls for a lock switch. Its operation is analogous to the mechanical combination lock. The prototype was constructed using nine push-button switches, grouped together like an adding machine keyboard. And the circuit provides a four-digit combination controlled by four SCR's-arranged in whatever order you choose.

The combination required to unlock the circuit shown in **Fig. 1** is A-D-C-H. It is first necessary to press the 'A' push-button. This applies B+ through R_1 to the gate of SCR_1. This positive gate signal switches the SCR ON allowing current to flow through Q_2, SCR_1 and R_3 and applies B+ potential to the anode of SCR_2. The next step similarly applies an ON signal to SCR_2 through push button switch 'D'. This SCR switches ON providing current to R_4 which holds the SCR ON, applying B+ at the anode of the next SCR, SCR_3. If the correct combination is followed through, each SCR in succession with switch on until power is applied to the load relay or solenoid.

An error in dialing the correct combination will turn off all the SCRs and reset the entire circuit. To illustrate, assume SCR_1 and SCR_2 are ON and the next correct digit is 'C' but switch 'H' is pressed instead. No power exists at

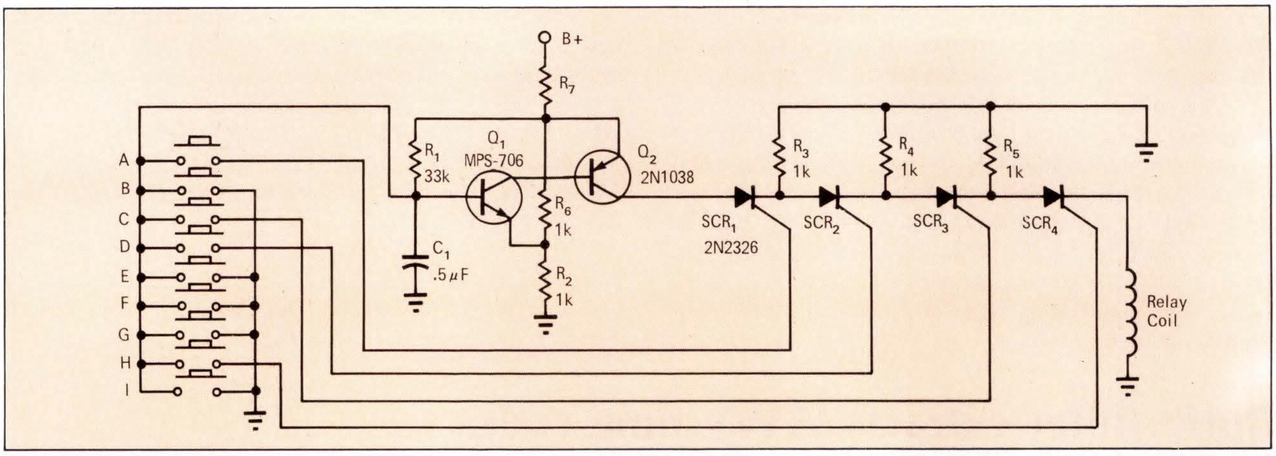


Fig. 1—**Electronic combination lock** can be built into electronic equipment or used separately with a solonoid. Changing of codes is simple. An incorrect or out of sequence combination will reset the lock, requiring the entire sequence of codes to be re-dialed.

the anode of this SCR (SCR_4), so it cannot turn on. The low impedance of the gate, which appears as a forward biased diode, turns transistor Q_1 OFF. In turn Q_2 is switched OFF, which results in loss of power to the SCR's. All SCR's switch to the OFF state, which resets the lock. Thus the entire combination must be repeated to unlock the circuit.

The unused push-button switches are tied to ground, so their use also switches off the transistors, resetting the circuit. Transistors Q_1 and Q_2 do not turn off when the SCR's are fired in correct sequence because the SCR cathodes quickly rise to B+ potential to reverse bias the gate and provide a high "ON" impedance to transistor Q_1.

To Vote For This Circuit
Circle 154

Diodes avoid accidental damage from power supply sensing

Alfred W. Zinn, Kearfott Div.,
Singer-General Precision, Inc., Pleasantville, New York

When remote power supply sense leads are accidentally disconnected from the output voltage terminals, the output voltage in some supplies may rise uncontrollably to its maximum value. Components which are still connected to the output lines, such as LOAD A in **Fig. 1**, can be damaged, or the overvoltage protector will be tripped. In any case, circuit operation will be impaired.

In order to avoid this situation, two diodes can be connected at the power supply output terminals as shown in the figure. When the sense leads are connected, they effectively short the diodes and do not affect the sensing operation. However, when a sense lead is opened, the diode takes its place. The only difference is that the output voltage will be increased by an amount equal to the forward voltage drop of the diode.

If it is found that the voltage drop along wire path A-B-C is larger than 0.5V, zener diodes can be used in place of the 1N914's. Simply choose a zener voltage larger than the wire voltage drop.

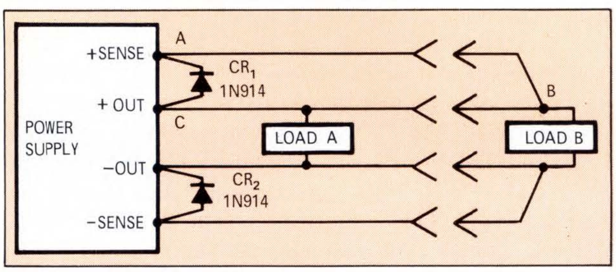


Fig. 1—**Remote sensing** feature of some power supplies can cause damage to unsensed loads. If the sense leads are accidentally disconnected, the voltage may rise to maximum. Diodes D_1 and D_2 will limit this rise and protect the unsensed loads.

To Vote For This Circuit
Circle 155

Rules & Announcements

Your vote determines this issue's winner. All circuits published win a $25 U.S. Savings Bond. All issue winners receive an additional $50 U.S. Savings Bond and become eligible for the annual $1000 U.S. Savings Bond Grand Prize.

Vote now, by circling the appropriate number on the reader inquiry card.

Submit your own circuit, too. Mail entries to Circuit Design Program Editor, EDN/EEE, 221 Columbus Ave., Boston, MA 02116.

Readers have voted:

Richard J. Buonocore winner of the December 1 Savings Bond Award. His winning circuit was called, "Under-voltage sensing circuit." Mr. Buonocore is with Dynell Electronics, Melville, N.Y.

Richard S. Burwen winner of the December 15 Savings Bond Award. His winning circuit was called, "Simple DC voltmeter uses single op amp." Mr. Burwen is with Analog Devices, Inc., Norwood, Mass.

Frederick R. Shirley winner of the January 1 Savings Bond Award. His winning circuit was called, "Thirty-second timer uses IC one-shot." Mr. Shirley is with Sanders Associates, Nashua, N. H.

Electronic typewriter/printer challenges IBM in low speed market

PROGRESS IN DATA HANDLING (EQUIPMENT)

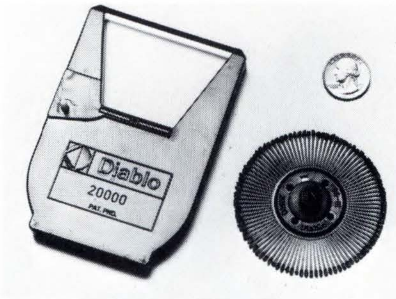
A new electronic typewriter recently unveiled by Diablo Systems, Inc. is aimed directly at low-cost printing markets now served by IBM Selectrics and teletypewriters. Named HyType I, it will rely on five major advantages to win the battle; cost, speed, flexibility, quietness and reliability. The key to these five benefits is the fact that several hundred moving parts have been reduced to just twleve, with the remaining functions being performed by electronics.

Instead of the multitude of levers, linkages, cams, mechanical stops, detents, and similar mechanical components of conventional typewriters adapted to computer output use, the Diablo machine develops its movements through four electric motors directly coupled to the elements being driven. Two of these motors are high performance servo motors used for character selection and column selection; the other two are "stepper motors", employed for controlling paper line feed and ribbon feed.

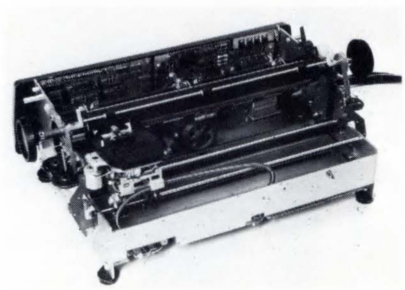
A 'daisy' print wheel is mounted directly on the shaft of one servo motor located in the print-head carriage. An angular position and velocity transducer mounted on the other end of the motor shaft provides information for a digital servo amplifier which drives the motor to the character position to be printed.

In such a character selection system, the advantages of conventional typewriters are retained—interchangeable type element, character-at-a-time asynchronous printing, graphic quality suitable for business correspondence applications, and low cost. These are packaged in an assembly that has nothing to wear out or require adjustment.

A second servo motor positions the moving print head carriage to the desired column position. In this assembly, the motor pulley is connected to the carriage through a symmetrically configured flexible steel cable which transmits the motion.



Snap-in ribbon cartridge shown at the left and snap-in "daisy" print wheel at the right make new typewriter/printer a simple machine to operate.



The absence of moving parts is seen in the printer without a keyboard.

All of these motors operate under electronic control responsive to electronic printing command signals sent to the HyType I by the system to which it is connected, whether it be a computer, a keyboard, or other type of controller.

HyType I uses a novel print element, called a "daisy," which an operator can quickly snap into position to change type styles or fonts. The "daisy" consists of a simple plastic disk about three inches in diameter, with 96 "petals," each containing one of the 96 print characters in the commonly used ASCII character set. Other daisies with different fonts including foreign language fonts will be available. ASCII is the standard coding; however, others are available through ROMs.

A single, small print hammer, shaped like a short pin, is actuated by a solenoid on command from the control logic and strikes the selected "petal" of the 96 petals that make up the full character set. The petal flexes toward the ribbon and paper, creating the character impression. This motion is much quieter than ordinary typewriters because the moving mass of the pin and petal is very small.

The electronic carriage positioning servo is not limited by mechanical constraints like a fixed mechanical pitch of 10 columns per inch. It was designed to provide positioning up to 60 positions per inch. Thus, with no mechanical changes in the printer, and operating solely from electronic command signals, it can print 10 columns per inch, 12 columns per inch, or any other integral sub-multiple of 60. Furthermore, it can be used for proportional spacing, again with no physical alterations of the printer.

