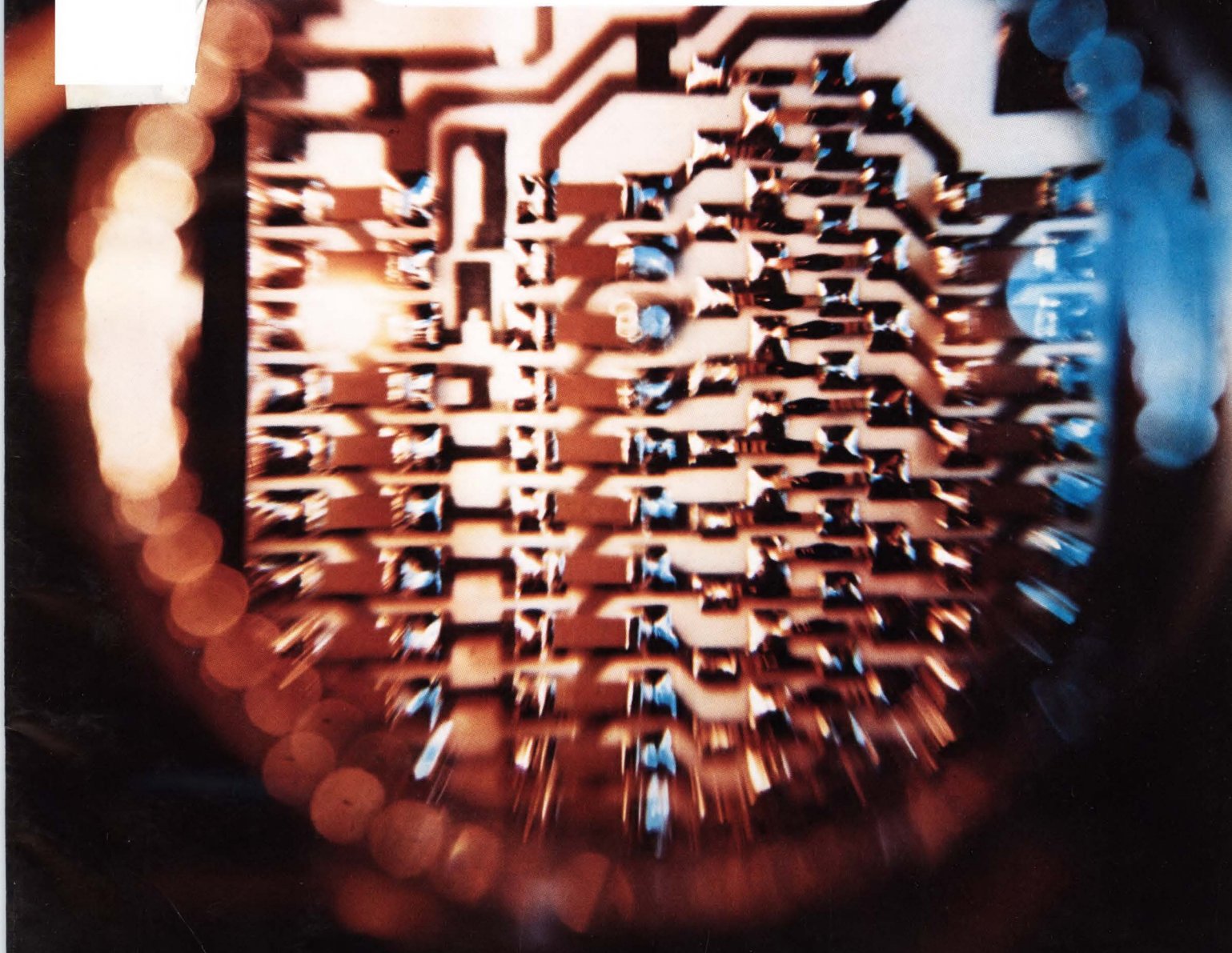
EDN

EXCLUSIVELY FOR DESIGNERS AND DESIGN MANAGERS IN ELECTRONICS

Hybrids Today
ICs Prepick Frequencies
'Union' Is a Dirty Word
Pulse Swallowing



A CAHNERS PUBLICATION

OCTOBER 1, 1970

Dale takes the headaches out of hybrids

If you want to move faster in converting your hybrid circuit ideas to reality—call Dale. Our proficiency in thick and thin film chips and microcircuits enables us to take your custom hybrid project and run with it. We'll go as far as you like...starting with circuit design...prototype testing...building the film resistive-capacitive platform...adding active or passive devices...and packaging to your requirements. Turnaround time between your idea and our prototype can be as short as two weeks for simple RC circuits ...and is always held to an absolute minimum. Your circuit information will, of course, be held in strictest confidence. Whether your application is commercial, industrial or military—get it moving. Our hybrid circuit specialists are waiting for your call—with action. *Call our Applications Engineering Department—402—564-3131 or write today.*

DALE®

DALE ELECTRONICS, INC.
1300 28th Ave., Columbus, Nebr. 68601
In Canada: Dale Electronics Canada, Ltd.
A subsidiary of The Lionel Corporation

CIRCLE NO. 46

How to improve your test equipment without blowing your budget.

Simply use Hewlett-Packard's new family of high-performance, wideband general-purpose power amplifiers and preamps. These low cost RF amplifiers improve the sensitivity of your scopes, spectrum analyzers, counters, network analyzers — anywhere you need low-noise, high-gain amplification. These amplifiers are the result of HP's hybrid thin-film microcircuit technology.

The table below gives frequency ranges, prices and performance of the six basic configurations. Dual channel versions of the preamps can also be supplied to improve the performance of 2-channel instrumentation.

They're ready for delivery now.

A call to your HP field engineer will bring you the details of how these amplifiers can help enhance the test equipment you're using now. Or write to Hewlett-Packard, Palo Alto, California 94304; Europe: 1217 Meyrin-Geneva, Switzerland.

HEWLETT hp PACKARD

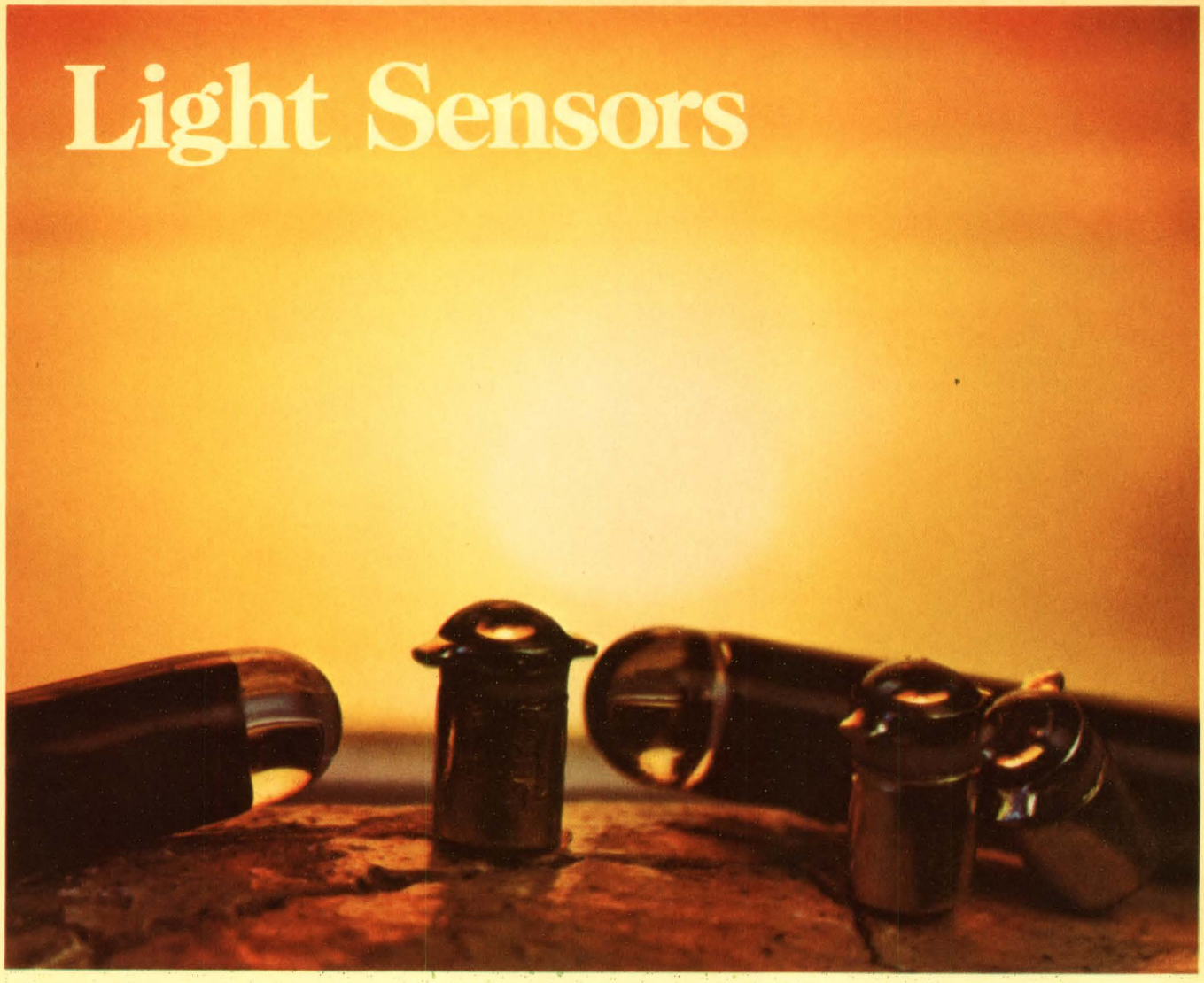
04021

HEWLETT-PACKARD 8447 SERIES LAB AMPLIFIERS

	HP 8447A Preamp	HP 8447B Preamp	HP 8447C Pwr. Amp.	HP 8447D Preamp	HP 8447E Pwr. Amp.	HP 8447F Preamp/Pwr. Amp.
Frequency Range	0.1-400 MHz	0.4-1.3 GHz	30-300 MHz	0.1-1300 MHz	0.1-1300 MHz	0.1-1300 MHz
Nominal Gain	20 dB	22 dB	30 dB	23 dB	22 dB	45 dB
Gain Flatness	±0.5 dB	±1 dB	±1 dB	±1.5 dB	±1.5 dB	±3 dB
Noise Figure	<5 dB	<5 dB to 1.0 GHz <6 dB, 1.0-1.3 GHz	<10 dB	<8 dB	<10 dB	<8 dB
Output Power @ 1 dB Gain Compression	>+7 dBm	>—3 dBm	>+19 dBm	>+7 dBm	>+14 dBm	>+14 dBm
Price	$550	$600	$450	$700	$800	$1225

CIRCLE NO. 35

Light Sensors



Any bright ideas?

How about a detector to track the sun, moon and stars for an inertial navigation system. Or an optoelectronic array to read punched cards and tape. Or in recognition equipment such as credit card readers, check recorders and bill changers.

Maybe a brushless motor needed in an explosive environment, or a tone generator for an electric organ. And there are burglar alarms, optical sound track readers and infrared film recorders. Also accelerometers and gyros. And instruments for measuring gas, liquids and even freight packages.

TI's light sensors are 1000 times faster than the electromechanical devices they replace and they're up to 20 times more reliable.

TI has eleven light sensors and two light emitters in its line of preferred semiconductors. That means they're "application proven," in volume production and are readily available from distributor and factory stocks.

For TI's *Preferred Semiconductors and Components* catalog, write Texas Instruments Incorporated, PO Box 5012, MS 308, Dallas, Texas 75222.

Try a few bright design ideas with TI light sensors.

TI Preferred Light Sensors and Emitters

LIGHT SENSORS	PACKAGE/LENS	SENSITIVITY
1N2175	Elongated/Round	0.1 mA
LS400	Elongated/Round	1.0 mA
LS600	Std/Round	0.8 mA
TIL601	Std/Round	0.5-3 mA
TIL605	Std/Flat	0.5-3 mA
TIL602	Std/Round	2-5 mA
TIL606	Std/Flat	2-5 mA
TIL603	Std/Round	4-8 mA
TIL607	Std/Flat	4-8 mA
TIL604	Std/Round	7 mA
TIL608	Std/Flat	7 mA
LIGHT EMITTERS	**PACKAGE/LENS**	**POWER OUTPUT**
TIL01	Std/Round	50 mW
TIL09	IR/Flat	500 mW

TEXAS INSTRUMENTS
INCORPORATED

OCTOBER 1, 1970
VOLUME 15, NUMBER 19

EDN

EXCLUSIVELY FOR DESIGNERS AND DESIGN MANAGERS IN ELECTRONICS

Cover

Cover photo shows Spacetac's 10-stage hybrid multi-dynode photomultiplier supply for space applications. Named a Cockroft-Walton supply after its developers, the 2500V output unit contains 40 capacitors, 24 resistors and 26 diodes. See article p. 23.

Design News

Design Predictions

Design Features

Design Ideas

Design Interface

Design Products

Design Departments

EDN's DESIGN ACTIVITY FILING SYSTEM is used to classify all Design Feature and Design Idea articles. The first word indicates the *activity* discussed in the article. The second word denotes the principal product being used in the activity. The third word modifies the second word. Finally, a number is used to specify frequency, where applicable. This number is the $\log_{10}$ of the frequency in hertz.

ABP CP MCR BPA

ibpa International Business Press Associates

DESIGN ELECTRONICS
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We make components for guys who can't stand failures.

The instruments say it's the earth that's upside down. But the pilot has a little more to say—about whoever built his instruments.

Funny how many guys there are today who can't stand failures, particularly failures in their electronic equipment.

And that's where we come in. We make resistors and capacitors for guys who can't stand failures. Guys like your most important customers, guys like you.

We build an extra measure of reliability into all our components to help you build extra reliability into all your systems.

To be specific, we make tin oxide resistors—now including both miniature RLR05's and flame proofs—and glass and Glass-K™ capacitors. They're the best you can get, though they'll cost you no more.

Take our tin oxide resistors—no other resistors can deliver the same stability and reliability over life. They offer guaranteed moisture resistance across all ohmic values, for reliability that can't be matched by metal film, wirewounds, carbon comps or metal glaze resistors.

This kind of extra performance comes in miniature size, too. Our new RLR05 (commercial style C3), developed for dense packaging applications, competes costwise with carbon comps.

And we lead the field with flame proof resistors. Ours will withstand overloads in excess of 100 times rated power without any trace of flame. And because they open rather than short under severe overload, they provide protection for the rest of the system—a vital consideration in critical and expensive EDP, telecommunications, and instrumentation gear.

Or take our glass capacitors. The Air Force has confirmed they have much better stability and much higher insulation resistance than the ceramic, mica, and other capacitor types tested. That's why our glass capacitors have been designed into so many major aerospace and missile projects. And why industry has designed them into the most important EDP and instrument applications.

Or our Glass-K™ capacitors—we developed them to give you the volumetric efficiency and economy of monolithic ceramic capacitors, but with the much improved stability and reliability that only a glass dielectric can add. Our Glass-K™ capacitors are now being used in pacemaker heart units and in several major EDP systems. And these Glass-K™ capacitors can now be used in BX characteristic applications.

As you might expect, both our resistors and capacitors meet Established and High Reliability standards, such as MIL-R-39017, MIL-R-55182, and Minuteman.

At Corning we make components for guys who can't stand failures. Guys like your most important customers. Guys like you.

And even though you might expect to pay a lot more for these features, you don't. Because as the largest manufacturer of these type components, our production volume affords us economies that enable us to be competitive in price.

So the next time you're designing a system, design-in an extra measure of performance. Reach for your CORNING® resistor and capacitor catalogs or look us up in EEM. Or for in-depth technical information write us at: Corning Glass Works, Electronic Products Division, Corning, New York 14830.

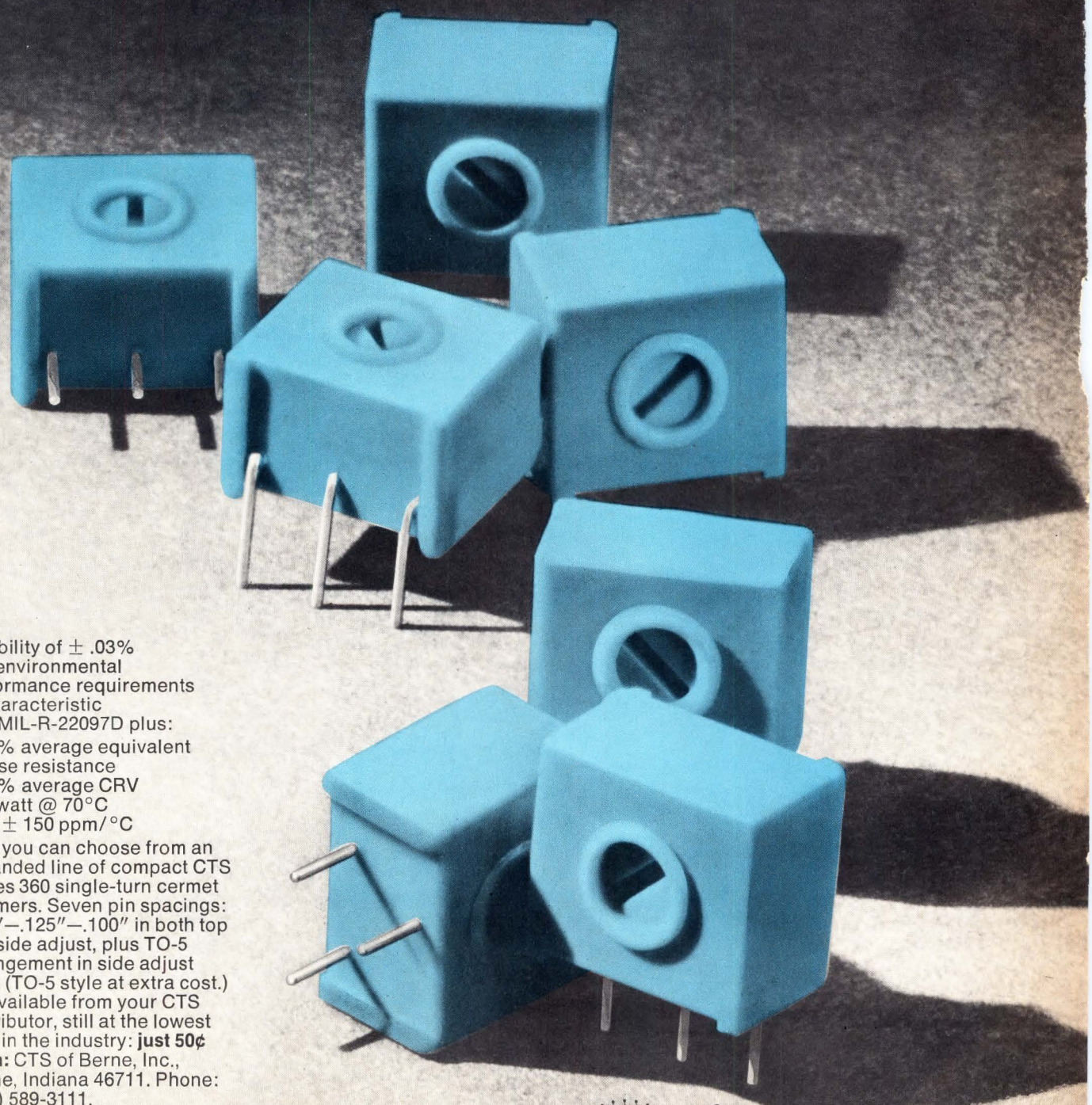
Then call your local CORNING authorized distributor for fast off-the-shelf delivery. He not only stocks components for guys who are demanding, but he offers service to match, too.

CORNING
ELECTRONICS

CIRCLE NO. 2

We've upped the line to 7 pin spacings without upping the price.

CTS cermet industrial trimmers still 50¢ each.*



Setability of ± .03% and environmental performance requirements of characteristic C of MIL-R-22097D plus:

- 1.5% average equivalent noise resistance
- 0.5% average CRV
- ½ watt @ 70°C
- TC ± 150 ppm/°C

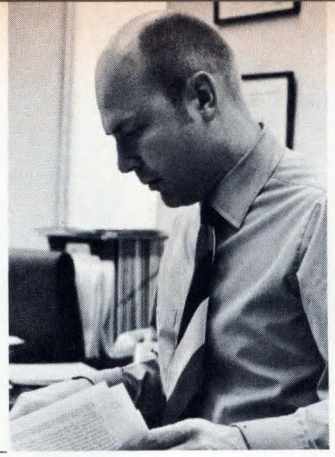
Now you can choose from an expanded line of compact CTS Series 360 single-turn cermet trimmers. Seven pin spacings: .150″—.125″—.100″ in both top and side adjust, plus TO-5 arrangement in side adjust only. (TO-5 style at extra cost.) All available from your CTS Distributor, still at the lowest cost in the industry: **just 50¢ each:** CTS of Berne, Inc., Berne, Indiana 46711. Phone: (219) 589-3111.

*in 50,000 quantity for ± 20% tolerance. Add 4¢ for 10% tolerance. Comparably low prices for smaller quantities.

CTS CORPORATION
Elkhart, Indiana

Your CTS Answer Man stands ready to fit our expanded trimmer line into your application.

CIRCLE NO. 43



Editorial

Get Ready to Try Harder

The U.S. scientific and engineering community soon will be in second place in the race for world leadership. Remember the last time that happened? It was on October 4, 1957, the day Sputnik I went into orbit. Being in second place made us try harder. It gave us national purpose. It made us reach for and attain the moon. Sometimes second place is a good place to be.

Sometimes first place is a harder place to be, especially when the race never stops. The guy up front sets the pace, is constantly challenged from every quarter. Remember the great New York Yankee dynasty? It got to be that fans rooted *against* the Yanks rather than *for* anyone else. So it is with the United States today. Because we're first, everyone expects concessions. "Beat the Americans" has become a worldwide goal.

More distressing, our own fans have deserted us. Rather than support us, they tear at the very trophy that is slipping from our grasp—each faction wanting a chunk of that loving cup which is largely attributable to technical superiority. There is so little of it remaining that basic research now goes begging. And any researcher who manages to acquire funds had better watch out for bomb wielders.

The day we slip into second place will pass without fanfare. There will be no Sputnik. But it will happen.

Perhaps our experiences as a second-rate scientific (ergo military and economic) power will teach us lessons that will stand us in good stead when once again our nation is united.

In the meantime, get ready to try harder.

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BROAD LINE GETS BROADER. 8 LOWER CAPACITANCE VALUES (100 pF thru 390 pF @ 200 V).

Type 192P Pacer® Polyester Film Capacitors are mass-produced to beat the space/cost squeeze in commercial and industrial applications. Extended-foil PETP film sections with metal end caps provide best possible non-inductive construction. End caps also act as moisture barriers. Ideal for automatic insertion on printed wiring boards. Expanded line includes capacitance values from 100 pF to .47 μF. Voltage range, 80 to 600 vdc. Write for Bulletin 2066C.

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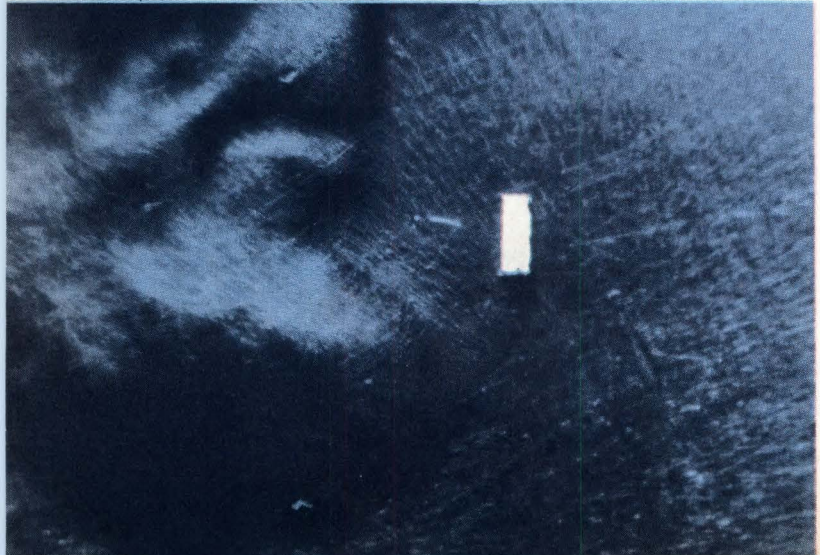
4SM-0143

CIRCLE NO. 5

Dry Cells Power Tiny New Lasers



Bell Laboratories' new laser, smaller than a grain of sand, is powered by ordinary dry cell batteries, and emits a beam of near-visible infrared light (8500Å).

Designed by Izuo Hayashi (photo at left) and Morton Panish, the new laser is a semiconductor device that operates continuously at normal room temperature (75-80°F). Such lasers, operating at room temperature, may one day speed the transmission of voice, data, and other information signals in high capacity optical communications systems. Semiconductor lasers are also expected to have a significant impact upon the new technology of optical electronics.

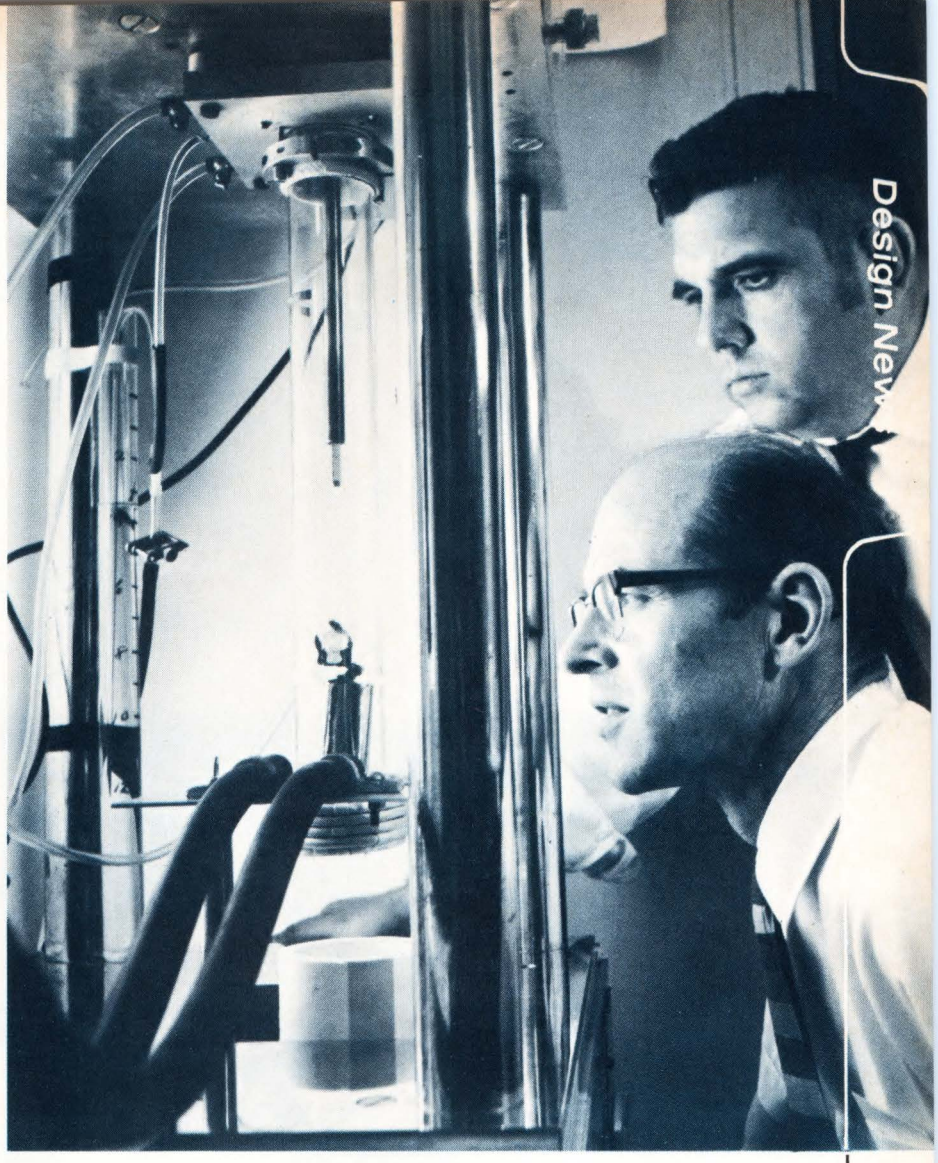
The new semiconductor laser is a double heterostructure diode comprised of four layers of gallium aluminum arsenide alternating with gallium arsenide. These layers are doped with tin, silicon, zinc and germanium, and are grown by liquid phase epitaxy.

With this new type of structure, semiconductor lasers can be operated continuously with room temperature current thresholds at about 2700A/cm^2. Current threshold is the point at which laser activity begins. Under these conditions the laser structure itself is about 25°C above the ambient temperature. When the devices are operated 30% above threshold, output power at room temperature is about 20 mW, with a power efficiency of about 1-1/2 to 2%.

In the past, heat generated in semiconductor lasers made pulsed operation imperative. As a result, only a fraction of the laser's vast message-carrying potential could be used. By fabricating a new semiconductor laser structure that can be driven by a smaller electric current, Hayashi and Panish with the aid of their co-workers P. W. Foy and S. Sumski, overcame the need for additional cooling processes and the problems of short-pulse operation.

Izuo Hayashi points to location of a new semiconductor laser on heat sink. The new laser is run by a power source no larger nor more complicated than an ordinary dry cell battery.

Honest, Abe—it's a laser! This new semiconductor laser is about 0.0015 in long by 0.003 in wide, the first of its kind to run continuously at room temperature.

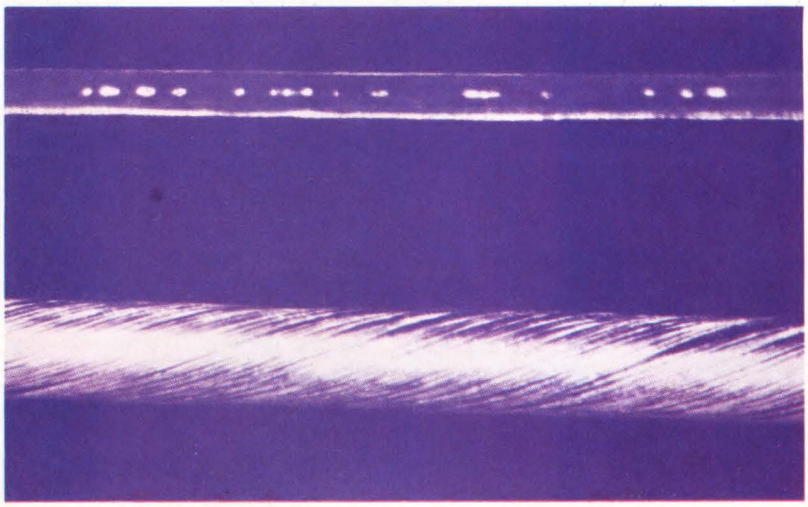


Purity Standard Hits New High

Quantity production of extremely pure single crystal germanium and cadmium telluride has begun at General Electric's Space Technology Products in Valley Forge, Pa. Purer than any material produced thus far, the germanium is purified through several generations of regrowth in a hydrogen atmosphere (photo). Its oriented Czochralski crystals contain fewer electrically active impurities than $10^{11}/cm^3$, or one part in 10^{12}. Expected application is in high-energy particle detectors that will not deteriorate at room temperature. The cadmium telluride crystals, available as 13-mm-diam slices, appear useful in infrared laser beam modulators. Both the Ge and CdTe crystals can be produced in either "n" or "p" types, and this characteristic is reversible in the CdTe crystals. Germanium crystals containing gradual junctions can also be grown, said GE spokesmen.

New Superconductor Can Carry AC

Microscopic view compares diameter thicknesses of Norton Co.'s new "Supercon" VSF multifilament superconductor and a strand of human hair. First commercially-available multifilament superconductor contains more than 400 highly stable superconducting niobium-titanium alloy filaments, each only 0.007 inch in diam, embedded in a copper matrix for high thermal and electrical stability. The very small diameter enables the superconductor to make possible variable high intensity magnetic fields used in nuclear research operations. It is capable of carrying pulsed or low frequency ac rather than conventional dc.



When is True RMS Really True RMS?

$$\sqrt{(DC)^2+(AC_{rms})^2}$$

TRUE RMS $=\sqrt{(dc)^2+(ac_{rms})^2}$ – and HP's new 3480 DVM is the only four-digit multi-function meter that can give you this true RMS value – ac, dc, or **ac plus dc.** And, the 3480 eliminates the errors caused by odd harmonic distortion added by average responding converters. With the 3480 you get measurements within 0.1%, not just to within 1%! (A 1% third harmonic distortion = ±0.33% error or ±33 counts of error in a four-digit average responding DVM.)

Whatever type of signal you're measuring – from the purest sine wave to the most irregular pulse train – the HP 3480 DVM gives you the results you need in one second. And, when you're working with an ac-plus-dc signal, you don't have to make two separate readings and then calculate the combined RMS value. It's all there, in one set of figures.

THE SECRET: A PAIR OF MATCHED THERMOPILES. At the heart of the 3480, there is a tiny chip, less than ¼" square, which contains matched sets of thermopiles. One measures the heat produced by the signal you're testing; the other does the same for a reference voltage.

The full scale ranges of the HP 3480 DVM are from 100 mV to 1000 Vac and the frequency range is from 1 Hz to 1 MHz. And with the correct plug-in, the 3480 can give you up to 1,000 **straight-dc** or **ohms** readings per second – with 5 dc ranges and 6 ohms ranges.

Prices range from $1150 for one range of dc to $3375 for multi-function ac, dc and ohms capabilities with isolated BCD and isolated remote control.

Find out how the HP 3480 DVM can help solve *your* measurement problems. Contact your local HP field engineer, or write to Hewlett-Packard, Palo Alto, California 94304. In Europe: 1217 Meyrin-Geneva, Switzerland.

