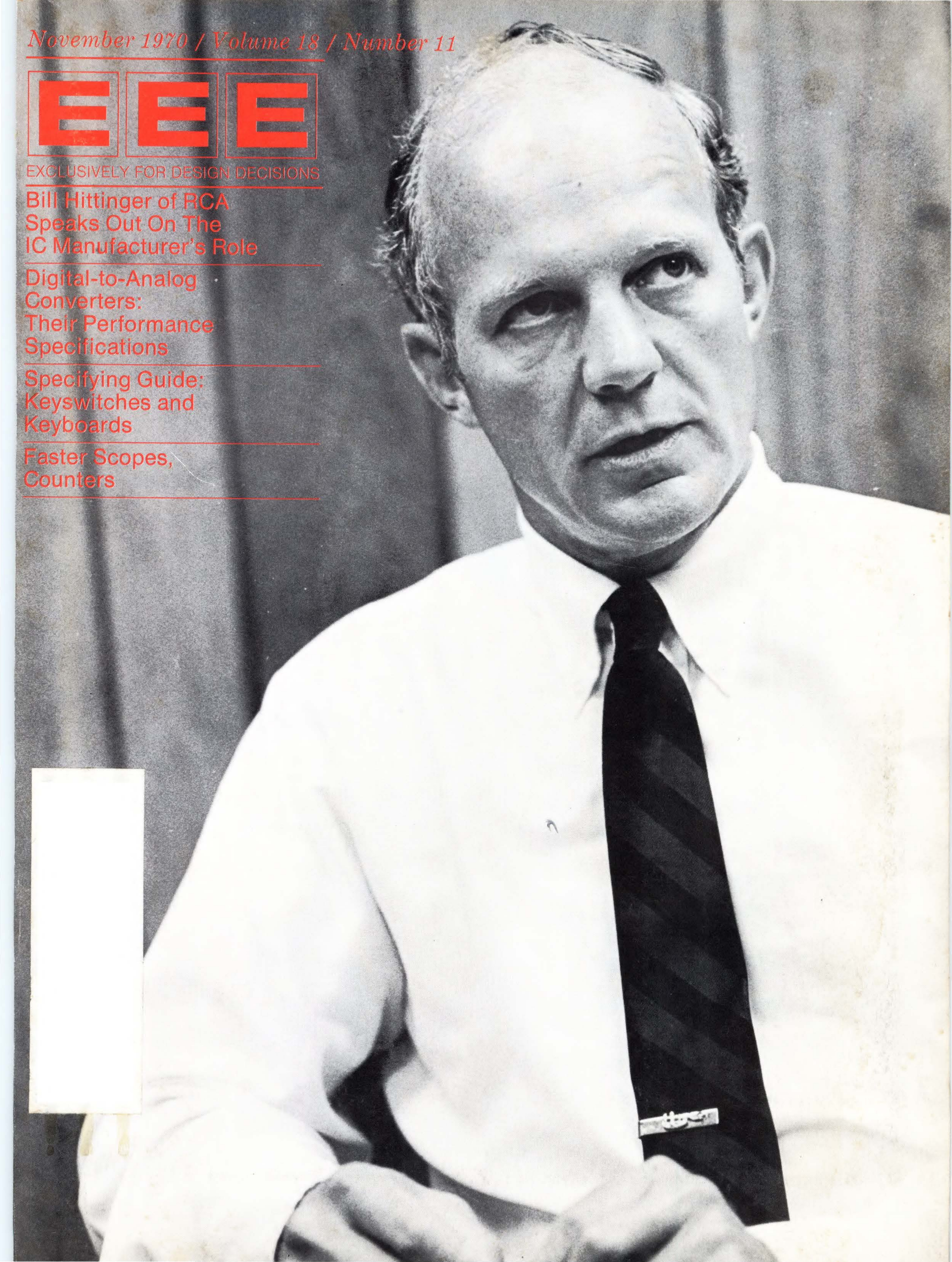
November 1970 / Volume 18 / Number 11

EEE

EXCLUSIVELY FOR DESIGN DECISIONS



Bill Hittinger of RCA Speaks Out On The IC Manufacturer's Role

Digital-to-Analog Converters: Their Performance Specifications

Specifying Guide: Keyswitches and Keyboards

Faster Scopes, Counters

New Helipot DAC & ADC Hybrids are MOS system compatible

Model 847 DAC & Model 871 ADC offer:

- Integration of the best DAC/ADC functional elements from MOS/LSI, Bipolar and cermet thick-film technologies into *complete* hybrid converters.
- MOS system compatibility (using 3750 & 3751).
- Small, hermetic metal package & environmental specs per MIL-STD-883.

	MODEL 847 DAC			MODEL 871 ADC		
■ Resolution	10 bit			12 bit		
■ Accuracy: (Code)	D1	D2	D3	D1	D2	D3
at 25°C	±0.025%	±0.05%	±0.1%	±0.025%	±0.05%	±0.1%
−20 to 85°C	±0.05%	±0.1%	±0.2%	±0.05%	±0.1%	±0.2%
■ Price (50-99 Quantity)	$165.00	$148.75	$136.00	$252.25	$191.25	$165.00
■ Power Consumption	350mW max.			950mW max.		

Call your local Helipot Sales Engineering Representative for additional information and application assistance.

Beckman® INSTRUMENTS, INC.

HELIPOT DIVISION FULLERTON, CALIFORNIA

INTERNATIONAL SUBSIDIARIES: AMSTERDAM; CAPETOWN; GENEVA; GLENROTHES, SCOTLAND; LONDON; MEXICO CITY; MUNICH; PARIS; STOCKHOLM; TOKYO; VIENNA

Circle 100 on Reader Service Card

NOVEMBER 1970
VOLUME 18, NUMBER 11

EEE

EXCLUSIVELY FOR DESIGN DECISIONS

Photo by John Semonish
Story on page 48

PROGRESS . . . in Design and Research

FEATURES

CIRCUIT DESIGN AWARD PROGRAM

DEPARTMENTS

EEE

EXCLUSIVELY FOR DESIGN DECISIONS

EDITORIAL
Jerry Eimbinder, Editor
Michael Elphick, Managing Editor
Jerome Lyman, Associate Editor
James A. Lippke, Contributing Editor
Mike French, Contributing Editor
Curt Cox, Assistant Editor
Rita Backer, Editorial Secretary
George Rostky, Editorial Director
K. N. Sauter, Art Consultant
V. Louis, Art Associate

Officers of the Corporation: Ralph Richardson, President; James Lippke, Vice-President; Lawrence C. Papp, Vice-President; George Rostky, Vice-President; Abraham Schwartz, Secretary-Treasurer.

Executive, editorial, circulation and advertising address: Mactier Publishing Corporation, 820 Second Avenue, New York, New York. 10017. Telephone (212) 661-0450. Telex 12-6466.

Also publishers of Electro-Procurement, BM/E—Broadcast Management/Engineering, Broadcast Equipment Buyers Guide.

Editorial Objectives

EEE serves electronic design engineers exclusively. EEE restricts its editorial coverage to material that can help engineers make design decisions. Such editorial material is intended to **help an engineer:**

- Decide for one design technique or design philosophy over another;
- Decide for one measurement technique over another;
- Decide for one packaging technique over another;
- Decide for one systems approach over another;
- Decide for one material, component, packaged circuit or instrument over another.