At a price of under $1000 in large OEM quantities and a printing speed of 30 characters per sec., the printer has features that make it suitable for use in four major functions: billing and accounting machines, word processing systems, computer terminals and consoles, and computer output writers.

The HyType I also prints an original and five copies of up to 132 columns each, a feature considered mandatory in most of the markets it is intended to serve.

Reliability will range from a minimum 500 hours to an expected 2000 hours MTBF.

Diablo Systems, Inc., 24500 Industrial Blvd., Hayward, CA 94545. Phone: (415) 783-3910. **303**

Family of A/D converters combines low cost with high performance

PROGRESS IN A/D CONVERTERS

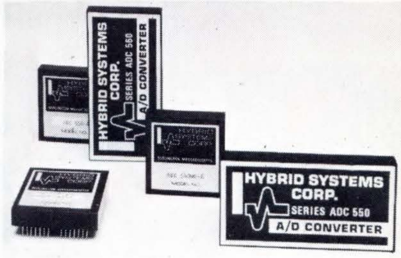
Low-cost A/D converters are plentiful. There are many 8-bit models on the market-selling for less then $60. But they aren't all of the same performance quality. Do they specify a number of burn-in hours prior to shipment? Are all internal active components sealed? These hidden specs can mean the difference between a low-cost converter that might work in your system for only a few hours to one that might cost a little more but provide a lot more reliability.

Hybrid Systems has introduced a family of A/D converters with both low-cost and superior-performance characteristics. Its ADC family of 8, 10 and 12-bit units are all specified with a 72-hour burn-in at the factory to ferret out infant mortality, use thin-film precision resistors for accuracy and stability and contain hermetically sealed active components, for greater reliability, something not always present in low-cost converters.

Three particular converters in the family are outstanding. One is the 8-bit 590-8 which has a competitive low price of $59. Its specs are quite good considering the low price. These include 0.2% relative accuracy, 50-ppm/°C TC accuracy and 20-ppm/°C TC linearity. Conversion time at 200 μsec is a bit slow however. Another plus is the small size—2 × 2 × 0.4 in. Inputs are ±5V or 0 to +10V. A more expensive version (540-8) at $95 is available for very fast conversions of 5 μsec.

The second outstanding a/d converter is Hybrid Systems' 8-bit 540WB-8. It has an ultra-fast conversion speed of 2 μsec and costs only $195. This one also comes in a 2 × 2 × 0.4-in case. It is 0.2% accurate, has TC accuracy and linearity of 50 ppm/°C and 20 ppm/°C, respectively, and a 0 to +10V input.

The third a/d converter is the Model



Three outstanding a/d converters—part of a family of new low-cost converters from Hybrid Systems Corp.—include some nifty performance characteristics.

550-10. This 12-bit unit has 20 μsec conversion speed, 50 ppm/°C TC accuracy and 5-ppm/° CTC linearity. It is 0.05% accurate and has inputs of ±5V or 0 to + 10V. Case size is 2 × 4 × 0.4 in. and price is $99.

All converters in the ADC family operate from ±15V and +5V. They are all dual-in-line-compatible and are suitable for PC-board mounting. Hybrid Systems, 95 Terrace Hall Ave., Burlington MA 01803. Phone (617) 272-1522. **302**

15-MHz, 5-mV/div. dual-trace scope retails at only $845

PROGRESS IN TEST EQUIPMENT

Ballantine Laboratories, an early pioneer of ac voltmeter technology, is taking on a new image—oscilloscopes. It is introducing a 15-MHz (±3% accuracy) dual-trace scope with 5-mV/div. sensitivity at only $845. The scope, their Model 1066A, is a British import, with Ballantine maintaining field engineering, maintenance and parts support.

The 1066A joins the growing list of high-performance foreign-made scopes making inroads into the U.S. market, thanks chiefly to their low cost. Tektronix recently introduced the D67, part of their British Telequipment line, a dual-trace 25-MHz scope at $975. This one however has only 10-mV/div. sensitivity.

Ballantine 100% tests every 1066A at their plant. The dc to 15 MHz bandwidth rating is actually a very conservative one. EDN/EEE observed six different 1066As that were being tested at Ballantine, each with a bandwidth of 20 to 22 MHz.

The first thing that strikes one about

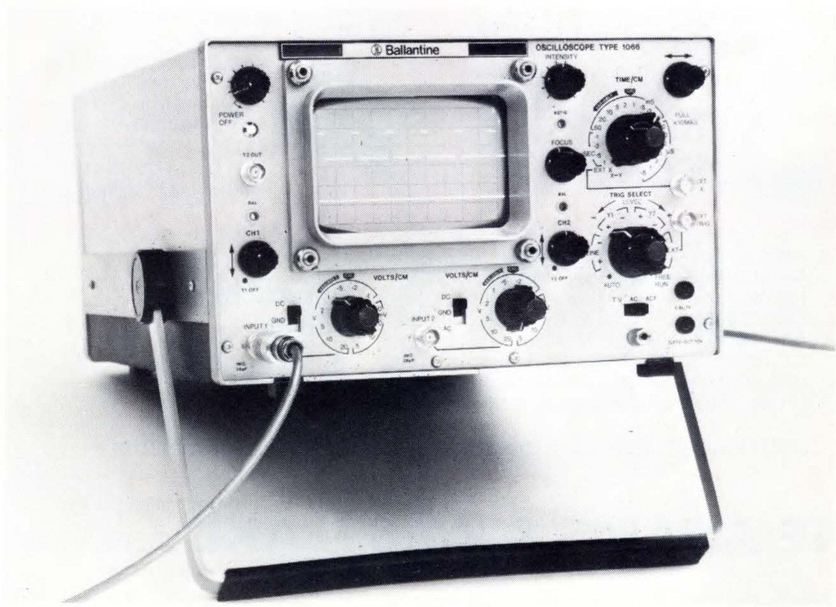


Fig. 1—Ballantine's $845 scope. Imported from England, the dual-trace 15-MHz instrument has sensitivity of 5 mV/div. which can be increased to 1 mV/div. (at reduced bandwidth) by cascading the two vertical-input amplifiers. Total weight is only 19-3/4 lb.

this lightweight (19-3/4-lb) scope is its simplicity. The front panel has been designed with a minimum of controls. As for performance, the 1066A is a professional instrument. It cleanly triggers on as little as 2 mm pk-pk internally (the 5-in. CRT is divided into a 6 × 10-cm display area). A built-in 150-nsec delay line permits the viewing of the leading edge of the triggering waveform.

By cascading the two vertical-input amplifiers, sensitivity of 1 mV/div. can be achieved at a reduced bandwidth (5 Hz to 5 MHz). Three input display modes are single-trace, dual-trace and X-Y display. The time base has sweep speeds ranging from 1 sec/cm to 1/2 μsec/cm in 20 calibrated steps. A X10 magnifier is included to extend the sweep range to 50 nsec/cm.

As for triggering, normal, free-run and automatic modes are available. A "TV" trigger-coupling position is also available that makes the 1066A ideal for CATV and TV applications.

To complement its new scope line, Ballantine is also introducing the Model 6125A universal scope calibrator. This instrument is really three precision instruments in one—a voltage calibrator, a sweep-time and delay-time calibrator and a rise-time calibrator.

As a voltage calibrator, it provides positive, zero and negative dc voltages and a 1-kHz positive-going square wave at ±0.25% accuracy.

The 6125A permits precise real-time scope calibration up to 500 MHz and costs $1875. Ballantine Laboratories Inc., P.O. Box 97, Boonton NJ 07005. Phone (201) 335-0900. ☐

301

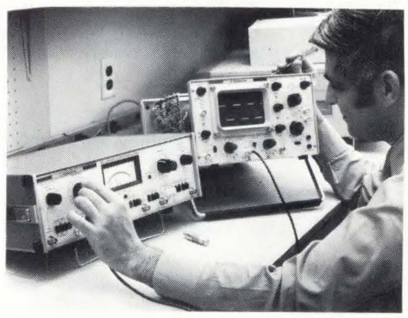
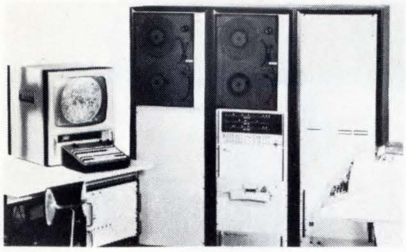
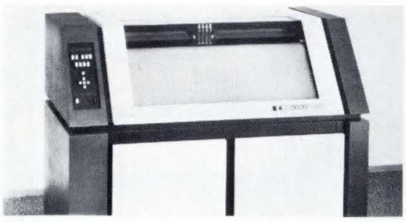


Fig. 2—A voltage, sweep and delay-time and rise-time calibrator in one is the Model 6125A. This precision calibrator allows easy real-time calibration of scopes with bandwidths up to 500 MHz. Ballantine's Model 1066A dual-trace 15-MHz scope with 5-mV/div. sensitivity and an $845 price tag is shown, being calibrated, on the right.