090/12

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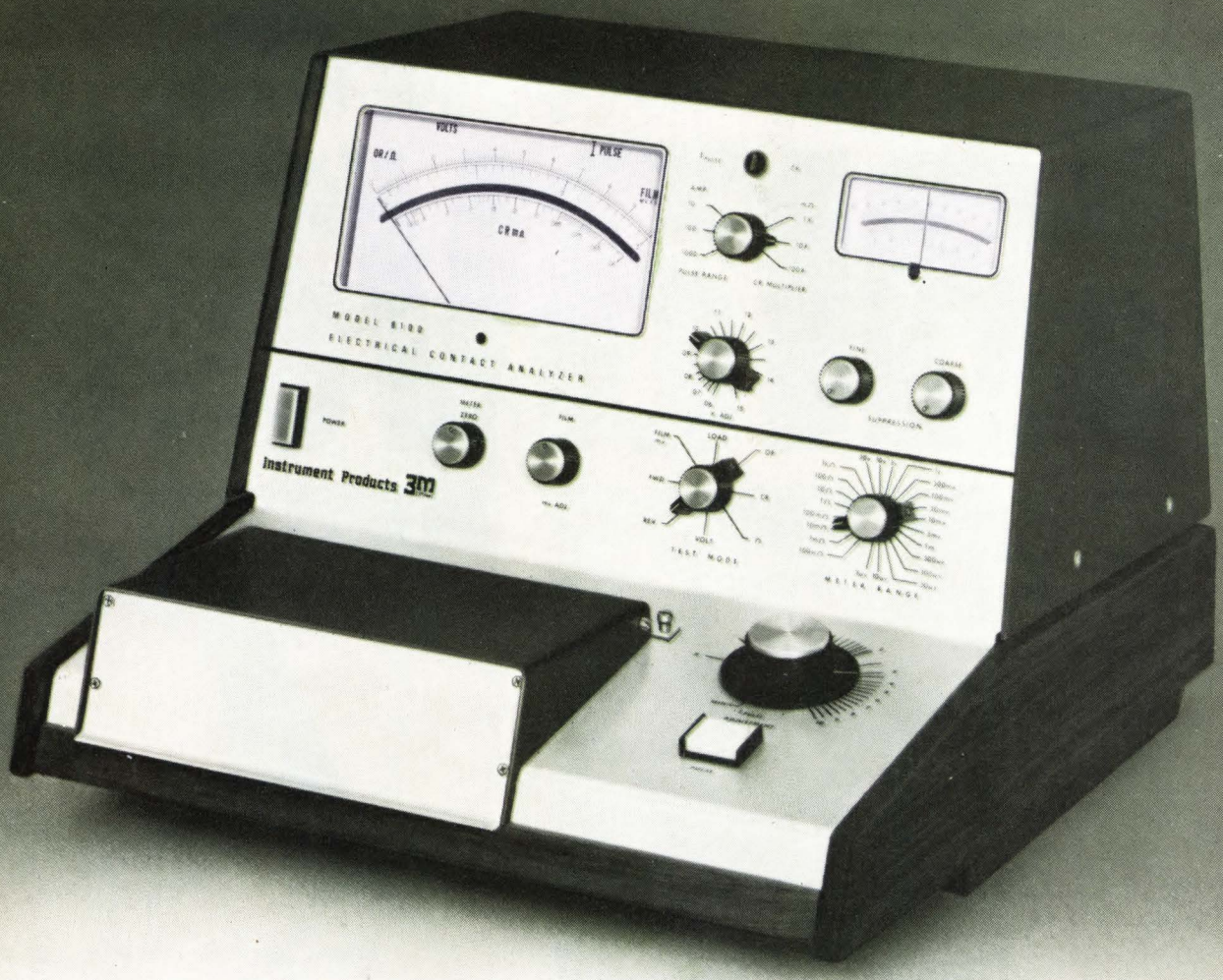
DIGITAL VOLTMETERS

CIRCLE NO. 35

3M PRESENTS
THE FIRST ELECTRICAL CONTACT ANALYZER



Measure Constriction Resistance — the Key to Contact Quality.

The 3M Model 8100 Electrical Contact Analyzer, using a unique technique developed by Burndy, measures **constriction resistance;** providing new insight into the quality and long-term reliability of Connectors, Switches, Relays and Reed Switches.

If you know about **constriction resistance,** you know it occurs at, and because of, the contact interface. You also know what it means to be able to measure it non-destructively, even though the interface itself is inaccessible.

If you **don't** know about constriction resistance, just remember this: Electrically, the interface is where a contact works—and also where it fails.

Incidentally, the **3M Electrical Contact Analyzer** will do some other things, too . . . like detecting films on contacts, making precise, ultra-low resistance measurements and DC null measurements using its own built-in supression supply.

Price: $4450.00, f.o.b. Camarillo, Calif.

Instrument Products 3M COMPANY

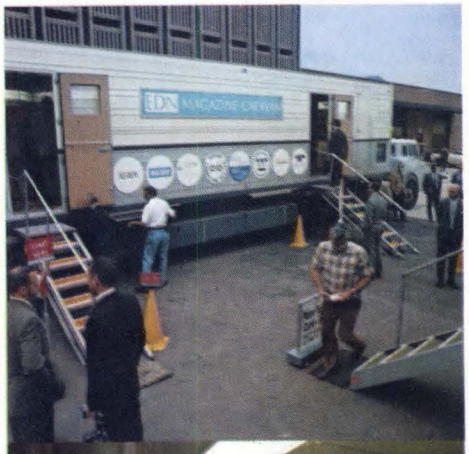
300 SOUTH LEWIS ROAD • CAMARILLO, CALIFORNIA 93010 • PHONE: (805) 482-1911 • TWX: 510-866-7099

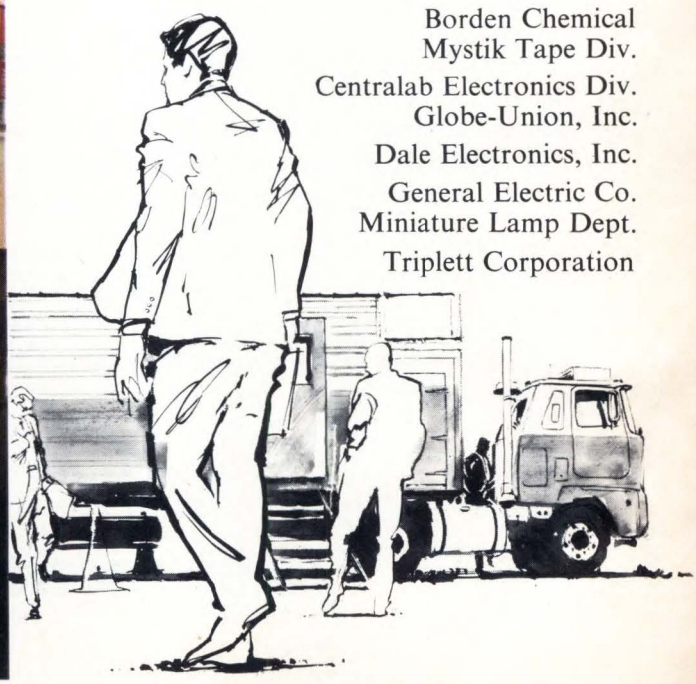
CIRCLE NO. 6

Watch for EDN's fourth annual Caravan tour, September-December 1970. A traveling exposition of products and ideas visiting over 100 leading electronic manufacturers throughout the U.S.A.

EDN MAGAZINE PRESENTS...

Caravan '70





Featuring new products, ideas and application assistance from:

Allen-Bradley Company
Bodine Electric Co.
Borden Chemical
Mystik Tape Div.
Centralab Electronics Div.
Globe-Union, Inc.
Dale Electronics, Inc.
General Electric Co.
Miniature Lamp Dept.
Triplett Corporation

EDN CARAVAN ROUTING

October 1 - October 30, 1970

Date / DAY / TIME	AREA	SITE
Thursday, October 1		
9:00 - 11:00 a.m.	Cleveland, Ohio	General Electric Lamp Dept.
Friday, October 2		
9:00 - 12:00 noon	Webster, N. Y.	Xerox
1:30 - 4:30 p.m.	Rochester, N. Y.	Eastman Kodak
Monday, October 5		
9:00 - 11:00 a.m.	Sidney, N. Y.	Bendix (Scintilla Div.)
1:30 - 4:00 p.m.	Endicott/Glendale, N. Y.	IBM
Tuesday, October 6		
9:00 - 12:00 noon	Binghamton, N. Y.	Link General Precision
Wednesday, October 7		
9:00 - 12:00 noon	Herkimer, N. Y.	Mohawk Data
Thursday, October 8		
8:30 - 10:00 a.m.	Nashua, N. H.	Sanders Associates
10:30 - 12:00 noon	Daniel Webster Hwy, Nashua, N. H.	Sanders Associates
1:30 - 4:30 p.m.	Canal St. Plant, West Lynn, Mass.	General Electric
Friday, October 9		
9:00 - 12:00 noon	Foxboro, Mass.	Foxboro
2:00 - 4:00 p.m.	Bedford, Mass.	EG & G
Monday, October 12		
9:00 - 11:00 a.m.	Bedford, Mass.	Sanders Associates
1:30 - 4:30 p.m.	Wayland, Mass.	Raytheon
Tuesday, October 13		
9:00 - 12:00 noon	Bedford, Mass.	Raytheon
1:30 - 4:00 p.m.	Framingham, Mass.	Honeywell
Wednesday, October 14		
9:00 - 11:00 a.m.	Waltham, Mass.	Honeywell
12:30 - 2:00 p.m.	Billerica, Mass.	Honeywell
3:00 - 4:30 p.m.	Waltham, Mass.	Hewlett-Packard
Thursday, October 15		
9:00 - 11:00 a.m.	Windsor Locks, Conn.	Hamilton-Standard
2:00 - 4:30 p.m.	Norwalk, Conn.	Norden
Friday, October 16		
8:30 - 10:15 a.m.	Norwalk, Conn.	Perkin Elmer
11:00 - 12:30 p.m.	Wilton, Conn.	Perkin Elmer
1:30 - 3:30 p.m.	Stamford, Conn.	CBS Labs.
Monday, October 19		
9:00 - 12:00 noon	Kingston, N. Y.	IBM
Tuesday, October 20		
9:00 - 12:00 noon	Green Lawn, N. Y.	Hazeltine
1:30 - 4:30 p.m.	Plainview, N. Y.	Potter Instr. Co.
Wednesday, October 21		
9:00 - 12:00 noon	Plainview, N. Y.	Sanders Associates
2:00 - 4:30 p.m.	College Point, N. Y.	EDO Corp.
Thursday, October 22		
9:00 - 12:00 noon	Teterboro, N. J.	Bendix
1:30 - 4:30 p.m.	Little Falls, N. J.	Kearfott Div., Singer - General Precision
Friday, October 23		
9:00 - 12:00 noon	Whippany, N. J.	Bell Telephone Labs., Inc.
1:30 - 4:30 p.m.	Plainfield, N. J.	Lockheed Electronics Co.
Monday, October 26		
10:00 - 1:00 p.m.	Camden, N. J.	RCA
3:00 - 4:30 p.m.	Ft. Washington, Pa.	Honeywell
Tuesday, October 27		
9:00 - 11:00 a.m.	No. Wales, Pa.	Leeds & Northrup
1:30 - 4:30 p.m.	Paoli, Pa.	Burroughs Corp.
Wednesday, October 28		
9:00 - 12:00 noon	Cockeysville, Md.	Westinghouse PSE
1:30 - 4:30 p.m.	Baltimore, Md.	Westinghouse Aero
Thursday, October 29		
9:00 - 12:00 noon	Germantown, Md.	Fairchild Hiller
1:00 - 4:00 p.m.	Reston, Va.	Scope Electronics
Friday, October 30		
9:00 - 12:00 noon	Waynesboro, Va.	General Electric
1:30 - 4:30 p.m.	Lynchburg, Va.	General Electric

New Processes Fabricate Film Photoconductors

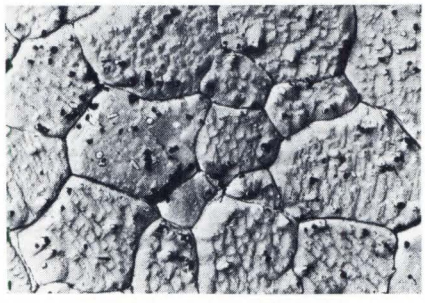
MILWAUKEE – Improved diffusion and electroding processes for high quality cadmium sulfide (or selenide) film photoconductors have been developed at Allen-Bradley Co.'s electronics division. The films are used for character recognition, position sensing and other applications.

The new processes activate and recrystallize photoconductors in a new type of diffusion system, yielding more uniform response over larger areas and much better topographic features than with conventional open tube flow systems.

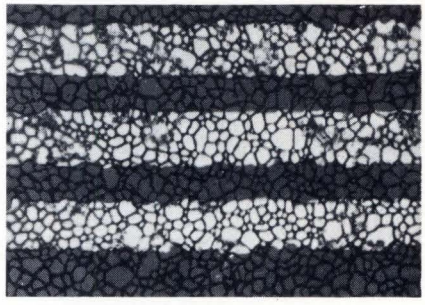
Improved topography in turn makes possible a new, high-resolution, high-density electroding process, applicable to quality sensing arrays. The new diffusion process's near-equilibrium conditions result in typical sensitivity changes of less than 50% over several square inches of film.

A proprietary sputtering electrode technique then deposits noble metal fingers of excellent ohmic character and inherent stability directly on the film photoconductor.

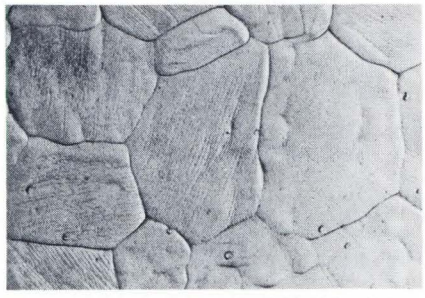
Through photolithography, finger spacings of 10μ are achieved. The new electroding process yields sensors with high photocurrents (typically, 1.5 mA per square at 100V and 100 fc), good light and voltage linearity, and extended life. After 120 hr, 65°C air exposure, units have shown light current drift of less than ±4%.



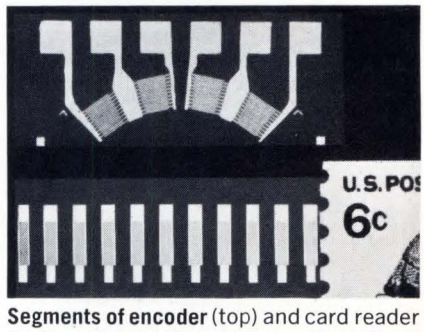
Electron micrograph (× 10,000) shows a CdS thin-film photoconductor activated and recrystallized by conventional open-tube flow process.



Optical micrograph (× 360) of a film photoconductor produced by sputtering electrode technique. Resolution approaches limits set by crystallite sizes.



Electron micrograph (× 10,000) of the same film activated and recrystallized by the new diffusion process. Surface is notably smoother and surface blemishes are absent.



Segments of encoder (top) and card reader (bottom) fabricated with new Allen-Bradley diffusion and electroding processes. Finger width and gap spacings are 0.002 in.

Let the Fingers Do the Walking—

BEDFORD, MASS. – Maybe not your fingers, but this card reader's mechanical fingers, permanent magnets and EDP equipment make direct reading of existing embossed credit cards an easy and inexpensive proposition. Developed by Athena Systems Inc., Bedford, Mass., a new card reader reads all 18 characters on a credit card and either transfers the information in binary code directly to a central computer via a magnetic reading head or stores it on a cassette cartridge for later processing.

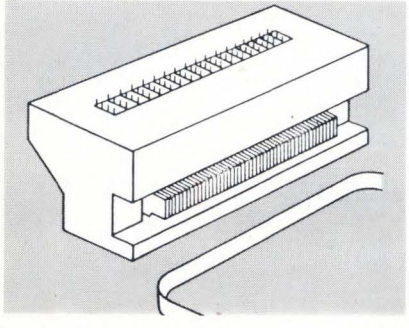


Fig. 1 – **Card reader records on magnetic tape** by bringing tape into contact with the back of character sensor as pressure roller moves into contact with card. Tape is cycled as roller if lifted.

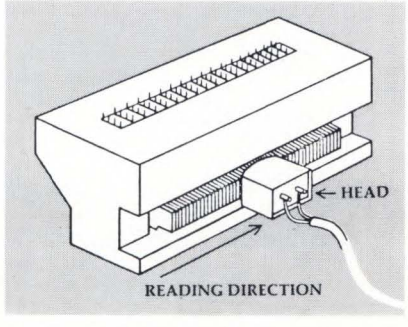


Fig. 2 – **Card reader with magnetic reading head.** As head moves along the track, it transmits serial data via an acoustical coupler over a voice-grade telephone line to a central computer.

Pins on one end of the mechanical fingers sense the depressions on the back of a credit card (7 pins/character) and transfer this information to EDP equipment by means of permanent magnets attached to the fingers' other end. Between the moveable magnets, stationary magnets supply timing marks. The reading head reads and transfers 100 data bits/s; binary "0" = 0.3V and binary "1" = 2.5V.

An on-line system has potential for immediate identification of stolen credit cards.

Now, Pixiepot® precision 10-turn wirewound pots priced as low as $3.25

Now, you can order *new, improved* Pixiepot® 10-turn wirewound potentiometers directly from this data sheet at the lowest pot prices anywhere! For as little as $3.25 (see price schedule), you get the world's smallest precision mini-pots for commercial and industrial applications, with all these special high performance features available: • High torque 2 to 8 oz. — in., • Custom bushing length, shaft configurations and lengths, • Any resistance within the range, • Linearity tol. ±.1%, • Resistance tol. ± 2%. Standard features include: • Newly developed superior high impact plastic housing, ¾" length and ⅞" diameter size. • Gold-plated terminals, welded terminations and slotted stainless steel shaft with bushing mounting. *Call your nearest Pixiepot distributor listed on the opposite side of this page for fast off-the-shelf delivery of standard models.*

PRICE LIST FOR PIXIEPOT POTENTIOMETERS

DESCRIPTION	1-9	10-24	25-49	50-99	100-249	250-499	500-999	1000-2499	2500-4999	5000-9999	10,000 UP
Model 3253, Std. Res.	4.95	4.90	4.80	4.70	4.50	4.30	4.10	3.90	3.65	3.47	3.25
SPECIAL FEATURES (ADDITIONAL CHARGES)											
±2% Res. Tol.	5.00	3.00	2.00	1.50	1.00	.75	.60	.50	.45	.40	.35
Hi-Torque (HT)	.95	.85	.75	.65	.60	.55	.50	.45	.40	.35	.30
Ind. Lin. ±0.1%	5.00	3.00	2.50	2.25	2.00	1.75	1.60	1.50	1.50	1.50	1.25
Shaft Lock	.50	.45	.40	.35	.30	.25	.25	.25	.20	.20	.20
Spec. Res. (1) Min. quan. 10 pcs.	3.50	1.60	1.05	.65	.30	.20	N/C	N/C	N/C	N/C	N/C

(1) Any value between 100Ω and 100K other than standard values shown in table. For resistance values outside this range, contact factory.

SPECIFICATIONS

ELECTRICAL
Actual electrical travel (+10° −0°) ..... 3600°
Normal resistance range ..... 100Ω to 100K
Extended resistance range ..... 25Ω to 150K
Resistance tolerance, standard ..... ±5%
special ..... ±2%
Power rating at 20°C derating to 0 at 85°C 2
End resistance ..... within linearity tolerance or 0.1Ω whichever is greater
Linearity, independent, tolerance, standard ..... ±0.25%
special ..... ±0.1%
Equivalent noise resistance, max. (ohms) meas. per VRCI stds. 100
Insulation resistance at 500 VDC, min. (megohms) 1,000
Dielectric withstanding voltage (volts RMS) 1,000

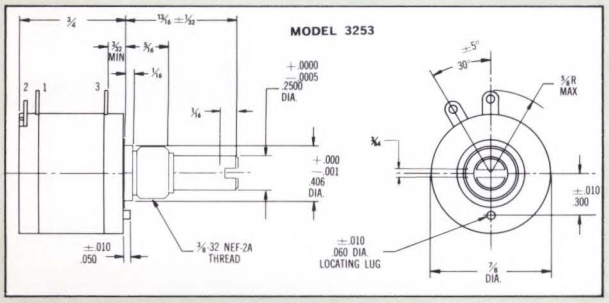
MECHANICAL
Total mechanical travel (+15° −0°) ..... 3600°
Mechanical life, shaft revolutions, normal conditions 500,000
Cups, max. number 1
Moment of inertia, approx. (gm-Cm²) 0.3
Weight (oz) 0.5
Stop strength, static (oz-in) 50
Torque: Standard starting, Max. (oz-in) 1.0
Special (designated H.T.) (oz-in) ..... 5±3

ENVIRONMENTAL
Temperature range, standard ..... −25° to +85°C
Humidity and dust protection ..... enclosed construction
Vibration ..... 10G to 2,000 cycles
Shock 50G

TYPICAL SPECIAL FEATURES AVAILABLE
Shaft lock • Any resistance within the range • High Torque • Resistance Tol. ±2% • Linearity Tol. ±0.1%.

CUSTOM FEATURES AVAILABLE
• Bushing length • Shaft configurations and length

Pixiepots are also available in a combination package with Model 61 miniature turns-counting dials at one super-budget price! Example: 5,000 . . . $6.95



NOTE: Lock washer and hex nut supplied with each unit. Design details subject to change without notice. Certified Drawings available on request. Tolerances unless otherwise specified: Fractional: ±1/64" Decimal: ±.005" Angular: ±1°

Talk to Duncan engineers direct for immediate answers to your special requirements. You can use this toll-free telephone number from anywhere in the nation: 800-854-3252. (California residents, call collect (714) 545-8261)

DUNCAN ELECTRONICS
SUBSIDIARY
SYSTRON DONNER
2865 FAIRVIEW ROAD COSTA MESA, CALIFORNIA 92626

TYPICAL COIL CHARACTERISTICS FOR STANDARD RESISTANCES

Standard Resistance (Ohms)	Theoretical Resolution Nominal (%)	Max. Appl. Voltage (Volts DC)
100	.051	14
200	.042	20
500	.036	32
1K	.025	45
2K	.023	63
5K	.021	100
10K	.016	140
20K	.015	200
50K	.011	316
100K	.008	447

All resistances shown are manufactured with resistance wire with temperature coefficient of .002%/°C (20 ppm) nominal.

HOW TO SPECIFY

When ordering a PIXIEPOT, indicate the model number, resistance, linearity tolerance and any additional special features. The letters "R" and "L" precede the resistance and linearity respectively.

Example: 3253 R1K L.25 HT

Model Number — 3253
*Resistance (Standard Tolerance) — R1K
Linearity Tolerance (±) — L.25
Code letter SL Shaft Lock / HT High Torque — HT

*If the resistance tolerance is ±2% show the tolerance in parenthesis ( ) after the resistance. E.g. R1K(2) designates a 1K resistance with a tolerance of ±2%. For resistance values less than 1,000 ohms (1K), show the actual value omitting the letter "K". E.g. 3253R100L.25 is a 100 ohms resistance.

Duncan Model 3253

Duncan Model 3253

Call your nearest distributor for fast delivery of in-stock Pixiepots

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(216) 762-8818

John A. Becker Elect. Co.
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Chicago, Ill. 60627
(312) 468-1017

Bodelle Co., Inc.
Detroit, Mich. 48235
(313) 273-6920

Bodelle Co., Inc.
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Mace Electronics
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(814) 838-3544

Radar Electric Co.
Seattle, Wash. 98119
(206) 282-2511

Richey Elect., Inc.
North Hollywood, Ca. 91601
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(213) 761-6133
*San Diego, Ca. 92103
(714) 291-4955
*Las Vegas, Nev. 89102
(702) 870-5996
*Agents of Richey Elect.

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Southwest Elect., Inc.
Houston, Texas 77036
(713) 782-3060

Sterling Electronics
Watertown, Mass. 02172
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Perth Amboy, N.J. 08861
(201) 442-8000
South Norwalk, Conn. 06854
(203) 853-3153

Terminal-Hudson Elect., Inc.
Mountain View, Ca. 94040
(415) 969-9240

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(412) 271-2800

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Montclair, N.J. 07042
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St. Louis, Mo. 63141
(314) 991-0262

Exon Electronics
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Tel: (612) 788-4111

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Grand Rapids, Mich. 49506
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(714) 545-8261

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Vestal, N.Y. 13850
(607) 748-7391
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(315) 463-8955

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28.20.70 (2 l.)

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Aero Sales Eng. Co.
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Ottawa, Ontario
(613) 828-8560

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Birmingham
EDG 6961/2

FRANCE
Radio TV Francaise
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722-70-40

GERMANY (WEST)
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(231) 528065

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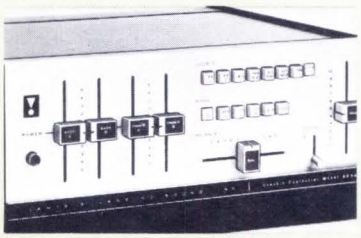
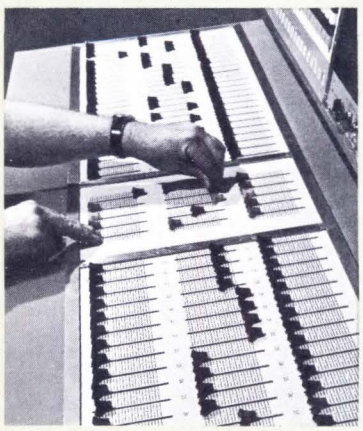
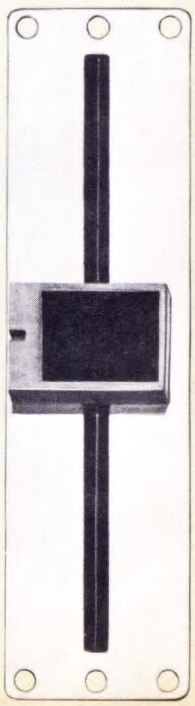


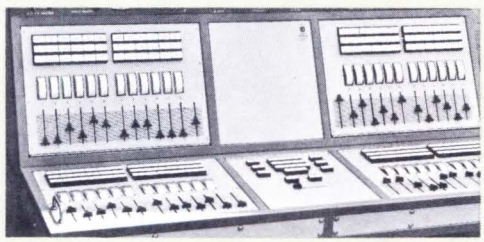


NEW! DUNCAN FADERS

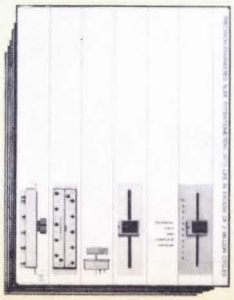
Slide actuated pots

The Duncan KP 200 series precision slide actuated potentiometer provides users with a 2¾" linear travel featuring essentially infinite resolution at low cost. The KP 200 series also provides: • Single or dual resistive elements • Linear or audio tapers • Standard tap positions • All metal housing and complete electrostatic shielding. Primarily used in the broadcast and recording industries, special applications in SCR lighting controls and commercial sound systems also have been numerous.





Send today for free catalog with complete specs.



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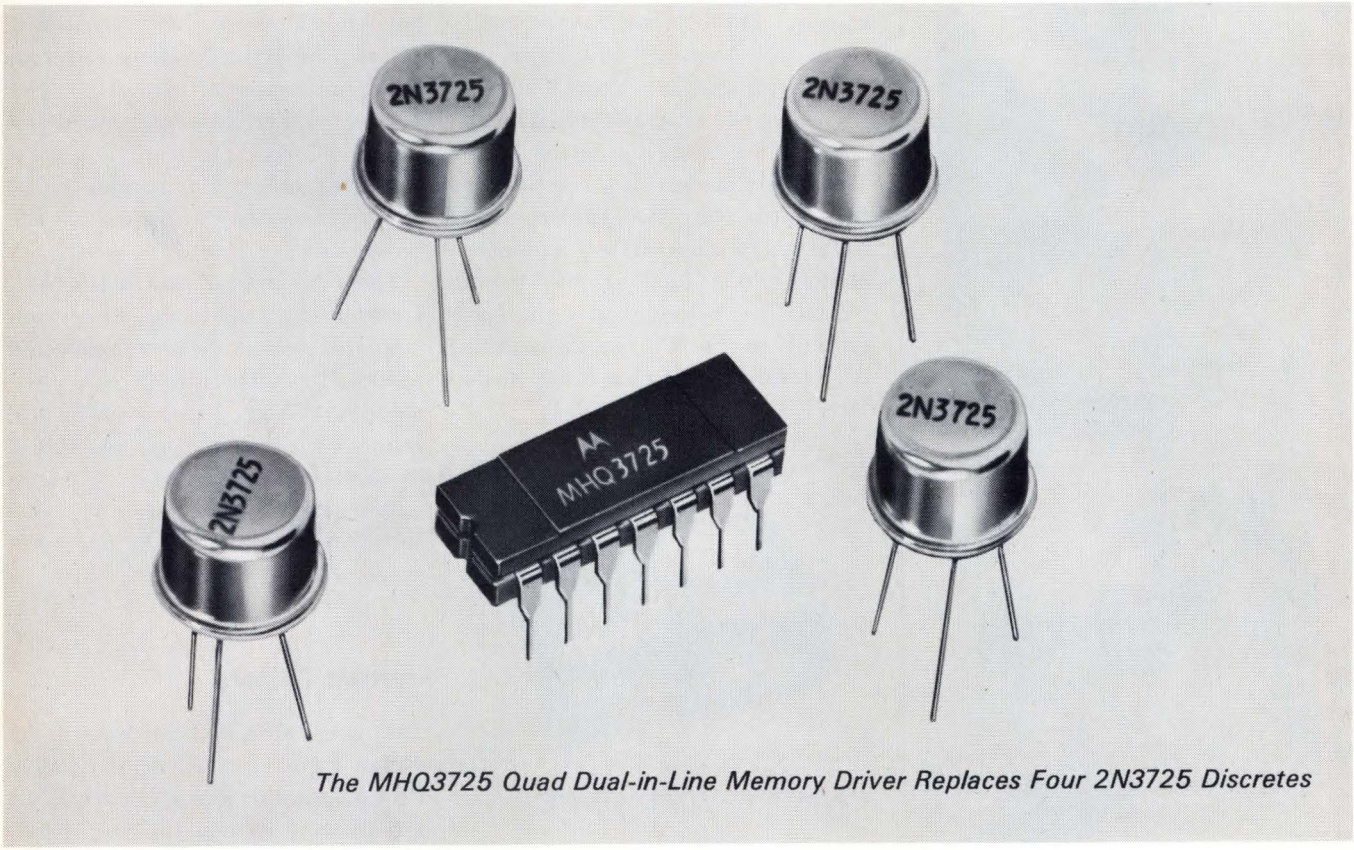
*At less than a third the price of competitive products...

QUAD MEMORY DRIVERS DRIVE A SOFT BARGAIN!

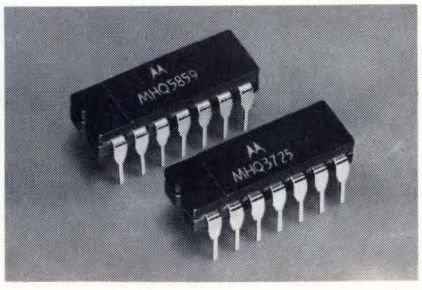


The MHQ3725 Quad Dual-in-Line Memory Driver Replaces Four 2N3725 Discretes

Motorola's new hermetic quads can *save you up to 66⅔%* on such computer applications as:

- ferrite-core and plated-wire memory drivers
- high-current, high-speed switches
- MOS translators

Thanks to our very high-volume manufacturing and testing techniques, our 14-lead dual-in-line quads in the hermetically-sealed ceramic TO-116 package cost less than a *third* of competitive devices' prices. And compared to using 4 discretes for the same functions, these new quads also give you the cost-saving advantages of employing automatic inserting equipment as normally available for IC mounting, and reducing both the size and weight of memory-driver components.



CERAMIC TO-116 PACKAGE (CASE 632)

SPECIFICATION HIGHLIGHTS and PRICES*

Characteristic	MHQ3725	MHQ5859
BV_{CEO} @ 10 mA	50 V (min)	40 V (min)
h_{FE} @ 500 mA/1 V	35 (min)	35 (min)
h_{FE} @ 1 amp/5 V	25 (min)	25 (min)
$V_{CE(S)}$ @ 500 mA/50 mA	.52 V (max)	.52 V (max)
t_{on}	35 ns (max)	35 ns (max)
t_{off}	60 ns (max)	65 ns (max)
P_D @ T_C = 25°C	4 W	4 W
Price Quantities	**Prices per Unit**	
1 — 99	$6.85	$5.50
100 — 999	5.95	4.75

The foregoing is only a part of the Quad Memory Driver, bargain-driving story. Get all the fascinating facts from your nearest Motorola representative. Or, write us direct: Motorola Semiconductor Products Inc., Box 20912, Phoenix, Arizona 85036.

MOTOROLA QUADS
—where the priceless ingredient is care!

♦ CIRCLE NO. 8

CIRCLE NO. 1

VTR Boom Looms

Panasonic has moved to make recording and playback tapes interchangeable among all Panasonic 3000 series video tape units. They utilize the newly established EIAJ standardized recording format for 1/2-in VTR. Four models in the series feature automatic video gain controls. Rotary head drive system and motor standby circuit offer nearby "instant on" pictures, with ability to play back on conventional TV sets through the use of an optional plug-in RF modulator.

Centralab Weds USCC

Globe Union, Inc. of Milwaukee recently announced the acquisition of U.S. Capacitor Corp., of Burbank, effectively marrying the West Coast high reliability capacitor and filter manufacturing facility and Globe Union's Centralab Electronics Div.

Globe Union President C. O. Wanvig, Jr. projected no operational or management change in the West Coast firm, other than installation of James W. Wolfe, erstwhile Centralab general manager, as USCC president. The Burbank-headquartered manufacturer of capacitors and RFI filters for industry and the military showed a profitable 1969 sales volume of nearly $3.5 million. USCC's product lines are expected to extend Centralab's participation in military industrial and consumer markets. Wolfe says he anticipates a beneficial melding of Centralab and USCC technologies.

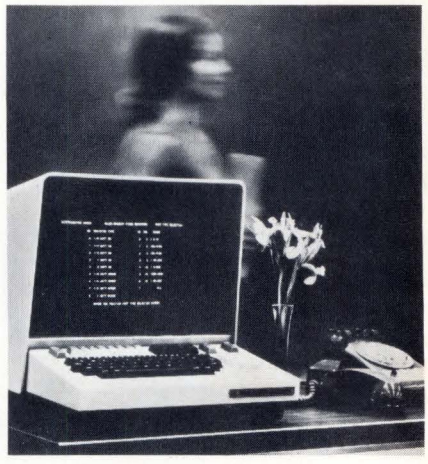
Hogan Keynotes ISHM

Dr. C. Lester Hogan will deliver the keynote address at the International Society for Hybrid Microelectronics 3-day international symposium November 16. Fairchild Instrument and Camera Corp.'s president and chief executive officer has picked a hot topic: "Business Prospectus for the Seventies".