EEE does not publish general-interest material that cannot contribute to a design decision. Nor does it publish material aimed at peripheral interests of an individual.

EEE is dedicated to articulate expression and clear visual presentation. It is pledged to encourage the exchange of sound engineering ideas.

EEE's editorial pages are open to engineers for bylined articles and correspondence.

A member of BPA ABP

EEE is a monthly publication circulated without charge to electronics engineers engaged in design functions.
Subscription price to others: $15.00 one year, $25.00 two years. Please notify publisher promptly of any change in job function or address, enclosing your old address label. The publisher assumes no responsibility for opinions of contributions or for the validity of claims reported in advertisements or editorial items. Controlled circulation postage paid at Waseca, Minn. Copyright 1970 by Mactier Publishing Corporation. Title Reg. Pat. Off. Contents may not be reproduced in whole or part without consent of copyright owner. Printed at the Brown Printing Company, Waseca, Minn. EEE is reproduced in microfilm form by University Microfilms, Inc., of Ann Arbor, Mich.

When is True RMS Really True RMS?

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.

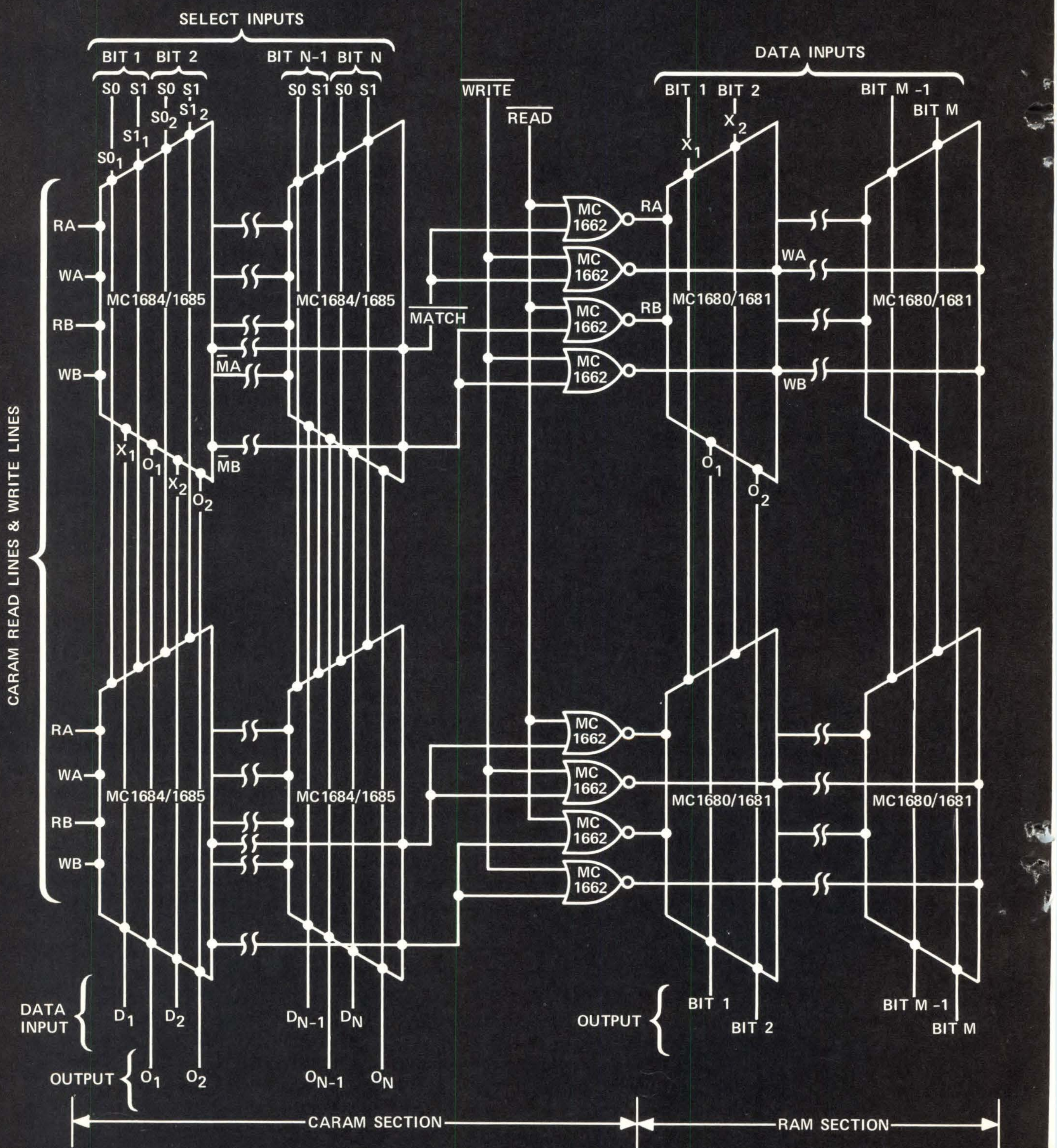
090/12

HEWLETT hp PACKARD

DIGITAL VOLTMETERS

Circle 103 on Reader Service Card

FOR A FLEETING MEMORY . . .



CAM/RAM BUFFER MEMORY

. . . MECL III OFFERS THE FASTEST

Picture a computer with limitless storage capacity and instantaneous retrieval. Impossible? Today, yes — but new technologies are providing more rapid access to data, and performance of high-speed memory functions outside the main storage memory are paving the way to the ideal computer. MECL III now introduces three basic memories to meet state-of-art requirements for high-speed buffers and applications requiring rapid storage and transfer of data.

The MC1684 (High Z)/MC1685 (Low Z) Content Addressable Random Access Memory performs the read-write (scratch-pad) function *plus* the content addressable (interrogate-match) function. In other words, information may be written-in, read-out and the memory may be interrogated to check its contents. Typical read, write and search delays are 2.5-3 ns, 4 ns and 2.5-3 ns, respectively.

The MC1680 (High Z)/MC1681 (Low Z) Random Access Memory is sometimes called a decoded scratch-pad memory. Data can be entered or read out of the memory from either of two words simultaneously. Recommended for ultra-high performance applications, the MC1680/1681 features typical 2.5 ns access times and a write delay of 3 ns. Computer interrogation is speeded through application of the MC1682 (High Z)/MC1683 (Low Z) Content Addressable Memory. Sometimes called an associative memory, the MC1682/1683 features a search (interrogate) delay of 2.5-3 ns and a write delay of 4 ns, both typical values.

As illustrated, the MC1684/1685 CARAM and MC1680/81 combine to form a very high speed buffer memory. When a word is required from the mass storage memory, it is placed in the RAM portion of the buffer for future access. The word's address in mass storage is placed in a content addressable memory tied to the random access section thereby allowing words to be addressed by their mass storage location in one cycle time of the buffer memory.

As the address of the desired word is presented to the content addressable section, the CAM will indicate (in one cycle time) if the address is in the CAM and if the desired word is available in the buffer. If the word is present, the desired read and/or write function can be performed at buffer RAM speeds. If the word is not present it must be brought from the slow mass storage through 'push-down pop-up" techniques. Through the use of the CAM/RAM Buffer Memory, the effective access time is a function of the memory access sequencing and not the mass storage access time.

For further details on these high-speed memories write to Motorola Semiconductor Products Inc., P. O. Box 20912, Phoenix, Arizona 85036. Evaluation devices are available at your nearby Motorola distributor. MECL III provides the fastest memory functions available today. Design in and THINK FAST!