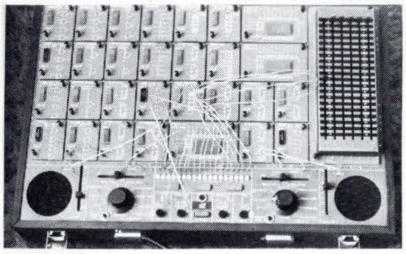


COLOR DISPLAY Model 805 has capabilities of up to 32 colors or black and white pictures/objects, halftones, graphs, charts, symbols, graphics and alphanumerics. Arrays are constructed rectangularly of 512 × 512 picture elements. The color keyboard controls picture elements according to their value. The refresh store contains 262,144 picture elements; constantly transmits them to the display at peak rate of 10 million/sec. Price: $54,500. Spatial Data Systems, Inc., 132 Aero Camino, Goleta, CA 93017. **170**

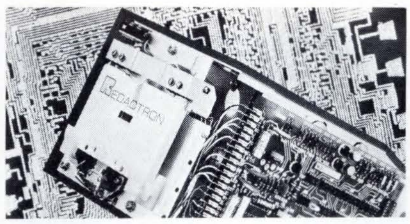


36 INCH DRUM PLOTTER. The basic Model 3600 operates at a maximum speed of 900 increments per second, while the 3600M provides speeds of 1800 increments per second. Both models may be operated in the remote mode by use of the standard Zeta Model 30 remote controller. Operating speeds of 810 increments per second are possible over voice-grade telephone lines. Prices start at $12,200. Zeta Research Corp., 1043 Stuart St., Lafayette, CA 94549. Phone: (213) 278-5000. **171**

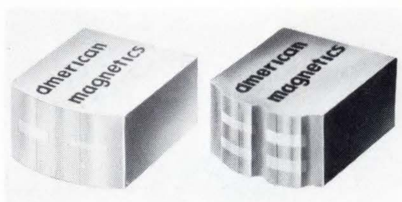
CASSETTE DATA LOGGER) The 6000 Series Incre-Logger is a complete cassette data acquisition system. Over 100,000 8-bit words may be recorded on each track of a 300 ft Phillips-type cassette. A variety of model configurations provide for analog and/or digital data inputs; continuous, synchronous or asynchronous scan control; manual digital data entry; and AC and DC input power. Prices start at $2000. Incre-Data Corp., 6405 Acoma Rd., S.E., Albuquerque, NM 87108. Phone: (505) 265-9575. **172**



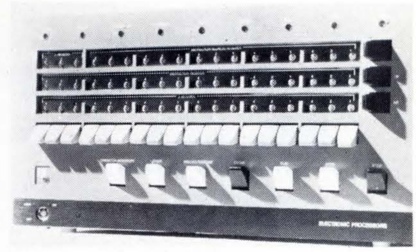
DIGITAL LOGIC LABORATORY consists of 40 individual ICs, each mounted on a PC board with appropriate symbology and truth tables. The lab has a switching capacity of 40^6 combinations, 2 clocks to 9 Mhz in 8 ranges, 2 channel audio output, 18 indicator lamps and 2 SET-RESET buttons and two push-button normally 1 or 0 switches. It also accomodates core memory, ROMs, RAMs and LEDs. Teaching Devices Inc., P.O. Box 169, Carlisle, MA 01741. Phone: (617) 369-7390. **173**



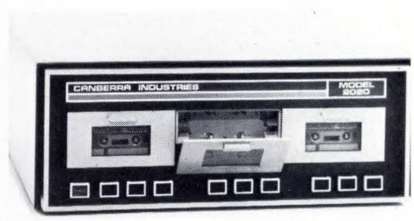
LOW-PRICED, TAPE CASSETTE TRANSPORT has a proprietary MOS chip controller that is insensitive to speed variation. The MOS chip controller sells for $40 in quantity. The transport is a read-after-write unit with a transfer rate of 1500 characters/sec. Each cassette stores 80,000 characters in 100 character blocks. Average packing density is 433 bits/in phase encoded. Redactron Corp., 100 Parkway Drive South, Hauppauge, NY 11787. Phone: (516) 543-8700. **174**



READ-AFTER-WRITE CASSETTE HEADS Models AMCH-12RAW (single channel) and AMCH-22RAW (dual channel) are .150 inch format precision cassette heads, feature all metal face, and meet standards recommended by ANSI and ECMA for digital data recording. Recording density up to 3200 FRPI, with a performance resolution greater than 85%. Crossfeed (write-to-read) is 5% maximum. American Magnetics Corp., 2424 Carson St., Torrance, CA 90501. Phone: (213) 775-8651. **175**



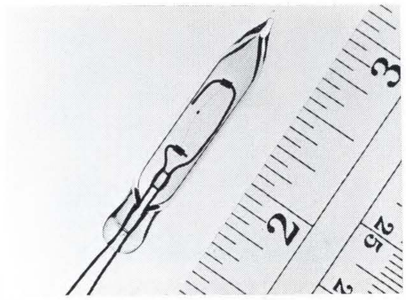
PRICES CUT ON THE 4K EPI-118 MINICOMPUTER. Previously sold at $5900, it is now available at $2790. This is the 18-bit, 900 nsec cycle time machine with a full set of software, including the octal binary loader, a 2-pass assembler, a tape editor, a tape butler, an interactive debug system, floating-point routines, diagnostic software, interactive BASIC, and a subroutine library. Electronic Processors, 5050 South Federal Blvd., Englewood, CO 80110. Phone: (303) 798-9305. **176**



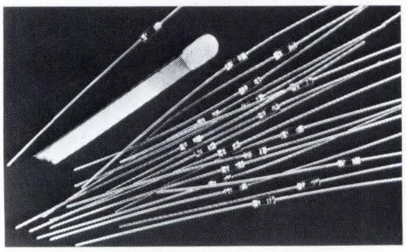
CASSETTE TAPE TRANSPORT Model 2020 is now available with complete hardware and software support packages for DEC PDP-8 and PDP-11 families, and the Data General NOVA family. Each package includes all necessary interfacing, interconnecting, and mounting hardware. A comprehensive diagnostic program is included to aid in system checkout and maintenance. System price is $6900. Canberra Industries, Inc., 45 Gracey Ave., Meriden, CT 06450. Phone: (203) 238-2351. **177**

DATA STORAGE SYSTEM for minicomputers combines performance characteristics of a disc drive with economy and compactness of a tape cassette system. IODISC Series One is a compact disc drive using a low cost, 8 in. dia. "Cartridisc" cartridge which contains an inexpensive flexible disc with approximately 250K byte capacity. The average access time is 60 msec and data transfer rate is 1.2 megabits/sec. Iomec Inc., 345 Mathew St., Santa Clara, CA 95050. Phone: (408) 246-2950. **178**

COMPONENTS/MATERIALS

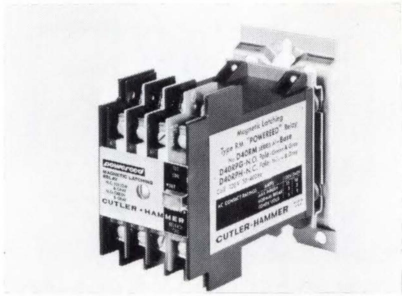


RUGGEDIZED BEAD THERMISTOR features high resistance to shock and vibration. This thermistor assembly is designed so that it is relatively unaffected by ambient temperature changes, but extremely sensitive to power level changes. A small change in current will cause a large resistance change within the thermistor. Units are available with a nominal resistance of 100Ω at 25°C. Fenwal Electronics, 63 Fountain St., Framingham, MA 01701. Phone (617) 872-8841. **182**

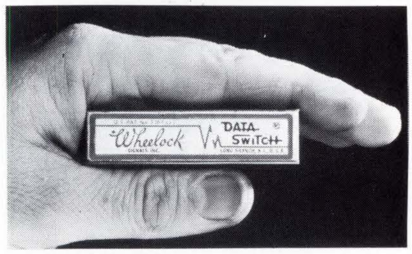


GLASS ENCAPSULATED CAPACITORS, called mini-glass are hermetically sealed in double-stud packages. Available in 3 sizes: 0.160 inch by 0.065 inch, 0.160 inch by 0.100 inch and 0.250 inch by 0.100 inch and a capacitance range of 1 pF to 47,000 pF, working voltages of 25, 50 and 100V. Monolithic Dielectrics, Inc., P.O. Box 647, Burbank, CA 91503. Phone (213) 848-4465. **183**

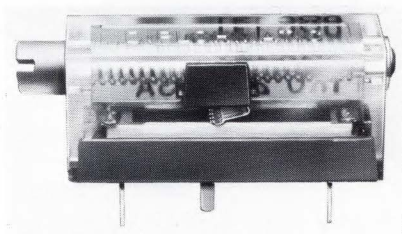
LOW-COST TURN-COUNTING DIAL provides direct manual drive for panel-mounted, ten-turn potentiometers. An associated three-digit readout registers the drive shaft rotation in turns to three significant figures. Designated DFD Series, the dial has a vernier wheel to permit interpolating to 250 parts per million. The dial assembly is less than one-inch wide and less than two-inches high. Amphenol Controls Division, 120 S. Main St., Janesville, WI 53545. Phone (608) 754-2211. **184**



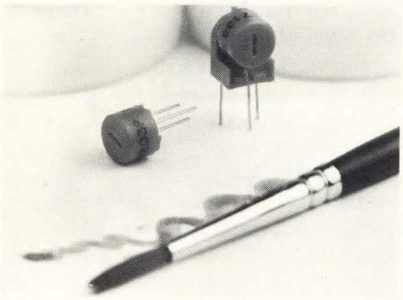
MAGNETIC LATCHING RELAY, the Type RM POWEREED, provides memory by performing the functions of SET (latch) and RELEASE (unlatch). The multi-pole, convertible circuit relay accommodates six contact poles in any combination not exceeding a maximum of 3 N.O. and 3 N.C. poles, and an indicator for visual display of the "SET" or "RELEASE" relay state. Cutler-Hammer, P.O. Box 463, Milwaukee, WI 53216. Phone: (414) 442-7800. **185**



REED RELAYS, Series 3000, are ideal for lamp, inductive and small motor loads. Electrically, the relays are available from single to five poles. Coil voltages include 6, 12, 24, 48 and 120 Vdc. The switch is replaceable without removal of the relay from the PC board. Units measure 2-45/64 inch long by 19/32" high and from 11/16 to 1-1/2 inches wide. Wheelock Signals, Inc., 273 Branchport Ave., Long Branch, N J 07740. Phone (201) 222-6880. **186**

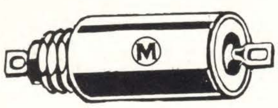


PC TRIMMER POTENTIOMETER features see through polycarbonate case. The 18-turn Type 131 uses a four-contact wiper and is supplied with printed circuit terminals. The unit is 0.75 inch long by 0.33 inch high by 0.25 inch wide. Available in standard resistance values from 100Ω to 1MΩ ±10%. Price in quantity of 100 is $1.23 each. Diplohmatic Div., Harry Levinson Co., 1211 E. Denny Way, Seattle, WA 98122. Phone (206) 323-5100. **187**



SINGLE-TURN POTENTIOMETERS feature multi-finger contact for reduced contact resistance variation. Designated 6203 Series, they are offered in either P (top adjust) or X (side adjust) PC pin termination styles, and have a rotational life of 200 cycles minimum with no discontinuity. Temperature coefficient is 100 ppm/°C. Amphenol Controls Div., 120 S. Main St., Janesville, WI 53545. Phone (608) 754-2211. **188**