The 3-day meet in Los Angeles will stress markets, methods and technology, with sessions devoted to each and talks by top authorities in each of the respective fields. A glance at the program discloses emphasis on hybrid applications in business machines and consumer electronics and a lessened interest in military and aerospace use.

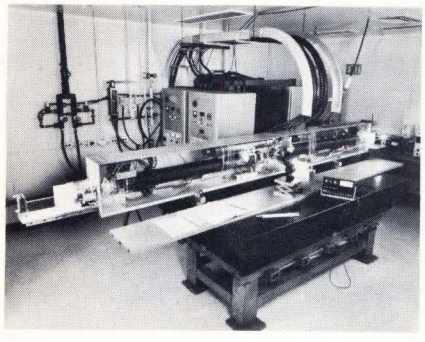
Instant Orders

Taking a leaf from the airlines reservation systems' book, Allen-Bradley Co. has installed a new visual computer ordering system in their distributors' offices. Called IRIS for "Instant Response Information System", it eliminates paperwork and mailing time associated with conventional order cycling, lets the distributor inform A-B immediately of his component needs – and get an immediate visual confirmation of the status of his order.



Double-Punch Laser

World's most powerful CW argon laser was developed recently by RCA Electronic Components in Lancaster, Pa., for the U.S. Army Electronics Command, Fort Monmouth, N. J. The new laser is said to be the most powerful (100W CW) argon unit ever produced by the company. It involves the use of new design concepts emanating from segmented-graphite, double ended construction for improved efficiency and power output.



NSF Cools It

Growth rate of R&D spending by universities and colleges has slowed down, a National Science Foundation survey shows. Chief cause of the relative decline is the leveling off of Federal obligations for research and development, a trend that began in the late 1960s and appears to be continuing.

Curtail Immigration

Engineers Joint Council Acting President John R. Kiely has urged that prospective immigrant engineers be required to have a job offer before entering the United States. He noted that reduced hiring of engineers on the part of employers could lead to a potential supply-demand imbalance for 1970 and 1971, and recommended that immigration be curtailed until engineering manpower demand has returned to its former levels.

Hmmmmmm. Let's talk about it.

An awful lot of people are buying our 42's and our 40-lead "skinny-dips" who don't need all those leads. Yet.

But with bits per pin and chip densities constantly increasing, tomorrow could be when they'll need extra leads. *Desperately!*

So with price about the same, they've wisely chosen to standardize on one of our larger Standards . . . packages we're producing in enormous volume. (We're now shipping over a *million* leads a day!)

Which makes delivery a lot easier. For *both* of us.

Why MetCeram in the first place? Because we're the leader in today's race to produce high-quality IC packages in dependable high-volume. Our no-glass, all alumina package is used for over 70% of all custom MOS devices shipped anywhere in the world!

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CIRCLE NO. 11

FUTURE CALCULATORS WILL INVADE NEW AREAS

Electronic calculators in 1975 can be predicted from the progress of transistor radios in the last decade says Ed Lesnick, Director of Product Planning for Wang Laboratories, Inc.

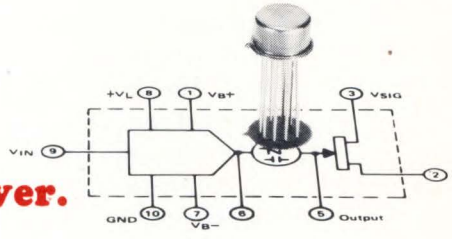
For the transistorized radio, two patterns were apparent—the earliest aimed at low cost, minimum performance and miniaturization; the second path led to stereo and high-fi units which were easy to use and provided new levels of superb performance. In electronic calculators, two similar patterns are now emerging. The first is preoccupied with low cost, miniaturized and low-capacity machines; the second brings the full gamut of electronic technology to bear on problem-solving in both the engineering and scientific disciplines as well as the business world.

In the next five years, when the novelty of sheer calculating speed and miniaturization have worn off, design engineers will look toward the total requirements of the jobs to be performed. In the office, the adding machine, calculator and distribution machines will become one. Typewriters will serve multiple functions such as correspondence machine, as a printer for output of the calculator and as a data input unit. Calculators will be customized by computer-produced read-only memories that will provide the combination of features required for that particular set of applications. Where required, tomorrow's calculators will serve as data-capturing devices, using their computer-like abilities to verify data prior to transmission.

In the engineering and scientific field, increased computational power will be brought to the desk and work bench. As the engineer expands his scope of interest in both the engineering and business areas, his calculator will provide features that will enable him to work in many fields. Both display and hard-copy printers will be provided to reduce the chance of misinterpretation and error. Means of entering data will be changed, again with the intent of minimizing error. As in the 1975 electronic office machines, computer design will permit customizing of features and functions for the individual engineering disciplines. Plug-in units, such as those used on oscilloscopes today, will be available as off-the-shelf modification units to increase each system's capabilities.

The target for design in 1975 by successful "calculator" companies will be to provide that equipment which most reduces manual labor. Although new technologies, as they are developed, will be incorporated in the new equipment, a realization will emerge that need is the proper functional design objective.

Our competitors may be upset, but customers are wild about our new $6* FET Analog Gate with Monolithic Driver.



The high cost of analog switching has just taken a nose dive. Our CAG30 low cost general purpose FET Analog Gate switches up to ±10 volt signals directly from DTL or TTL, and provides high logic noise immunity (typically 1.0V). The CAG30 turns off faster than it turns on, allowing multiplexing without crosstalk. The 

CAG30 is a break-before-make switch with 60 ohms maximum on-resistance and full military temperature range. The built-in CDR5 monolithic driver is also available separately in an 8-lead low profile TO-5 package for $4.90* For your best buys in digital interface microcircuits, check Crystalonics. 38 stock types available.

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HYBRIDS TODAY

Definite performance and cost advantages are possible with hybrid technology. But to realize these advantages there are many precautions to observe in fabricating a hybrid. Here's an up-to-date look at this fast-moving technology.

EDN STAFF

Companies enter the hybrid business initially for many reasons. All are related to either performance or cost. Examine the processes and some of the products, and you'll quickly see exactly where hybrids stand today.

If you're getting ready to jump into the hybrid circuit arena by making your own or approaching initial contact with a custom hybrid house, this look at hybrid technology should help to make the transition easier.

Why Hybrids?—The Technical Viewpoint

Hybrid technology offers certain technical advantages over both conventional PC board construction and monolithic integrated circuits, as the following examples illustrate. These advantages include power, frequency, stability, reliability, size, flexibility, accuracy, form factor, weight, circuit density and speed—depending on what you're comparing against.

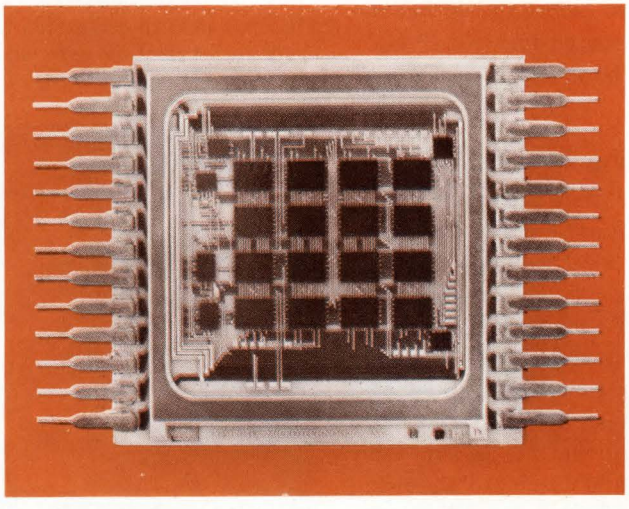


Fig. 1—**"Classical Hybrid"** aptly describes Computer Microtechnology's 4096-bit RAM. Within the 1.5-in DIP are 16 MOS chips (memory) and 6 bipolar chips (sense/drive). All chips employ "all aluminum" beam leads, are bonded to a substrate with two layers of metal. (*COMPUTER MICROTECHNOLOGY*).

Reason—High Density/High Speed

A hybrid package that demonstrates the prowess of hybrid technology is Computer Microtechnology's 4096-bit random access memory (**Fig. 1**). Here they combined the best of MOS and bipolar technologies. By using MOS for storage and bipolar for the sense/drive circuits, a memory resulted in a 1.5-in-wide package that boasts a 400-ns (max) access time and 0.4 mW/bit power consumption.

Reason—High Power

Further testimony for the hybrid approach comes from TRW Semiconductors, Inc. They built a 2.1-kW power amplifier (**Fig. 2**) on a 2-in^2 beryllia substrate. Without the hybrid approach they employed, this feat would have been a tough nut to crack. As one TRW spokesman pointed out, "When you switch 30A in 10 ns, an inch of wire begins to generate a lot of volts." TRW plans to extend their off-the-shelf line of power hybrids with

(Continued)

switching regulators and dc-to-dc converters. This latter addition will probably replace the 60-cycle power transformer in many future product designs.

Reason – High Frequency

As designers move to higher frequencies, the advantages of hybrids become dramatically apparent. Avantek's latest offering is a 2-4-GHz transistor amplifier (**Fig. 3**) designed for airborne applications where small size and light weight are essential. Modular in construction, this recent entry provides the user with a gain up to 45 dB in 5-dB increments. Avantek is about a year away from a similar version that will work in the 6 GHz range while providing 25 dB gain. At these frequencies, hybrid construction appears to be more than just a packaging method. As Avantek emphasizes, the key to their success in making hybrids lies in their high-frequency transistor chips. Probably the smallest in the business, Avantek's chips typically measure 10 mils^2. Without their high-integrity chips, the hybrid approach would have little to offer as a packaging scheme.

Reason – Stability in Small Area

Hybrid techniques also are being implemented on monolithic chips, as demonstrated by Intersil's low-power/low-input current comparator (**Fig. 4**). By depositing chromium/silicon thin-film resistors directly on the chip, Intersil has been able to place high-value resistors in a small area (10 kΩ/square) while at the same time achieving high stability (2000 PPM/°C). Because the chip is passivated before depositing the thin-film resistors, resistors can be laid out directly over diffused transistors, without any dielectric isolation.

Reason – LSI with Building Blocks

At Fairchild Semiconductor, they title their hybrid effort "Integrated Microsystems". When designing hybrids with complex chips, a total system function is, in effect, being developed. As opposed to developing high-complexity LSI chips, Fairchild feels that it's generally more economical to go hybrid with available MSI chips. A good example of Fairchild's "Integrated Microsystems" approach is shown in **Fig. 5**. Currently about 80% of Fairchild's hybrid work is custom. They look forward, however, as does Motorola, to a growing standard product line – suggesting that they will offer more products like D/A converters.

Reason – Accuracy

For Beckman Helipot, the standard hybrid product has created some very profitable business. With their thick-film technology, they continue to develop a wide

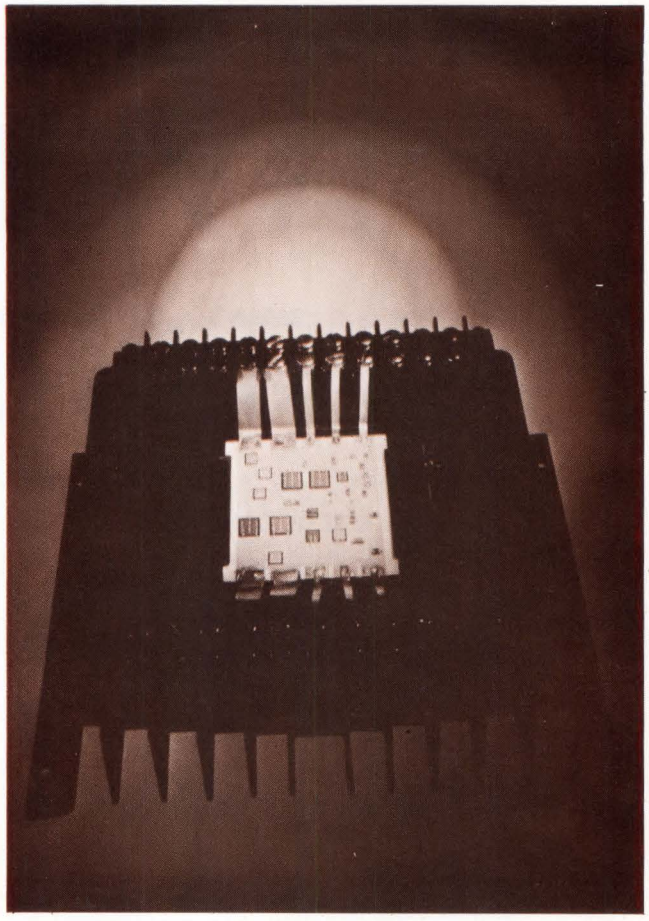


Fig. 2 – **2.1-kW power amplifier** has package size of 2 by 5 by 6.5 in. Using saturated switching techniques and pulse-width modulation, this class "D" amplifier operates at 90-95% efficiency and can deliver 20A (average). A 2-in^2 beryllia substrate mounted on a heat sink easily handles the 100W power dissipation. (*TRW SEMICONDUCTOR*)

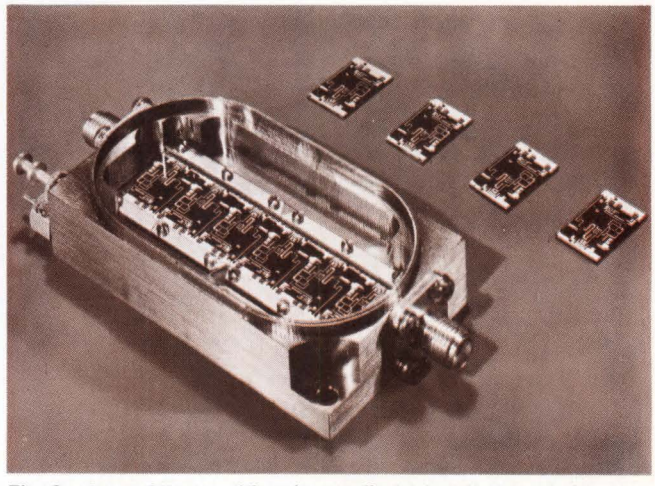


Fig. 3 – **A 2-4-GHz amplifier** aims to find a berth aboard airborne vehicles. Measuring about 3 in long, this modular hybrid employs thin-film circuitry deposited on a sapphire substrate and high-performance transistor chips to provide a total 45 dB gain. (*AVANTEK*).

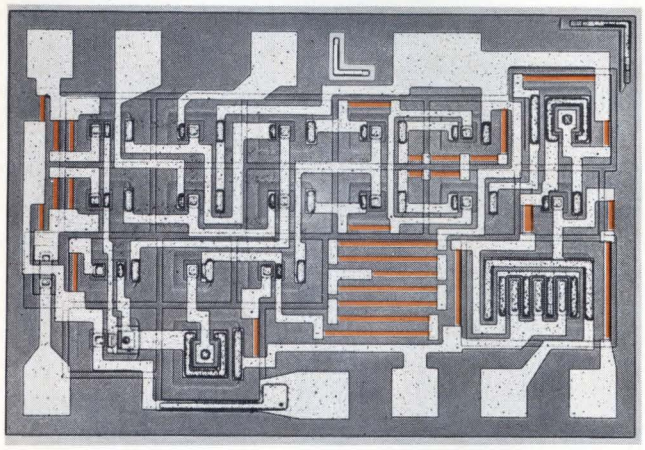


Fig. 4—**Hybri-lithic** might be a good name for this current comparator chip. To achieve ultrahigh stability, thin-film resistors are dc sputtered (colored lines) directly on the silicon chip. Apart from high stability, this technique also permits high resistance values to be placed in a small area. (*INTERSIL*).

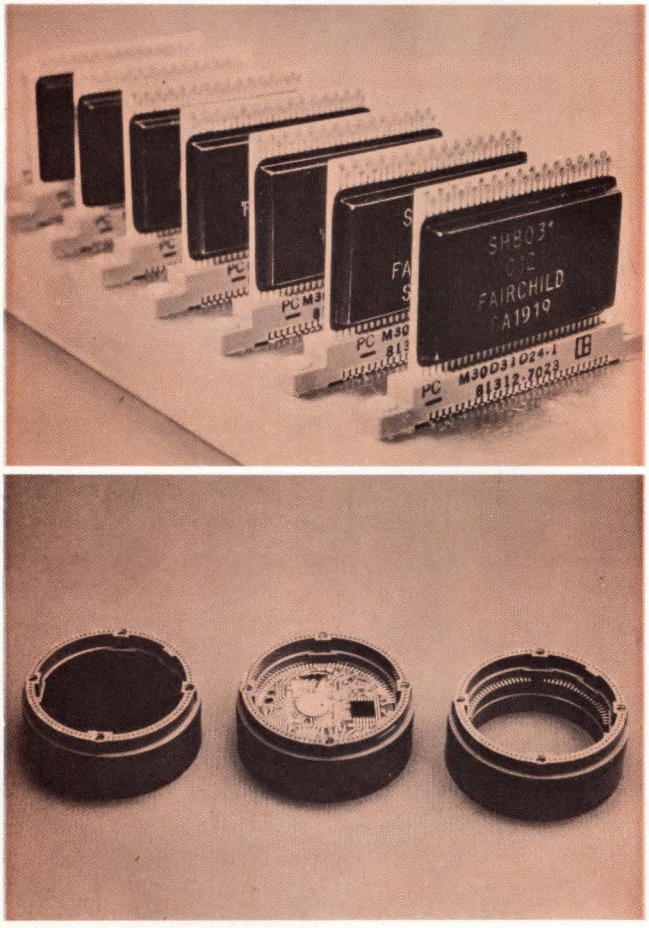


Fig. 5—**"Integrated Microsystems"** are demonstrated by two examples. At the top is a packaging concept developed for a major computer firm; each plug-in module is a hybrid circuit that replaces an entire PC board. Below is a hybrid canister (5-in-diam) for an airborne application. *(FAIRCHILD SEMICONDUCTOR).*

range of off-the-shelf hybrids ranging from binary ladder networks to D/A converters (**Fig. 6**). As an example of their thick-film capability, Beckman recently introduced MOS-compatible A/D-D/A converters that boast ±0.5% accuracy over the −20 to 85°C temperature range. In building an R-2R ladder network for the D/A converter Beckman explained, "temperature coefficient of the thick-film is not that important. What's really important is the fact that all resistance values track each other. This is simple to achieve when all resistances are made with the same thick-film batch."

Reason—Reliability

Also devoted to thick-film, Centralab has directed much effort toward the development of high-reliability products. Their latest hybrid innovation is the "opto-hybrid" reader—a light-sensing subsystem for punched card and tape data reading. Combining a silicon photovoltaic detector with a highly stable hybrid amplifier/digitizer circuit, the "opto-hybrid" package measures one-tenth the size of similar units made with discretes (**Fig. 7**). Before the end of the year, Centralab plans to enhance their "opto-hybrids" by adding light emitting diodes for light sources—thus producing a total light source-and-sense system for reading punched media.

Reason—Many Circuits Needed in Small Space

The 150-MHz oscillator module (**Fig. 8**) also contains additional analog and digital circuitry. Rather than procuring the hybrid circuits individually and proceeding with design of the module, this customer turned the entire job over to engineers at Circuit Technology. This action relieved the customer of many problems.

Substrate Processing

In fabricating any hybrid circuit, the prime requirement to be met is materials compatibility. As many as four or five different firing temperatures may be employed in a thick-film circuit for example, and all materials must successfully "survive" these temperatures to insure satisfactory circuit function as a hybrid.

The first step is selection of a substrate material. This probably is the easiest part of getting started, because the manufacturers of substrate materials include in their literature standards for such items as size and tolerance, thickness, holes, camber and surface finish. Tecnetics, for example, orders a standard catalog item from Coors Porcelain and subjects incoming substrates only to a go/no-go test for camber. They perform a camber test, they explain, because camber is critical for achieving consistent screening and wire bonding

(Continued)

integrity. Standard camber on a Coors substrate is 0.004 in/in.

With about 75% to 80% of its substrates for hybrid work going to thick-film users, Coors offers both 96% and 99.5% alumina substrates. The 96% material comes with a surface finish of from 20 to 25 μin or with a glazed finish less than 1 μin. Today, less than 5% of the substrates sold by Coors are of the glazed type. The 99.5% material, used primarily for thin-film work, is offered with a surface finish of 8 to 10 μin. In 100,000-piece lots, cost for each 96% unglazed 1- by 1-in substrate is about a nickel.

To make multiple substrate handling easier for the user and to improve yields, companies like Coors have installed CO_2 pulse lasers for scoring substrates as well as clean rooms for improving surfaces of thin-film substrates.

Conductors and Dielectrics for Thick Films

There is a host of materials systems used for thick-film conductors, according to CTI. Some companies use gold-platinum, some use silver-based combinations, some screen conductive epoxies for conductors and screen nonconductive epoxies for component attach.

Processing a thick-film circuit begins with the highest firing temperature first (conductors, crossovers) and progresses through intermediate (resistors, capacitors) and low temperatures (over-glazes). Conductors usually are fired from 850-960°C, as are crossovers. Reheating during subsequent firing usually is harmless because of progressively lower firing temperatures.

Whether companies mix their own thick-film inks or buy from outside suppliers, a temperature profile must be established to determine the best firing method for both bonding to the conductor and adhesion of the conductor to the substrate. Suppliers include recommended firing profiles for their inks to assist the user.

One of the more common problems encountered in the manufacture of the thick-film circuits, according to Spacetac, is poor solderability of the conductor after substrate processing. Successive refiring of a conductor can cause excessive glassiness or wetting of the film and attendant soldering difficulties. This problem can be minimized only by proper in-house formulation or through vendor supplied material evaluation. Another consideration in conductive materials selection is resistor-conductor overlap compatibility. Reaction or bubbling here can result in high contact noise and higher TCR. In addition, conductors for crossovers must not dissolve into or react excessively with the crossover material, otherwise loss of conductivity and/or solderability may result.

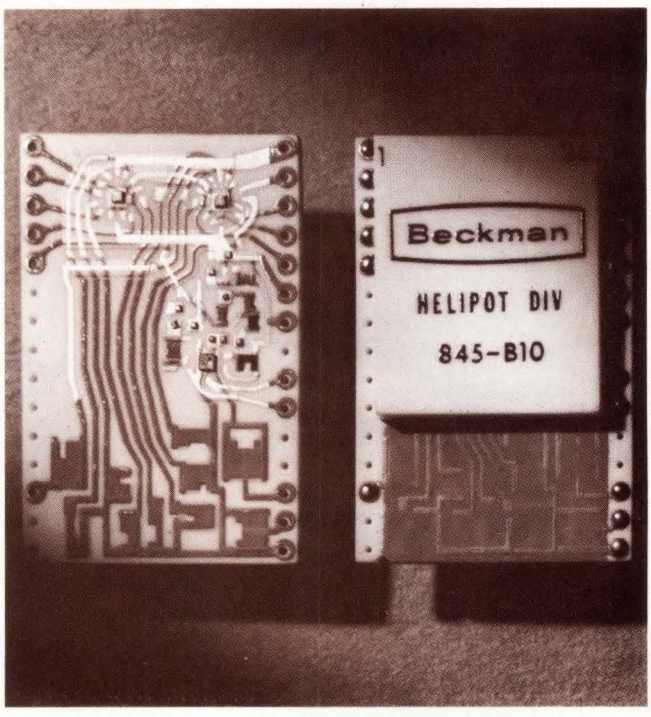


Fig. 6—**Thick-film** D/A converter, shown above, handles 8 bits. A more recent entry handles 10 bits with ±0.5% accuracy over −20 to 85°C. This demonstrates the accuracy that can be obtained with thick-film cermet. *(BECKMAN).*

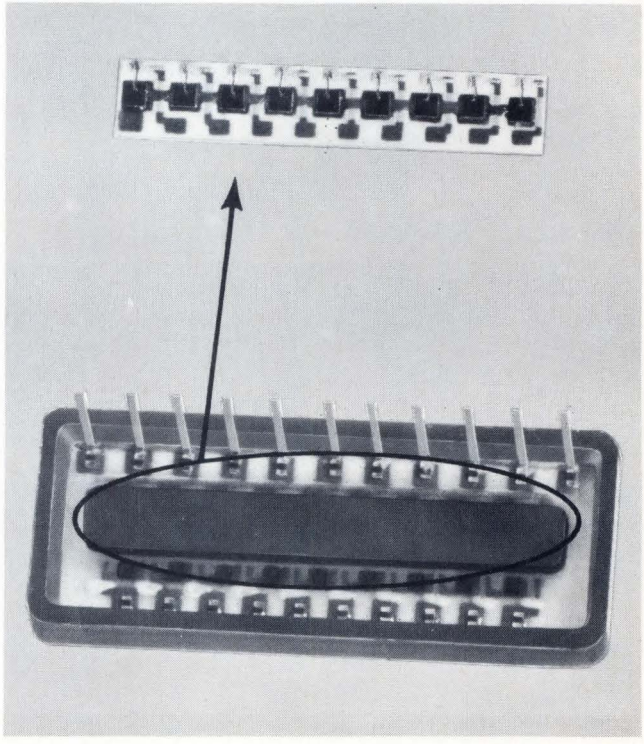


Fig. 7—**Internal view** of thick-film "Opto-Hybrid" punched tape reader shows amplifier substrate with transistor cover, matching resistors and welded lead frame. Substrate with photodiodes was developed for "Opto-Hybrid" products. *(CENTRALAB ELECTRONICS DIV., GLOBE-UNION, INC.).*

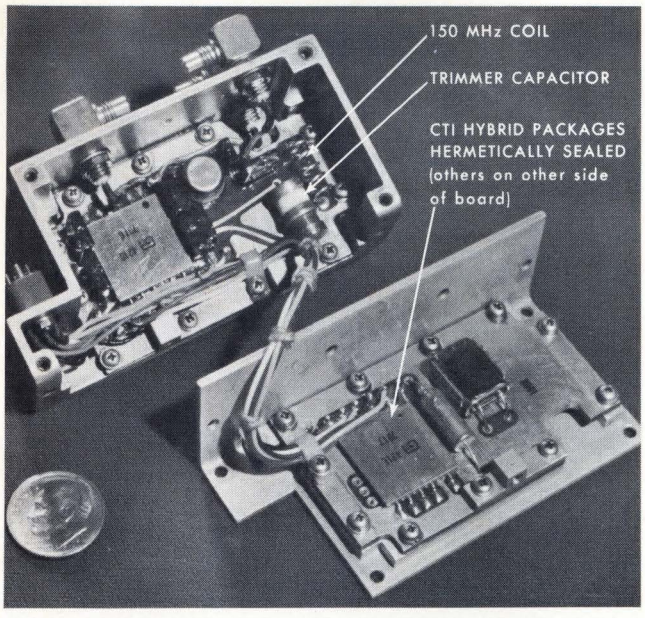


Fig. 8—**This 150-MHz oscillator module** contains a great deal of analog and digital circuitry packaged in a tiny space. There are six LSI chips contained within the hermetically sealed hybrid packages. (*CIRCUIT TECHNOLOGY*).

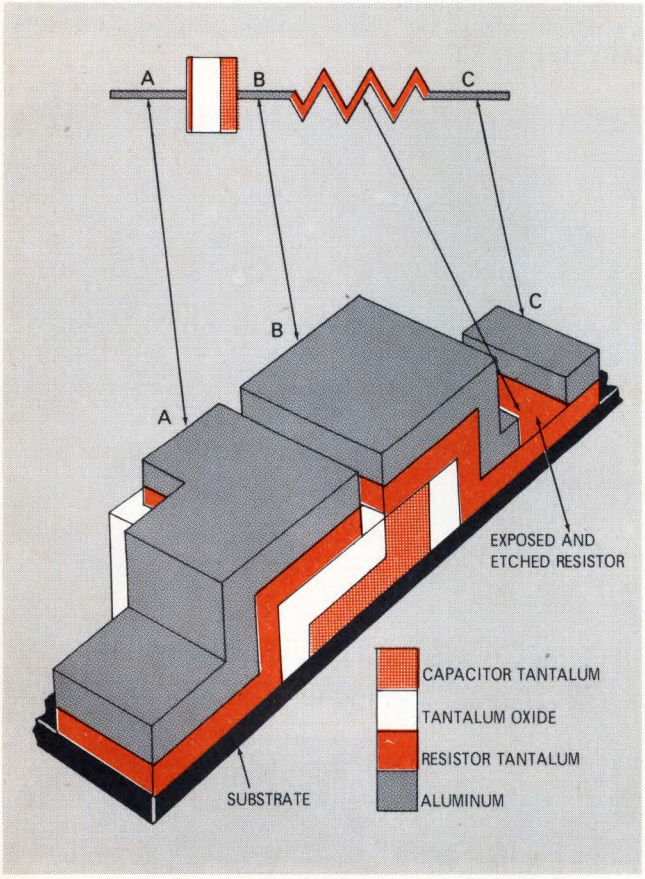


Fig. 9—**Idealized cross-section** of thin-film build-up. Elements of series RC network are related to physical portions of cross-sectional view. (*COLLINS RADIO*).

A final precaution to be considered in all materials selection is thermal expansion. Materials should be compatible, both with one another and with the substrate material. By designing components to operate in a state of thermal compression, failure caused by microcracking or crazing can be minimized.

The firing operation makes the screened-on films more dense and causes them to adhere to the substrate (resulting from the glassy phase melting and wetting both the substrate and the powdered film constituents). Temperature profiles are calculated to cause as little glassy reaction and particle dissolution as possible, yet achieve desired physical or geometrical dimensions and electrical properties. The glasses used in the various thick-film components are selected for softening-point ranges compatible with the intended firing temperatures (conductors and dielectrics typically higher, resistors and overglazes lower).

After firing, the following electrical characteristics may be expected:

Conductors: Sheet resistivities ranging from 3-10 mΩ/square for certain fluxed silver and golds, to 50-100 mΩ for palladium alloy compositions. Soldering, when required, reduces resistance to that of Sn/Pb eutectic.

Dielectrics: Characteristics do vary with k value, but a typical dielectric will exhibit the following:

Dissipation factor	1.0%
Dielectric strength	300V/mil
Insulation resistance	10^{10} MΩ

Resistors—Thick-Film

Pastes for thick-film resistor work usually are purchased from outside suppliers, but several hybrid houses such as Beckman, CTS, CTI and Centralab use their own proprietary brews. CTS developed its own resistor paste system based on oxides of ruthenium. They elected to go this way because they found these to be more stable than commercially available inks. Centralab's proprietary resistor inks are silver-free and were developed to fulfill a need for lower TCR. CTI's edge is in high dissipation per unit area.

At Tecnetics and Ball Bros. Research, where resistor pastes are purchased commercially, they speak of permanent drift problems that once existed. Now, however, paste improvements result in drifts less than 0.05%. The possibility still exists for long term degradation at temperatures of 200°C, said Tecnetics spokesmen, but this is a function of the paste used, which points out the simple need for a user to learn how to handle the pastes he has selected.

Thick-film resistors are fired between 700° and 850°C. When an overglaze is required, it is fired at 500° to 550°C to minimize any reaction between the glaze and other passive components, especially resistors.

Hybrids Today (Cont'd)

After firing, besides attaining the desired resistivity, the thick-film resistor also should possess these electrical properties to be considered a "state-of-the-art" device:

1. TCR: 50 PPM, 25-125°C (Microtek has become so proficient at screening resistors of different TCs that positive, negative and zero TC resistors are manufactured routinely).
2. Noise: −30 to −120 dB for all resistivities except >100 kΩ/sq.
3. VCR: ≦10 PPM/V/in.
4. Drift: essentially able to hold to within 0.5% of initial trim value for 5000 hours of load life or shelf storage.
5. Capable of being overglazed.
6. TCR matched within ±10 PPM typically, 2-5 PPM when specially processed.

Thin-Film Systems

Although thin-film and thick-film circuits exhibit some visual similarities, the approaches are strikingly different. While thick-film work is characterized by particles and binders, thin films equate to chemically pure elements and compounds. Thick films are perhaps more like small printed circuits—first the conductors go down, then components are attached to the conductor pattern. Thin films smack of large monolithic ICs where metallization is the final layer that interconnects components created by etching and oxidation.

Thin-film materials systems vary, but, like semiconductors, there is little variation within any one system. For example, Collins Radio Co. in Dallas had standardized on a tantalum-gold system. Aluminum also is a common conductor, while NiCr is widely used for resistors. Many thin-film circuits include capacitors fabricated on the substrate. However, real estate restrictions and the lower yield and higher cost attributable to extra process steps are making discrete chip capacitors more attractive all the time.

After substrate processing, thin-film circuit fabrication proceeds much as thick film. Semiconductor dice and passive discrete components are attached and interconnected, and the circuit is usually hermetically sealed in one of a nearly-infinite number of suitable packages.

Although a thorough investigation of thin-film techniques is beyond the scope of this article, a typical process that yields a resistor-capacitor-interconnect network is as follows:

1. A layer of tantalum is sputtered onto the substrate, then thermally oxidized to protect the substrate from subsequent etchants.
2. A second layer of tantalum is deposited, then is etched to form the lower capacitor electrodes.

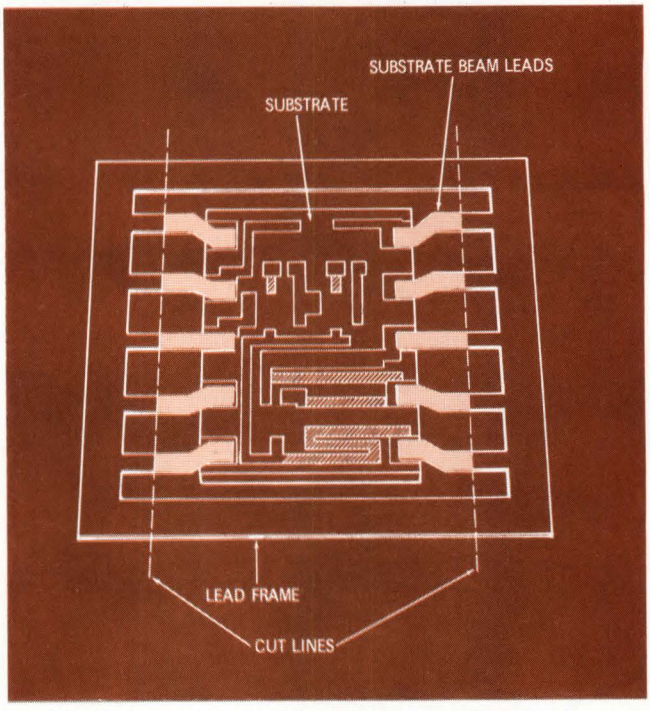


Fig. 10—**Beam-lead substrate** is easy to make if you follow this example. After bonding a lead frame to the substrate, snip around the edges—and that's all there is to it! (*RAYTHEON SEMICONDUCTOR*).