MOTOROLA MECL

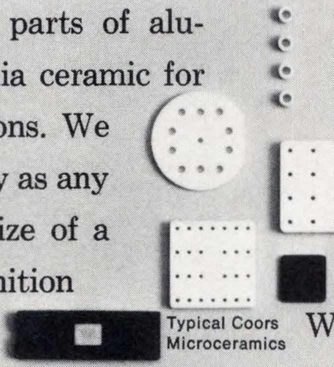
the only way to go . . . FASTER

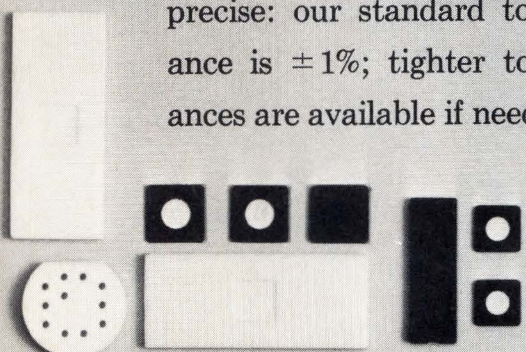
THE WHAT, WHY, WHEN, HOW AND WHOM OF COORS MICROCERAMICS

Q. WHAT ARE COORS MICROCERAMICS ANYWAY?


Dime
BB

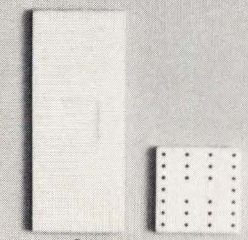
A. Glad you asked. They are small, precise parts of alumina or beryllia ceramic for microelectronic applications. We define small rather loosely as any part between, say, the size of a dime and a BB. The definition of precise is more precise: our standard tolerance is ±1%; tighter tolerances are available if needed.


Typical Coors Microceramics


More Microceramics

Q. WHY SHOULD I USE COORS MICROCERAMICS?

A. (1) Because you can be sure they will be manufactured exactly to your specifications and not modified to suit our production capabilities; (2) Because you can be sure they will be of uniformly high quality; (3) Because of (1) and (2) your yields will improve and your unit costs will be lower.

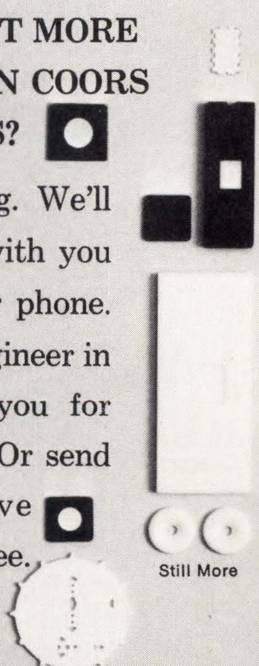

And Others

Q. WHEN SHOULD I USE COORS MICROCERAMICS?

A. When you want ceramic components of highest quality and reliability. Also when you need a ceramic producer with dependable, high-volume production capacity—or one that can turn out prototype and small-run quantities economically. We're geared to do both.

Q. HOW CAN I GET MORE INFORMATION ON COORS MICROCERAMICS?

A. Simply by asking. We'll be glad to counsel with you anytime by letter or phone. Or have our sales engineer in your area contact you for personal assistance. Or send you an informative data pack. Or all three.


Still More

Q. WHOM SHOULD I ASK?

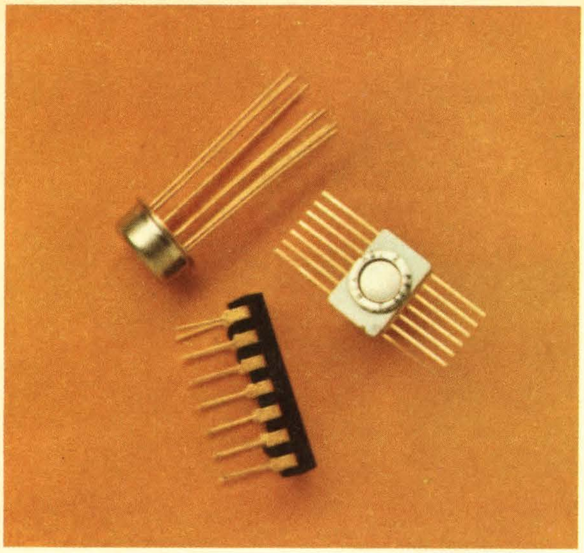
A. Who else?

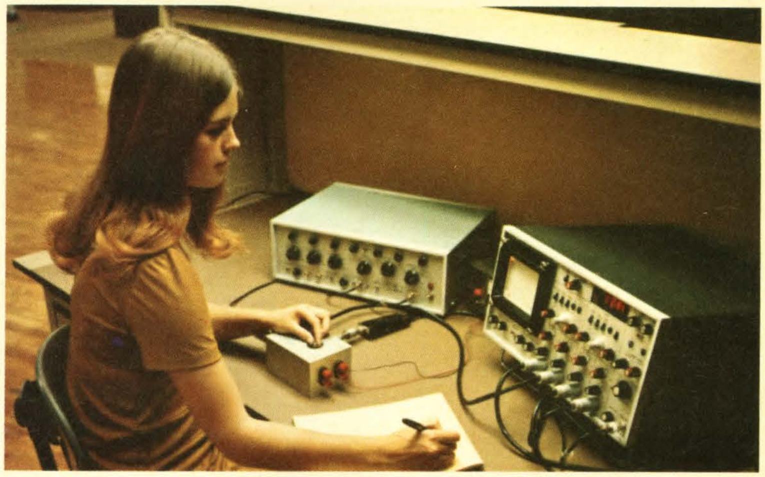
Coors Porcelain Company • 600 Ninth Street
Golden, Colorado 80401 • (303) 279-6565

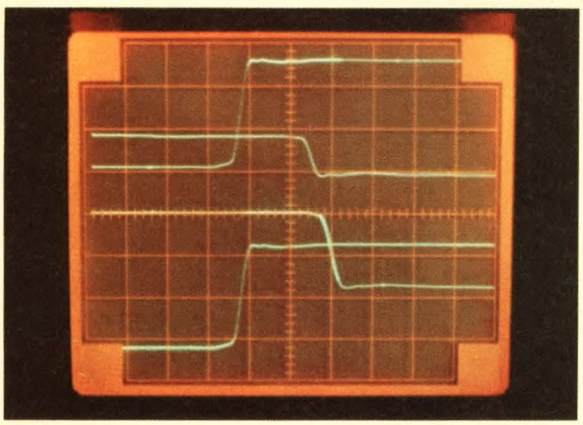
Coors/CERAMICS
the tough stuff

CP-137

Circle 105 on Reader Service Card







E-H
the simple solution

If you want to simplify your testing operations to the point where a relatively untrained technician can make sophisticated tests with complete confidence and accuracy, E-H Research Laboratories, Inc., and its subsidiary, Automated Measurements Corporation, offer the simple solution.

First, take a look at the **AMC Model 1100 Digital Readout Oscilloscope.** It's the only four-channel, four-trace digital readout oscilloscope on the market. It was developed for the most versatile laboratory and benchtop applications, using remote sampling units to give you greater freedom in your testing operations. It has the capability for simultaneous viewing of four waveforms. And the digital display can show time accuracy to 1% f.s. and voltage accuracy to 1% f.s.