THUMBWHEEL FUNCTION SWITCH offers wide window readout. The 0.700 inch wide window will accommodate a variety of character legends or readouts. Maximum character height is 0.200 inch in the 10-position subminiature switch. Overall dimensions are 1.15 inches by 1.91 inches wide, including end caps. The switch can be encoded with any standard thumbwheel code. Cherry Electrical Products Corp., 3600 Sunset Ave., Waukegan, IL 60085. Phone (312) 689-7600. **189**



MINIATURE LOW PASS FILTERS are designed for operation from 30 kHZ to 10 GHz. The filters, with standard current ratings from 60 mA to 10A are available in L, π, and T configurations. Attenuation is maintained over the temperature range of −55°C to +125°C. Standard body diameter is 0.375 inches. Republic Electronics Corp., 176 E. 7th St., Patterson, N J 07524. Phone (201) 279-0300. **190**

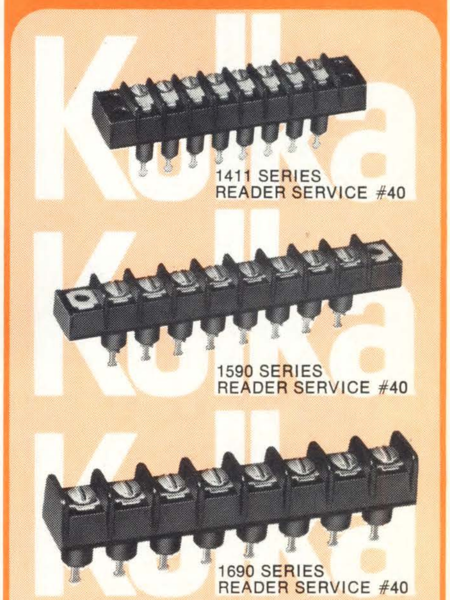
22 CONTACT DIP SOCKETS offer printed circuit or wire wrap terminations. The new molded sockets include machined beryllium-copper gold-plated contacts with a choice of gold or tin plated sleeves. The 1/8 inch thick, glass-filled nylon sockets accept DIPs with round or flat leads on 0.100-inch spacing with 0.44-inches between rows. Approximate price range is $1.00 to $2.00, depending on style and quantity. Augat Inc., 33 Perry Ave., Attleboro, MA 02703. Phone (617) 222-2202. **191**

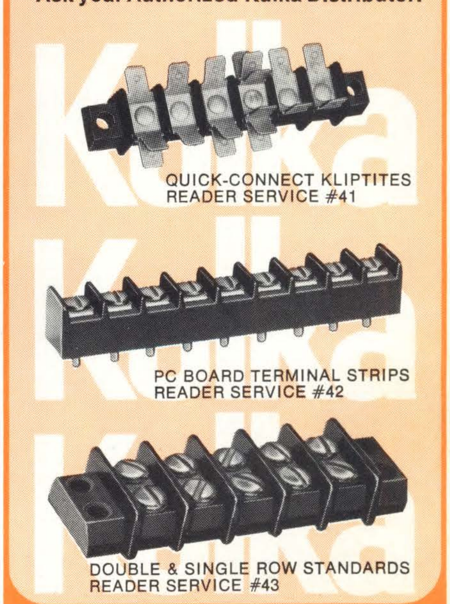
PVC INSULATED CABLE consists of single, twisted pair, coaxial, or shielded round conductors laid in parallel rows and chemically bonded together. The ribbon cable meets all requirements of MIL-W-16878D Types B, C, D, and is U.L. and C.S.A. approved over a wide range of wire gauges and strandings. Most ribbon cable types are available with varicolored coding, the standard sequence being repeated every 10 strands. Circuit Assembly Corp., 3025 S. Kilson Dr., Santa Ana, CA 92707. Phone (717) 540-5490. **192**

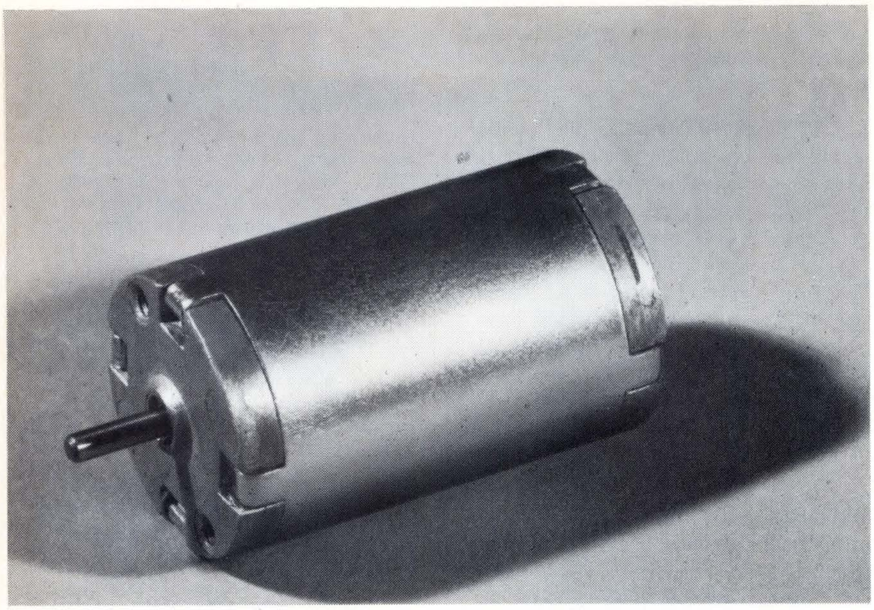
OPTICAL SWITCH available with two channels. Air gap between the LED and sensor is either 0.200-inch or 0.060-inch. Switches are available with two types of optical sensors: Phototransistors and photodarlington transistors. The phototransistor models are also available with or without an amplifier and a Schmitt Trigger. Price is $7.10 each in 1000-lot quantities. HEI, Inc., Jonathan Industrial Center, Chaska, MN. 55318. Phone (612) 448-3510. **193**

LED/PHOTOCELL MODULES utilize a gallium phosphide light emitting diode and a fast response cadmium selenide photoconductive detector. Optical coupling is enhanced with a clear epoxy encapsulant. Since the CdSe photocell is directly compatible with ac circuitry, these solid state modules are ideal for switching triacs or feedback applications. National Semiconductors, Ltd., 331 Cornelia St., Plattsburgh, NY 12901. Phone (518) 561-3160. **194**

LEAD-ACID BATTERY is water-activated. The rechargeable unit is an 8-volt, 10-ampere hour (at 20-hour rate) battery weighing only six pounds, and capable of being recharged up to 150 times. This battery measures 5-1/2 inches by 3-1/4 inches by 5-3/4 inches and features built-in specific gravity indicators. It is spill-proof and operable in any attitude. Wisco Div., ESB, Inc., 1222 18th St., Racine, WI 53403. Phone (414) 637-9131. **195**







COMPONENTS

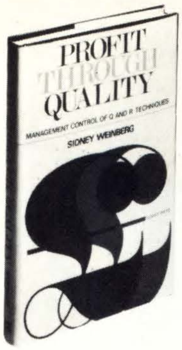
VOLTAGE-TO-FREQUENCY CONVERTERS convert input signals from 0 to +10V to a proportional output frequency from 0 to 100 kHz. This provides analog-to-digital resolution approaching .001% on a 1 second sampling counter. A step change of input voltage results in a step change of output frequency within one cycle of the operating fequency. Solid State Electronics Corp., 15321 Rayen St., Sepulveda, CA 91343. Phone (213) 785-4473. **196**

IMPATT OSCILLATOR boasts output power rated at 100 mW from 5.5 to 6.5 GHz. It is mechanically tunable ±300 MHz. The SSC-21010's frequency coefficient of temperature is 80 PPM/°C. Operating temperature is −55 to +71°C., bias voltage required is 100 Vdc and conversion efficiency is 4%. Sperry Electronic Tube Division, Dept. 9002, Waldo Rd., Gainesville, FL 32601. Phone (904) 372-0411. **197**

BELLOWS CONTACTS for electronic assemblies offer lifetime spring repeatability. Manufactured of nickel, they are 24-carat-gold surface plated. Compression of the contact is equal to 50% of the length of the bellows, allowing movement to take care of assembly tolerances. Nine standard contacts are available for immediate delivery from stock. Servometer Corp. Dept. R, 82 Industrial East, Clifton, N J. 07012. Phone (201) 227-3443. **198**

DIP PACKAGE BLANKS designed for mounting switching components and crossovers provide quick-change programming. Identical in all dimensions to standard IC packages, the Aura standard and custom DIP packages have various sized interlocking covers which can be cemented for airtight circuit protection. Devices as high as 1/4-inch and as wide as 5/32-inch can be accommodated. Electronic Packaging and Hardware Div. of Aura Manufacturing Co., 50 McDermott Rd., North Haven, CT 06473. Phone (203) 777-2541. **199**

FREE SAMPLES OF REED SWITCHES designed to handle low-level RF loads. The MRMF-2 incorporates a special contact material for low losses. The MSRF-2 has physical dimensions that lend themselves to 52.5Ω packaging techniques, recommended for use over 30 MHz. The MTRF-2 has a trimmed stub that approximates the 1/4λ of 5000 MHz, for high speed pulse work. Hamlin Inc., Lake & Grove Sts., Lake Mills, WI 53551. Phone (414) 648-2361. **200**



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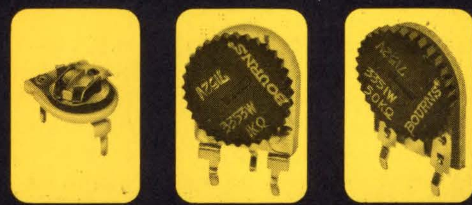
MODEL 3359 — MODEL 3353 — MODEL 3351



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SPECIFICATIONS:

	MODEL 3359	MODEL 3353	MODEL 3351
RESISTANCE RANGE	100Ω-2 megohms	500Ω-5 megohms	500Ω-1 megohm
RESISTANCE MATERIAL	CERMET	COMPOSITION	COMPOSITION
POWER	½ watt at 70°C	⅓ watt at 60°C	⅓ watt at 60°C
OP. TEMP.	—65 to +125°C	0 to +100°C	0 to +70°C
HUMIDITY	±1% T.R. Change	±12.5% T.R. Change	±7.5% T.R. Change
LOAD-LIFE	1000 hrs at 70°C	500 hrs at 60°C	100 hrs at 60°C
RESISTANCE CHANGE AFTER CLEANING	1%	1%	1%
PRICES*	.50	.20	.15

*1000-1999 quantity prices, U.S. dollars, F.O.B., U.S.A.