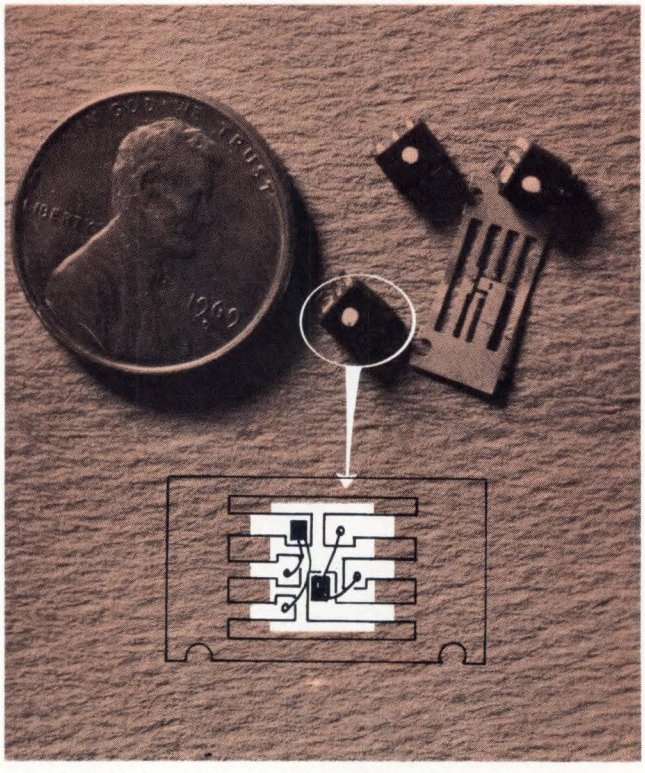


Fig. 11—**Multichip micropackages** can hold up to three transistor chips. After chips are wire bonded to the miniature lead frame, they are encapsulated to form the easy to handle micropackages. (*CERMETEK*).

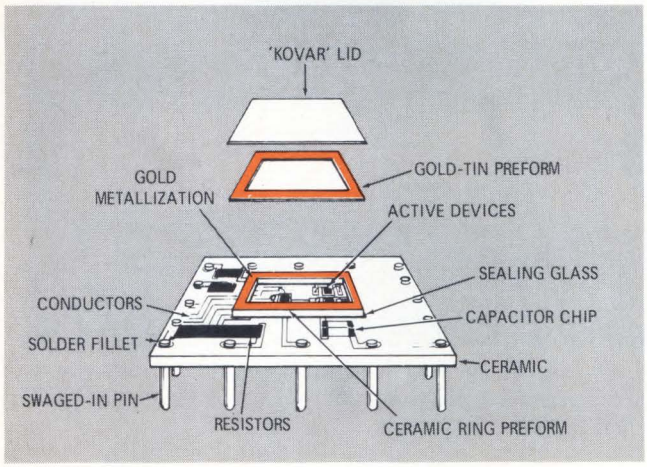


Fig. 12—**Hybrid integrated packaging** (HIP) approach readily achieves economical hermetic package. All active devices are hermetically sealed on one section of substrate. (*RCA AEROSPACE SYSTEMS DIV.*).

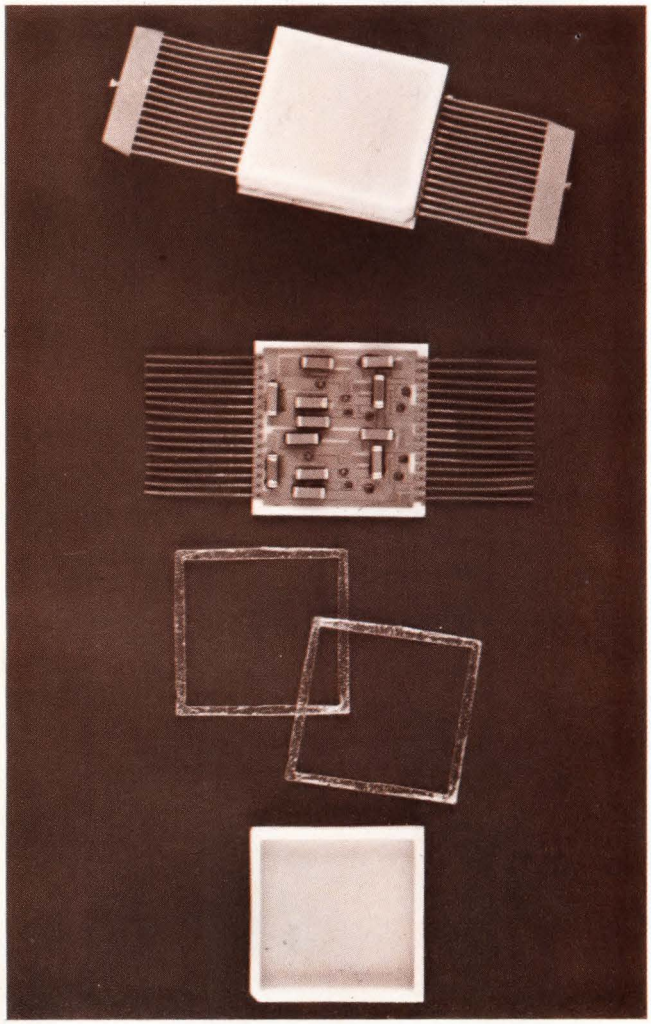


Fig. 13—**Hermetic thin-film package** is sealed by clamping and heat fusing epoxy-glass preforms between lid and substrate. (*COLLINS RADIO*).

3. The capacitor tantalum then is oxidized to form the capacitor dielectric.

4. Another layer of tantalum is added to provide the second capacitor electrode and resistors.

5. A layer of aluminum is deposited on top of the resistor tantalum layer.

6. The aluminum is etched to form the conductor pattern.

7. The resistor tantalum is etched to form the individual resistors.

8. After cleaning and testing, the network is ready for discrete device attach and packaging.

Fig. 9 shows an idealized profile of a circuit built up in this manner.

Thick or Thin Films?

Unlike many others who have taken either one stance or the other, Amperex thinks that both have applications that depend on many factors like cost vs complexity vs performance. Sometimes even a combination of the two is best, as in microwave circuits.

RCA Aerospace, looking at thick-film approaches only, foresees more use of noble metal inks, with higher materials costs being offset by better yields, higher performance and higher reliability. Screen printing is improving on two fronts: finer lines through contact printing and multiple image screening. The former results in smaller size and improved yields and performance, while the latter reduces labor costs. Because laser-scored substrates are flatter and smoother, they have made practical multiscreened images (that is, printing many identical patterns on a single scored substrate).

In defense of thin-film techniques, Micro Networks notes that the ability to make precision thin-film nichrome ladder networks and the ability to adjust the values for mismatch in other circuit components significantly increase the yield of thin-film circuitry. As a result, thin films, once considered a high cost item, are becoming the cost-competitive approach for new dense packaging solutions to instrumentation, computer and military circuitry.

Crystalonics points out that, while in thin films pure materials are applied directly to a substrate without a carrying medium, thick-film conductors and resistors are actually suspensions in glass, and consequently characteristics are sensitive to firing conditions and other materials and process variables. Further, large quantities of resistor-conductor coated thin-film ceramic substrates can be made at one time and stocked. Individual circuits then require only a mask-and-etch technique similar to PC boards.

The battle of thick vs thin films is being won by the former, says Sylvania, thanks to the variety of new ma-

(Continued)

Hybrids Today (Cont'd)

terials being made available; however, thin will probably always hold an edge in circuits requiring radiation hardening, ultraprecision or in certain microwave applications.

The controversy over "which technology" also extends to discrete components and monolithic ICs. When constraints of cost, performance, size and delivery are considered, it is difficult to tell which technology or combination of technologies will do the best all-around job.

Chip Attachment

Conventional Si-Au eutectic bonding is the most common means of attaching semiconductor chips to hybrid circuits. The eutectic temperature is 370°C and bonding is done at 400°C or higher. Twenty-four-karat gold is screened and fired directly on ceramic or on a previously metallized ceramic. When a base silicon or gold-back silicon die makes intimate contact with the 24-karat gold (under a prescribed pressure and temperature), the die becomes metallurgically bonded. If many dice are bonded to a substrate, a "hot gas" technique is preferred, so that heat is directed to the die being bonded, rather than holding the substrate above 400°C for long periods.

Conductive epoxies are convenient, especially if there is any concern about substrate temperatures exceeding 400°C. With good conductive epoxies, contacts are made when attached to gold-backed silicon dice. Thermal conduction is acceptable in many applications, especially low power. There are many advantages to conductive epoxies: because dice are bonded at room temperature, other circuitry is not thermally stressed during bonding; chips can be placed in smaller areas because scrubbing-in is not required; damaged chips are easily removed and replaced. Some consider epoxy to be messy, and careless application can result in shorts, especially when laying down chip capacitors.

An example of the good use of both the above attachment techniques is found at CTI. Here, smaller chips (e.g. single transistors) are eutectically bonded to the substrate while larger MSI/LSI chips are attached with conductive epoxy. This eliminates the need to heat the larger chip.

Another common means of die attach is to use eutectic preforms between die and substrate. Because this method requires heat, pressure and ultrasonic scrubbing, dice are individually attached.

Varadyne is considering switching their production from eutectics to a high-grade gold epoxy. As they explained it, aside from minimizing the hybrid circuit's repeated exposure to high temperatures, the gold epoxy can be screened on the substrate and batch cured—thus increasing production throughput.

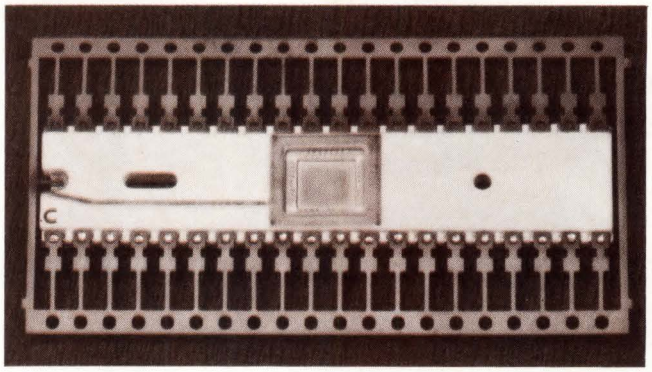
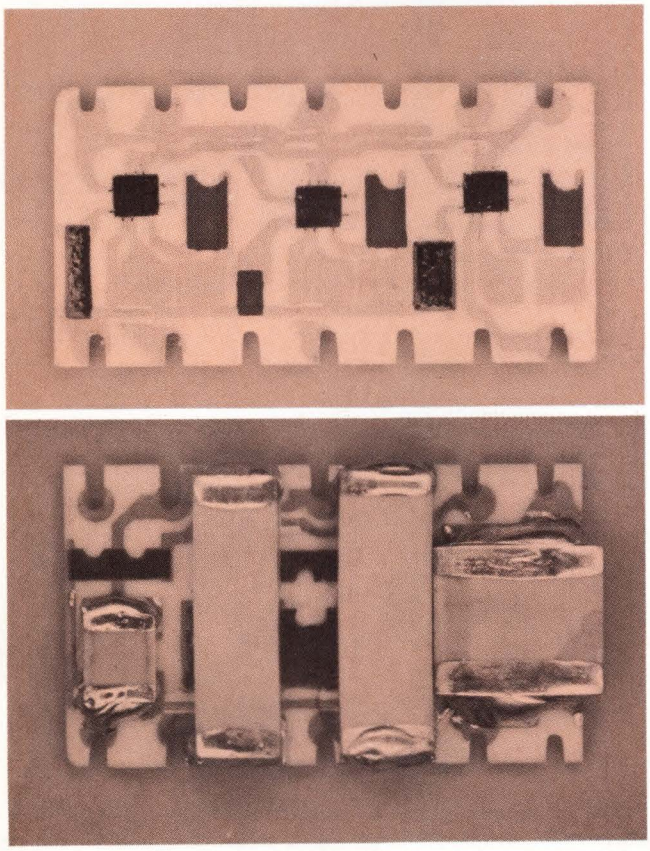


Fig. 14—**New 40-pin dual in-line package** with lead rows having 600-mil separation is member of new family for the MOS/LSI market (*COORS PORCELAIN*).

Fig. 15—**CO_2 laser trimmer** was recently given a WESCON award for its outstanding product design. This trimmer uses a sealed-off type CO_2 laser that allows it to be compact and relatively inexpensive. (*APOLLO LASERS*).

Fig. 16—**Multiple laser-trim station** uses the high-power output of a single YAG laser. The laser beam is split and fed to the various stations. Each operator can monitor and adjust the laser power to his workpiece. (*HUGHES AIRCRAFT*).



Hybrid active filter. Beam-lead devices are on one side of the substrate and layer-built monolithic ceramic capacitors on the other. (*SPRAGUE ELECTRIC*).

For their die attach, Beckman Helipot developed a proprietary cermet material that thermally, mechanically and electrically compares with eutectic materials. Because the cermet can be screened on the substrate, the hybrid circuit need withstand only one high-temperature exposure during the die-attach process.

Collins Radio bonds its semiconductor dice to gold-plated tabs eutectically, then attaches this assembly (and chip capacitors) to the substrate with an epoxy-impregnated glass-fabric preform. This allows probe-testing of devices after eutectic bonding but before committing to a circuit and affords unusual freedom in the placement of components. They can be mounted over conductors or resistors and therefore require no private real estate on the substrate. Both semiconductor and capacitor chips are then electrically connected to the substrate network with 0.7-mil gold wire.

Dionics, Inc., has developed what it calls dielectrically isolated monolithic chips. Although originally developed for radiation-hardened applications, these devices offer several advantages to the hybrid manufacturer: they are compatible with nonconductive epoxies; chip bottom is polycrystal silicon electrically isolated from the chip itself with breakdown exceeding 1000V; chips can be bonded by nonconductive epoxy, since electrical integrity is not required; chips can be eutectically bonded to a metal surface (such as package metal can) for optimum heat sinking and thus higher power capability; and, since all devices on a wafer are isolated from all others, they can be scribed and diced as singles, duals, quads or strings of any number. This permits many isolated devices to be put down on a substrate with a single die bond.

Chip Interconnection

Gold thermocompression ball bonding is still the most popular wiring technique used in chip-and-wire systems. Aluminum ultrasonic bonding also is somewhat popular but it is a time-consuming high-labor operation because it requires first and second bonds of each wire to be in a straight line—a rarity with hybrids. Although it eliminates "purple plague" problems, its pull strength is only about one-half that of ultrasonic gold-ball bonds, the weakest point being at the substrate. Ultrasonic gold-ball bonding looks like a good compromise, because production rates are high and bonds are made on a cold substrate.

Beam Leads

Both semiconductor suppliers and hybrid circuit manufacturers look to beam leads as the ultimate solution to lots of problems. Yet there is some question about just how and when beam leads will take over the world.

(Continued)

Hybrids Today (Cont'd)

The user says, "I can't get the variety of beam leads that I need, so I'm going to stay with chip-and-wire until I can switch to beam leads altogether. It doesn't make sense to mix beam leads and chip-and-wire in the same package. Besides, our ability to handle chips is very good and improving every day. It sure will be nice, though, when we can completely test a device (beam lead) before we commit it to a circuit, and can forget about hermetic circuit packages."

Semiconductor manufacturers say, "Beam leads offer so many advantages that sooner or later they are bound to be the way to go in hybrids. As soon as the market develops, we'll be there with devices."

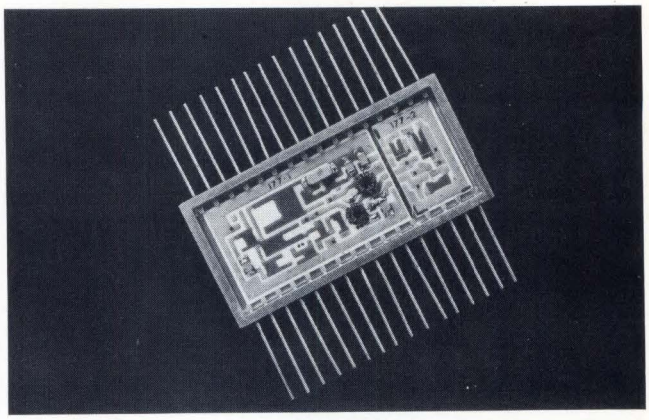
Spokesmen from both users and suppliers believe that the beam leads will be a major factor within a year or two.

Beam-leaded devices are commonly bonded by a "wobble-bond" technique where the thermocompression bonding head rotates around the chip in a wobbling fashion, bonding leads one by one. Compliant bonding, fast becoming popular, bonds all beams at once and sports an order-of-magnitude decrease in cost of assembly. A soft metal, like aluminum, is used as a intermediate layer (a preform) to transmit thermocompression power to the beams. The soft metal makes up for uneven beams and insures equal transmission of power.

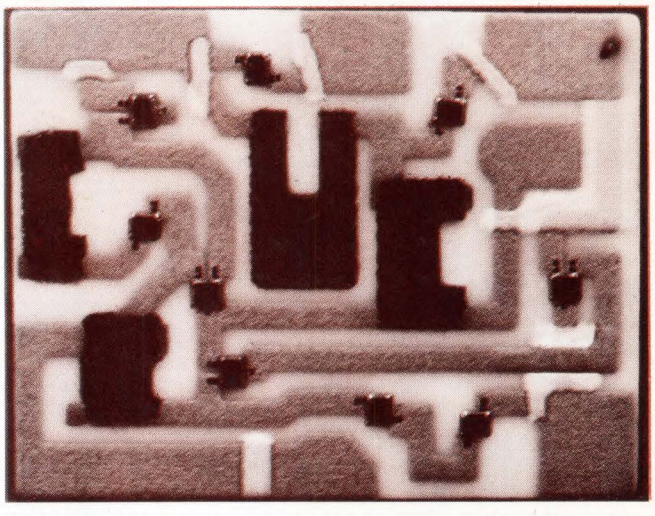
A very new interconnection technique called beam-lead substrates (EDN June 1, 1970) is still too new for fair evaluation but holds promise of economical chip interconnections and high densities.

While the holdoff continues, with hybrid users still wanting to go beam lead when conditions are right, Computer Microtechnology offers a solution to this problem. They say that they'll put their aluminum beams on anyone's chips for a nominal fee. When asked for specifics, they gave the following ball-park figures: After a one-time tooling charge of about $500 (to make metal mask), it would cost around $10/wafer (2-in-diam) to install the aluminum beams. These cost figures are predicated on being able to interdigitate the beams of adjacent chips as they are laid out on the wafer. If the wafer's chip matrix needs to be altered to accommodate the beam leads, there would, of course, be an additional charge.

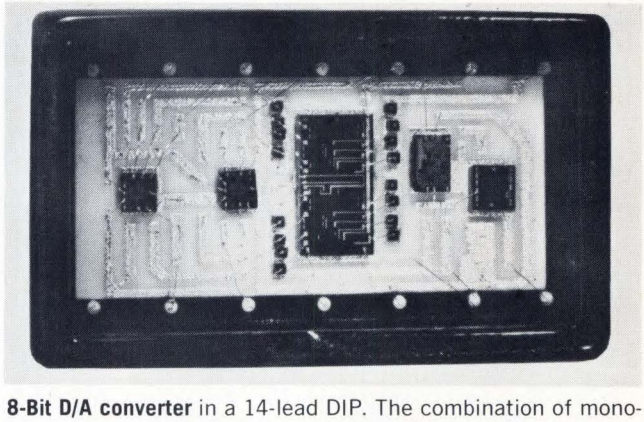
Raytheon Semiconductor, long-standing devotee of multimetal beam leads, have begun developing their own hybrid circuits "to better understand their customer's problems." Raytheon believes that beam-lead devices produce top performance and quality by eliminating the most common failure modes of chip-and-wire assembly. As if to extend their beam-lead approach to the total package, Raytheon uses a lead frame to create beam leads for the substrate (**Fig. 10**).



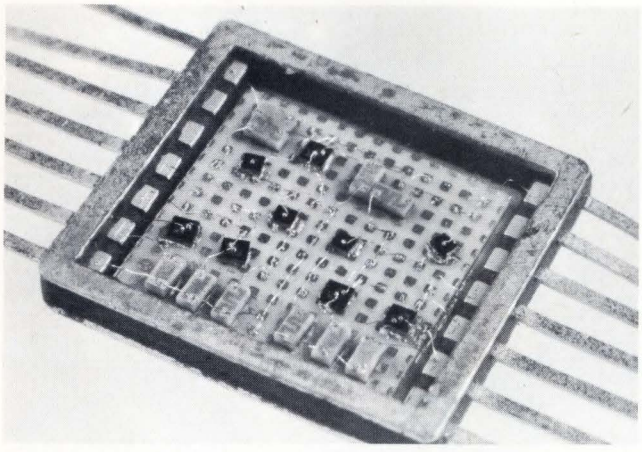
This high-speed clock driver is for applications requiring clocking in excess of 20 MHz. It can drive up to 15 flip-flops in the SUHL II line. (*SYLVANIA ELECTRIC*).



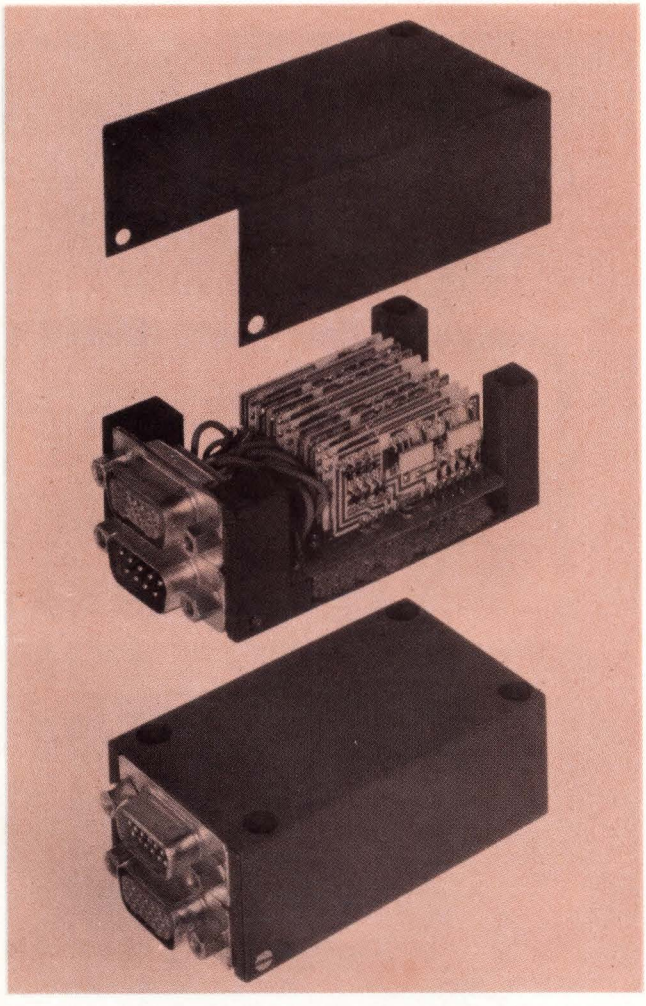
Thick-film microcircuit manufactured by Centralab (Milwaukee Operations) for U.S. Army Electronics Command Night Vision Lab. at Ft. Belvoir, Va. The circuit applies beam-leaded diodes and transistors to produce the Army's starlight scope. (*CENTRALAB ELECTRONICS DIV., GLOBE-UNION, INC.*).



8-Bit D/A converter in a 14-lead DIP. The combination of monolithic op amp, monolithic gates and precision thin-film nichrome resistor ladder network allows unit to be price competitive with discrete modules as much as 10 times its size. (*MICRO NETWORKS CORP.*).



Fast reaction breadboarding of hybrids. Components are bonded to standard substrate with conductive epoxy and circuit connections made by wire stitching. Circuit shown ready for testing and sealing is made in one day from design layout to finished assembly. (*SYLVANIA ELECTRIC*).



This 16-channel analog commutator with decoding is contained in a 1- by 1- by 2-1/2-in package. With this scheme no more than a two-sided mother board is ever needed—even to make a complete computer. (*SPACETAC*).

Both Fairchild and Intersil have been looking into the feasibility of beam leads with the intention of including that technology in their "bag of tricks," while both Motorola and TI have announced the availability of a number of beam-lead devices. According to Computer Microtechnology, a cross-license agreement permits Fairchild to implement CMI's patented all-aluminum beams. Intersil, on the other hand, is leaning toward a multimetal beam-lead approach. They feel that, while every semiconductor firm has the capability to make beam leads, the technology is too expensive to get into unless there's a high volume order.

As if to select an approach somewhere between wirebond and beam leads, Cermetek has devised a multichip micropackage (**Fig. 11**). This easy-to-handle package was developed for a custom T-1 hybrid repeater. However, Cermetek may offer their multichip micropackage to industry if the demand is great enough.

A Varadyne spokesman feels that the spider bond technique developed by Motorola offers some big advantages. Apart from getting away from the flip chip (which you can't inspect), the spider bond allows semiconductor manufacturers to make less expensive dice. Varadyne is currently using wire bonding on their hybrids.

Wire bonding at Tecnetics is performed with 1-mil aluminum wire with changeover to 3-mil aluminum wire being planned for the future. Tecnetics is making this change to obtain more current-carrying capacity than the 350-mA 1-mil wire. Because of a new setup required on its bonders and the need for retraining, the change is slow in coming. In the interim, Tecnetics bonds multiple 1-mil wires when more current capacity is needed.

Flip-chip work is, for all practical purposes, an IBM exclusive. Universal complaints are "you can't see what's going on when you bond, and you can't inspect after you bond." The concensus says that only IBM-sized volume can justify the automation necessary to make this approach work. Yet there are compelling arguments in favor of glass-passivated chips such as IBM uses. Similar to beam leads, glass-passivated devices can be fully tested before mounting, and they virtually eliminate the need for hermetic circuit packages.

How About Multilayer Circuits?

Potentially, multilayer circuits can reduce layout complexity, circuit size and cost. Most agree that multilayers with their higher densities will penetrate the market and become competitive with PC boards. All indications are that they will become quite common in thick-film circuits.

Three basic multilayer techniques are currently in

(Continued)

use with thick films:

1. Interconnections imbedded in the substrate material before firing (platinum wire or ribbon).

2. Interconnections applied in sandwiches (laminated) and co-fired.

3. True thick-film multilayers achieved with alternating layers of metallization and insulating dielectric, built up to the desired number by repeated firings. The trick is to maintain solderability of each metallization layer as it is repeatedly refired for subsequent layers. Microtek has achieved up to five metallization layers separated by four dielectric layers with no sacrifice in solderability.

Electro Materials Corp. of America has recently made available five alumina ceramic pastes for use in multilayer hybrid circuits. The five differ in firing temperature and dielectric constant. These ceramic pastes are compatible with the company's resistor and conductor pastes, and trimming can be accomplished without damage to the dielectric layer.

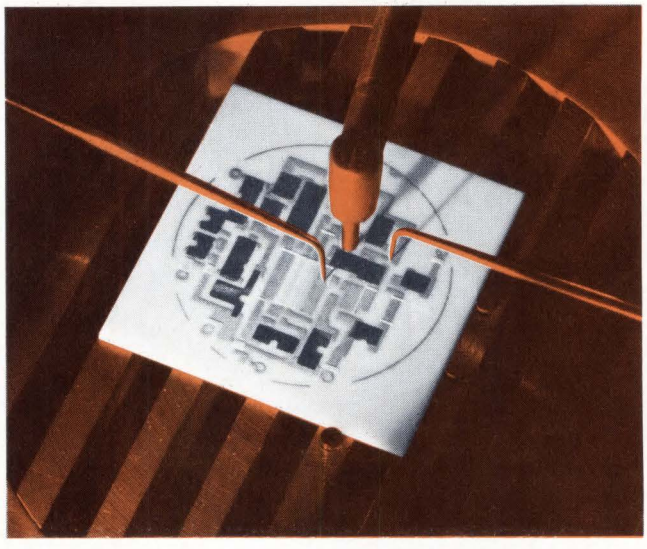
Screen-and-fire methods are relatively inexpensive and use straight thick-film technology. Laminated methods are more reliable (less chance of shorts), more rugged and more expensive.

Up to three layers are performed by CTI for crossovers. With several complex monolithic chips placed into one package, the need for additional wiring freedom shows itself. The use of thick-film dielectrics and metal crossovers to obtain this wiring freedom is, according to CTI, becoming quite common.

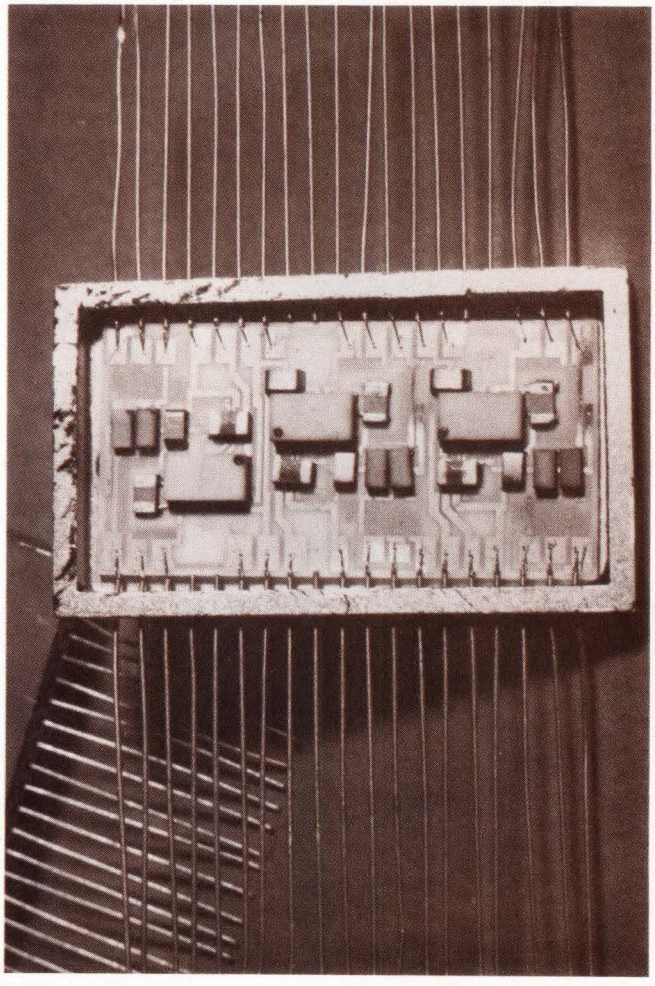
Hybrid Packaging

Although hybrids are considered a packaging technology or philosophy, there is a common complaint that packages are inadequate, particularly in cavity size. This has resulted in a multitude of self-designed packages that has retarded standardization for high volume general-purpose circuits. RCA, however, is optimistic that standardization is coming, and Micro Networks has had success using a glass package made by Sprague with an oversized cavity and standard DIP pinning. Paradoxically, almost all agree that packaging must remain flexible to meet specific customer needs. Hybridyne would like to see vendors develop larger cavity sizes without degrading the strength of the cavity walls. They feel that if package vendors aren't more responsive, many hybrid firms will develop their own in-house packaging capability.

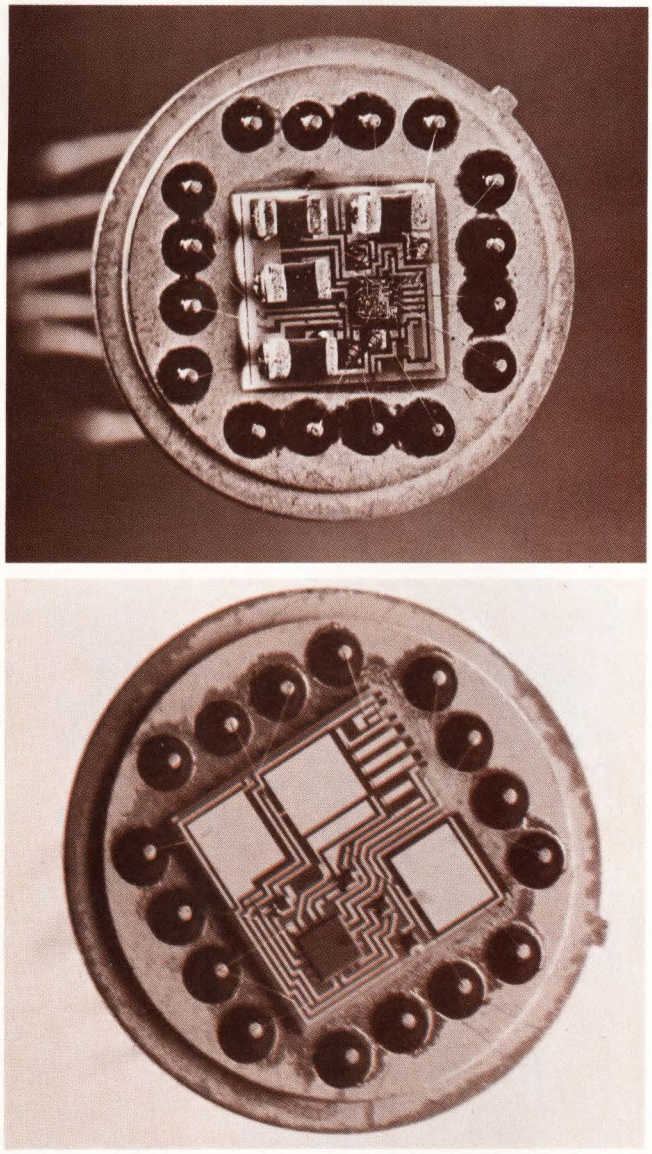
It appears that package manufacturers are beginning to become more responsive to the industry's needs. Tekform Products Co., for example, continues to develop a wide variety of packages for hybrids. In a speech before the International Society of Hybrid Microcircuits (ISHM), Tekform General Manager Ron Chal-



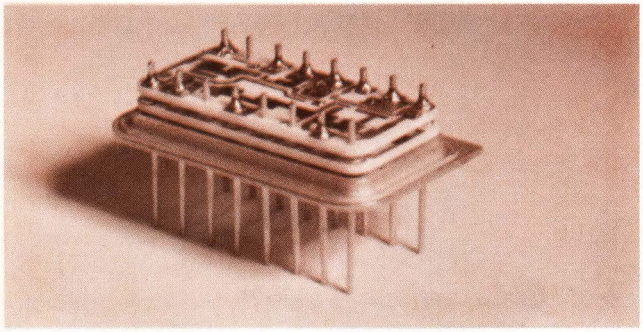
Abrasive resistor trimmer in operation on a modulator circuit. *(BALL BROS. RESEARCH).*



LIDS and thin films guarantee reliable performance in missile application. This demodulator has 3 IC op amps, 6 chopper transistors, 33 thin-film resistors and 6 capacitors. *(AMPEREX ELECTRONIC CORP.)*



FET-input preamplifiers contrast chip-and-wire (top) and beam-lead (bottom) technologies. Each circuit contains a 709 op-amp, four FETs and associated passive components. (*TEXAS INSTRUMENTS INCORPORATED*).