The ideal companion for the AMC Model 1100 is the **E-H 135 Pulse Generator.** It's fondly called the Universal Pulser because of its great versatility and capability of handling just about any pulser requirement you might have today and for some time to come. The E-H 135 is the only 50 MHz pulser available that has unattenuated baseline offset to ±5V into 50 ohms. It also features rise and fall times of from 3 ns to greater than 8 ms.

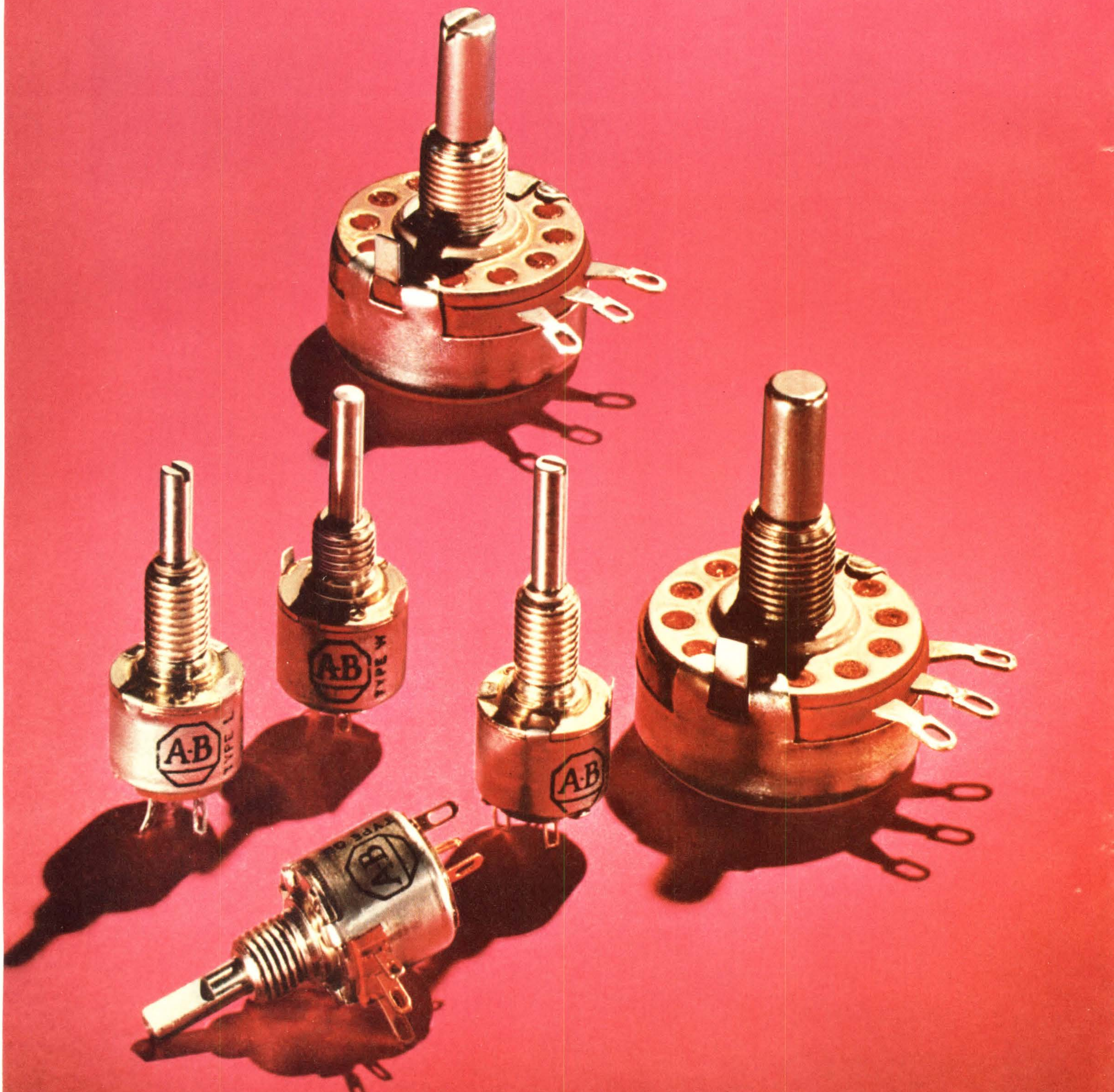
The two instruments mentioned above are just a sample of a complete line of E-H and AMC equipment available. So no matter how complex your testing problems are, get to the simple solution fast. Contact your E-H representative today.

E-H RESEARCH LABORATORIES, INC.

515 Eleventh Street • Box 1289, Oakland, California 94604 • Phone: (415) 834-3030 • TWX 910-366-7258
In Europe: E-H Research Laboratories (Ned) N.V., Box 1018, Eindhoven, The Netherlands, Telex 51116
In Japan: Iwatsu Electric Company, Ltd., 7-41, 1-Chome Kugayama Suginami-Ku, Tokyo 167, Japan

Circle 106 on Reader Service Card

Fight noise pollution



with this quiet family.

Hot Molding with Allen-Bradley's exclusive technique, gives these composition variable resistors an unusually low noise level. And importantly, this low noise level actually decreases in use. Under tremendous heat and pressure the resistance track is molded into place. A solid element with a large cross-section is produced.

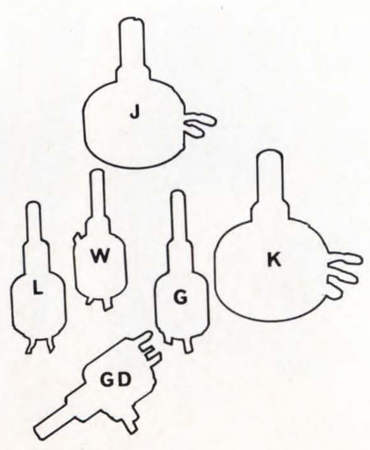
This important Allen-Bradley difference means better short-time overload capacity and a long operating life. Control is smooth, resolution almost infinite. These variable resistors are ideal for high frequency circuits. Why should you trust the performance of your designs or your reputation to anything less than Allen-Bradley quality? Use the most thoroughly "field tested" (over 20 years) variable resistors available today. Quantity stocks of popular types J, G, W and GD available for immediate delivery from your appointed A-B industrial electronics distributor.

For information write: Marketing Department, Electronics Division, Allen-Bradley Co., 1201 South Second Street, Milwaukee, Wisconsin 53204. Export office: 1293 Broad Street, Bloomfield, N. J. 07003, U.S.A. In Canada: Allen-Bradley, Canada Ltd., 135 Dundas Street, Galt, Ontario.