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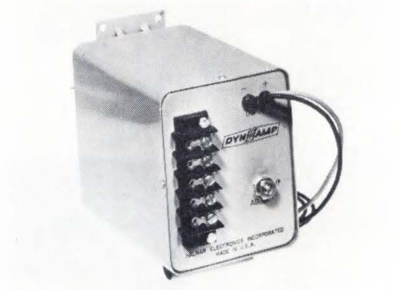
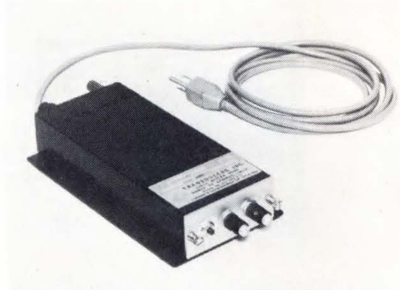
CIRCLE NO. 21

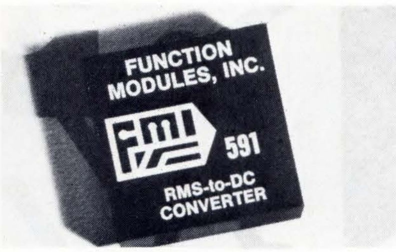
400-HZ-TO-DC CONVERTERS, Series W15, convert 115V 400-Hz power to any desired output voltage between 5 and 16V dc at a full-load output current of 15A. The Series regulates line voltage to ±0.05% or 10 mV (whichever is greater) for input changes of 105 to 125V rms at a constant load. The load regulation is ±0.05% or 20 mV (whichever is greater). Price is $434. Abbott Transistor Laboratories, Inc., 5200 W. Jefferson Blvd., Los Angeles, CA 90016. Phone (213) 936-8185. **212**



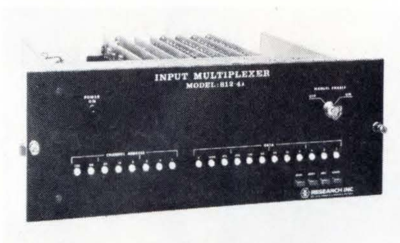
BI-POLAR VOLTAGE ISOLATOR Model BVI is designed to completely isolate a low-voltage source from its load, in the first and third quadrants. The input is ±50 mV dc at an impedance of 1kΩ and can accept 20V continuously. The output signal is scaled 1:1 (other ratios are optional) at an impedance of 200Ω. Minimum load resistance is 5kΩ. The unit is accurate to 1% of full-scale. Halmar Electronics, Inc., Columbus, OH 43223. Phone (614) 276-0131. **215**



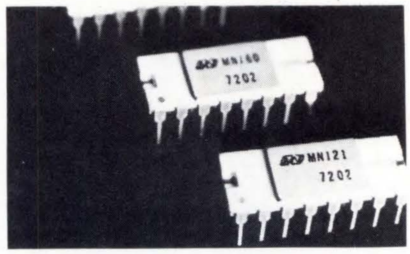
NEW SIGNAL CONDITIONERS for force and pressure transducers allow engineers to employ building block systems engineering. Designated TSC-42/43 and TSC-72/73 for aerospace and industrial models, respectively, they are designed for use with 2-mV/V and 3-mV/V transducers. The standard models provide zero and sensitivity adjustments and a calibration check circuit. Transducers, Inc., 11971 E. Rivera Rd., Santa Fe Springs, CA 90670. Phone (213) 693-2711. **218**



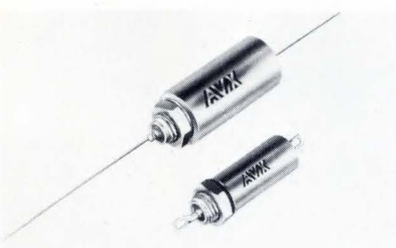
RMS CONVERTER MODULE Model 591 computes the true-rms level of an input voltage. The input voltage waveform may be any combination of ac and dc up to peak values of ±10V. This low-cost module, only $98 in quantities of 1 to 9, computes the rms level directly by squaring, averaging, and square-rooting. Accuracy is 0.05% of full-scale ±0.2% of reading. Function Modules, Inc., 2441 Campus Dr., Irvine, CA 92664. Phone (714) 833-8314. **213**



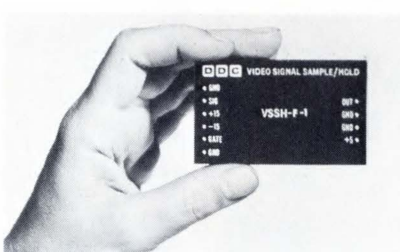
MULTIPLEXER-A/D CONVERTER for rack mounting accepts 32 differential analog input signals and is expandable by adding 32-channel plug-in switch cards to a maximum capacity of 256 differential channels. It converts inputs to outputs of 11 bits plus sign. Signal recognition and conversion occurs at rates up to 10,000 signals/sec in either the random-access or sequential mode. Research, Inc., Box 24064, Minneapolis, MN 55424. Phone (612) 941-3300. **216**



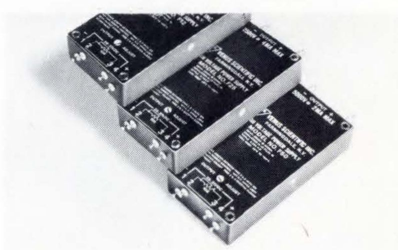
DIP 12-BIT LADDERS made of thin-film materials are available at low cost. Model MN160 16-pin nichrome unit is available with 10kΩ and 20kΩ R/2R values at 50-ppm/°C TC and costs $32 (single quantities) or $16 (1000 units). Model MN121 16-pin unit has R/2R values of 50kΩ and 100kΩ and costs $10 (single quantities). Delivery is stock to 2 weeks. Micro Networks Corp., 5 Barbara Lane, Worcester, MA 01604. Phone (617) 756-4635. **219**



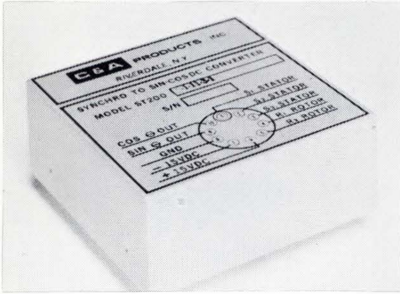
LOW-PASS EMI FILTERS made of ceramic operate to 10 GHz. They meet or exceed requirements of MIL-F-15733. Rated for 50, 100 and 200V dc at 125°C, Types FL and FP L-section and Pi-section filters are available with current ratings from 70 mA (FL) and 250 mA (FP) to 10A dc. Minimum insertion loss is 48 to 70 dB at 10 MHz and 70 dB at 1 GHz. Aerovox Corp., New Bedford, MA 02741. Phone (617) 994-9661. **214**



VIDEO SAMPLE-HOLD MODULE Model VSSH has a fast aperture time of less than 300 psec and acquisition time of 20 to 50 nsec depending on the model. Input impedance is 10MΩ. The unit operates over a dynamic range of ±5V with a linearity of 0.1%. ILC Data Device Corp., 100 Tec St., Hicksville, NY 11801. Phone (516) 433-5330. **217**

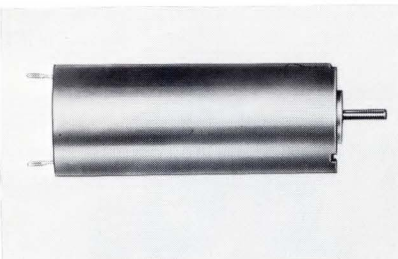


HIGH-VOLTAGE POWER SUPPLIES offer 10W of regulated output power in 6.4-in.^{3} packages. The "F" Series of dc-to-dc converters is offered in four output ranges: 5 to 2.5 kV (F-50), 2.5 to 1.25 kV (F-25), 1.25 to 0.6 kV (F-12) and 0.6 to 0.3 kV (F-6). Input is 24 to 32V dc. Venus Scientific Inc., 399 Smith St., Farmingdale, NY 11735. Phone (516) 293-4100. **220**



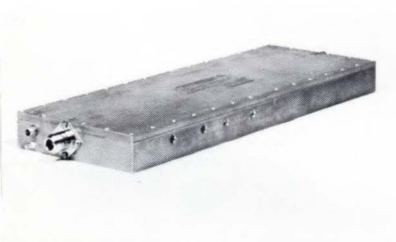
SYNCHRO-TO-SINE-COSINE DC CONVERTER has ±3-minutes accuracy. The ST200 Series module transforms either a 3-wire synchro or a 4-wire resolver input to a pair of dc outputs proportional to the sine and cosine of the synchro shaft angle. Dynamic lag error is 5 arc-seconds per rpm. Price is $235 and delivery is stock to 2 weeks. C & A Products, Inc., 28-17 33rd St., Astoria, NY 11102. Phone (212) 796-2770. **221**

HIGH-VOLTAGE POWER SUPPLY measuring 0.75 × 1.8-in. in dia and weighing 3.5 oz delivers −550 to −3 kV linearly adjustable by varying an input voltage of 14V dc maximum. Fully encapsulated in thermally conductive epoxy, it can maintain rated current of 300 μA at any ambient temperature from −55 to +75°C. Capitron Div. of Amp, Inc., Elizabethtown, PA 17022. Phone (717) 564-0101. **224**

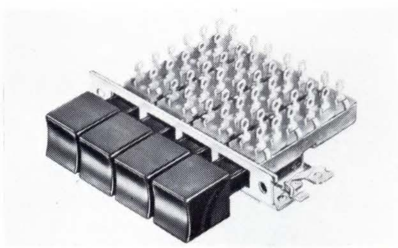


MINIATURE DC MOTOR Series 16-35 features high power/volume ratios, with efficiencies up to 75%. Utilizing a coreless cylindrical design, these motors operate in either clockwise or counter-clockwise directions. They are also available with gearheads to provide up to 20 oz-in. of output torque for high-torque applications. Stettner-Trush, Inc., 67 Albany St., Cazenovia, NY 13035. Phone (315) 655-8141. **222**