High component density is one feature of this hermetic dual-in-line hybrid package. Substrates can be printed on both sides if necessary, then stacked. Resistance-welded cover completes the package. (*CTS MICROELECTRONICS, INC.*).

man conveyed his company's sensitivity to the needs of hybrid houses. At the conclusion of his talk on package sealing, he said, "The days are over when the package supplier gave you a package, the solder preform vendor the preform, and the sealing vendor a sealer with a 'good luck' wish. We are trying to provide you information on sealing the package when it is not even in our capability to do so. But if we are willing to try, you should help us and let us know the problems so we can correct them."

Although plastic and conformally coated packages are popular in low-cost markets, there is still a need for large, yet inexpensive hermetic packages. Raytheon is happy with its Ray Pak technique and RCA uses its HIP approach (**Fig. 12**) to minimize sealing problems and costs for large circuits.

Collins Radio's standard 1-in thin-film hermetic package includes two noteworthy features. The 30-pin lead frame is thermocompression bonded to substrate pads in a single operation, thus avoiding wire bonding between substrate and package leads. Another unique aspect is the sealing technique that allows defective sealed packages to be opened and repaired. Responsible for this capability are epoxy-glass preforms used to seal the package (**Fig. 13**). If necessary, the package can be opened simply by heating and removing the lid.

CTI's experience with epoxy packages has been all bad. Where they have had an epoxy potting compound come into contact with the very fine gold wires, the gold sooner or later fatigued. On the other hand, leaving the wire alone, supported only by its bonds, CTI has been able to run centrifuge tests to 50,000 or 60,000G with no problems. CTI therefore has stopped working with potting compounds, and they now package exclusively with a hermetic environment.

The packaging technique used at CTS combines plastic with a soft gel to protect the wire leads. CTS uses Dow Corning Sylgard (about the consistency of Jello) to cover the circuit, then encapsulates with potting compound.

Coors Porcelain Company's packaging capability is currently being expanded to three times its present size in order to meet industry demands. By the end of 1970 its capability will be 750,000 packages per month. With announcement of a family of packages that includes a 40-lead DIP with rows having 600 mils separation (**Fig. 14**), Coors Porcelain is turning most of its attention to the MOS/LSI market.

Now moving out of the lab into production, General Electric's standard process is especially suited to microwave circuit design. With this process, GE can hold microstrip lines to within $\pm 1\Omega$. In this proprietary technique, GE places a sheet of FEP "Teflon" over the chips, then etches through to chip connections.

(Continued)

Hybrids Today (Cont'd)

Power microwave circuits can thus be constructed that take the signal to and from the chip via a sort of microwave controlled impedance line (cuts down unwanted L and C in leads) that permits the transistors to be bonded on the package bottom directly against a heat sink.

Trimming Techniques

Practically every means imaginable has been used to alter resistor values in hybrid circuits. They can be broadly categorized as (1) physical removal of material and (2) altering the composition of the material.

For thin-film work, both alteration of the resistor material through heat or electrochemical means and various micromachining techniques are widely used.

For thick-films, abrasive trimming (particles of alumina or silicon carbide in a high-velocity air jet erode resistor material) and high energy machining (laser or sometimes electron beams evaporate and/or oxidize resistor material) are the most common.

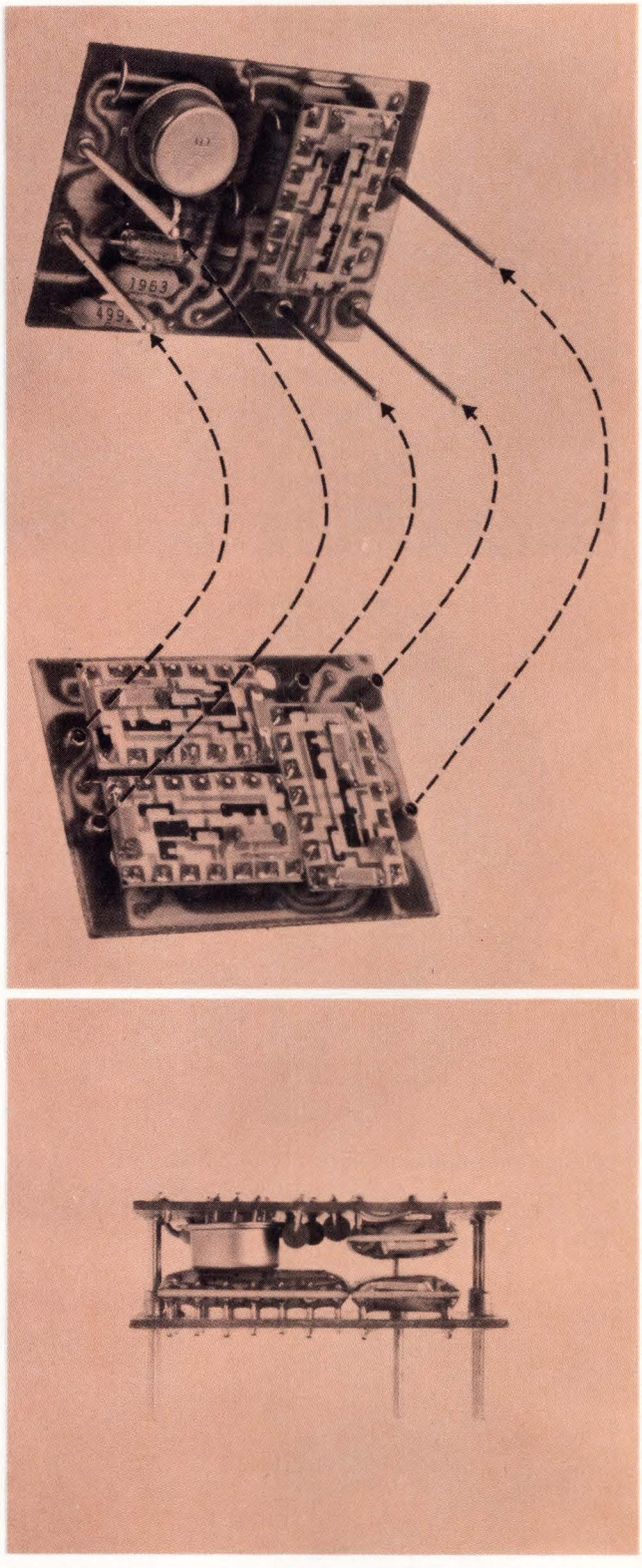
Practically all thick-film hybrid manufacturers agree – for trimming resistors, the laser is the only way to go. Despite this widespread support, the laser has yet to make strong inroads into hybrid houses. Much of the inertia seems to stem from companies unwilling to make a capital investment at this time. Many firms have the older "sandblast" trimmers – and are content to live with them until business gets better.

Basically, there are two types of laser systems that are popular for trimming film resistors – the CO_2 type and the Nd:YAG (neodimium doped: yttrium aluminum garnet). Of the two, the CO_2 type is the less expensive. Both types, however, have advantages and disadvantages. A manufacturer of both types of laser trimming systems, Electro Scientific Industries, Inc., recommends CO_2 for thick film and Nd:YAG for thin film.

Apollo Lasers, Inc. has developed a CO_2 laser trimming system that sells for $12,000 (**Fig. 15**). They feel that many of their customers buy a laser system because of the advantages it offers over air-abrasive trimmers.

Hughes Aircraft also has been very busy developing laser trimming systems for industry. In addition to the CO_2 and Nd:YAG types, Hughes also offers an argon-type laser trimmer for thin films. Hughes manufactures both the lasers and the completely automated test systems (with numerically-controlled tables, **Fig. 16**).

An active user of laser trimming is TRW Semiconductors. TRW has found laser-trim systems they developed for in-house use, very useful – particularly in making active filters. Because they use a proprietary cermet (chromium/silicon) for their thin-film resistors, TRW can both increase and decrease resistance values.



Best solution to cost-size-performance problem often involves hybrids, discretes and monolithics. For this bandpass filter with an output buffer amplifier, each pole-pair is produced on a hybrid substrate. The four pole-pairs and necessary discrete components are mounted on PC boards to complete the module. (*BURR-BROWN RESEARCH CORP.*)

Increasing the resistance value is achieved by conventional trim methods – whereas decreasing it is accomplished by "spot annealing". In other words, the laser is used to heat the cermet without cutting it. This spot heating reduces the resistance value.

Advantages of air-abrasive trimming include: relatively low cost for initial equipment, maintenance and operation; ability to make large, wide cuts where substantial areas must be removed; the ability to cut through relatively thick resistors or other components quickly; and the ability to gang multiple heads and trim several resistors at once.

Disadvantages are: trim widths less than 10 mils are very difficult, limiting resistor size; abrasive particles rebounding from the trim area can scratch or damage adjacent areas; a fresh resistor surface on glazed resistors is opened to the air and instability may occur; and, finally, it is considered just plain dirty because substrates and surroundings become coated with overspray material.

Advantages of laser trimming include: high accuracies in the order of 0.01%; trim widths are extremely fine; no overspray to damage or interfere with other components; active (or dynamic) trimming is possible; glazed resistors usually reflow, minimizing instability by exposure to air; it's clean, and it is computer programmable.

Disadvantages are: initial cost is high; skilled operators and technicians are required to control complex electronics and mechanics; possible recondensation of vaporized materials over substrate; glazed resistors require higher laser power; possible high temperature gradients during trim; and cut must be perfectly clean to minimize leakage current across trim region.

Wrap Up

This brief look at the hybrid technology should have pointed out a number of items to be considered. If you're thinking of entering the game, know that it will take a considerable amount of lab time to get on board – it appears that no two people encounter the same set of problems. Know also that books can be and are being written on each step in the fabrication process and that companies differ in opinion on what causes problems at each step. Observe that the chances for success improve with the cleanliness of your operation.

EDN talked to many companies gathering information for the report. None who is now in the business of turning out hybrid circuits, thick or thin, projected anything but a bright future for this technology. These companies see hybrid technology making more inroads into such areas as: LSI for linear IC and multichip digital systems; applications where device parameters cannot be compromised; high-speed circuits where parasitic effects cannot be tolerated; computer, industrial, consumer, microwave and radar fields; battery-operated electronic equipment designs because hybrids generally consume less power. And they believe hybrids will dominate such circuit designs as active filters, voltage regulators, converters, both A/D-D/A and dc-to-dc, interface circuits, transducer amplifiers, phase-shift oscillators, high-frequency circuits for CATV function modules and microwave.

To keep up to date on the changing hybrid scene, we recommend the activities of ISHM. An ad elsewhere in this issue gives particulars on this society's upcoming meeting in Los Angeles. □

ACKNOWLEDGMENTS

EDN greatly appreciates the information and other help given by each of the listed companies. Without their cooperation much of the story would have remained untold.

AMPEREX ELECTRONIC CORP., Cranston, RI; ANALOG DEVICES, Cambridge, MA; APOLLO LASERS, INC., Los Angeles, CA; AVANTEK, INC., Santa Clara, CA; BALL BROS. RESEARCH, Boulder, CO; BECKMAN HELIPOT, INC., Fullerton, CA; BURR-BROWN RESEARCH CORP., Tucson, AZ; CTS MICROELECTRONICS, INC., West Lafayette, IN; CENTRALAB ELECTRONICS DIV., Globe-Union, Inc., Milwaukee, WI; CENTRALAB SEMICONDUCTOR, INC., El Monte, CA; CERMETEK, Mountain View, CA; CIRCUIT TECHNOLOGY, INC., Farmingdale, NY; COLLINS RADIO CO., Dallas, TX; COMPUTER MICROTECHNOLOGY, INC., Sunnyvale, CA; COORS PORCELAIN, Golden, CO; CRYSTALONICS, Cambridge, MA; DICKSON ELECTRONICS CORP., Scottsdale, AZ; DIONICS, INC., Westbury, NY; ELECTRO MATERIALS CORP. OF AMERICA, Mamaroneck, NY; ELECTRO SCIENTIFIC INDUSTRIES, INC., Portland, OR; FAIRCHILD SEMICONDUCTOR, Mountain View, CA; GENERAL ELECTRIC CO., Syracuse, NY; GENISCO TECHNOLGY CORP., Compton, CA; HRB SINGER, State College, PA; HUGHES AIRCRAFT (ELECTRON DYNAMICS DIV.), Torrance, CA; HYBRIDYNE, INC., Los Angeles, CA; HYCOMP, INC., Maynard, MA; IERC, Burbank, CA; INTERSIL, INC., Cupertino, CA; LOCKHEED ELECTRONICS, Los Angeles, CA; MICRO NETWORKS CORP., Worcester, MA; MICROTEK, Cambridge, MA; MOTOROLA SEMICONDUCTOR PRODUCTS DIV., Phoenix, AZ; MULTITECH MICROELECTRONICS, Monterey Park, CA; NOVA DEVICES, INC., Bedford, MA; RCA AEROSPACE SYSTEMS DIV., Burlington, MA; RAYTHEON MISSILE SYSTEMS DIV., Bedford, MA; RAYTHEON SEMICONDUCTOR, Mountain View, CA; SPACETAC, Bedford, MA; SPRAGUE ELECTRIC, North Adams, MA; SYLVANIA ELECTRIC, Needham, MA; SYLVANIA ELECTRIC, Waltham, MA; TRW SEMICONDUCTORS, INC., Lawndale, CA; TECNETICS, INC., Boulder, CO; TEKFORM PRODUCTS CO., Anaheim, CA; TEXAS INSTRUMENTS INCORPORATED, Dallas, TX; VARADYNE SEMICONDUCTOR, INC., Santa Monica, CA; ZELTEX, Concord, CA.

Microelectronics For the Seventies

1970 INTERNATIONAL SYMPOSIUM

INTERNATIONAL SOCIETY FOR HYBRID MICROELECTRONICS

LOS ANGELES, CALIFORNIA

CONDENSED PROGRAM

MONDAY, NOV. 16, 1970

Session I:
"BUSINESS PROSPECTUS FOR THE SEVENTIES"

Keynote Paper and Business Machines/Consumer Electronics.
Dr. L. Hogan, President and Chief Executive Officer, Fairchild Instrument and Camera Corp.

Automotive Products Technology
H. G. Riggs, General Manager, Delco Radio Division

Aerospace Products Technology
J. Skull, General Manager, Astrionics Division, J.P.L.

Medical Products Technology
D. Morton, Gen. Mgr., Medical Electronics Div., Hewlett Packard

Session II:
"CIRCUITS AND DEVICES"

Evening Panel Session:
"TECHNOLOGY PROSPECTUS FOR THE SEVENTIES"

Business Machines/Computer Technology
Dr. E. Davis, Director of Development, Comp. Div., IBM

Aerospace Technology
R. Gardner, Deputy Director, Electronic Systems and Engineering and Development, NASA

Medical Technology
Dr. D. Rounds, Director of Laser Biology Lab and Tech. Director, Pasadena Foundation of Medical Research

Unique Devices
Dr. E. Leith, Professor of Physics, Univ. of Michigan

TUESDAY, NOV. 17, 1970

Session III:
RELIABILITY (In parallel with Session IV)

Session IV:
PACKAGING AND INTERCONNECTIONS
(In parallel with Session III)

Session V:
EQUIPMENT MECHANIZATION and Process Control Banquet

WEDNESDAY, NOV. 18, 1970

Session VI:
MATERIALS TECHNOLOGY

Session VII:
FILM TECHNOLOGY I

Session VIII:
FILM TECHNOLOGY II

*Abstracts for 10 minute late news presentations should be brought to the symposium. These will be presented as time permits.

TECHNICAL EXHIBITS

Exhibits will emphasize educational/professional values in preference to de facto commercialism. Application and service oriented technical personnel will be available at each exhibit to answer questions and explain their respective technologies.

LADIES PROGRAM

A memorable program including a fashion show, a tour of Universal Studios, a visit to the Los Angeles Music Center, a walking tour of the shops of Beverly Hills, and a tour of the Sunset Strip and homes of the stars has been arranged for the wives of the attendees.

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CIRCLE NO. 13

PULSE SWALLOWING

Designing high-speed programmable dividers with economical MSI/TTL circuits can be easy—if you employ a novel logic technique that allows pulses to be "swallowed".

JOHN NICHOLS and CHARLES SHINN, Fairchild Semiconductor

Designing a programmable divider that must operate at speeds beyond what TTL can handle can get messy. Apart from having to use the more expensive logic, such designs require hefty power supplies to supply high-current levels, ICs run hot—and the low number of logic functions per package requires more space. Of course, all of these problems stem from using high-speed logic. To minimize the use of high-speed logic, a "pulse swallowing" technique was devised recently for a phase-locked loop (PLL) frequency synthesizer. This same technique can be applied to any system that contains a high-speed programmable divider. Reviewing the equations developed for the PLL frequency synthesizer will demonstrate the benefits of using the new logic technique.

Conventional Approaches

For low-frequency operation (less than 15 MHz), **Fig. 1a** depicts the optimal configuration for a PLL frequency synthesizer. This "straight-through" counter method, though optimal at lower frequencies, is nothing short of brute force at higher frequencies. Aside from having to use expensive emitter-coupled logic (ECL) for high-frequency operation, you must also contend with heat dissipation problems because of high-power consumption. And unlike TTL, ECL is not available in MSI building blocks—so the low number of functions per ECL package creates a high package count along with its attendant nuisances. Despite these disadvantages, the straight-through method does offer a distinct advantage for the PLL application—the

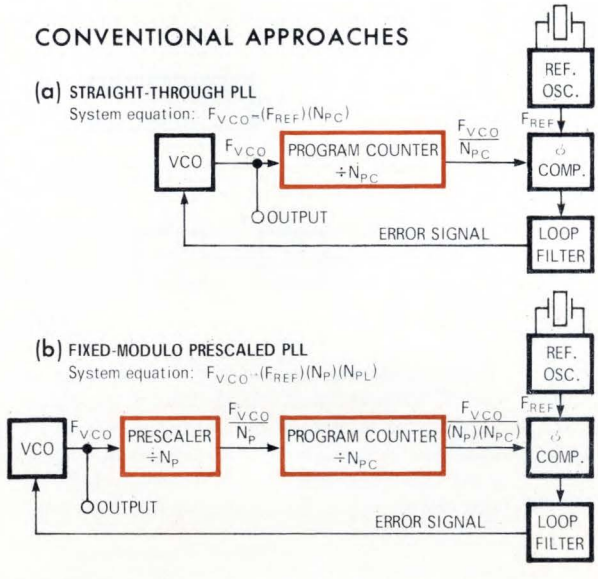

Fig. 1a—**Basic PLL frequency synthesizer** operates as follows: The system output generated by a VCO is also divided by the program counter and then compared in frequency and phase to the signal generated by the reference oscillator. Any frequency difference between the two signals produces an error signal which is filtered, then fed back to the VCO, which then corrects its frequency output. Though costly to implement at frequencies above 15 MHz, the "straight-through" method shown does have a favorable channel-spacing characteristic. Because the VCO frequencies (F_{VCO}) are integer multiples (N_{PC}) of the reference oscillator frequency (F_{REF}), the desired channel spacing dictates F_{REF}.

Fig. 1b—**Prescaling minimizes** the costly high-speed logic that's required to operate at high frequencies. But there is a trade-off. By adding the "fixed-modulo" prescaler, F_{REF} is reduced by a $1/N_P$ factor.

(Continued)

Pulse Swallowing (Cont'd)

reference frequency (F_{REF}) at which the phase comparison takes place is as high as it can be. A high reference frequency provides a fast phase-lock and effectively moves the spurious VCO outputs farther away from the fundamental.

For the straight-through system, the equation

$$F_{VCO} = (F_{REF})\ (N_{PC})$$

shows that increasing the program counter's modulo (N_{PC}) by one count will increase the VCO frequency (F_{VCO}) until the F_{VCO}/N_{PC} ratio equals the reference oscillator frequency (F_{REF}). Therefore, the desired channel spacing (frequency difference between adjacent channels) dictates what F_{REF} must be.

An obvious solution to minimizing high-speed logic is shown in **Fig. 1b**. By inserting a prescaler (fixed-modulo counter) ahead of the program counter, we can divide F_{VCO} down to a frequency that TTL can handle. Though this method minimizes the use of ECL, it does introduce a trade-off—the frequency at which the phase comparison is made is reduced by a $1/N_P$ factor. To see why, consider the loop equation for the fixed-modulo system:

$$F_{VCO_1} = (F_{REF})\ (N_P)\ (N_{PC})$$

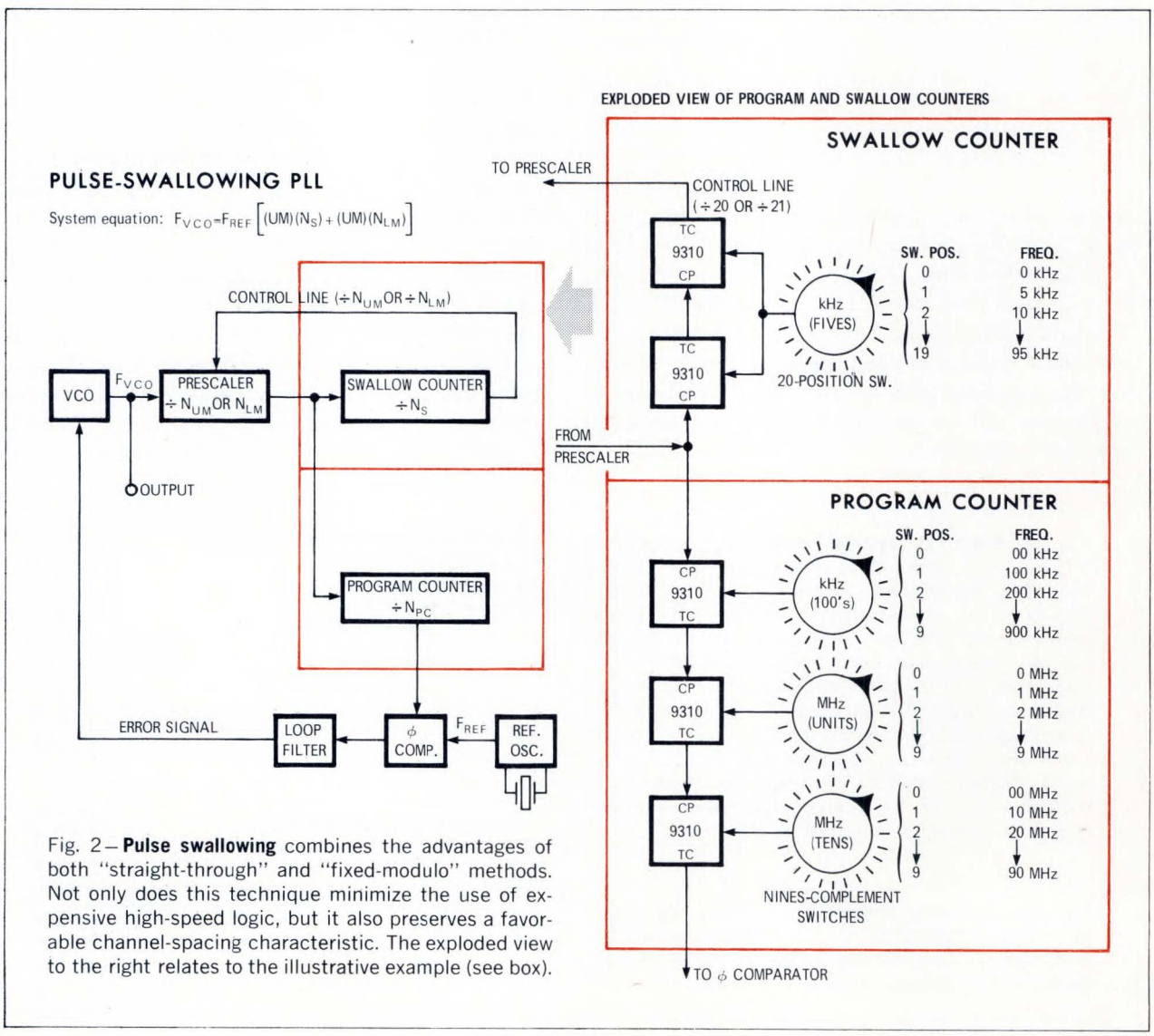

Fig. 2—**Pulse swallowing** combines the advantages of both "straight-through" and "fixed-modulo" methods. Not only does this technique minimize the use of expensive high-speed logic, but it also preserves a favorable channel-spacing characteristic. The exploded view to the right relates to the illustrative example (see box).

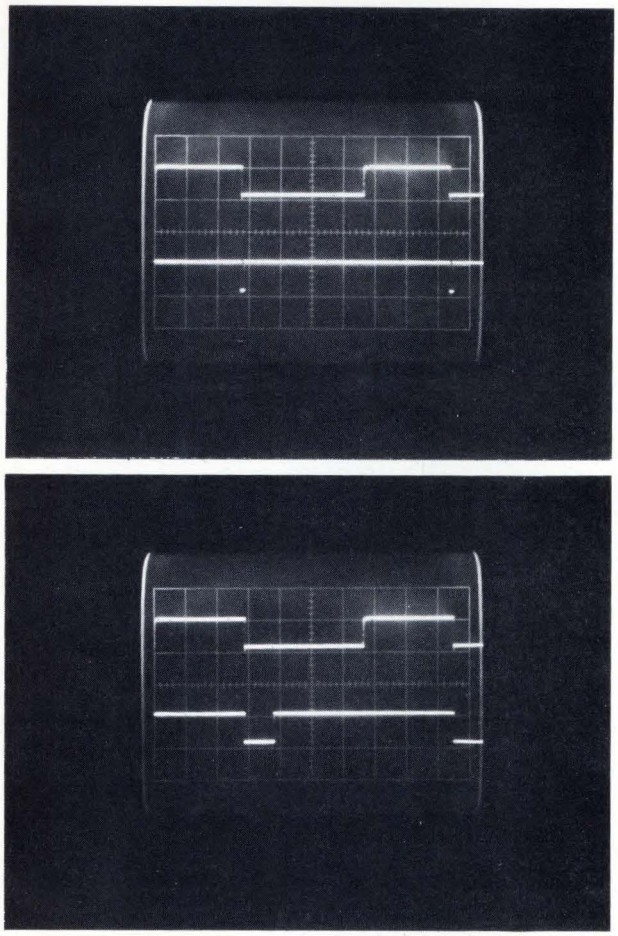

Fig. 3 – **Typical swallow count waveforms** (lower trace, both photos) are displayed with the signal output of the program counter. In the upper photo, 130.1 MHz is the input to the program counter and the swallow count (N_S) = 2. In the lower photo, 130.9 MHz feeds the program counter while N_S = 18. (Horiz: 3 μs/cm; Vert: 5V/cm).

As before, the adjacent channel is obtained by increasing (or decreasing) the program counter modulo by one:

$$F_{VCO_2} = (F_{REF})\ (N_P)\ (N_{PC}+1)$$

Thus the channel spacing, ΔF, is:

$$\Delta F = V_{CO_2} - V_{CO_1} = (N_P)\ (F_{REF})$$

$$\therefore F_{REF} = \frac{\Delta_F}{N_P}$$

Consequently, F_{REF} must be reduced by the factor $1/N_P$ if the same channel spacing is to be maintained.

Pulse Swallowing

For high-speed applications, pulse swallowing combines the advantages of both the "straight-through" and "fixed-modulo" counters. More specifically, it minimizes high-speed logic by prescaling the program counter's input – *without* the need to reduce F_{REF} to maintain a favorable channel-spacing characteristic.

Pulse swallowing is achieved by using a two-modulo prescaler ($\div N_{UM}$ or $\div N_{LM}$) which is controlled by a "swallow counter". Because the upper modulo (UM) is only one count more than the lower modulo (LM), it takes only one extra gate to convert the fixed, single-modulo prescaler to the two-modulo type. As we will see, adding the swallow counter not only improves system performance, but also reduces design cost.

For the pulse swallowing system of **Fig. 2**, the prescaler can be controlled to divide by either a lower modulo (N_{LM}) or an upper modulo (N_{UM}). In operation, the prescaler initially divides F_{VCO} by N_{UM}. After a predetermined count, the swallow counter feeds back a control signal to the prescaler, that causes it to divide F_{VCO} by N_{LM}. Subsequent to receiving the sequence of both these pulse trains at its input, the program counter produces a pulse at its output. Consider now the system equation for **Fig. 2**

$$F_{VCO} = (N_T)\ (F_{REF})$$

where N_T is the total count given by

$$N_T = (UM)\ (N_S) + (UM)\ (N_{LM}).$$

To get the next channel with pulse swallowing, the swallow count (N_S) is merely increased by one. Since N_{PC} hasn't changed, the number of times F_{VCO} is prescaled by the lower modulo (per output pulse of the program counter) is decreased by one.

For example:

$$N_{PC} = N_S + N_{LM} = \text{Constant}$$

Now if $N_S \longrightarrow N_S+1$,

then $N_{LM} \longrightarrow N_{LM}-1$.

Note that, although the program counter has not been changed, increasing the swallow counter by one results in the overall divide ratio being increased by one. The prescaler has effectively "swallowed" an extra pulse, hence the name for the technique. Some typical swallow count waveforms are shown in **Fig. 3**.

Channel Selection

Though you could perform channel selection by programming the swallow counter for each channel, this

(Continued)

Pulse Swallowing (Cont'd)

would waste logic power. A better idea would be to use the swallow counter for the least significant digits of the channel selector—and the program counter for the more significant digits. (See exploded view in **Fig. 2**). Since you can't get more out than you put in, the maximum channel spacing available from the pulse swallowing system would, of course, be equal to F_{REF}. Hence the pulse swallowing technique preserves the maximum F_{REF} characteristic of the straight-through system as verified by the following equations:

$$F_{VCO_1} = F_{REF}\,[(LM+1)\,(N_S) + (LM)\,(N_{LM})]$$

For the adjacent upper channel: $N_S \longrightarrow N_S+1$

as $N_{LM} \longrightarrow N_{LM}-1$

hence:

$$F_{VCO_2} + F_{REF}\,[(LM+1)\,(N_S+1) + (LM)\,(N_{LM}-1)]$$

Now the channel spacing is given by

$$\Delta F = F_{VCO_2} - F_{VCO_1}$$

Plugging in and expanding:

$$F = F_{REF}\,[(LM)\,(N_S) + N_S + (LM) + 1 + (LM)\,(N_{LM}) - LM] - F_{REF}\,[(LM)\,(N_S) + N_S + (LM)\,(N_{LM})]$$

Thus, $\Delta F = F_{REF}$.

In addition to achieving a maximum F_{REF} that equals the channel spacing, pulse swallowing further permits the majority of logic to be implemented at lower speeds. This latter advantage alone greatly reduces logic cost, design time and PC board complexity through the use of MSI/TTL instead of costly ECL. □

John Nichols (left) and **Charles Shinn** (above) collaborated to present the "Pulse Swallowing" approach that was recently used to design a hybrid PLL frequency synthesizer. Both men are design-oriented applications engineers for Fairchild Semiconductor. Nichols holds a degree in mathematics from California State Polytechnic Inst. and Shinn is a B.S.E.E. from Drexel Inst. of Technology.

Design Guidelines and Example

Though many different combinations of swallow, prescale and program count modulos can be used for any one design, it's generally convenient to follow these guidelines:

1. Make the reference oscillator frequency (F_{REF}) equal to the input channel spacing.
2. Make the program count modulo (N_{PC}) equal to some convenient factor of the input frequency.
3. Make the swallow count modulo (N_S) large enough to reach the least significant digit for which the program counter must account.

To show how the above guidelines are implemented, the following example is presented:

Problem

Design a programmable divider with a 5-kHz channel spacing that will operate over the 20- to 25-MHz frequency range.