SPECIFICATIONS

	TYPE J— STYLE RV4	TYPE K	TYPE G— STYLE RV6	TYPE L	TYPE W	TYPE GD
CASE DIMENSIONS	5/8" deep x 1-5/32" dia. (single section)	5/8" deep x 1-5/32" dia. (single section)	15/32" deep x 1/2" dia.	15/32" deep x 1/2" dia.	15/32" deep x 1/2" dia.	35/64" deep x 1/2" dia.
POWER at + 70°C	2.25 W	3 W	0.5 W	0.8 W	0.5 W	0.5 W
TEMPERATURE RANGE	−55°C to +120°C	−55°C to +150°C	−55°C to +120°C	−55°C to +150°C	−55°C to +120°C	−55°C to +120°C
RESISTANCE RANGE (Tolerances: ±10 and 20%)	50 ohms to 5.0 megs	50 ohms to 5.0 megs	100 ohms to 5.0 megs	100 ohms to 5.0 megs	100 ohms to 5.0 megs	100 ohms to 5.0 megs
TAPERS	Linear (U), Modified Linear (S), Clockwise Modified Log (A), Counter-Clockwise Modified Log (B), Clockwise Exact Log (DB). (Special tapers available from factory)					
FEATURES (Many electrical and mechanical options available from factory)	Single, dual, and triple versions available. Long rotational life. Ideal for attenuator applications. Snap switches can be attached to single and dual.	Single, dual, and triple versions available. Long rotational life.	Miniature size. Immersion-proof. SPST switch can be attached.	Miniature size. Immersion-proof.	Commercial version of type G. Immersion-proof.	DUAL section version of type G. Ideal for attenuator applications. Immersion-proof.

ALLEN-BRADLEY



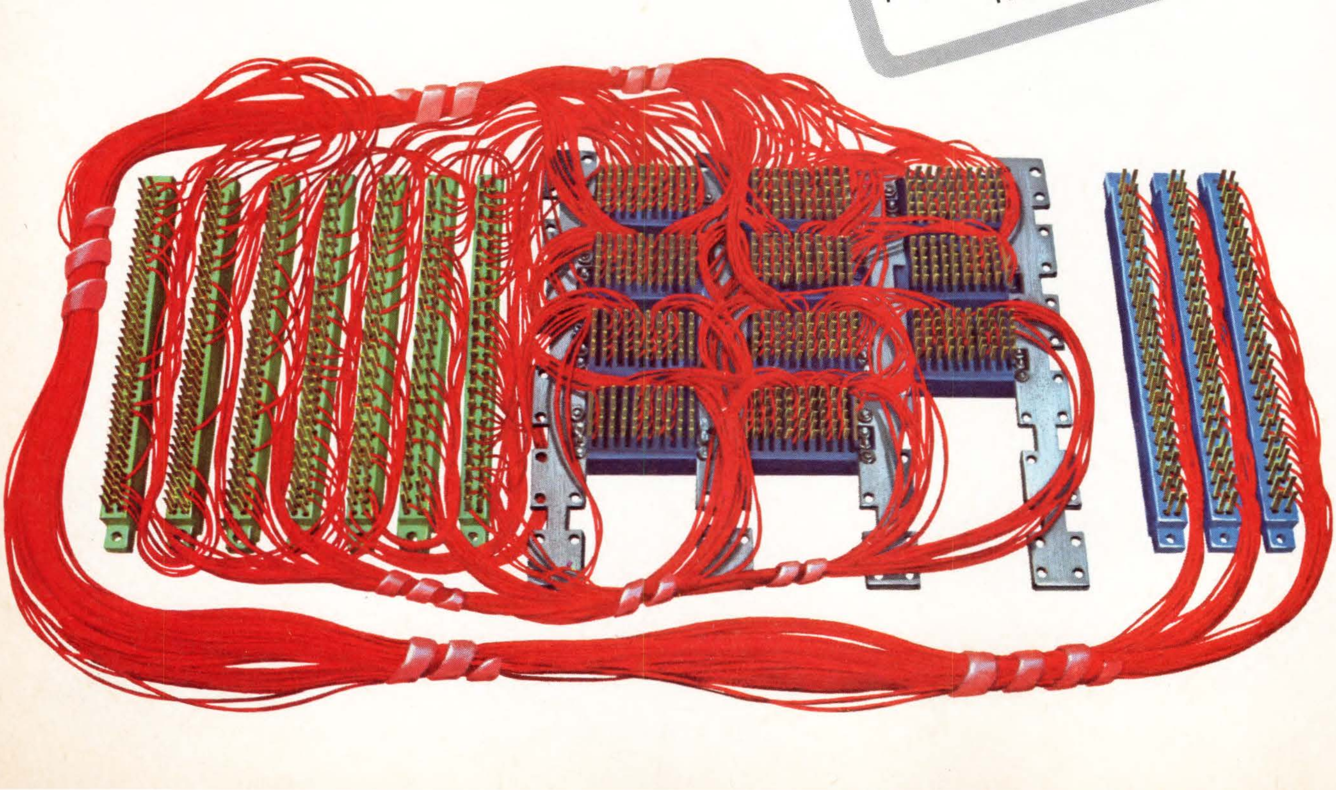
Circle 107 on Reader Service Card

Now there's a pack Everything includ plant or ours.

Our plan is whatever you want to make it. It can be everything you need for your panels. Or just some of the things.

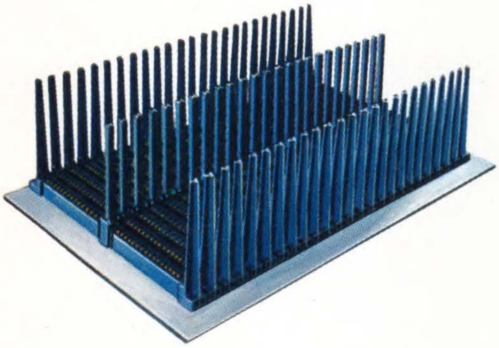
We can start serving you at the design stage. Or we can provide components to meet your designs. We can supply all the wiring, too. Our own TERMI-POINT★ point-to-point automatic wiring system that works with solid or stranded wire, and is easily maintainable. Your capital investment to get your panels wired with our method is zero. Whether you wire in your plant or we do it in ours.

See us at booth #1311
Fall Joint Computer Conference
Nov. 17, 18, 19.

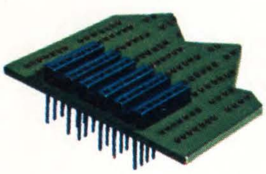


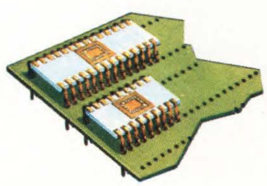
age plan for panels.
ing wiring...in your

Printed Circuit Connectors. One piece or two piece. In a great variety of sizes that can all be wired automatically on TERMI-POINT or wrap-type posts.

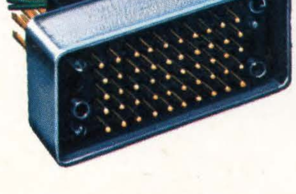


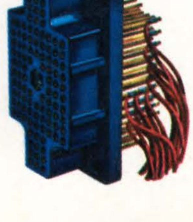
IC Packaging Panels. We can supply header components in a wide variety including Dip Headers, Miniature Spring Sockets, and various IC Sockets. All available with TERMI-POINT, wrap-type or solder posts.





Input/Output Connectors. Both M Series and High Density Rectangular Connectors are available with rear posts for automatic wiring. They can be panel mounted and are obtainable in a host of position sizes. Both are furnished with TERMI-POINT or wrap-type posts.





★Trademark of AMP Incorporated

Your plant or ours. It doesn't really matter which. You can wire with our machines in your plant. Or let us do it for you in our plant. To your specifications, of course.

If you're interested in what else we can do with panels, write for more information to: **Industrial Division, AMP Incorporated, Harrisburg, Pa. 17105.**

AMP
INCORPORATED

DAMON ANNOUNCES...