MAGNETIC VOLTAGE REGULATOR provides filtered and regulated ac-line power to operate machines and tools in environments with poor ac sources. The VRC-2000 2000-VA regulator operates from 105 to 130V ac 60 Hz and produces 120V ac with ±1% line and ±1-1/2% load control. Price is $95. Tele-Dynamics/Wanlass Div. of AMBAC Industries, Inc., 525 Virginia Dr., Fort Washington, PA 19034. Phone (215) 643-6161. **225**

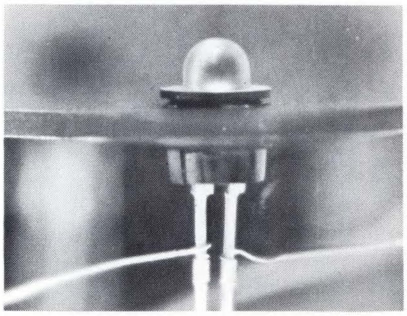


RF POWER AMPLIFIER is transistorized and delivers 5W from 500 to 1000 MHz. Model LWA510-4, operating as a linear amplifier, delivers a minimum of 4W at the 1-dB compression point, and exhibits second-order harmonics 33-dB down. The input and output VSWR is 1.5:1 and 1.8:1, respectively. Price is $2850 and delivery is 4 to 6 weeks. Microwave Power Devices, Inc., 556 Peninsula Blvd., Hempstead, NY 11550. Phone (516) 538-7520. **223**

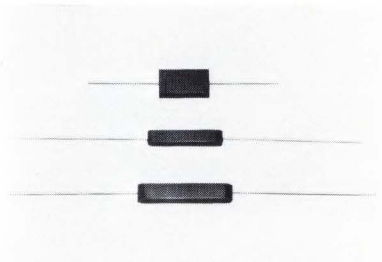


MULTI-PUSHBUTTON SWITCHES Series 65000, 66000, 67000, 70000 and 71000 can be specified with up to 12 stations in a row, which combines all mechanical functions with a momentary common release at any location on the switch frame. By simply depressing a common release pushbutton, all previously depressed stations are restored automatically to normal position. From $1.90 to $14.60. Switchcraft, Inc., 5555 N. Elston Ave., Chicago, IL 60630. Phone (312) 792-2700. **226**

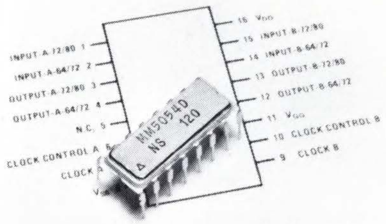
SEMICONDUCTORS



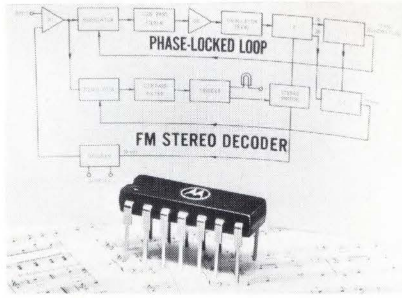
HIGH-BRIGHTNESS LEDs are designed for wire-wrap assembly. The 5082-4880 series of GaAsP devices is available in three light levels, each with three different lenses. Levels available are 0.5, 1.0 and 1.6 millicandelas. Lenses available are red diffused, clear diffused and clear. Hewlett Packard, 1501 Page Mill Rd., Palo Alto, CA 94304. Phone: (415) 493-1501. **236**



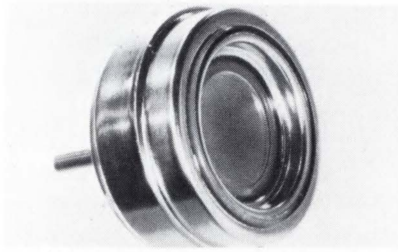
HIGH-VOLTAGE DIODE STACKS are offered in new rectangular packages. The series is numbered US45A through US200A, and USR40A through USR180A. These devices are manufactured using monolithic fused-in-glass diodes, and have voltage ratings from 4500 to 20000V and 4000 to 18000V. Delivery is from stock with prices as low as \$2.45 each in 100 piece quantities. Unitrode Corp., 580 Pleasant St., Watertown, MA 02172. Phone: (617) 926-0404. **237**



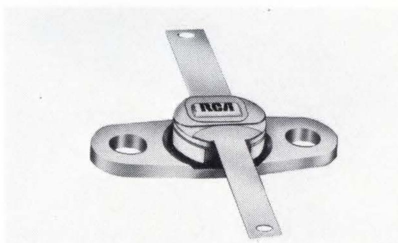
MOS STATIC SHIFT REGISTER is bipolar compatible all around. The clock inputs as well as the data inputs and outputs connect directly to TTL circuits. Other features of the new MM4054/MM5054 are length and logic flexibility. The device contains two registers that are 64, 72 or 80 bits long, depending on the taps used. Unit price is \$8.00 in 100-up quantities. National Semiconductor Corp., 2900 Semiconductor Dr., Santa Clara, CA 95051. Phone: (408) 732-5000. **238**



STEREO DECODER uses phase lock loop concept. The monolithic IC is capable of decoding multiplexed FM signals in radios and tuners without the use of tuning inductors. MC1310 locks onto the 19 kHz pilot signal and creates a signal which is in phase with the pilot signal and twice the frequency. This 38 kHz subcarrier is then used to demodulate the stereo information. \$4.35 each in 100-up quantities. Motorola Inc., Semiconductor Products Div., P.O. Box 20924, Phoenix, AZ 85036. Phone: (602) 273-6900. **239**



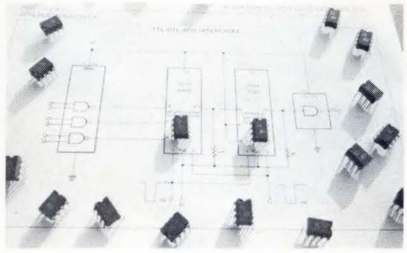
HIGH-SPEED VACUUM PHOTODIODES are capable of sub-nanosecond rise times. They are obtainable with S-1, S-20, and S-25 surfaces and are impedance matched with a coaxial design for 50 or 125 ohms. The devices feature low dark current and long term stability. Manufactured by Instrument Technology Ltd., of England and marketed in the USA by EG&G. EG&G Inc., Electro-Optics Div., 35 Congress St., Salem, MA 01970. Phone: (617) 745-3200. **240**



VHF/UHF POWER TRANSISTOR delivers 30W cw with 5-dB gain at 400 MHz. The RCA-2N6104 is designed for use in large-signal high-power cw and pulsed amplifiers at frequencies from 200 to 600 MHz, and operates from a 28V supply. It features the overlay multiple-emitter-site construction and emitter-ballasting resistors. Price is \$33.00 in 1000-unit quantities. RCA Solid State Div., Box 3200, Somerville, N J 08876. Phone: (201) 722-3200, Ext. 2561. **241**

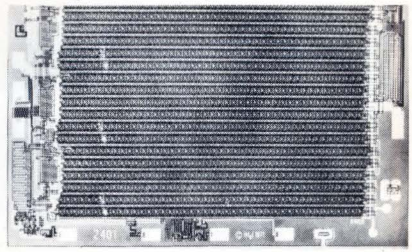
RESISTOR STABILIZED TRANSISTORS deliver 20W within 400 to 1200 MHz range. The D20-28 power transistor offers highest available power from a 24 to 28 V supply. Also available are the 1W D1-28, the 3W D3-28 and the 10W D10-28. Prices range from $7.50 to $70.00 each in unit quantities. Communications Transistor Corp., 301 Industrial Way, San Carlos, CA 94070. Phone: (415) 591-8921. **242**

SOS/MOS MULTI-TRANSISTOR features 2 pA leakage. The tracking between pairs of transistors in the L03 and LO3M enable them to be used effectively as high input impedance unity gain buffers in conventional operational amplifiers. Prices begin at $12.00 each in orders of 100-999. Inselek, 743 Alexander Rd., Princeton, N J 08540. Phone (609) 452-2222. **243**



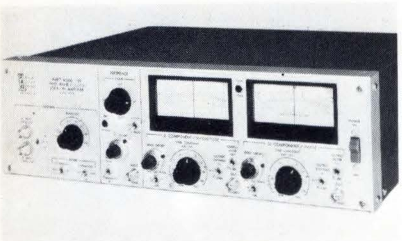
DYNAMIC SHIFT REGISTERS contain recirculation logic. The low-threshold registers operate at 5 MHz. The 512-bit register is designated as the "2524V," and the 1024-bit version as the "2525V." Both are in an 8-pin mini DIP. "2524V" in quantities over 250 is $4.00 each; "2525V," in the same quantity, is $9.20 each. Signetics, 811 E. Arques Ave., Sunnyvale, CA 94086. Phone (408) 739-7700. **244**

DUAL 480-BIT DYNAMIC SHIFT REGISTER, designated the 3337, is a two-phase ratioless shift register that features a 2 MHz clock frequency. The device requires only +5 and −12V power supplies. The 100 to 999 price in a 12-pin TO-8 is $8.50. Fairchild Semiconductor Components Group, 464 Ellis St., Mountain View, CA 94040. Phone (415) 962-5011. **245**



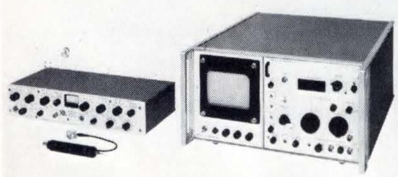
MOS IC SHIFT-REGISTER is longest ever produced, according to its maker, the Intel Corp. Type 2401 is packaged in a 16-lead silicone plastic DIP as a dual 1024-bit register. These N-channel devices drive a 100 pF load at 1 MHz. Power dissipation averages only 120 microwatts per bit at top speed. Price in 100-piece quantities is $24 each. Intel Corp., 3065 Bowers Ave., Santa Clara, CA 95051. Phone: (408) 246-7501. **246**