Solution

Following the above guidelines:

1. Make F_{REF} = 5 MHz
2. Choose 100 kHz as program counter's frequency factor; therefore (N_{PC}) (100 kHz) = desired frequency. For example: N_{PC} = 200 for 20 MHz. N_{PC} = 250 for 25 MHz.
3. Thus $N_{S(max)} = \dfrac{100\text{ kHz}}{F_{REF}} = 20$

With the above modulos determined, the following table can be constructed:

FREQUENCY DESIRED	N_{PC}	N_S	N_{LM}	N_{TOTAL}
20.000	200	0	200	4000
20.005	200	1	199	4001
20.010	200	2	198	4002
20.095	200	19	181	4019
20.100	201	0	201	4020
20.105	201	1	200	4021
20.995	209	19	190	4199
21.000	210	0	210	4200
21.005	210	1	209	4201
25.000	250	0	250	5000

To calculate the required prescale factors:

$N_{total} = (N_S)\,(UM) + (N_{LM})\,(LM)$

At 20 MHz:

$4000 = (0)\,(UM) + (200)\,(LM)$

Therefore: LM = 20

Hence: UM = LM + 1 = 21

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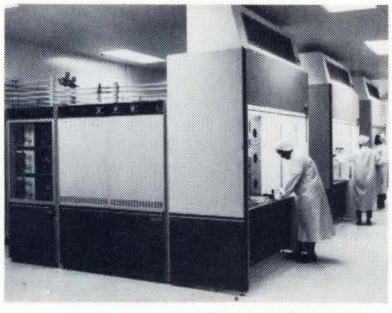

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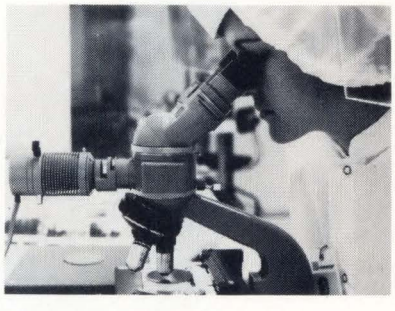

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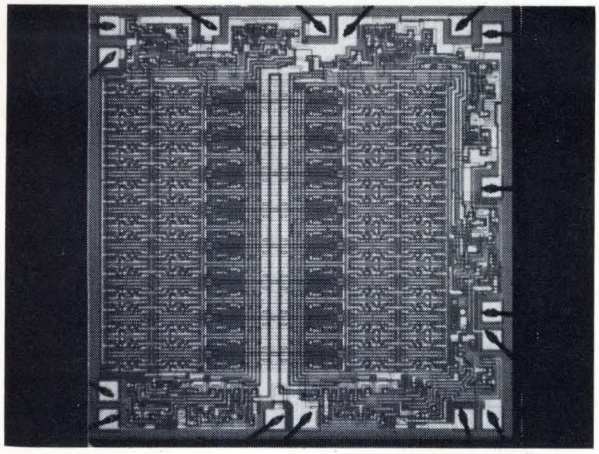

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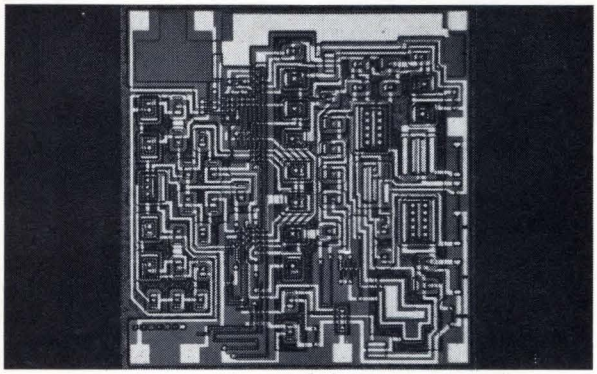

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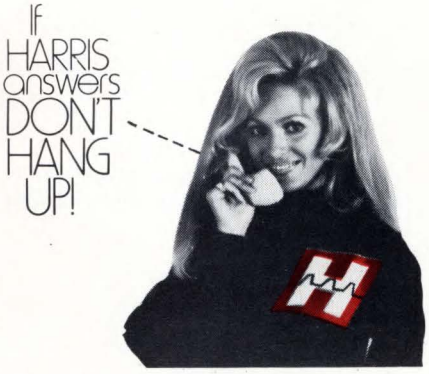
2560 MOS ROM	9309 DUAL 4 INPUT MPX	
	9312 SINGLE 8 INPUT MPX	
	9316 HEX COUNTER	



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CIRCLE NO. 17

Modified Schmitt Trigger Stabilizes Pulse Generator

Variable-frequency, variable-pulse-width square waves can be preserved despite supply voltage changes.

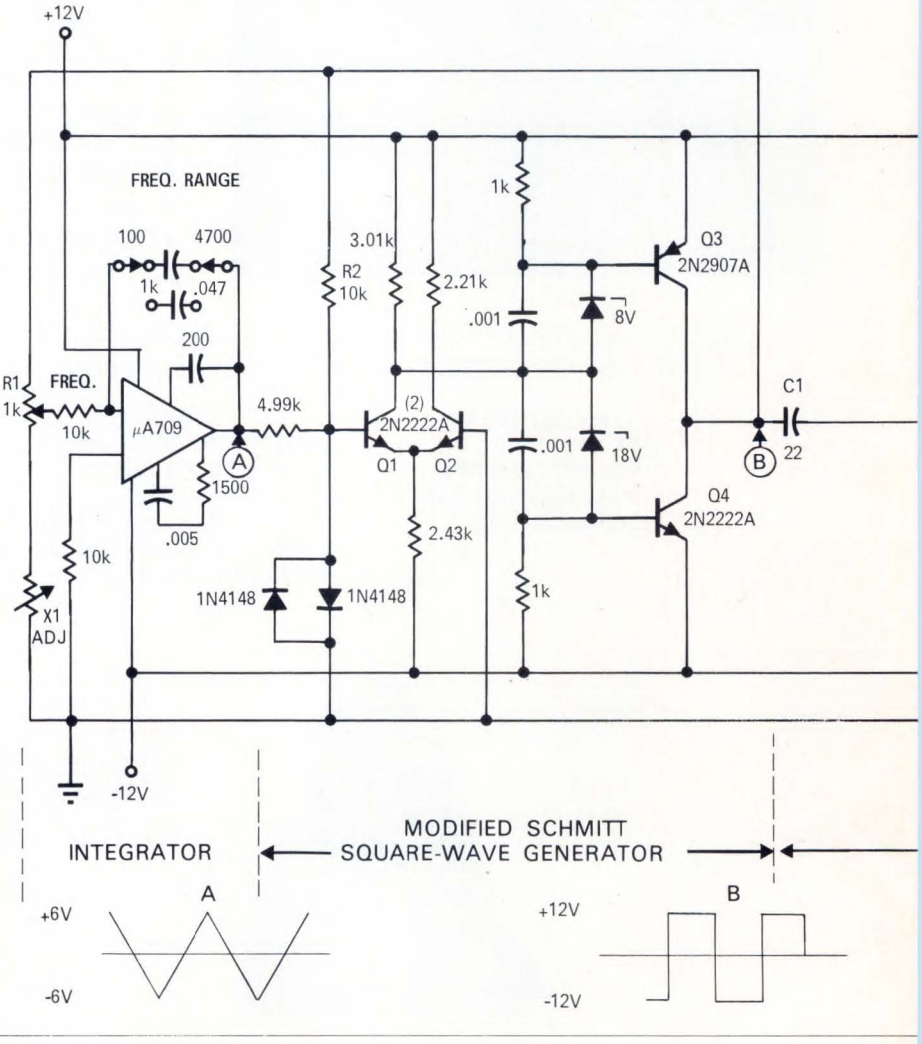
Generating high-speed square-wave pulses that are variable over both a range of time and frequency and yet are insensitive to supply voltage variations can be a mean task. A method of feeding back the output accomplishes the insensitivity, and as a bonus, a differential pair driving a complementary series output stage preserves the fast rise and fall times.

Basically, the line-up for this useful circuit is a Miller integrator driving a single-ended differential pair. The single-ended output will switch one or the other of the complementary series output pair. Two zener diodes provide a small offset in order to insure that both output transistors are not ON at the same time. Since the output is taken at the junctions of the complementary pair which is connected across a ±12V supply, the output signal obtained is a ±12V square-wave signal. This square wave is fed

Square-wave pulse generator feeds back output to input to achieve high-speed latching action and to compensate for supply variations. Miller integrator input is derived from output square wave and attenuated in R1. Op amp output is triangular wave with ±6V peaks. Voltage at Q1 base switches between ±600 mV. Positive-going triangular wave overcomes −600 mV base voltage when it reaches the +6V peak and turns on Q1, pulling down its collector. When collector voltage falls to +3V, zener CR1 conducts and Q3 turns on making output +12V. Feeding back +12V to Q1 base via R2 latches the switch. Op amp output now ramps negatively toward −6V. At −6V, Q1 turns off, collector rises toward +7V to turn on zener CR2 and Q4, thereby latching the output to −12V and causing integrator to ramp up toward +6V,

Output square wave is differentiated by C1 R3. Positive spike triggers Q6 which, together with Q5, comprises a regenerative latch equivalent to an SCR except for R4 connected to Q6 collector. Latch resets capacitor C2 or C3, whichever is charged from constant-current source Q7. Regenerative latch turns off when C2/C3 voltage reaches 0V. Sawtooth wave at output of emitter follower Q8 is biased up or down with dc level (time) control R5, then mixed with ±12V square wave from Q11 or Q12 output and applied to Q9 base of differential pair Q9 and Q10.

R1 adjusts charging period of integrator to provide FREQUENCY control. R5 biases sawtooth up or down, varying duty cycle (or pulse width) of output square wave to provide TIME control. Any change in ±12V supply voltage has no effect on triangular wave frequency.



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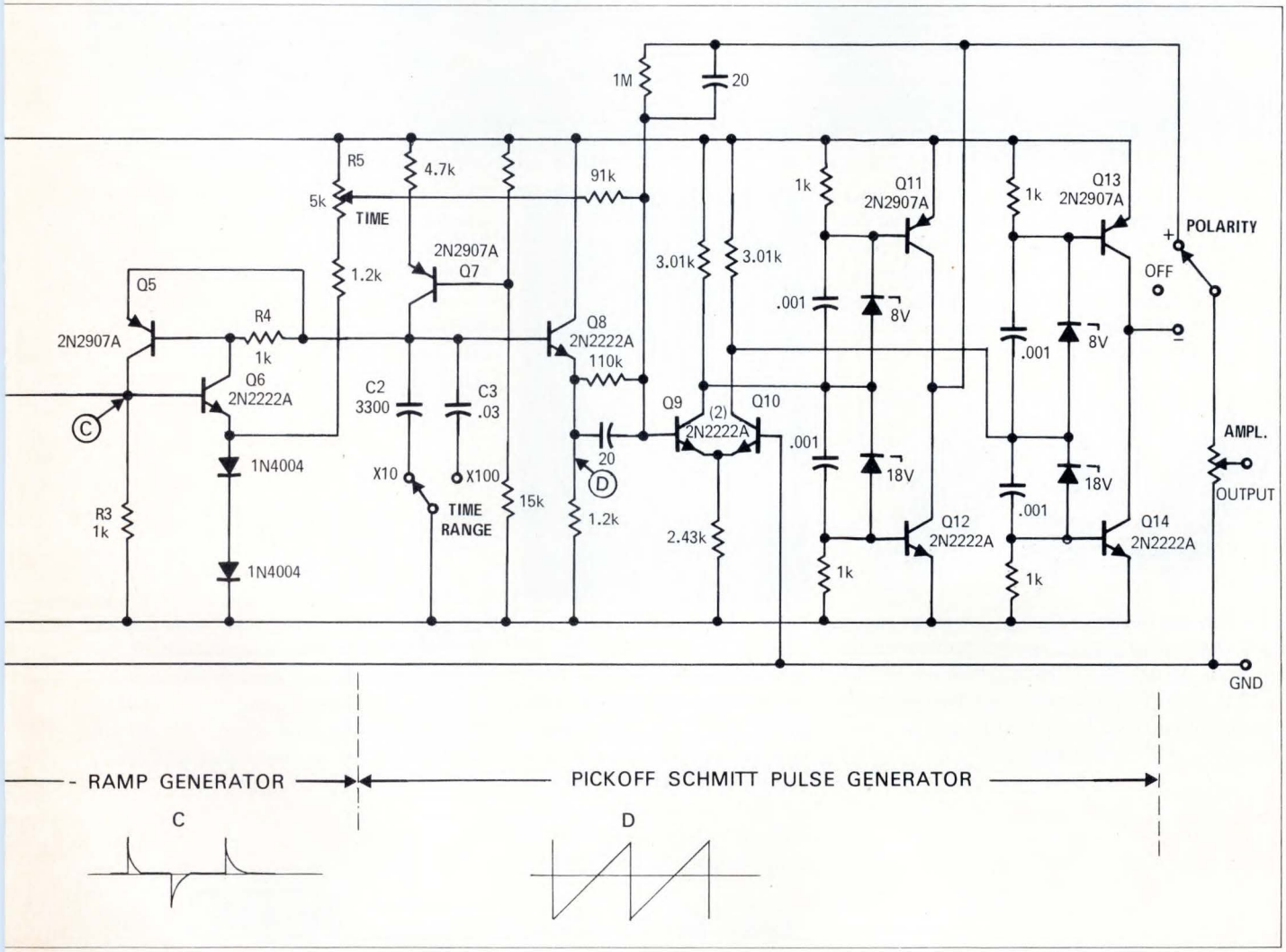
back to the input of the differential pair and to the input of the Miller integrator. Feeding back the output square wave provides a high-speed latching action and compensates the integrator for supply-voltage variations. The output square wave synchronizes a linear ramp generator whose output is mixed with dc to drive a similar square-wave generator. By varying the dc, the duty cycle or width of the pulse can be easily varied. □

OECO Corp., Portland, Ore., designed this pulse generator for their production test equipment.

Robert P. Lewis is a staff engineer for the OECO Corp. where his responsibilities include technical design and development of avionic products. He attended the University of Alaska.



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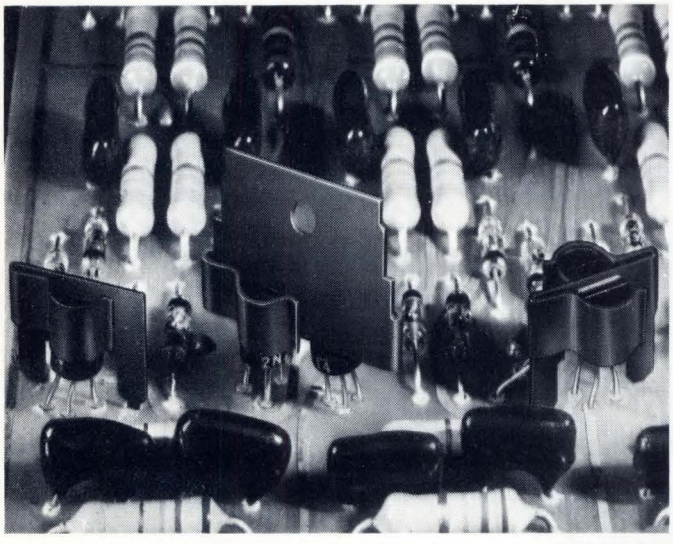

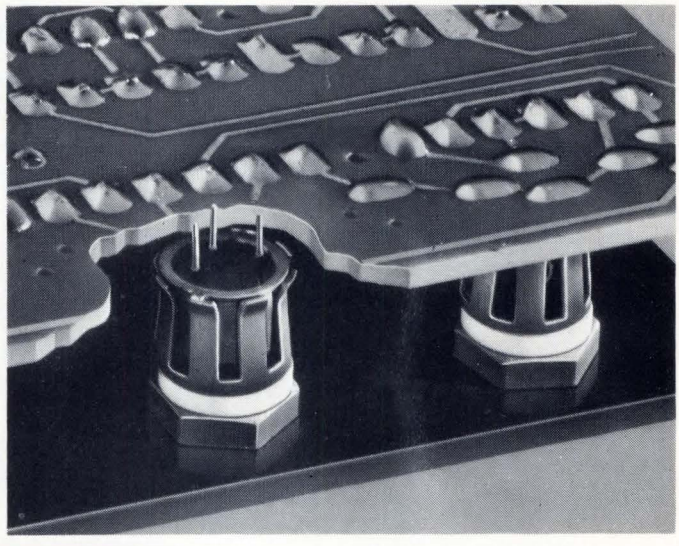

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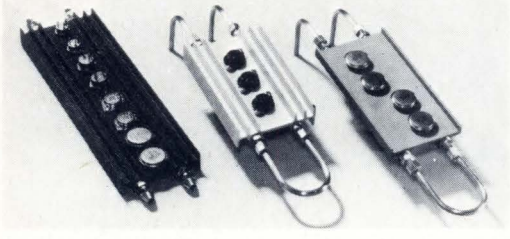

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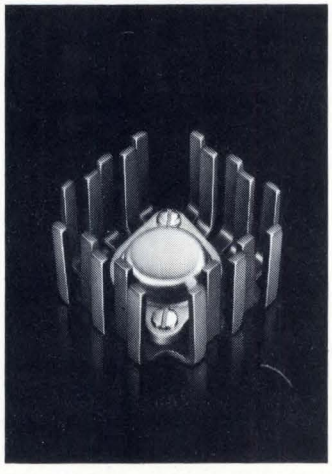

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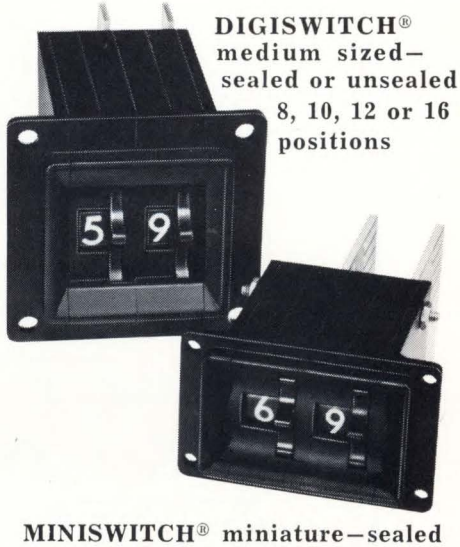

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CIRCLE NO. 19

ICs Pick Frequencies For Untuned Power Amplifier

Integrated-circuit frequency synthesizers make a transmitter with pushbutton channel selection practical. Simply feed the synthesizer's output into a broadband amplifier.

RICHARD BRUBAKER, Motorola Semiconductor Products

Pushbutton channel selection in the 118-136 MHz civil aircraft communications band is now feasible using IC frequency synthesis. Feeding the synthesizer output to a power amplifier with wideband response avoids the need for manual tuning adjustment. Amplifier design criteria include:

– 25W CW minimum output (50Ω load)

– capability of modulation in excess of 80%

– tuning, 118-136 MHz

– deliver full output with 10 mW input from 50Ω source

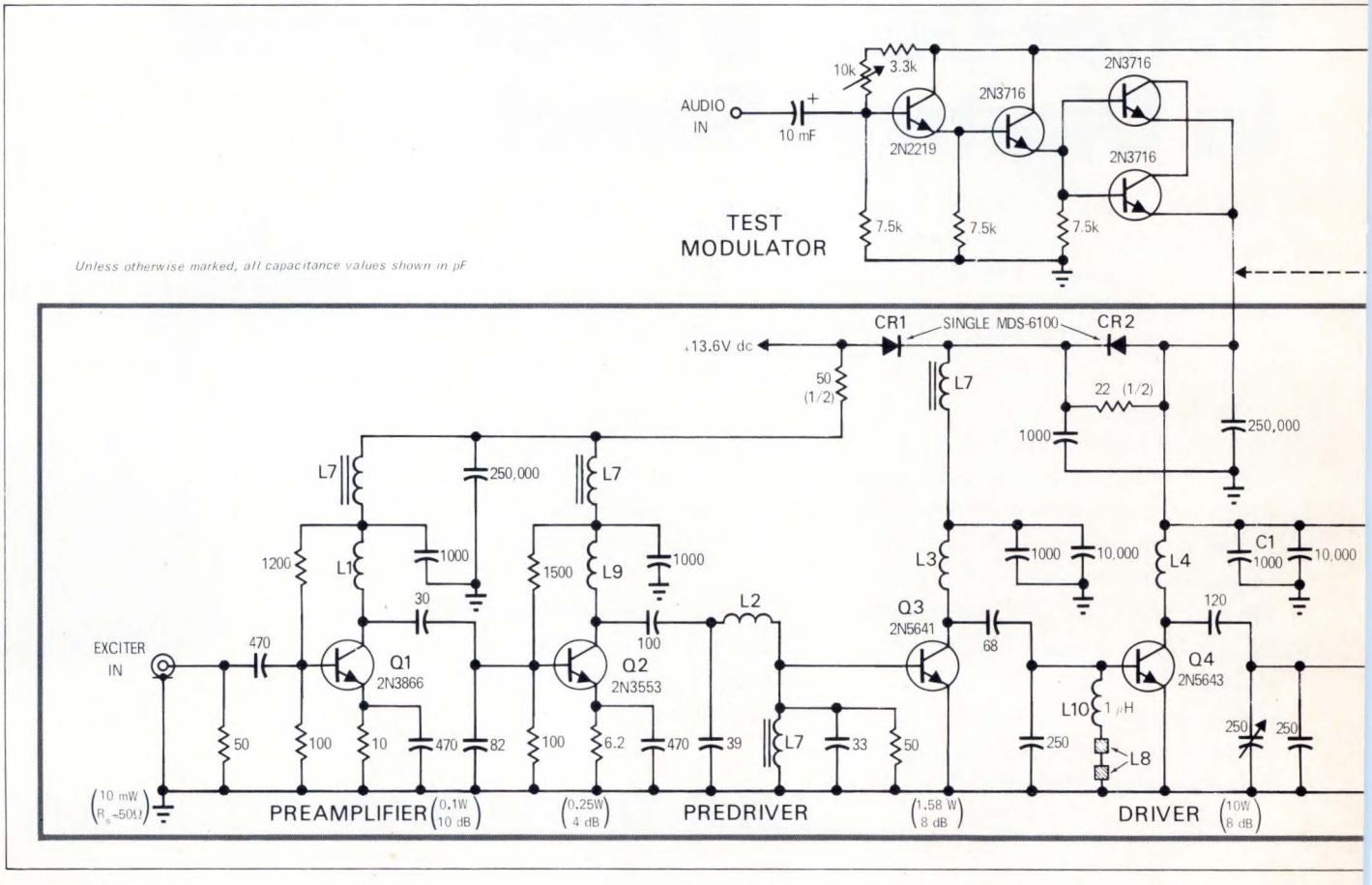
– operate from 14 or 28V dc aircraft power

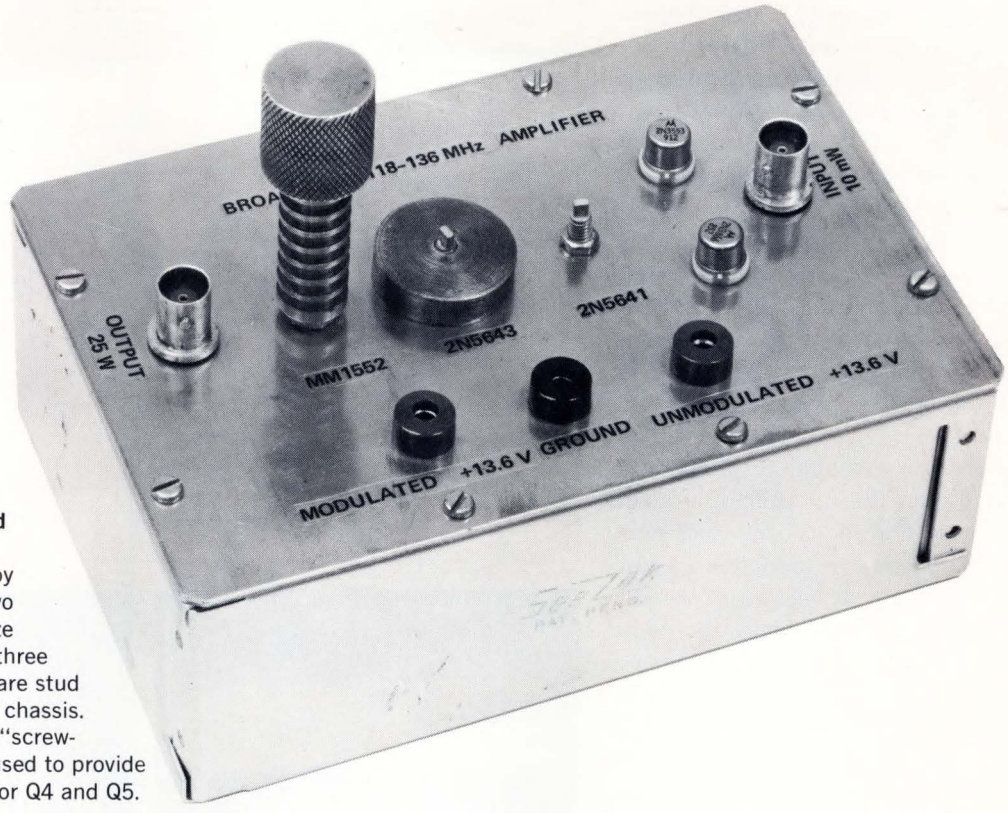
– tolerate infinite output SWR.

The design is based upon use of a new Motorola transistor, MM1552. This is a high power, stripline device, in which the emitter is internally tied to the mounting stud to facilitate grounding to the chassis. Stripline leads are provided for base and collector.

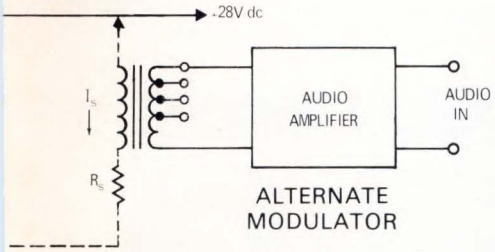
Actual circuit design did not follow general practice. Circuit values could not be determined using data sheet admittance and loading characteristics. It was found that, to obtain the required bandwidth, each stage had to be overdriven. Published admittance data under overdrive conditions was not available. Further, the overall design objective calls for wideband

(Continued)





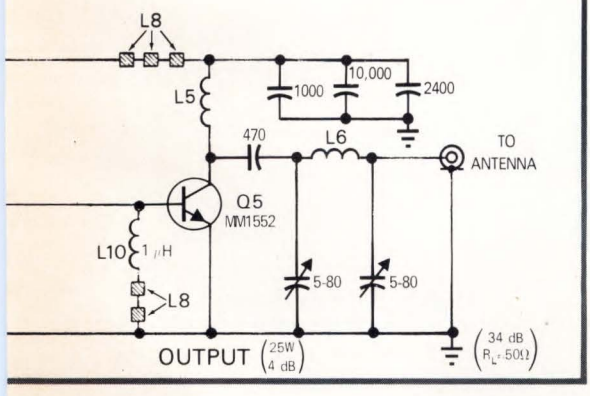
The circuit is constructed on a phosphor bronze metal sheet 6 by 3-3/4 by 1/32 inches. The first two stages, Q1 and Q2, utilize sockets. The remaining three stages (Q3, Q4 and Q5) are stud mounted directly on the chassis. A small copper block or "screw-on" heat sink also was used to provide better heat dissipation for Q4 and Q5.



ALTERNATE MODULATOR

COIL DETAILS

NUMBER	TURNS	WIRE SIZE	I.D. (inches)	LENGTH (inches)	MANUFACTURER	NUMBER
L1, 1 req	2			1/4		
L2, 1 req	2 1/2			1/8		
L3, 1 req	1	#18 AWG	3/16	1/8		
L4, 1 req	2			3/8		
L5, 1 req	3			3/8		
L6, 1 req	1			1/4		
L7, 4 req					Ferroxcube	RFC,VK-200
L8, 7 req					Ferroxcube	RFC,5659065/3B
L9, 1 req					1 μH	
L10					1 μH	



All transistors are common emitter, operated in Class C. Preamplifier transistors Q1, Q2 are unmodulated. Predriver, Q3, is half-wave modulated upward, downward modulation being limited by dual-diode CR1, CR2. Driver, Q4, supplies approximately 10W to base of output transistor Q5 through an interstage network with an adjustable shunt capacitor, C. Base lead of Q5 is intentionally made about 1/8 in long to permit neutralization by adjustment of C. Resultant higher parallel impedance level is further transformed to required level by adjustment of capacitive tap network C1, at collector of Q4. Output circuit of Q5 is a π network which transforms the 50Ω load down to required collector loading of 3.7Ω shunted by 240 pF.

Series collector modulation is conventionally done using modulation transformer (dotted connections). However, to provide continuous amplitude control without tap-changing, and to eliminate Is Rs dc voltage drop, transistorized test modulator was devised. An improved version, using feedback to minimize distortion, and thermal compensation could be used to eliminate modulation transformer in flight equipment.

(Continued)

modulated response, in excess of 80% throughout the band. Single-frequency design proved inadequate.

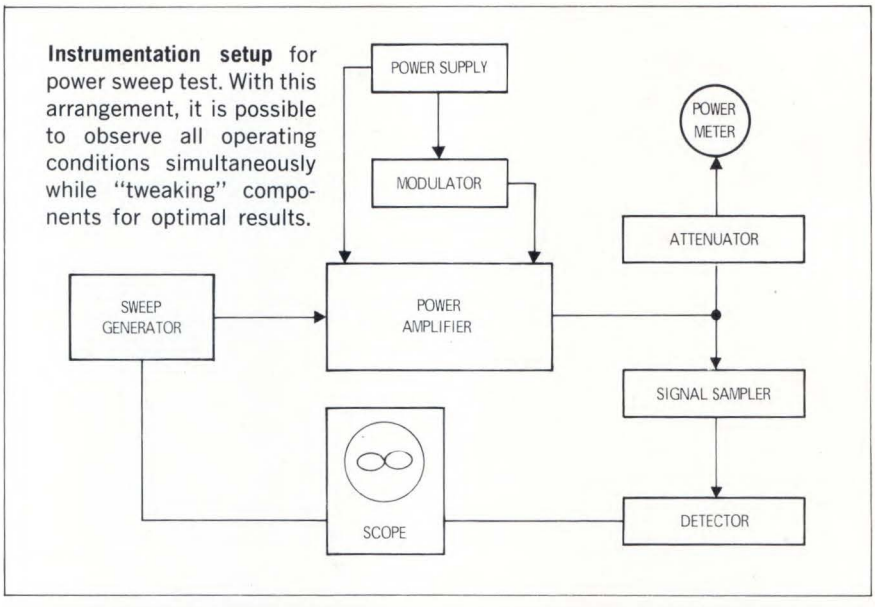
The actual design resulted from using the available large signal admittance data to obtain ball park component values. These were used in a design prototype, and were tailored for optimum results while driving the transmitter with a power sweeper, and modulating. Using this technique, modulation amplitude, instabilities and power output can be simultaneously monitored across the band.

Collector modulation usually requires a significant amount of audio power at high dc collector currents. If a transformer is used, it must handle this heavy dc current in the secondary as well as supply the audio power. It should have a tapped secondary, with low dc resistance to minimize the dc voltage drop in series with the power amplifier. The test modulator shown was used, rather than a modulation transformer and associated audio amplifier, for simplicity and continuous control. Although the transistorized modulator displayed such disadvantages as thermal drift and distortion, it proved a convenient method of modulation. Thermal compensation and feedback could make it a practical replacement for the conventional modulation transformer.

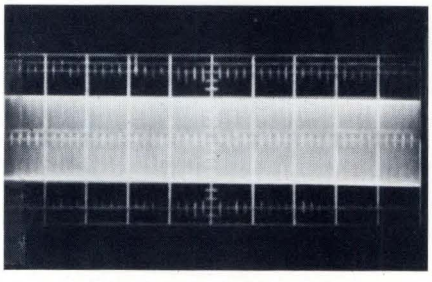
In concluding the testing of this power amplifier, the output was driven into a special network consisting of a variable coaxial transmission line and a large variable reactance shunt across the load. Throughout this essentially infinite SWR "Smith Chart" type test, no device failures were experienced. □

A typical frequency-determining stage is described in Motorola Application Note AN-463, "An Integrated Circuit Phase–Locked Loop Digital Frequency Synthesizer."

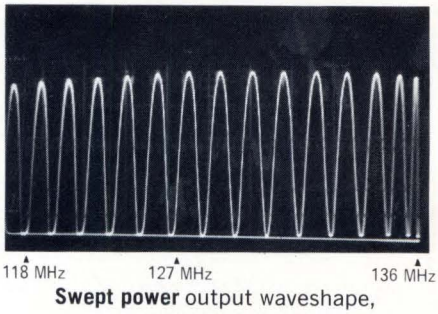
The author thanks Edward Loupe for his collaboration in conjunction with the design and testing of this power amplifier.



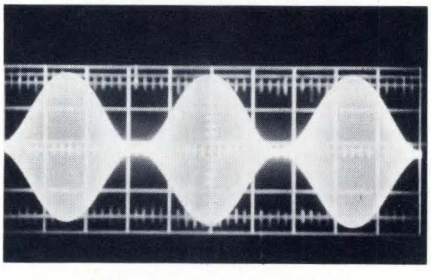
Instrumentation setup for power sweep test. With this arrangement, it is possible to observe all operating conditions simultaneously while "tweaking" components for optimal results.



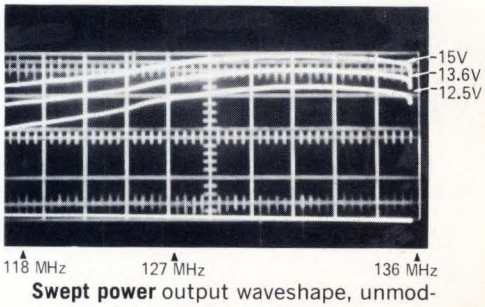
118 MHz unmodulated carrier waveform, 25W.



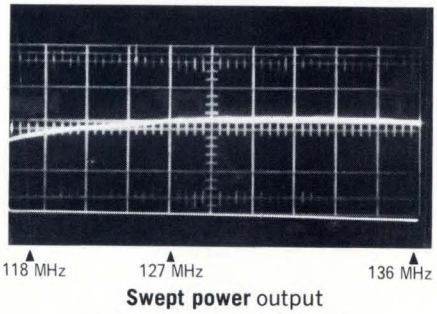
Swept power output waveshape, modulated at 1 kHz.



118-MHz carrier, modulated by 1-kHz tone, 33W rms.



Swept power output waveshape, unmodulated, for various supply voltages.



Swept power output waveshape, unmodulated.

	118 MHz	127 MHz	136 MHz
POWER OUTPUT (unmodulated)	25.1 W (rms)	31W	28W
POWER OUTPUT (modulated)	33W (rms)	42.5W	38.5W
POWER SUPPLY VOLTAGE (at collector of Q5)	13.6V dc	13.6V	13.6V
COLLECTOR CURRENT, Q5	3.3A dc	3.4A	2.9A
POWER INPUT (unmodulated)	10 mW (rms)	10 mW	10 mW
TYPICAL UPWARD MODULATION	80%	86%	88%
ENVELOPE DISTORTION	8.5%	7.9%	8.0%
SPURIOUS RESPONSE			
2f	-22 dB	-20 dB	-21 dB
3f	-49 dB	-45 dB	-48 dB
other frequencies	<-52 dB	<-52 dB	<-58 dB

Typical performance data of power amplifier.

Response of power amplifier under various operating conditions.

CUSTOMER ENGINEERING CLINIC

Resistors Restore Regulation and Redundancy

PETER J. KLEIN, Dynage Inc.

Problem: When power supplies are hooked up as in **Fig. 1** to provide redundant operation, load regulation is lost, and under certain conditions so is redundancy when the redundant supply is slow in coming up to full output. The load requires 24V at 0-10A at all times.