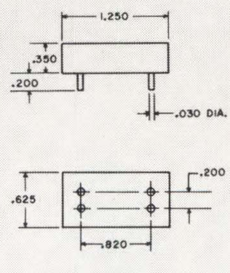
A new 7-pole monolithic crystal filter line that surpasses those previously available in shape factor and spurious mode suppression. Provides performance comparable to the highest state-of-the-art currently available with discrete filters – yet incorporates all of the inherent advantages monolithics have over conventional multi-component configurations. Now Damon provides the best of both worlds: critical performance, superior temperature characteristics, improved aging, small size, and significantly lower price. All are available in hermetically-sealed metal cases within miniature rectangular packages ranging in size from 0.080 cu. in. to 0.274 cu. in. Immediate off-the-shelf delivery of evaluation quantities. Damon also offers a wide variety of computer-assisted designs, but these take a little longer. Damon/Electronics Division, 115 Fourth Ave., Needham, Mass. 02194, Tel: (617) 449-0800.

The second generation in Monolithic Crystal Filters.

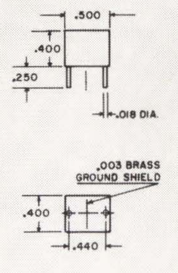
"STANDARD" 7-POLE MONOLITHIC CRYSTAL FILTERS

Model No.	6457MA	6457MB	6458MA	6458MB
Center Frequency:	10.7 MHz ± .7 KHz	10.7 MHz ± 1 KHz	21.4 MHz ± 0.7 KHz	21.4 MHz ± 1 KHz
Bandwidth, 3 dB:	6 KHz min.	15 KHz min.	6 KHz min.	15 KHz min.
Bandwidth, 60 dB:	18 KHz max.	40 KHz max.	18 KHz max.	45 KHz max.
Ripple, Max.:	1 dB	1 dB	1 dB	1 dB
Insertion Loss, Max.:	6 dB	6 dB	6 dB	6 dB
Spurious Returns:	> 55 dB down	> 50 dB down	> 55 dB down	> 50 dB down
Terminations (Resistive):	2.0 kilohms	5.1 kilohms	0.38 kilohms	1.3 kilohms
Ultimate Atten.:	80 dB	70 dB	80 dB	70 dB
Op. Temp. Range:	0°-60° C	0°-60° C	0°-60° C	0°-60° C
Case Size:	"A"	"A"	"A"	"B"

CASE "A"
0.274 cu. in.



CASE "B"
0.080 cu. in.



DAMON

Circle 109 on Reader Service Card

Editorial

Still innovating

EEE Magazine has been enjoying its role as an innovator in integrated-circuit seminars. During the past three years, we've held more than 20 IC seminars ranging from completely formal paper presentations to all-day panel discussions.

Our next two seminars, in Boston on November 6 and Chicago on December 8 will be two of our most informal sessions. We've rounded up a team of IC applications experts to tackle a list of searching questions on current IC application problems and controversies.

There won't be any papers delivered. But there will be a lot of opinions expressed.

Here are some samples of the questions to be fielded:

What are programmable ICs? How do manufacturer-programmed and user-programmed ICs differ? When should which be used?

Now that there are a number of low-threshold-voltage MOS ICs available, are the high-threshold-voltage (non-bipolar-compatible) MOS ICs obsolete?

What are the modes of operation in which a content-addressable semiconductor memory may be used?

How do characteristics compare for Schottky, ion-implanted, silicon gate, p-channel enhancement and other types of MOS ICs?

How serious a problem is thermal feedback from pass transistors to reference circuitry in currently available voltage regulators?

What are the best ways to compare analog multipliers?

The answers to one day's worth of important questions concerning IC application will be forthcoming at EEE's Boston and Chicago seminars. It costs $35 to register and you can use the form appearing in this issue. For more information or to reserve a seat, call EEE Seminars, 212-661-0450, Ext. 25.

JERRY EIMBINDER
EDITOR

ACROSS THE Editor's Desk

Performance of ac DACs

We would like to clarify Perkin-Elmer's viewpoint on some of the questions raised in the recent *EEE* article "Multiplying Digital-to-Analog Converters" by Michael Neidich (September, 1970, pp. 52-57). While Mr. Neidich's article was useful in illustrating some of the many possible applications for multiplying DACs, we feel that the article was somewhat slanted towards the types of DACs manufactured by the author's company, and, therefore, did not do full justice to those ac DACs that use transformers.

In the article, Mr. Neidich states that switch resistance, R_{ON}, is critical in ac-reference DACs. While this may be true with DACs that have resistive weighting networks, it is not true for the transformer approach. This is because the total series resistance of the transformer and R_{ON} is relatively small when compared with the high impedance of the transformer.

Mr. Neidich also states that the transformer type of DAC tends to have higher cost than other types. We disagree with this statement since it is not true if one makes a fair bit-for-bit comparison with a unit that offers the same accuracy over the full military temperature range.

The major advantages of transformer-type ac DACs can be summarized as follows:

1. The transformer ratios are extremely precise, and these ratios remain constant over large variations in environment including the full military range (-55 to $+125$°C).
2. The cost is comparable to that for alternative methods.
3. The overall accuracy is a function only of "on" resistance of the switches and series resistance of the transformer which are both small when compared with the high impedance of the transformer.

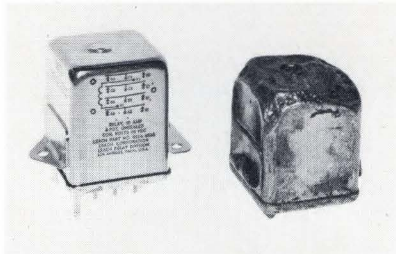
We are achieving quarter-bit accuracy in an 11-bit unit and better than half-bit accuracy in a 12-bit unit. A 15-bit converter with compatible accuracy within one bit is entirely feasible. All of these accuracies can be maintained over the full temperature range of -55 to $+125$°C. These units are capable of operation over a wide frequency range.

We hope that this information will be useful in providing a more complete picture of ac DAC capabilities.

Michael Redovian
Perkin-Elmer Corp.
Wilton, Conn.

Crashing success

The relay at the right, a 10-amp 4pdt Leach unit that started life looking like the relay at the left, doesn't look so good any more — but it still works.

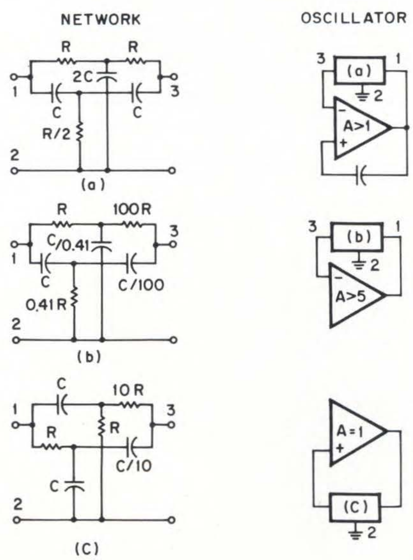


It was fired to an altitude of 60,000 feet in a Little Joe missile, then plunged, rather rapidly, into the New Mexico desert. Except for the appearance of the case, there was no observable degradation. It's now resting in Leach's corporate archives. It's not for sale, but others are. Interested? Circle **347.**

Twin-tee oscillators

Dear EEE:

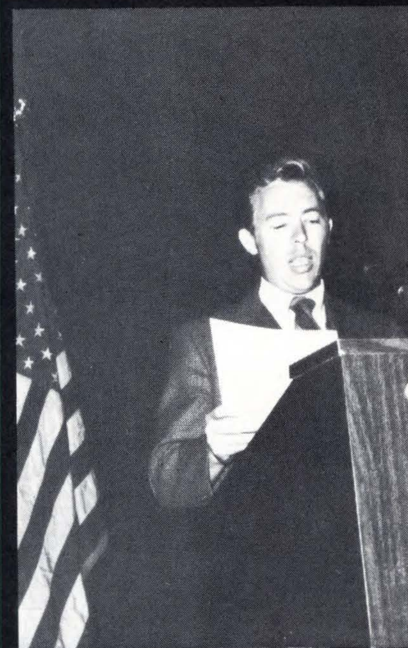
The exchange between J.O.G. Darrow and M. J. English (*EEE,* May, p. 20) discussing twin-T networks prompted this letter. Virtually all designers are familiar with the symmetrical RC twin-T, fewer are familiar with one other version and very few are familiar with the three main classes of twin-T's. Each class is used in a completely different manner to implement an RC



tuned oscillator. The circuits shown in the figure are typical of their class.