D/A CURRENT SWITCHES 8018A, 8019A and 8020A, are used in building current-summing converters. 8018A has a 0.01% absolute error, the 19A 0.1% and the 20A 1%. Prices for the 0° to 70°C switches, in 100-piece quantities are $5.00, $2.20 and $1.80. Intersil, 10900 N. Tantau Ave., Cupertino, CA 95014. Phone (408) 257-5450. **247**



VECTOR VOLTMETER/TWO-PHASE LOCK-IN AMPLIFIER is a new instrument that provides simultaneous measurement of in-phase and quadrature components of a low-level signal, and at the flip of a switch, the equivalent vector's angle and magnitude. The Model 129 offers 1-μV full-scale sensitivity, 0.5-Hz-to-100-kHz bandwidth, internal noise of less than 10 nV/ Hz at 1 kHz. Price is $1895 and delivery is 90 days. Princeton Applied Research Corp., Box 2565, Princeton, N J 08540. Phone (609) 452-2111. **251**

DIGITAL COUNTER Series 100 is a solid-state uni-directional totalizing counter with counting rates to 30 million counts/sec and up to 8 digits of display. It weighs but 3 lbs and has maximum size of 4.5-in wide, 4.35-in deep and 2.6-in high (1.5-digit models). A typical 3-digit counter sells for $171. REO Data Products, Inc., 7346 Bolsa Ave., Westminster, CA 92683. Phone (714) 892-3396. **252**

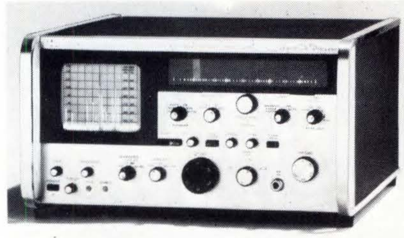


SPECTRUM ANALYSIS SYSTEM model CAS-290 provides rapid, graphic tests for calibration and trouble-shooting of modern single-side-band, AM and FM transmitters and receivers. Signals from 10 Hz to above 40 MHz are displayed with 10-Hz resolution and a 70-dB distortion-free dynamic range. Price is $4950. Nelson-Ross Electronics, 5 Delaware Dr., Lake Success, NY 11040. Phone (516) 328-1100. **253**

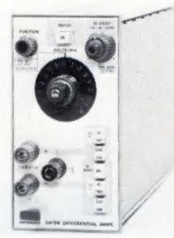
DIGITAL PANEL COMPARATOR Model PPM-600 provides selectable preset alarm limits for any functional mode on any Anadex digital instrument provided with BCD output. Two output signals are provided upon coincidence of the preset level and the input signal. A dc DTL/TTL level change and/or a Form C relay closure rated at 3A at 115V ac are standard. Prices start at $130 and delivery is 4 weeks. Anadex Instruments, Inc., Van Nuys, CA. Phone (213) 782-9527. **254**

A PORTABLE, COMPACT TEMPERATURE RECORDER uses an inkless stylus to record on pressure-sensitive paper. The Mimigraph records temperatures in the ranges of 0-500°F to 0-2000°F, or 0-300°C to 0-1000°C, with a simple thermocouple probe. Thermistor probes permit temperature records from −20 to +130°F. Accuracy is ±2%. Esterline Angus, Div. of the Esterline Corp., Box 24000, Indianapolis, IN 46224. Phone (317) 244-7611. **255**

LED DPMS, 3-digit unipolar and 3-1/2-digit bipolar instruments are priced under $100 in production quantities. Features include suppression of insignificant leading zeros, externally programmable scaling, input filtering and decimal location. BCD output is optional. United Systems Corp., 918 Woodley Rd., Dayton, OH 45403. Phone (513) 254-6251. **256**

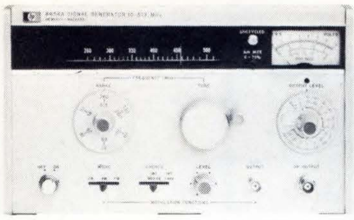


SPECTRUM ANALYZER Model AL-60 features a 70-dB distortion-free display over the frequency range of 1 MHz to 3 GHz. The frequency range is covered in three bands: 1MHz to 1 GHz, 1 GHz to 2 GHz and 2 GHz to 3 GHz, all bands having the same −105-dBm sensitivity and 1-GHz maximum dispersion. Resolution is determined by three switch filters, with bandwidths of 200, 10 and 0.5 kHz. Price is $4500 and delivery is 3 to 4 weeks. Texscan Corp., 2446 N. Shadeland Ave., Indianapolis, IN 46219, Phone (317) 357-8781. **257**

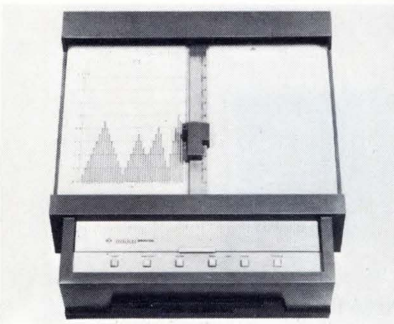


LOW-COST DIFFERENTIAL AMPLIFIER plug-in unit for 5100 Series scopes is the 5A19N which has deflection factors from 1 mV/div. to 20V/div, accuracy to within 2%. Bandwidth is 2 MHz. An internal, continuously variable offset voltage may be used to display millivolt variations on signals up to 15V, or 1/2V variations on signals up to 350V. Price is only $150. Tektronix, Inc., Box 500, Beaverton, OR 97005. Phone (503) 644-0161. **258**

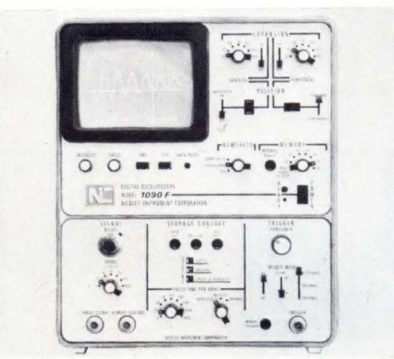
5-DIGIT MULTIMETER Model DMM 50 employs two types of logic: successive approximation logic for speed, and integrating logic for noise rejection. Each reading taken starts with an "automatic set zero," then the most significant of the five decades is examined. Price is from $1200 and delivery is 30 days. Cimron Instruments EID Div., Anaheim, CA Phone (714) 774-1010. **259**



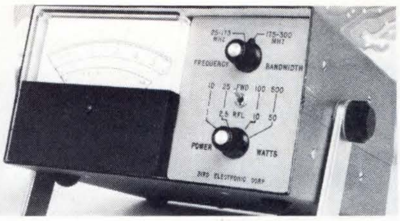
512-MHz PORTABLE SIGNAL GENERATOR costs only $1135. The Model 8645A generates power levels between +3 dBm and −120 dBm into a 50Ω load with an output-power accuracy of ±1.5 dB plus the attenuator accuracy which ranges from ±0.5 to ±1.5 db. The output power is automatically leveled to within ±1 dB over the entire frequency range. Model 8654A has a stability of 0.002% over a 5-minute period. Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, CA 94304. Phone (415) 493-1501. **260**



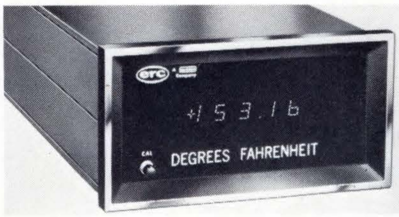
BRUSH 511 GRAPHIC PLOTTER accepts 8-level ASCII code and produces clear hard-copy plots at the rate of 2-1/2 strokes/sec at 10 characters/second, 5 strokes/sec at 30 characters/sec. It interfaces with any time share terminal or acoustic coupler. The Brush 511 is an absolute coordinate device. Gould Inc., Instrument Systems Div., 3631 Perkins Ave., Cleveland, OH 44114. **261**



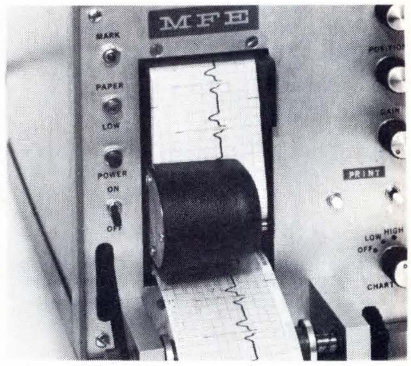
DIGITAL STORAGE SCOPE Model 1090, comprised of a main-frame and plug-in unit, has a 100-kHz real time bandwidth with 12-bit precision and sweep times that range to as long as several days per sweep. The 4096 × 4096 storage resolution makes it possible to record as much information about a single waveform as 160 storage-scope screens. Nicolet Instrument Corp., 3979 Triverton Pike, Madison, WI 53711. Phone (608) 271-6771. **262**



WIDEBAND WATTMETER, the Thruline Model 4370 covers 25 to 500 MHz and measures 1W to 500W full scale without changing plug-in elements. It has 4 forward-power levels (10 to 500W) and four reflected-power levels (1 to 50W). Accuracy is ±5% on all ranges over 25 to 500 MHz. Insertion VSWR is a low 1.1:1. Cost is $475. Bird Electronic Corp., 30303 Aurora Rd., Cleveland, OH 44139. Phone (216) 248-1200. **263**



DIGITAL THERMOMETER Model 9300 measures temperature with 0.5°C accuracy. Silicon sensor has a sensitivity of approximately 2.5 MV/°C. Display resolution of 0.01°C (or F) is available in the standard models. Probes are available with lead length up to 1000 feet or more. Prices range from $495 for a resolution of 1° or 0.1°C (or F) to $595 for a resolution of 0.01°. Electronic Research Co., 10,000 W. 75th St., Overland Park, KS 66204. Phone (913) 631-6700. **264**



ANALOG/DIGITAL STRIP-CHART RECORDING SYSTEM Model ADP is designed for use with any MFE single or multi-channel strip-chart recorder. The system provides the capability to print a continuous line of alpha-numeric or special characters without interruption of the analog record. Digital information is printed at a maximum rate of 5 characters/sec while the paper is moving at speeds of up to 50 mm/sec. Prices start from $300. MFE Corp., 340 Fordham Rd., Wilmington, MA 01887. Phone (617) 658-5500. **265**