Discussion: CR1 in **Fig. 1** is an isolating diode for the two power supplies. With sense leads connected to supply output instead of the load (as shown), the sum of line and clamping diode voltage drops could reduce load regulation below necessary minimum requirements.

If sense leads are connected directly to the load in order to overcome the above problem, one sense amplifier will detect a higher voltage at the load (both supplies rarely have exactly equal outputs) and drive that supply to zero output voltage. Redundancy would then be lost momentarily if the loaded supply should later fail, because the output voltage will fall momentarily as a result of the delay in the redundant supply coming up to rated output voltage.

Solution: Clamping resistors R_c (**Fig. 2b**) on the sense lines allows them to be connected to the load (**Fig. 2a**), thus eliminating regulation loss from line and isolating diode voltage drops. Redundancy also is maintained, because the redundant supply is always maintained at approximately 90-95% of full output voltage level, thus reducing time required to come up to full output voltage if the loaded supply fails. R_c is sized to allow approximately 0.5V drop; therefore total output drop is approximately 1.0V dc. □

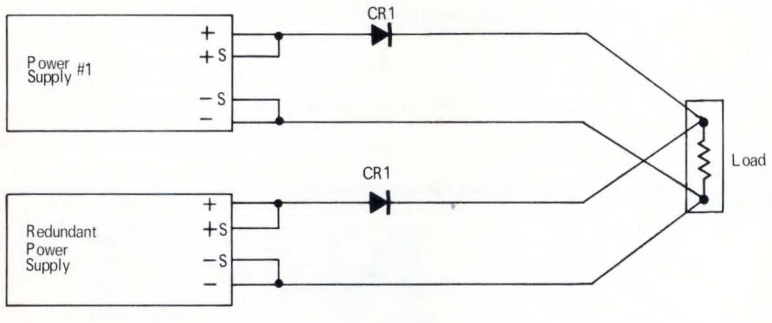


Fig. 1 – **Redundant power supplies** without clamping resistors.

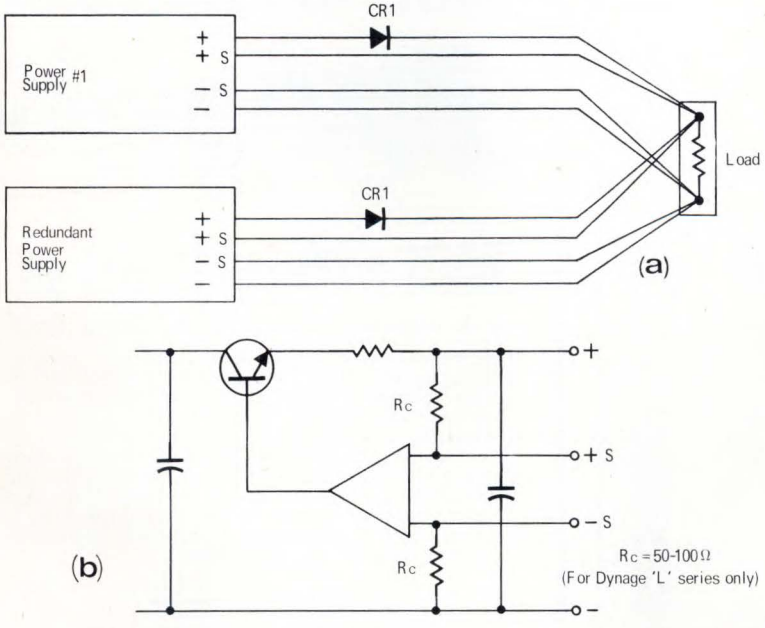
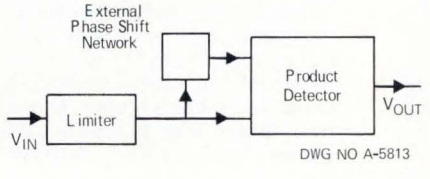


Fig. 2a – **Redundant power supplies** with clamping resistors and output sensing at the load. Fig. 2b – Front-end of power supply showing pass transistor, current sensing resistor, sense amplifier, and clamping resistors (R_c).

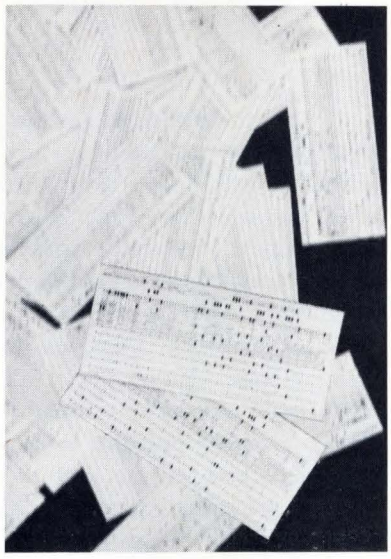
EDN will pay $50 for any problem-solution article accepted for publication.

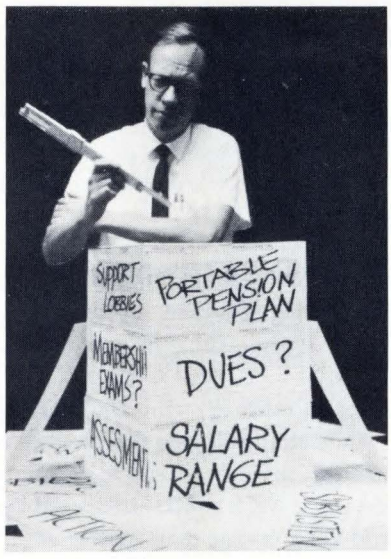
NEXT ISSUE'S PROBLEM:



FM DETECTOR

Parallel-Tuned Network Cuts "Off-Station" Noise. Evaluating a sound IF IC showed "off station" noise to be about three times that of a conventional ratio detector.





Sounding Board/70: 'Union' Is a Dirty Word

Despite frequent mention of an "AMA-type" organization, the kind of group that engineers want looks a great deal like the American Civil Liberties Union.

DONALD K. COLLINS, Staff Editor

Early in July, EDN mailed a questionnaire to 600 randomly-selected Sounding Board/70 members. Its announced purpose was to profile an organization that would be most acceptable to the largest number of members. By early August, 412 had returned the completed questionnaire, and a profile began to emerge.

The inescapable conclusion is that engineers, particularly those in electronic design, want an organization that furnishes some very basic services, that demands little or nothing of them except dues, and that will come running with all kinds of help if the engineer gets into trouble in his relations with his employer.

According to the survey, "involvement" in such a program is not a strong point—the engineer is willing to support such an organization with money, but not with cooperative participation or by relinquishing his prerogatives in order to give the organization the leverage it may need.

In short, the engineer wants his group to stick a gun in management's ribs, but he is unwilling to load it.

The Structure Emerges

Sounding Board/70 members strongly favor (5:1) a national organization, as opposed to a regional one. In accompanying comments, regional chapters or sections were frequently mentioned as desirable, and the similarity to IEEE and other current professional groups was obvious. In their experience with such organizations, members have apparently found the national set-up satisfactory.

Also favored, although not as strongly, was administration by professionals hired for that purpose. But

(Continued)

this choice outranked the alternative, administration by officers elected from membership, by only 20%. Other proposals for administration received only negligible numbers of votes.

Engineers State Pressing Needs

From a wide range of benefits and services, SB/70 members chose six as representing the most urgent needs of engineers today.

They were nearly unanimous (22:1) in their support of any group that would help improve the employee's right to profit by his own inventions and to safeguard him against unreasonable work contracts or trade secret agreements. This is by far the most overwhelming response that EDN has seen to this issue so far.

Second in the Board's opinion is the desirability of a portable pension plan, supported by joint contributions from both employer and employee. There's not much question that this need is very much on the engineer's mind today, as indicated by the more than 11:1 approval given it by SB/70.

Other strong endorsements reflect the tenor of the times. In order, they were: (1) provide re-employment services for members whose jobs have been terminated, (2) support (but not maintain directly) lobbies and other legislative actions that are in line with engineers' needs, (3) provide a health and life insurance program, and (4) maintain internal educational standards and programs for members. Board members endorsed these services by majorities no less than 5:1.

Simple majorities of notably smaller magnitude were given to organization services in collective bargaining for members' wages and salaries, hours, working conditions, overtime compensation, termination conditions and compensation. This service garnered 246 votes of approval against 116 who disapproved. EDN considered this question to be a strong indicator of the break-point between the conservative professional organization at one end of the scale and the "labor-union" type of organization at the other end. Many respondents who were willing to go this far would go no further, even to the details of empowering their organization to enforce its demands made in the course of collective bargaining.

Nearly the same margin (239 for, 119 against) favored provision of subsistence for *unemployed* members as loans secured by pension funds. But right here is where Board members drew a fine line—it's all very well to say you're against strikes by engineers, but the proof of your determination lies in whether you're willing to back disapproval with action. In this case, when the same Board members were asked whether the organization should assess working members to provide subsistence for *striking* members, they said "no" by 231 to 130, or almost 2:1.

Contemplate that for a moment, if you will. This group of engineers, as typical of the average engineer as statistics can make it, would help the victim of the economic system in which he works, but not the engineer who takes overt action to reform it.

Such assessments to support striking members are standard labor union practice, and if you need a weathercock for this survey, this is it. Succinctly, if it smells like a labor union, engineers are against it. While SB/70 members said it would be okay, for instance, for the organization to run a credit union, provide legal services to members, represent members in grievance disputes and engage in political activities, typically "union" tactics were taboo.

Board members killed (266 to 90) any attempt at a "closed shop". (The question read "Secure exclusive employment agreements with companies, excluding nonmembers from employment".) By a vote of 239 to 120, they nixed jurisdictional agreements with other organizations such as labor unions, guilds. They disapproved (but not so strongly—191 to 174) of economic strictures such as work stoppages (read "strikes"), and rejected (211 to 159) the notion of supporting strikers economically.

Regulatory Provisions

Any organization has something to say about its members' conduct. SB/70 respondents indicated that they would go along with dues and assessments (306 to 51), the establishment of grades of competence and appropriate salary ranges (240 to 122), and perhaps even examinations to qualify applicants for membership (201 to 167). But that's as far as they would go.

They balked at exams and timetables for advancement in grade (241 against/119 for), required attendance at meetings (252 against/111 for), and penalties for non-attendance (295 to 65).

As questions in this section progressed toward the "labor union" end of the spectrum, SB/70 respondents became more and more adamant. They were asked, for instance, how they would react to an organization that

prohibited its members from working for companies that didn't recognize the organization and/or its internal regulations. Negative replies numbered 269, while only 25% of the total, or 94, would accept this degree of regulation. They couldn't swallow a boycott of products of companies that wouldn't recognize the organization, either. Here the vote was 244 against, 117 for.

And any organization that tries to regulate members' revenue-producing activities outside regular employment (read "moonlighting") is in for big trouble. So said a whopping 318 SB/70 respondents, with only 43 who would accept such an extreme of regulation.

When it came to barring management from membership and proscribing certain duties as not being part of the engineering function, opinion was nearly evenly divided. One-hundred and eighty-three SB/70 members favored an organization that would decide when a member had risen to a management level that made him ineligible, and 177 said "no". When it came to defining what is engineering and what isn't, 189 were content to let the organization do it, but 175 weren't. Far from being indifferent to these two very fundamental questions, opinion was simply well divided, as indicated by the number of comments received.

Pay the Piper

It's a truism that you get what you are willing to pay for, and organizations are no exception. The trouble is that, in any really aggressive organization, the cost may run more to time and effort than to dollars and cents. In some cases, the individual is called on to subordinate his rights and privileges and delegate them to the group, so that it can accomplish collectively what he could not accomplish alone.

How many individual rights and privileges are SB/70 members willing to surrender to their ideal organization? Very few.

They gave a clear mandate in only three areas: administration of a portable pension plan (298 to 64); fight exploitation (254 to 110); and negotiate conditions of employment termination (273 to 93). Some areas of responsibility got a "well, maybe" response. Among these were "adherence to regular, scheduled salary increase" (198 to 163) and "accept or reject demands to work overtime without compensation" (213 said to let the organization do it; 149 said they'd take care of the decision.) And when it came to negotiating terms of em-

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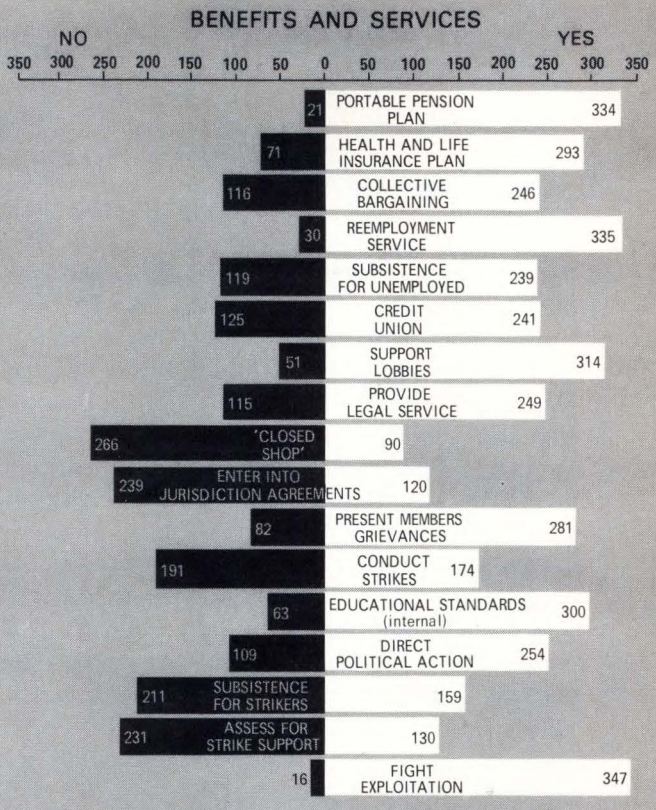


Fig. 1 – **How they voted** on Question 4: "Such an organization should provide the following benefits and services for members." Note strong endorsement of a re-employment service (d), corresponding support for subsistence (e). Rejection of strikes (1) correlates with rejections of subsistence for strikers (o) and assessment for strike support (p).

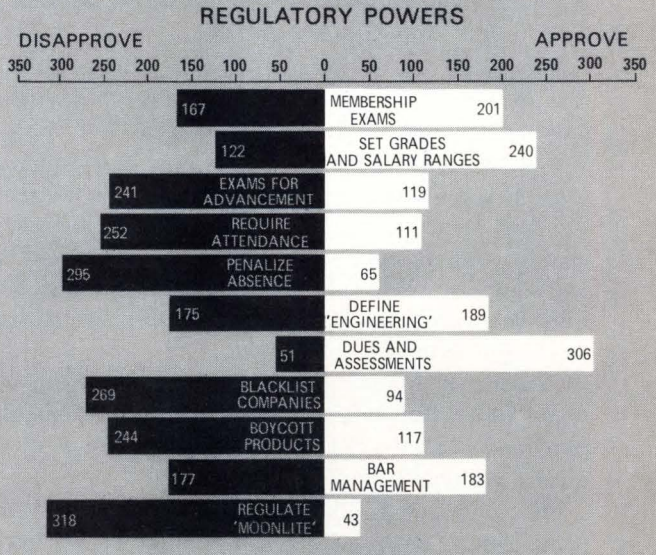


Fig. 2 – **Here's how respondents** expected the ideal organization to regulate its members. Note heavy disapproval of most regulation, strong approval of single measures – dues and assessments.

ployment such as salary, vacation, sick leave and so on (which implies collective bargaining), only 201 would empower an organization to negotiate for them, while 164 would reserve the right to make their own deal.

Other proposals for the organization to take over individual prerogatives took a terrible shellacking. "Accept or refuse transfer within company" should be the individual's decision, said 340 SB/70 members; only 21 said the group should pass on it. Nearly the same proportion (332 to 28) applied to relocation by the company. Acceptance of performance review and evaluation also was reserved for the individual (294 to 69), and a mere 6 respondents out of 360 would let their organization accept or refuse promotion for them.

The story was little different when it came to accepting or rejecting a change in assigned duties (with or without change in compensation); here 279 would rather do it themselves; 89 said the organization could handle it. And when questioned on who would determine the direction and rate of continuing education, 66 okayed organizational control, while 298 told the organization to "get lost".

Members solidly rejected (311 to 50) the notion that their organization could dictate whether or not individual engineers accepted additional responsibility (with or without additional compensation). They also maintained the individual's right to accept the company's definition of authority, 214 to 141.

Two strong trends were particularly interesting in this survey—the avoidance of any taint of unionism, plus a strong concern about education. We won't speculate on the reasons for the former (and the graphs in **Figs. 1**, **2** and **3** tell their own story), but what doesn't show is the number (46) who declined to check any answer except "No" to the first statement on the questionnaire: "I favor an organization for those who work in electronic design." Many of these commented on the questionnaire.

Perhaps the single most cogent comment read: "An organization that has the rights, enforces the regulations and provides the 'benefits' outlined is no alternative to a union—it *is* a union."

This respondent, like several others, missed the point. The questionnaire provided a spectrum of choices that ran the gamut from honorary fraternities to unionism a la Hoffa in his heyday. Its purpose was to determine how far engineers would be willing to go to alleviate their plight. And it did.

The other trend was also indicated most strongly in the comments, and it is typified by this terse remark. "Limit entry into field—and accredit institutions." This evidenced a genuine concern with the quantity and quality of formal education, plus a desire to see some organization coordinate continuing education so the engineer in the field could keep up.

A third persistent comment throughout the questionnaires received was that any organization should include other engineers, not just those in electronics. It was not clear whether this was motivated by "misery loves company", or by "in union, strength", however.

Since the sample was closed in August, a close check has been kept on late returns. These show no substantial deviation from the established position described here. To sum it up, if engineers are to look to an organization to solve their predicament, it will have to be one that finds new methods of making and enforcing demands for its members. □

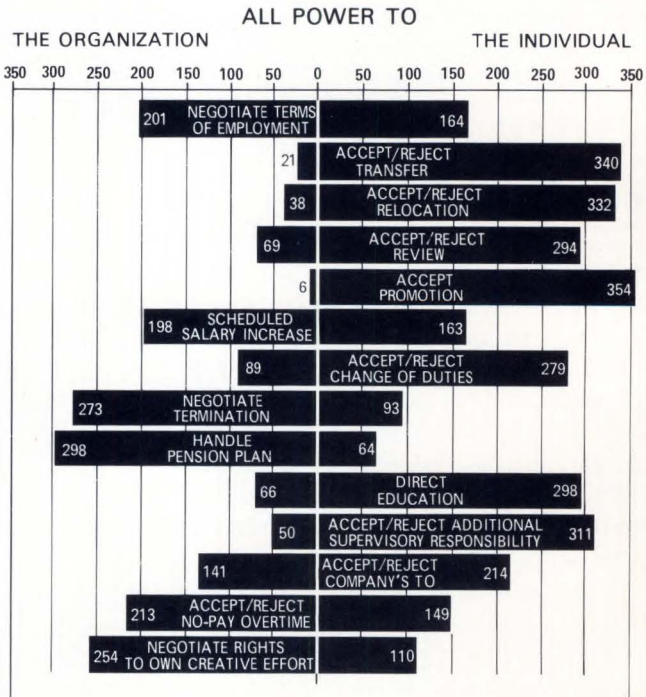


Fig. 3—**Engineers are individualists** as indicated by strong trend to reserve most rights to the individual. Compare reluctance to delegate authority to group for "leverage" items, with benefits and services desired (**Fig. 1**) to see how organization could be hamstrung.

Solid-State Angle Indicator Offers ±0.01 Deg Resolution

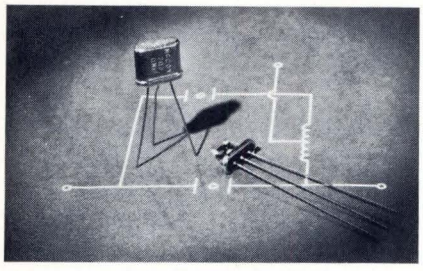
In their debut into the instrument field, DDC announces the Model SR-101 Synchro/Resolver Angle Indicator, which continuously converts and visually displays the shaft angle sensed by a high- or low-level synchro or resolver. Priced at $1895 the SR-101 embodies the most advanced concepts available to provide ±0.01° resolution, with an angle range of 000.00° to 359.99° (continuous rotation).

Worst case error from all causes combined will not exceed ±0.03°. The solid-state unit has a LED seven-segment visual readout with Polaroid filtering for observing readout in bright sunlight.

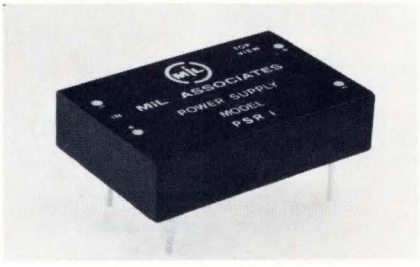
Employing a tracking approach, the SR-101 tracks angular rates of up to 1080°/s with no error and only 0.01° error for each 100°/s² of acceleration. This unit automatically checks its own performance—built-in test circuit causes the display to be blanked if a malfunction occurs or the converter is not tracking due to excessive input slew rates.

Small physical size enables two SR-101s to be mounted in only 1-3/4-in of rack space. Its simple physical design—one PC assembly—and removable top and bottom covers allow ease of maintenance and trouble shooting.

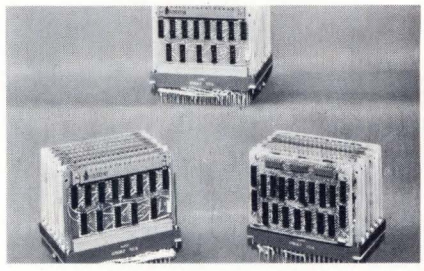
Complete solid-state circuitry assures no warm-up. The SR-101 has no adjustments and is guaranteed driftfree for the life of the instrument. In addition, the SR-101 generates five decades of BCD data (buffered DTL outputs) for input to a process control computer, as well as giving a visual angle indication. Because of high accuracy and repeatability, the SR-101 can be used to evaluate the performance of synchro-to-digital converters, digital-to-synchro converters and stable platform gyro systems. DDC, 100 Tec St., Hicksville, NY 11801. **325**



Monolithic crystal filter offers advantages in size, weight, economy and reliability over conventional filters. It has center frequency of 99 MHz, 1 dB bandwidth of 20 kHz min, 3 dB maximum insertion loss and 1 dB maximum ripple. Package size is HC-18U but with a 0.34-in height. McCoy Electronics Co., Mount Holly Springs, PA 17065. **326**

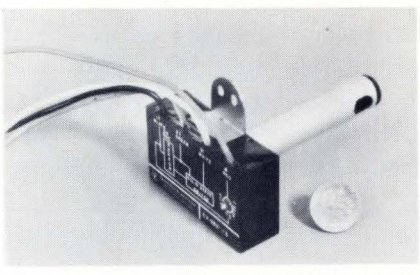


Negative bias supply PSR-1 converts 12V dc to −10V dc without the use of a transformer. Measuring only 0.37-in high and weighing 15g, the PSR-1 plug-in module delivers output power of 150 mW with output ripple (50 kHz) of <20 mV pk-pk. Output resistance is <100Ω. Price in 100 quantities is $15.60. MIL Electronics, Inc., Dracut Rd., Hudson, N H 03051. **329**



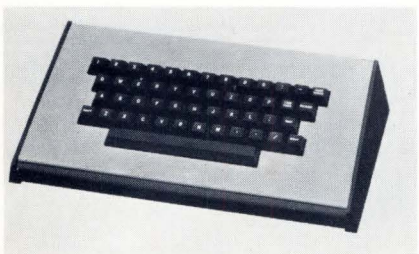
Groups of DTL and TTL cards, called MONI-BLOC, are prewired to perform specific functions. Available units include binary-to-BCD converters, BCD-to-binary converters and an eight-channel multiplexer with A/D converter and necessary timing. These units are pretested functional logic blocks. Monitor Systems, 401 Commerce Dr., Fort Washington, PA 19034. **332**

Chopper-stabilized operational amplifier, Model 233, sells for $45 in unit quantity. Specifications include size of 1.5 in² by 0.4 in high, 500 kHz bandwidth and 4 kHz full power response. Maximum voltage drift is 1, 0.3 and 0.1 μV/°C and current drift is 2, 1, and 0.5 pA/°C for Models, J, K and L respectively. Analog Devices, Inc., 221 Fifth St., Cambridge, MA 02142. **327**

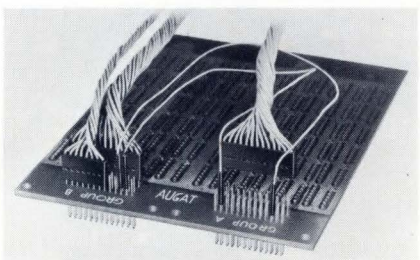


Solid-state vane switches, "KLIXON" 2SE operate on unregulated 24 or 115V ac. Containing no moving parts or contact, these devices eliminate the shock, vibration and orientation problems inherent in conventional vane switches. Normally Open or Normally Closed models are available with 1A switching capability. Texas Instruments Incorporated, 34 Forest St., Attleboro, MA 02703. **330**

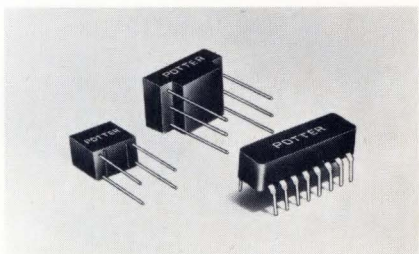
Constant current module, Model 925, displays output impedance >100 MΩ at 10 mA. Output current range is 10 to 50 mA, 0 to 10V max with 0.001% current regulation. Weighing only 2 oz, the unit measures 1.5 by 1.5 by 0.7 in. Temperature stability is 0.01%/°C. Price is $54.60 each in lots of 100. California Electronics Mfg. Co., Box 555, Alamo, CA 94507. **333**



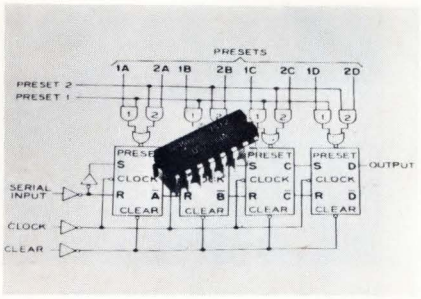
Solid-state optoelectronic keyboard is a compact low-cost unit designed for OEM and end-user data input applications. The DTL/TTL-compatible electronics, requiring a 5V dc supply, produce output levels of 0.6 and 3.8V dc. Optical code generation eliminates contacts and results in extremely high-reliability and long life. Most codes can be generated on request. TEC, Inc., 6700 S. Washington Ave., Eden Prairie, MN 55343. **328**



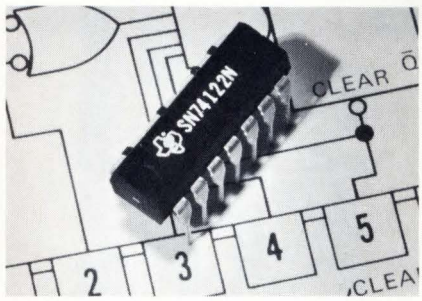
Wire-wrap plug assembly can be used on socket side of panel as well as wire-wrap side. Molded phenolic plugs are available in eight or 26 contacts. Contacts are beryllium copper, gold-over-nickel plated and are easily removed from plug for replacement. Wire is 24 gauge stranded copper with PVC insulation in standard lengths of 12, 24 and 36 in. Augat Inc., 33 Perry Ave., Attleboro, MA 02703. **331**



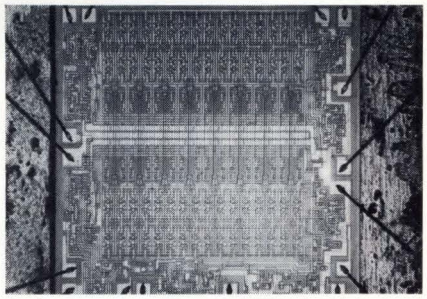
Pulse transformers, in both conventional and DIP configurations, have been designed for use in core memory systems. Ranging in inductance from 10 μH to 100 mH, units have turns ratios from 1:1 to 10:1, with up to four windings. Special types feature high permeability and temperature stability. Price range is from $0.50 to $1 in production quantities. The Potter Co., 500 W. Florence Ave., Inglewood, CA 90301. **334**



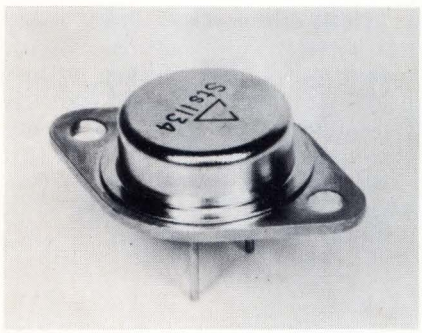
Parallel-input, serial-output 4-bit register, Type US7494A, has been added to the Series 74 high-speed TTL logic line. The 0 to 70°C unit features two-input OR-gate preset for individual bits, a two-input OR-gate preset for all bits in parallel, serial input and all bit clear. Sprague Corporate Technical Literature Service, 491 Marshall St., North Adams, MA 01247. **335**



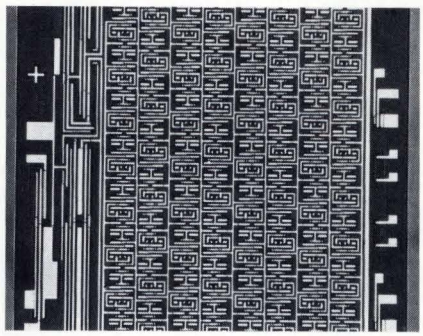
Retriggerable monostable multivibrator SN-54/74122 is a pin-for-pin replacement for the 9601, except that the new unit has an added clear input feature. Prices for lots of 100 to 999 pieces range from $2.95 (plastic, 0 to 70°C) to $10.08 for a ceramic or flat package, −55 to 125°C unit. Texas Instruments Incorporated, Inquiry Answering Service, Box 5012, M/S 308, Dallas, TX 75222. **338**



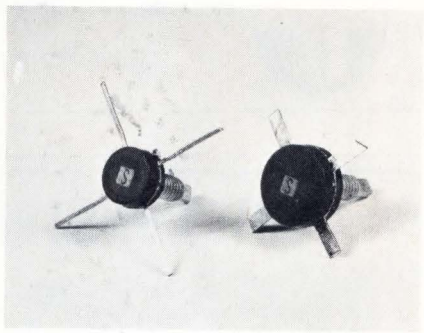
Random-access memory (RAM) Model RAM-0064 is a 64-bit bipolar unit with 35 ns access time. Organized as a 16 word by 4-bit array with full decoding, the unit operates from −55 to 125°C, and power dissipation is 6 mW/bit. Operation is from a single 5V power supply, and price in lots of 100 to 999 is $32 each. Radiation Microelectronics Div., Box 37, Melbourne, FL 32901. **341**



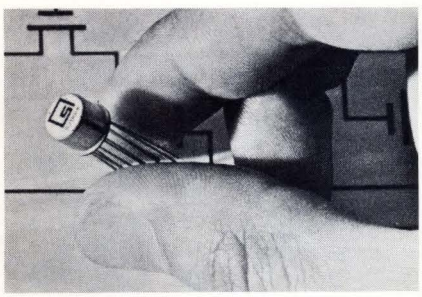
Silicon high-voltage power transistors STS-1131 to STS-1134 are triple-diffused npn units that feature collector-emitter voltage ratings from 225 to 400V and a current gain at 3A of 18 min and 60 max. Sensitron Semiconductor, 221 W. Industry Ct., Deer Park, NY 11729. **336**



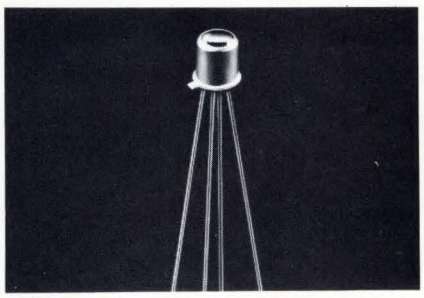
C/MOS, 64-bit shift register MS612 operates from dc to 25 MHz, requires a single power supply from 5 to 16V, has a temperature range from −55 to 125°C and input clock capacitance of 5 pF. Ragen Semiconductor, 53 S. Jefferson St., Whippany, N J 07981. **339**



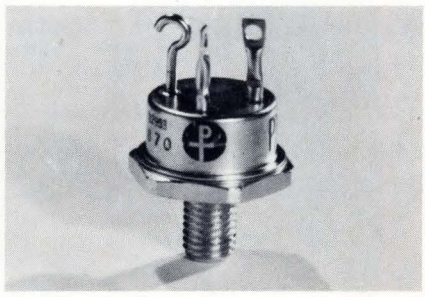
Communications transistors for broadband applications in the 100- to 200-MHz frequency range include the SRF53214-R, 20W unit, the SR53215-R, 25W unit and the SRF54216-R, 28W unit. Solitron Devices, Inc., 1177 Blue Heron Blvd., Riviera Beach, FL 33404. **342**



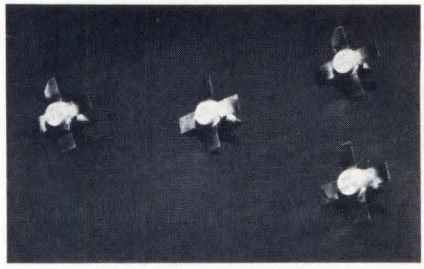
MOS dual 100-bit static shift register N2010K operates from 0 to 3 MHz, requires two external 28V clock phases as well as −14 and −28V dc supplies, operates from 0 to 70°C and in lots of 100 to 999 is priced at $4 each. Signetics Corp., 811 E. Arques Ave., Sunnyvale, CA 94086. **337**



Light sensitive FETs (FOTOFET) now have flat-glass devices included in the line. They offer high sensitivity, low dark current and fast response. In lots of 100 items, price for the flat-glass units ranges from $6 to $19.40 each. Crystalonics, a Teledyne Co., 147 Sherman St., Cambridge, MA 02139. **340**



Silicon power transistors, PT-7509 through PT-7511, feature collector breakdown voltages V_{CEO} sustained of 200V and have h_{FE} specified at 90A. V_{CE} sat is <0.6V at 50A, and units are rated 200W at 100°C in the TO-63 package. Prices range from $66 to $84.75. PowerTech, Inc., 9 Baker Ct., Clifton, N J 07011. **343**