Network (a) is the most familiar

(Continued on page 16)



Mike Markkula
of Fairchild Semiconductor

This engineering / engineering management seminar will cover the positive aspects of designing with standard ICs. It'll analyze the degrees of flexibility that different standard ICs provide the circuit/system designer and it'll survey what can be accomplished with existing digital and linear ICs including bipolar and MOS MSI/LSI. The seminar's main goals are to show the IC user the ranges of capability offered by standard devices and the best ways from technical and economical viewpoints, to take advantage of these capabilities.

As with previous EEE Seminars, this special seminar permits key applications engineers at leading IC manufacturers to interface as a group with IC users. This helps attendees gauge the opinions of several leading IC engineers on each topic discussed.

PROGRAM:

Session One

Key innovators from leading digital/linear IC manufacturers will discuss groundrules for making standard available-off-the shelf ICs fit the requirements of various circuits and systems.

Session Two

The controversies concerning which

EEE Seminars Announces an Important New IC Seminar For Engineers and Engineering Management:

"Designing With Commercially Available Integrated Circuits"

of competing IC approaches is best for various systems will be examined.

Session Three

The present range of capabilities of most types of ICs (LSI/MSI, RAMs, ROMs, op amps, regulators, comparators, etc.) will be explored.

Date/Place

Friday, November 6
Holiday Inn (Charles River), Boston
Tuesday, December 8, Sheraton-Blackstone, Chicago

8:45-9:15	Coffee/Danish
9:15-11:45	Morning Session
11:45-1:00	Luncheon
1:00-3:00	First Afternoon Session
3:00-3:15	Coffee/Coke Break
3:15-4:30	Second Afternoon Session

Registration Fee

Advance registration is $35 ($40 at the door if seats are available). Registration includes detailed program, materials, luncheon, coffee breaks. Fee is tax deductible. Cancellations honored one day before seminar.

To register, use the form below.

Make your check payable to
EEE Seminars
820 Second Avenue
New York, New York 10017

Please register me for

☐ **Seminar on "Designing With Commercially Available Integrated Circuits," Friday, Nov. 6, 1970, Holiday Inn, Boston, Mass. Fee: $35.**

☐ **Seminar on "Designing With Commercially Available Integrated Circuits," Tuesday, Dec. 8, 1970, Sheraton-Blackstone, Chicago, Ill. Fee: $35.**

☐ **My purchase order or check is enclosed, or**
☐ **Bill me, or** ☐ **Bill my company.**

Name________________ Title________________

Company______________________________

Address______________________________
(Street) (City)

State________________ Zip________

Your ticket will be mailed to you.

ACROSS THE
Editor's Desk

and requires at least two active elements to make a transformerless oscillator. It also has the sharpest network frequency response and therefore the best stability of the three. At the oscillating frequency, the network gain is 0 at 0^0 phase shift. [1-4]

Network (b) is a tapered twin-T and requires only one active element for an oscillator. For the particular circuit shown, the gain is 0.2 at 180^0 at the oscillating frequency. [4] It has the poorest frequency stability and is frequently used where a phase-shift oscillator with the same number of components would be a better choice.

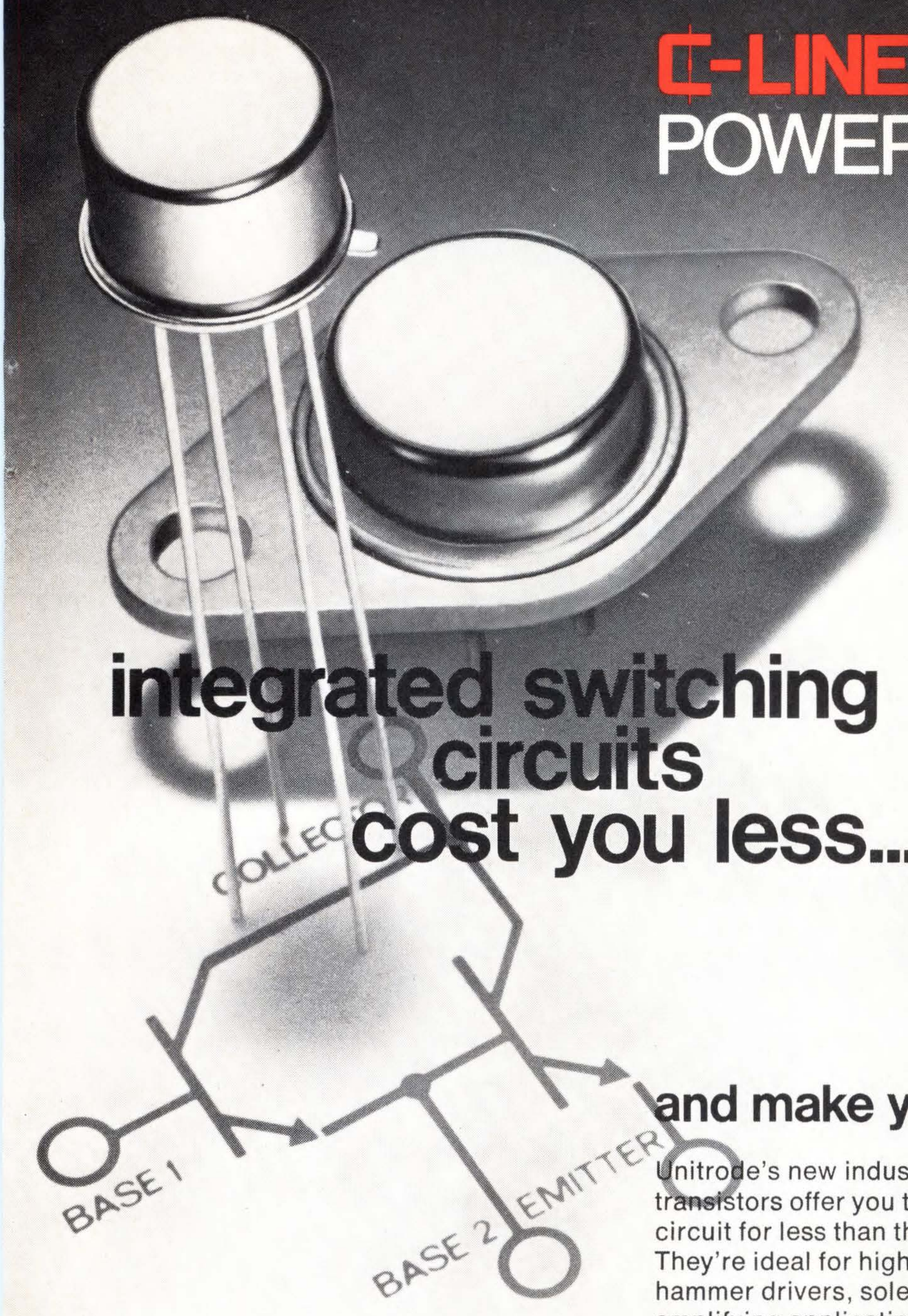
Network (c) requires ony one active element per oscillator provided the' amplifier input impedance does not load the network unduly. At the oscillating frequency the network shown has a voltage gain of 1.2 at a phase angle of 0^0. [5-7] This network class (of which the twin-T is only one member) is subject to the most controversy for two reasons: (1) engineering intuition predicts gains of less than unity from an RC network and (2) in an oscillating circuit the cathode, emitter, or source follower is argued to be a bootstrap amplifier. If you are unconvinced by network analysis, couple this network to a signal generator and monitor input/output voltage on a two-channel scope as you tune the generator. You will observe a voltage gain (not power) greater than unity. A high degree of frequency stability may be realized with this circuit, not because of the network frequency response, but rather the ease with which we achieve long-term stable-amplifier gains near unity.