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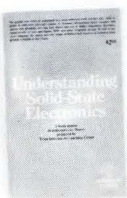
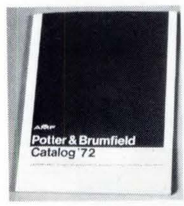
LITERATURE

MAGNETIC SHIELDING products catalog describes facilities and complete line of standard precision magnetic shielding materials and components. Included are: 7 types of round data tape protectors; 312 types of magnetic shields for photomultiplier tubes; a table of physical characteristics of AD-MU shielding alloys and available dimensions of these alloys. Ad-Vance Magnetics, Inc., 226 E. Seventh St., Rochester, IN 46975, Phone (219) 223-3158. **271**

TANDEM SLIDE SWITCHES provide "two switches in one" for quicker production line installation. Presented in a new product bulletin, the switches provide instrument-quality switching in equipment requiring precision, reliability and long life. Special "Sliders" assure continuous action of terminals, and the switch is self-cleaning. Switchcraft Inc., 5555 N. Elston Ave., Chicago, IL 60630. Phone (312) 792-2700. **274**



UNDERSTANDING SOLID-STATE ELECTRONICS, a 242-page paperback was developed to help solve a problem common to all high-technology companies—how to maximize effective cooperation between electronic engineers, their counterparts in other fields of engineering and their administrative peers. The self-teaching course is ideal for persons interested in obtaining a sound working foundation in electronics. Texas Instruments Inc., P.O. Box 5012, Dallas, TX 75222. Phone (214) 238-2011. **272**



RELAY CATALOG '72 is largest ever. The catalog provides 228 pages describing electromechanical, dry reed, mercury-wetted relays; hybrid relays, solid state time delays; custom assemblies; and precision snap-action switches. New products featured in the catalog include two new open-style dry reed relays and a new track mount system for industrial screw terminal sockets. Potter & Brumfield, Princeton, IN 47670. Phone (812) 385-5251. **275**

THUMBWHEEL SWITCH details all series of Digitran thumbwheel switches and devices using these switches. Included are the new Series 29000 miniature switch, designed to replace the rotary switch at a similar price, and the new B29 Pure Binary Switch. The catalog contains complete descriptions of DIGISWITCH and MINISWITCH types, incorporating photographs, drawings, specifications and diagrams. Digitran Co., 855 S. Arroyo Pwy., Pasadena, CA 91105. Phone (213) 449-3110. **273**

MERCURY RELAYS, contactors and tilt switches are described in a two-color, twelve-page catalog. Bulletin 100 is designed to fully inform the designer/specifier on the proper selection and capabilities of each product in the line. The section on timer relays includes photographs and dimensional drawings as well as information on contact action. Pages devoted to mercury switches show cut-away photographs. Durakool, Inc., 1010 N. Main St., Elkhart, IN 46514. Phone (219) 264-1116. **276**

UNIVERSAL TONE-BURST GENERATOR is described in a four-page brochure. The instrument generates any four tone frequencies in all of the time formats used for tone-selective paging systems. The brochure lists all call systems with which the instrument can be used. Applications are presented together with specifications. Singer Instrumentation, Los Angeles Operation, 3211 S. LaCienega Blvd., Los Angeles, CA 90016. Phone (213) 870-2761. **277**

INTEGRATED UNITY-GAIN AMPLIFIER literature, bulletin AF2, describes a new high-performance unity-gain follower amplifier featuring input resistance greater than 1 million M, input capacitance less than 0.1 pF, and rise time less than 30 nsec. Bioelectric Instruments, General Microwave Corp., 155 Marine St., Farmingdale, NY 11735. Phone (516) 694-3600. **278**

FREE WALL CHART provides engineers theoretical and applications data. The chart presents material in individual panels containing tables, charts, curves, nomographs, equations and formulae. A few of the panel headings are: Digital Codes & D/A Conversion Factors; Time Domain/Frequency Domain Conversions; Units, Constants & Conversion Factors; Universal Resonance Curves. The Wall Chart is available free of charge from the Marketing Dept., Ballantine Laboratories, Inc., P.O. Box 97, Boonton, N J 07005. Phone (201) 335-0900. **279**

WIRING/SOFTWARE CATALOG offers a complete wiring and software system which provides all the steps necessary to convert wire lists or logic equations into assembled and wired hardware. A flow diagram illustrates the steps from wire list or logic equations clear through to the update program which allows revisions of the original wire list. Scanbe Manufacturing Corp., 3445 Fletcher Ave., El Monte, CA 91731. Phone (213) 579-2300. **280**

COMBINATION DVM for systems and laboratory measurements is described in a new four-page data sheet on Dana's 4700 4-digit multimeter. The 4700's general features, systems performance, and reliability are all described. And, in addition, complete instrument specifications are given in detail. This information is contained in Data Sheet #1362. Dana Laboratories, Inc., 2401 Campus Drive, Irvine, CA 92664. Phone (714) 833-1234. **281**

PANEL METER SPEC TERMS defined in new publication. Precise definitions of terms used to describe d'Arsonval movement panel meter performance are presented and the discussion draws distinctions among such concepts as "accuracy", "calibration accuracy", "full-scale accuracy", and "tracking accuracy", as well as related terms. Booklet PM-300 is available on request to Beede Electrical Instrument Co., Inc., Penacook, N H 03301. Phone (603) 753-6362. **282**

MINICOMPUTER REFERENCE MANUAL for the Micro 1600 minicomputer has seven chapters and an appendix with a microcommand reference table. The seven chapters contain design features, system description, microcommand repertoire, control panel operation, micro assembler program, input/output information, physical characteristics and system power. 88 pages. Microdata Corp., 644 East Young St., Santa Ana, CA 92705. **283**

DRAFTING TEMPLATE CATALOG issued featuring latest revisions of electrical, electronic and computer symbols. The catalog lists and illustrates two hundred templates and guides including circles, ellipses, frequency response curves, audio-visual equipment symbols, geometric, mathematical, processing, public utility and general wiring diagram symbols. Fisher & Crome Inc., 2427 N. Mascher St., Philadelphia, PA 19133. Phone (215) 426-3232. **284**

VACUUM BALANCE operating features, specifications, and accessories for the Cahn Model RG ELECTROBALANCE are detailed in a new 4-page brochure. Included are six principal applications: thermogravimetric analysis; surface area measurements; magnetic susceptibility; particle size distribution; surface tension and density. Each is illustrated and described briefly. Cahn Instruments Div. of Ventron, 7500 Jefferson St., Paramount, CA 90723. Phone (213) 634-7840. **285**

ADVERTISERS' INDEX

Application Notes

TEST REPORT cites advantages of epoxies over eutectic bonding. Complete details on the test program comparing electrically-conductive epoxies with eutectic techniques of mounting semiconductor chips are included in a 20-page test report which is offered free of charge. Epoxy Technology, Inc., 65 Grove St., Watertown, MA 02172. Phone (617) 926-0136. **304**

MICROWAVE POWER TRANSISTORS brochure, Publication No. MPT-700, provides basic design and application information on power transistors intended for use at microwave frequencies. The brochure describes significant technological developments in both the transistor pellet structure and the external package. RCA Solid State Div., Rte. 202., Somerville, N J 08876. **305**

LOGARITHMIC LOCK-IN AMPLIFIER. Application Note IAN-22 covers theory and operation. Starting with basic lock-in theory, this note shows how the new techniques are used to provide precise logarithmic outputs over a 10,000:1 signal range. IAN-22 provides valuable information for persons with an interest in detecting weak or noisy ac signals over a wide dynamic range. Ithaco Inc., 735 W. Clinton St., Ithaca, NY 14850. Phone (607) 272-7640. **306**

SOS/MOS QUAD TRANSISTORS described in application note. The LO1 family consists of four P-channel-enhancement type MOS transistors fabricated with silicon-on-sapphire (SOS) technology. Features of the LO1 make it suitable in a variety of applications, notably vhf amplification, analog switching, and high input impedance differential amplifiers. University Park Plaza, 743 Alexander Rd., Princeton, N J 08540. Phone (609) 452-2222. **307**

FET INTERCHANGEABILITY GUIDE, CRG-103, provides a comprehensive cross reference. Each of the more than 1000 device types listed is keyed with a manufacturer's code, and a total of 13 different FET makers and their devices are noted. Listed in the guide in a convenient cross-checking chart are the in-house numbers used by FET suppliers. JEDEC types are given as well. Texas Instruments Inc., 13500 N. Central Expressway, Dallas, TX. 75231 Phone (214) 238-2011. **308**

"CUTTING WITH WIRE" AND "POLISHING WITH DIAMONDS" covers sawing of semiconductors, crystals, glass, fiber optics, and structural materials. It also covers polishing semiconductors, sapphire, gemstones, laser rods, etc. For a free copy of this booklet write Laser Technology, Inc., 10624 Ventura Blvd., North Hollywood, CA 91604. Phone (213) 763-7091. **309**

MICROWAVE FERRITE SWITCHES are described in a new six-page bulletin, # SMDO-4 offered by Ratheon Company's Special Microwave Devices Operation. The theory of operation of ferrite switches is presented along with information on applications in radiometry, attenuators, and real time delays. Fifteen devices for operation at L, S, C, X, and Ku bands are described. Raytheon Co., 130 Second Ave., Waltham, MA 02154. Phone (617) 862-6600. **310**

"PHOTOFABRICATION METHODS with *Kodak* photosensitive resist," a 36-page publication, # P246, presents a process-oriented sequence of photofabrication methods. The book replaces # P-125, "Photofabrication of Printed Circuits," and # P-131, "Chemical Milling With *Kodak* Photosensitive Resists." Available at the price of $1.75, the 8-1/2 × 11-inch data book can be obtained from Dept. 454, Eastman Kodak Co., 343 State St., Rochester, NY 14650. Phone (716) 724-4642. **311**

TESTING RF TRANSMISSION LINE, coax and waveguide, is the subject of a new 16-page Data Sheet from Hewlett-Packard. Test arrays covering 0.01 to 18 GHz are detailed for swept measurements of insertion and return loss. Data Sheet "8325A Microwave Test Set." Hewlett-Packard Co., 1601 California Ave., Palo Alto, CA 94304. Phone (415) 493-1501. **312**

REFERENCE COPIES AVAILABLE

Reference copies of the following articles are available without charge:

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