VHF communications transistors contain three compatible 12V units designated B3-12 (3W, 10 dB gain), B12-12 (12W, 6.8 dB gain) and B25-12 (25W, 6.2 dB gain). When used in an amplifier chain with one B3-12, one B12-12 and two B25-12's, the line-up provides a 50W output from a 250 mW input. Price in lots of 100 units is $37.82 for the three transistors. Communications Transistor Corp., 301 Industrial Way, San Carlos, CA 94070. **344**

COS/MOS plastic ICs (DC4000E Series) are a low-cost family containing 19 circuits that include basic building blocks and MSI functions. With a −40 to 85°C temperature range and 4.5V noise immunity, units cost from $2.20 to $9.50 each in 1000 lot quantities. RCA/Electronic Components, 415 S. Fifth St., Harrison, N J 07029. **345**

Monolithic voltage regulators TVR2000 Series maintain an output voltage in the range from 0 to 38V to within ±5.5 mV. The units can supply output currents to 200 mA. Output is short circuit and overload protected. Package includes the TO-100 as well as the 14-lead plastic DIP. Transitron Electronic Corp., 168 Albion St., Wakefield, MA 01880. **346**

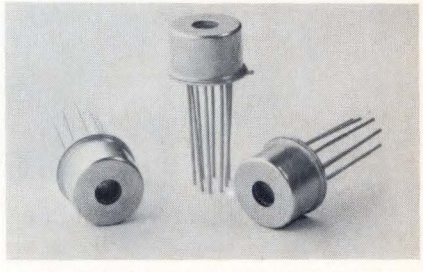
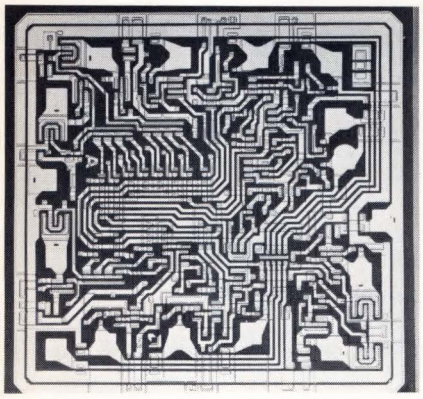
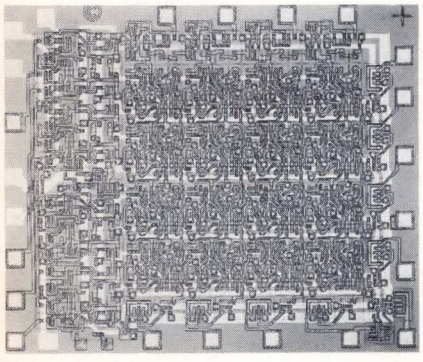


Photo detector amplifiers in TO-5 cases feature a peak sensitivity of 2.5×10^4 V/W/cm² and bandwidth of 10 MHz. Micro-Electronic Subsystems, Inc., 20 Burr St., Framingham, MA 01701. **347**



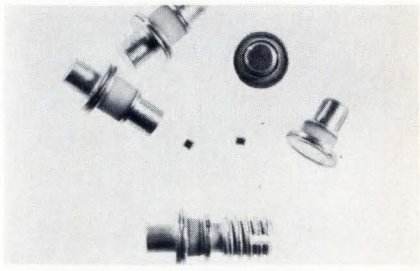
Eight-input priority encoder 9318 encodes eight active low-input signals to a 3-bit binary code, giving priority to the most significant input. The 100-up mix price is $15.40 (−55 to 125°C), and $10.25 each (0 to 70°C). Advanced Micro Devices, Inc., 901 Thompson Pl., Sunnyvale, CA 94086. **348**

Transistor PT6729 is a 150-MHz communications unit that delivers 120W of RF power output with 6 dB gain from a 28V source. At the 1 to 24 level, the units are priced at $140 each. TRW Semiconductor Div., Communications Transistor Plant, 14520 Aviation Blvd., Lawndale, CA 90260. **349**

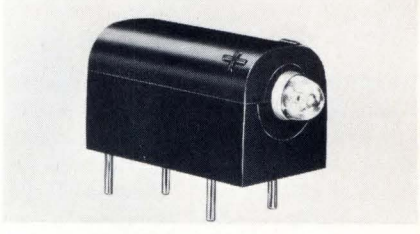


Sixteen-bit random access associative memory MμL4102 is a bipolar IC that combines logic circuits and memory cells on the same chip. The unit is designed to signal a match whenever data at its inputs correspond to data already stored. Match time is 35 ns max, and price in lots of 100 to 999 is $50 each. Fairchild Semiconductor, 313 Fairchild Dr., Mountain View, CA 94040. **350**

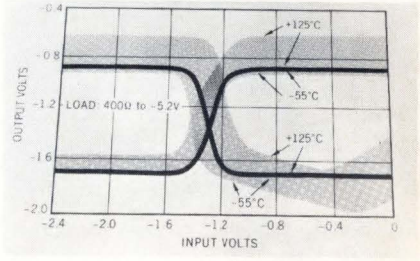
New SC's



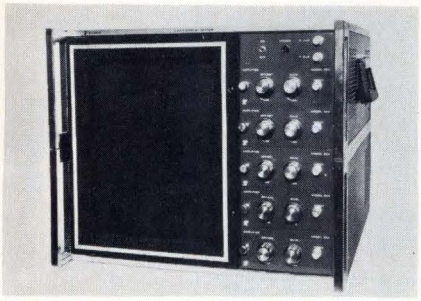
Low-cost X-band IMPATT diodes generate 100 mW with 3% efficiency in the 5 to 14 GHz range and are priced lower than 50 mW devices. The 5082-0430 Series offered in three frequency ranges 5-9, 8-12 and 10-14 GHz, will produce 100 mW from a dc power source supplying 80 to 120V at 25 to 40 mA. Prices for the units in the series are $29 (1), $14 (100) and $9.95 (1000). Inquiries Manager, Hewlett-Packard Co., 1601 California Ave., Palto Alto, CA 94304. **351**



Gallium arsenide phosphide light source with maximum spectral emission region between 630 and 690 mm is packaged for either PC-board or panel-board mounting. With a forward current of 50 mA, luminance is 1250 fL average, and prices in lots of 100 items are $2.40 (PC-board type) and $1.50 (panel-board type). Solar Systems, Inc., Box 128, Skokie, IL 60076. **352**



Emitter-coupled logic (ECL) ICs in the 9500 Series include five low-cost devices, each of which incorporates a unique on-chip temperature compensation network. The family includes three gates with propagation delay of 2 ns, one flip-flop and an eight-input multiplexer with 3 ns data input-to-output characteristic. With a temperature range of 0 to 75°C, prices in lots of 100 to 999 range from $2.05 to $17.50 each. Fairchild Semiconductor, 313 Fairchild Dr., Mountain View, CA 94040. **353**

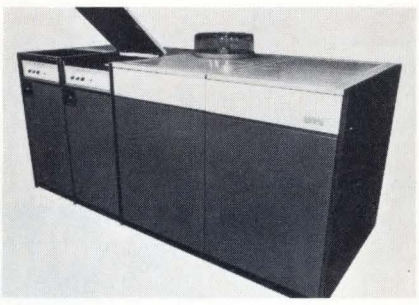


Color display system with large-screen CRT, Model 203, can display up to three input signals simultaneously on the 8- by 10-in viewing area. The system may be operated either as an X-Y display or as an oscilloscope. Price, including amplifiers, starts at $3950. Telonic Industries, Inc., 21282 Laguna Canyon Rd., Laguna Beach, CA 92652. **354**

Ratio computer, Model 853, calculates the ratio of two voltages having any value between 0.1 and 2V dc. The answer is provided at the end of a 300 ms operating cycle. For 0.5% accuracy, the ratio ranges from 0.1 through 9.999 and overrange is indicated by an FFFF display. Price is $1250. MSI Electronics Inc., 34-32 57th St., Woodside, NY 11377. **357**

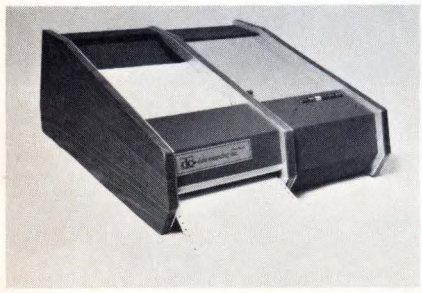
Peak wattmeter is direct reading on pulses as short as 10 ns. Model CTS-1 covers from 1 mW to 10W peak with resolution of 0.5 dB. It handles PRFs from 1 kHz to 20 MHz and is accurate to 5% from 350 MHz to 2 GHz. Maximum VSWR is 1.3 over that range. Cartwright Engineering, Inc., 1020 E. Elm Ave., Fullerton, CA 92631. **360**

Idle line motor control turns teleprinter on for traffic and off for idle conditions. The Model 202-11 offers standard intervals of 1, 5, 10 and 20 min. The control may be mounted in any position. Pulsecom, Box 1225, Alexandria, VA 22313. **355**

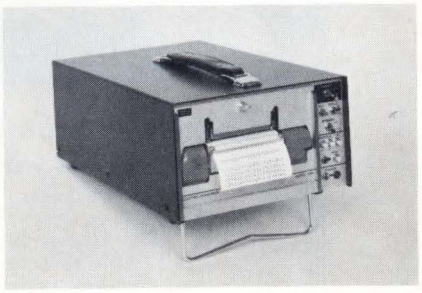


Disc drive has 29-million 8-bit byte capacity and 30 ms average random access time, yet is only 17.5-in wide, 38-in tall and 36-in deep. The Model M2700 has self-contained cables. Marshall Data Systems, 2065 Huntington Dr., San Marino, CA 91108. **358**

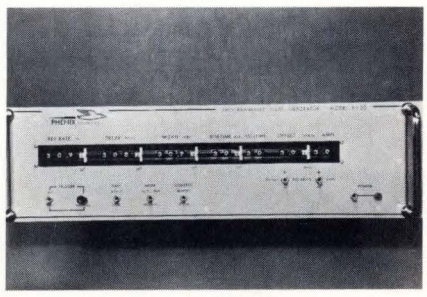
Differential thermometer, with ranges of 0 to ±20, ±50 and ±100°C, operates in three modes: Probe A, probe B and probes A-B. Circuit accuracy is 0.1°C and meter accuracy is 2%. Price of the Model 102 is $159. TC Products, 151 Evelyn Ave., Mountain View, CA 94040. **361**



Impact printer is a full 132 column unit with 64 character ASCII set, including both upper and lower case alphabetic characters. It operates at 100 lines/min and can produce up to six copies on 14-7/8-in pinfeed, fanfold stock. Model IV, plug-to-plug compatible with CRTs and any MODEM, uses the standard EIA RS-232-B interface. Monthly rental is $315 on a 1-year lease. Data Computing, Inc., 2219 W. Shangri La Rd., Phoenix, AZ 85029. **356**

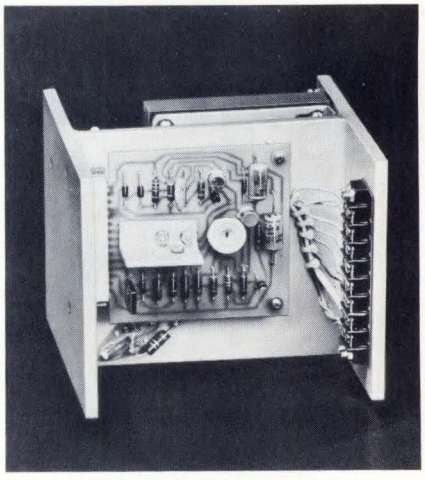


Digital printer, Model 2000, features up to 21 columns, BCD or 10-line input, floating decimal points, black or red printout, single and double space paper advance and parameter identification. Useful with any system with BCD (1-2-4-8) outputs, it is compatible with RTL, DTL and TTL without additional interface or buffer circuits. Price ranges from $800 for 7 columns to $995 for 21 columns. Electro-Numerics Corp., 2961 Corvin Dr., Santa Clara, CA 95051. **359**



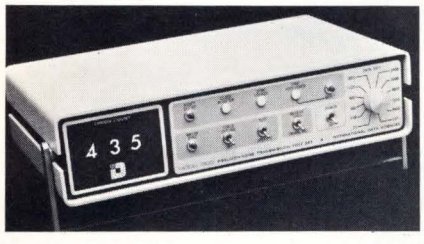
Programmable pulse generators, PX 30 series, provide the capability of remotely programming all parameters of the pulse output, using either serial or parallel entry. Basic specifications include repetition rate from dc to 10 MHz, delay from 0 to 10 ms, width from 20 ns to 100 ms, rise and fall times from less than 5 ns to 10 ms and pulse amplitudes from 0 to ±10V from a 50Ω source impedance. Phenix Electronics, 13724 Prairie Ave., Hawthorne, CA 90250. **362**

"Resistor factory" permits its user to produce precision subminiature fixed metal-film resistors with any resistance value between 10Ω and 100 kΩ to an accuracy of 0.1%. Included are a precision measurement system, a stock of 14 sizes of resistors and the necessary adjusting tools. Angstrohm Precision Inc., 7811 Lemona Ave., Van Nuys, CA 91405. **363**

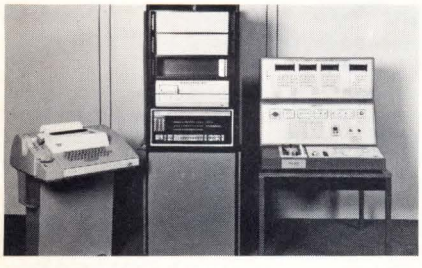


Power supply module for ICs, Model MIC5-7A, operates from 105 to 125V, 60 to 400 Hz, delivers 5V at 7A and has line and load regulation of ±25 mV max. Ripple and noise are 10 mV RMS max and operating temperature range is −20 to +50°C. Price, with 10-year guarantee, is $58. Armour Electronics Corp., 51 Jackson St., Worcester, MA 01608. **364**

Power supply kits that include over 200 predesigned versions covering the voltage span from 5 to 48V, the current range from 0.25 to 50A and regulation from 20% to 0.01% are priced between $15 and $250. Designs are fully pretested and debugged, avoiding such common problems as hidden flaws, over- or under-specified components and components that fail under turn-on surges. Lambda Electronics Corp., 515 Broad Hollow Rd., Melville, NY 11746. **365**

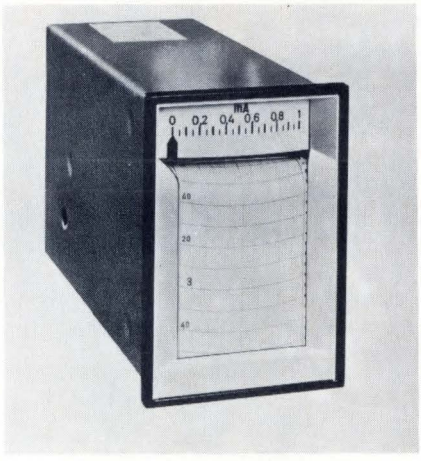


Pseudo-noise transmission test set, Model 1100, tests both synchronous and asynchronous digital data devices. When externally timed for synchronous operation, capability is dc to 0.5 MHz. When internally timed for asynchronous operation, data rates are selectable from 75 to 9600 bits/s. The unit is capable of simplex, half duplex or full duplex operation. International Data Sciences, Inc., 100 Nashua St., Providence, RI 02904. **366**

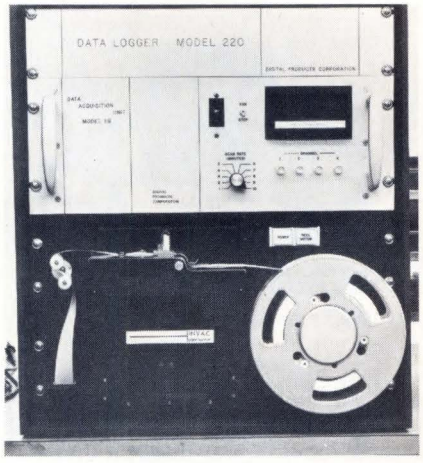


Transistor test system, the computer-operated Model T243, is designed for high-speed production testing of small-signal transistors and will supply forward current to 1.19A and reverse voltage to 600V. It will check dc parameters and ac beta for transistors, plus many diode and FET parameters. Price including 10-year warranty is $39,000. Teradyne, Inc., 183 Essex St., Boston, MA 02111. **367**

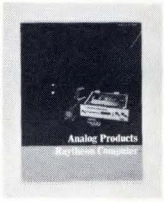
Dual-channel scope features dc to 18-MHz bandwidth. Other specifications include 2 mV/cm to 50V/cm rangeability, time-base of 200 ns/cm to 1s/cm (5X magnifier extends time base to 40 ns/cm) and a 10- by 8-cm CRT with P31 phosphor. The Model SM111 weighs only 25 lbs and occupies less than 1 ft^3. Price is $1195. B & F Instruments, Inc., Cornwells Heights, PA 19020. **368**



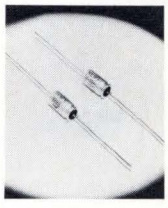
Servo-drive panel recorders, 2765 Series, deliver ±1% of full-scale accuracy under severe conditions of shock or vibration. Chart speed is 20 mm/h with standard motor drive, which can be increased up to 6000 mm/h with optional gearbox changes. Basic range is 0 to 1V dc/0 to 1 mA dc. Simpson Electric Co., Div. of American Gage & Machine Co., 5200 W. Kinzie St., Chicago, IL 60644. **369**



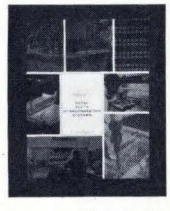
Data logger, Model 220, digitizes four channels of analog data (0-199 mV) and records that data on eight-level punched paper tape in ASCII code along with elapsed times from start of run. Variable scan rates from 1 to 10 min are provided, and a digital panel meter displays the value of channel 4 between scans. Price, complete, is $4950. Digital Products Corp., Fort Lauderdale, FL 33309. **370**



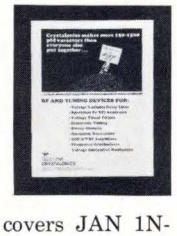
Conversion equipment, including A/D and D/A units as well as multiplexers and sample-and-hold amplifiers, is described in a six-page brochure. Raytheon Computer, 2700 S. Fairview St., Santa Ana, CA 92704. **425**



Subminiature aluminum electrolytic capacitors ranging from 1 to 1000 mF in voltage ratings from 3 to 150 VDCW are described in a new technical bulletin. Cornell-Dubilier Electronics, Div. of Federal Pacific Electronic Co., 150 Ave. "L", Newark, N J 07101. **426**

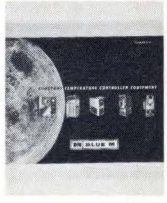


Back-panel connector arrays are the subject of a revised and expanded 40-page handbook. Defined is the VARIPLATE metal plate interconnection concept and its associated terminating technique, automatic wire wrapping. Elco Corp., Maryland Rd. & Computer Ave., Willow Grove, PA 19090. **427**



RF and Tuning Devices covers JAN 1N-5139A-5148A diodes, the first JAN-qualified high-Q varactor diodes, VA5139-5148 90V versions of the above, the CV1858D series of pill diodes for waveguide or stripline circuits to 2 GHz and the 1N5714-5718 high-Q epoxy types for HF band tuning. Teledyne Crystalonics, Inc., 147 Sherman St., Cambridge, MA 02140. **428**

Capacitors, transistors, resistors, filters and pulse transformers make up the full line of 148 types (22,764 items) covered in 76-page Catalog C-560. Sprague Products Co., 491 Marshall St., North Adams, MA 02147. **429**

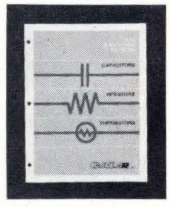


Environmental test chambers, ovens, furnaces and baths are covered in a 216-page catalog. Thermal cycling, shock test chambers and refrigerated cabinets are among the items discussed. Blue M Engineering Co., 138th & Chatham St., Blue Island, IL 60406. **430**

Calculators (Series 100) for statistical, engineering and scientific calculations are described in a four-color brochure. They are priced from $1495 to $2295. Memory is MOS and programming of from 60 to 120 steps is available. Wang Labs., Inc., 836 North St., Tewksbury, MA 01876. **431**

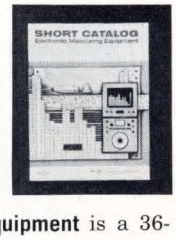
Fractional horsepower synchronous, nonsynchronous and motor gearheads for computer peripheral equipment are covered in a new 40-page precision motor catalog. Fans and centrifugal blowers ranging from 32 to 1650 CFM also are described. Rotating Components Div., Instrument Systems Corp., 1560 Fifth Ave., Bay Shore, NY 11706. **432**

Steppers and Controls contains 40 pages devoted to the basic theory of operation, excitation modes, the selection factors and applications of steppers. IMC Magnetics Corp., 570 Main St., Westbury, NY 11591. **433**



Precision thick film and wirewound resistor networks, cermet chip resistors, precision wirewound resistors, thermistors, balco sensors and ceramic capacitors are covered in an 11-page publication. Cal-R, Inc., 1601 Olympic Blvd., Santa Monica, CA 90404. **434**

54/74 brochure contains 52 pages of descriptions for 63 off-the-shelf products in the 54/74 series. This thoroughly updated edition reflects a nearly threefold expansion in the company's line of 54/74 TTL ICs. Distribution Center, Fairchild Semiconductor, Box 880A, Mountain View, CA 94040. **435**



Electronic Measuring Equipment is a 36-page short form catalog that covers a complete line of electronic measuring equipment and includes equalizers, oscillators, noise generators, accelerometers, microphones, sound meters, frequency analyzers and tape recorders. B & K Instruments, Inc., 5111 W. 164th St., Cleveland, OH 44142. **436**

Metricize Time?

Dear Sir:
We hear much clamoring today from the scientific community to convert to the metric system, in use in almost all civilized countries. But who is speaking out in favor of changing our horse and buggy system of measuring time to a system more appropriate with the space age in which we live? Why should we be required to write A.M. or P.M. each time we write

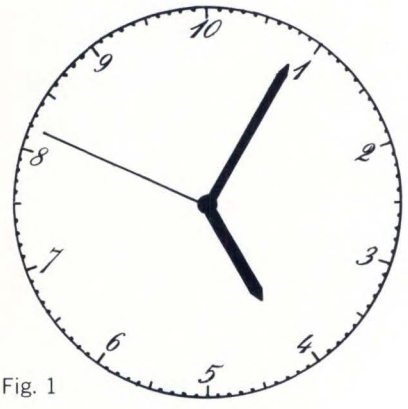


Fig. 1

the time of day? How much confusion has resulted from not specifying whether we mean nine o'clock in the morning or nine o'clock at night? How many appointments have been missed because the A.M. or P.M. was not clearly indicated? How many mistakes in scientific work have been made because of incorrectly converting minutes to a fraction of an hour? The military made a step in the right direction when they instituted the 24-hour system. When an officer says 2200 hours there is no mistaking that he means 10 P.M. However, I maintain that this system does not go far enough.

I propose that we switch to a time measuring system in which there are 10 "hours" in a day, 100 "minutes" in each "hour", and 100 "seconds" in each minute. A clock face might look like the clock illustrated in **Fig. 1**. Three pointers or hands are required as with present clocks. For those who do not need precise time measurement, the clock indicates that the time is 3.28 ("hours" understood). For those who are satisfied with nothing less than the ultimate accuracy, the time is 3.27.84.

In my proposed system the day is divided into 10 "hours", 1000 "minutes", and 100,000 "seconds". In the present system the day is divided into 24 hours, 1440 minutes, and 86,400 seconds. It is obvious which system is easier to work with. Thus, 3.27.84 means 3 "hours" 27 "minutes" and 84 "seconds" or simply 3.2784 "hours". Conversions between "hours" "minutes", and "seconds" involve nothing more complicated than moving the decimal.

The next logical step would be to change weeks, months, and years to the metric system. This will require some cooperation from the moon and the sun. So I leave this part of the problem to the next generation.

D. R. Barnhill
Sr. Staff Engineer
Sperry Rand Space Support

"It's a singing **hologram!**"

Communique from Quatt Wunkery

Dear Sir:
In reply to Mr. Owens' and Mr. Fredrick's comments in your column (1 May 70), I am inclined to agree with Mr. Ownes that I may have been too casual in my toxicity comments on beryllia dust; it is indeed toxic. I do feel, however, that the procedure of sanding a "Berlon" encapsulated object in order to obtain a flat surface for heat sinking is a safe procedure when done wet. That is to say, using wet-or-dry sandpaper and sufficient water to trap the small beryllia particles created. A thorough washing of the area and work when the job is done has, in my experience, proven quite sufficient. Any dry cutting or sanding is to be avoided like the plague.

I am much more concerned with Mr. Fredrick's comment "Boron Nitride Beats Beryllia". First, it is absolutely impossible to obtain a filled epoxy with the conductivity of "Berlon" by filling it with boron nitride rather than beryllia; the point of the article was that beryllia-filled epoxy is the superior high-thermal-conductivity encapsulant for irregular shaped parts. Second, boron nitride is definitely the material to use for machineable high-thermal-conductivity insulating heat sinks, and in the latter context I would refer him and your readers to an article of mine on the subject in *Insulation*, July 1969, p. 26. Boron nitride is indeed a versatile material, being quite strong and machining very nicely with conventional tools. Its thermal conductivity, however, is about a fifth or less than that of beryllia, and each has its place. I would be happy to discuss this subject further with anyone who was interested.

Steve Smith
Director of Research
Quatt Wunkery
Richmond, CA 94804

Advertiser's Index

Subject Index to Articles

Index to Ads, Products and Literature

Application Notes

"More and More REs in Sophisticated Electronic Circuit Components" is a four-page study on the use of rare-earth oxides in the development of ceramic capacitors. Molybdenum Corp. of America, 280 Park Ave., New York, NY 10017. **475**

"Philosophy and Design of MSI" by R. C. Ghest is a 12-page application note, TP-54. Semiconductor processing and packaging constraints also are discussed. Fairchild Semiconductor, 313 Fairchild Dr., Mountain View, CA 94040. **479**

"The Impulser" is the first issue of a new instrumentation house organ. This issue contains information on calorimeters, both waveguide and coaxial. Electro Impulse, Inc., 116 Chestnut St., Red Bank, N J 07701. **483**

High capacitance energy storage devices (ESD) are the subject of a note that contains circuit and performance data for timing circuits ranging from seconds to months. Gould Ionics Inc., Box 1377, Canoga Park, CA 91304. **476**

Class S kilowatt amplifiers are the subject of a four-page technical memo, TM-12A. Typical circuits and behavior with reactive loads are discussed. Instruments, Inc., 3434 Midway Dr., Box 10764, San Diego, CA 92110. **480**

Active notch filters are the subject of an application note that includes discussions on amplitude and phase distortion, overshoots, ringing and sensitivity. A. P. Circuit Corp., 865 West End Ave., New York, N.Y. 10025. **484**

Description and Application of RCA Numitrons, Application Note AN-4277, describes the features, operation and several applications for these incandescent digital display devices. RCA Electronic Components, Commercial Engineering, Harrison, N J 07029. **477**

DES-COMP is a computer program that provides a quick and efficient means of computing many mathematical functions and displaying the results in tabular or graphical form without programming. Remote Computing Corp., One Wilshire Bldg., Los Angeles, CA 90017. **481**

Modern X-Ray Analysis is a booklet that contains 24 pages and compares wavelength dispersive X-ray analysis with energy dispersive X-ray analysis with X-ray, electron and isotopic excitation. Nuclear Diodes, Inc., Box 135, Prairie View, IL 60069. **485**

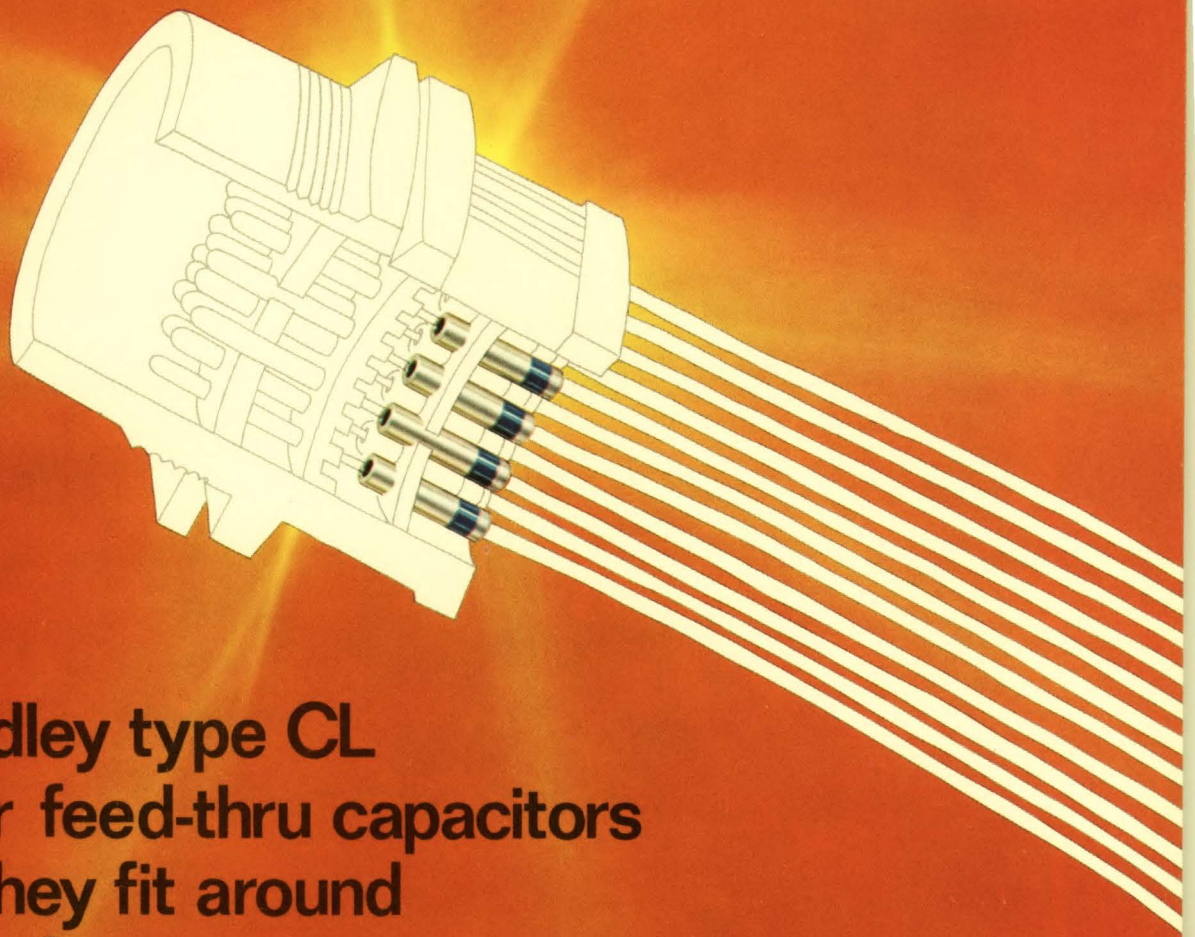
Beryllia-filled epoxy adhesives for bonding ICs and for preparing electrically insulating, heat sinking barrier coats include three new products that are described in Technical Bulletin 3400. National Beryllia Corp., Greenwood Ave., Haskell, N J 07420. **478**

Timing module is the subject of a four-page note that details the timing module used in a small digital computer that performs sequencing, counting, relay logic and timing functions by means of software modules. Modicon Corp., 200 Sweetwater Ave., Bedford, MA 01730. **482**

Settling Time of Operational Amplifiers, containing 16 pages, explores both linear and nonlinear factors affecting settling time and offers suggestions for maximizing settling performance in circuits based on op amps. Analog Devices, Inc., 221 Fifth St., Cambridge, MA 02142. **486**

Reprints Available **in this issue are offered as follows:**

R.S. No.	Title	Page No.
L61	Hybrids Today	23
L62	Pulse Swallowing	39
L63	Modified Schmitt Trigger Stabilizes Pulse Generator	46



Allen-Bradley type CL multi-layer feed-thru capacitors so small they fit around the head of a pin.

VOLUMETRIC EFFICIENCY. Big words that explain why Allen-Bradley type CL feed-thru capacitors are so small. Our unique multi-layer concept shaves size to a minimum, without affecting performance. It took Allen-Bradley to get filter capacitors down to their fighting weight. Now rolled capacitors are no longer a design alternative.

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ALLEN-BRADLEY

NEW DIMENSION ELECTRONICS

CIRCLE NO. 7

RSVP game (U.S. Patent #3427028) used by permission of Selchow and Righter Co., makers of SCRABBLE.

You Win With RCA P-N-P Power... New 2N5954 Family (2N3054 Complement)

This new RCA p-n-p transistor has the qualifications that can make winners of you and your designs. The 2N5954 is a silicon power unit in a hermetically-sealed TO-66 package. Complementing the 2N3054 (already widely known in sockets in military, industrial, and commercial equipment), the 2N5954 features controlled second-breakdown ratings. To be sure, each transistor is individually tested to meet specified parameters before it is shipped.

The new 2N5954 family with its multiple epitaxial structure and emitter ballasting techniques add up to a traditionally rugged RCA power device...giving you the design capability to achieve high performance levels in your equipment. One of three new RCA p-n-p types now offered for switching and amplifier applications, 2N5954 (or its family types, 2N5955 or 2N5956), together with its n-p-n complement, provide bi-directional control and phase inversion advantages.

P-n-p/n-p-n complements are particularly advantageous if you're trying to cascade four or five stages. In a power supply design, for example, the use of complementary types can eliminate voltage build-up that would be encountered if cascaded n-p-n, or cascaded p-n-p types were employed.

Check the chart on these new types. For more information, consult your local RCA Representative or your RCA Distributor. For technical data, write: RCA Electronic Components, Commercial Engineering, Section 50J-1/UT8, Harrison, N. J. 07029. In Europe: RCA International Marketing S.A., 2-4 rue du Lièvre, 1227 Geneva, Switzerland.

Type No.	V_{CBO} (V)	V_{CEX} (sus) (V)	V_{CER} (sus) (V)	V_{CEO} (sus) (V)	I_C (A)	P_T (W) @ $T_C = 25°C$
2N5954	85	85	80	75	–6	40
2N5955	70	70	65	60	–6	40
2N5956	50	50	45	40	–6	40

RCA

CIRCLE NO. 34