References:

1. R. F. Field, "A bridge-type frequency meter, " *General Radio Experimenter,* Vol. 6, pp. 1-3 Nov., 1931.
2. H. H. Scott, "A new type of selective circuit and some applications," *Proc IRE,* Vol. 26, pp. 226-253 Feb., 1938.
3. W. N. Tuttle, "Bridged T and Paralled-T null circuits --" *Proc IRE,* pp. 23-29, Jan., 1940.
4. R. W. Landee, D. C. Davis, A. P. Albrecht, *Electronic Designers' Handbook,* McGraw-Hill, pp. 16-21, 25, 1957.
5. C. L. Longmire, "An RC circuit giving over unity gain," *Tele-Tech* pp. 40-41, April, 1947.
6. H. Epstein, "Synthesis of passive RC networks with gains greater than unity" *Proc IRE,* pp. 833-835, July, 1951.
7. S. C. Dunn, "RC cathode-follower feedback circuits," *Wireless Engineer,* pp. 10-19, Jan., 1953.

T. C. Penn
Systems and Information Sciences Lab
Texas Instruments, Inc.
Dallas, Texas

₵-LINE
POWER DARLINGTONS



integrated switching circuits cost you less...

and make your work a lot easier.

Unitrode's new industrial 10 Amp silicon planar NPN Darlington transistors offer you the advantages of a monolithic two transistor circuit for less than the price of comparable discrete devices. They're ideal for high gain switching applications such as print hammer drivers, solenoid, servo and lamp drivers and for amplifying applications such as motor controls and linear amplifiers. They're available in two hermetically sealed metal packages — a lead-mounted TO-33 (U2T101) and a chassis-mounted TO-66 (U2T201). Both utilize overlay (multiple emitter) techniques on driver and output transistors. Saturation voltage is 1.5V max. @ 5A and current gain is 2000 min @ 5A. Collector-Emitter voltage ratings are available up to 150 volts. U2T201 has a power dissipation rating of 25W @ a case temperature of 100°C. For whatever Darlington application you have, Unitrode ₵-Line Darlingtons are more efficient and less expensive than any other method of performing the function. Why not make us prove it? (U2T101 is $2.75 ea. in lots of 100.)

For fast action, call sales engineering collect at (617) 926-0404
Unitrode Corporation,
Dept. 11A, 580 Pleasant St., Watertown, Mass. 02172

Free samples on request.

UNITRODE quality takes the worry out of paying less.

Circle 113 on Reader Service Card

Progress in Design and Research

Fastest, costliest real-time scope

PROGRESS IN INSTRUMENTATION

HEWLETT-PACKARD SNATCHED the bandwidth crown in high-sensitivity real-time scopes last year (see "Leapfrog in fast scopes," *EEE*, Sept. 1969, pp 14-18), and lost it this year. Tektronix held the lead (with the 454 at 150 MHz, 25 mV/cm) from 1967 to 1969, at which time it pushed sensitivity to 5 mV/cm at 150 MHz with the 7704.

Iwatsu, a Japanese firm with instruments marketed here by E-H Research Labs, took the lead briefly in 1968-69 with a bandwidth of 200 MHz and sensitivity at that bandwidth of 10 mV/cm. Then HP moved in impressively with the 183A, which offered sensitivities to 10 mV/cm at bandwidths up to a stunning, 250 MHz. For a year now, that's been the number to beat and Iwatsu has beat it with a new scope, the SS-311.

The Iwatsu SS-311, marketed here by E-H Research Labs, now enjoys the speed lead, with a bandwidth of 300 MHz and top-frequency sensitivity of 10 mV/cm.

The dual-trace instrument (an integral scope with no provision for plug-ins), offers 10 mV/cm up to a dazzling 300 MHz. Sensitivity is even more impressive at lower frequencies — 5 mV/cm to 250 MHz (besting HP's 10 mV/cm at that frequency), and 1 mV/cm to 30 MHz.

The scope has sweep speeds to match its vertical bandwidth. Top sweep rate (without benefit of the 10 × magnifier) is 10 ns/cm, matching HP's figure.

Like other scopes except the HP (which has a 50-Ω input system), the Iwatsu SS-311 has high input impedances — 1 MΩ shunted by 14 pF. Unfortunately, at 300 MHz, 14 pF has a reactance of 38 Ω, which tends to make 1 MΩ vanish.

The 311 has another limitation — price. At this writing, the final cost hasn't been firmed, but it should be about $5000, making the unit the most expensive commercial scope. For comparison, HP's 183A, with a dual-trace plug-in and a time-base plug-in, costs $3150. ■

For more information, circle 351.

(Progress continued on page 20)

"Top-speed" counter topped -- by 25 MHz

PROGRESS IN INSTRUMENTATION

Quietly — all too quietly — Beckman, the company that gave the world the first commercial counter 20 years ago, introduced the fastest counter — with a direct-counting frequency range to 525 MHz. That tops the 500-MHz range of a scope plug-in, the Tektronix 7D14, which *EEE* erroneously cited for taking the high-frequency-counting lead. (See "Scope plug-in takes fast-counter crown," *EEE,* August 1970, pg 20.)

Beckman had actually beat Tek by several months and 25 MHz. It showed the model 6421 at the IEEE Show in March, but *EEE* missed it. In August, Beckman sent out a newsletter hailing the 6421 and, in September a company spokesman told *EEE* that a press release was forthcoming.

The new instrument is, in fact, most impressive. It measures frequency from 10 Hz to 525 MHz and permits 1-Hz resolution in one second. It's ac coupled so it's not necessary to diddle any trigger-level control to measure ac signals riding on dc. Further, the instrument can accept an enormous range of input voltage. It has a superb sensitivity of 50 mV rms but it can also take 10-Vrms sinusoids. At the bottom of its frequency range (from 10 to 400 Hz) it won't be damaged by a 150-Vrms sine wave.

The basic model 6421-O comes with 8-digit gas-ionization readout and costs $1575. A crystal in a switch-controlled oven provides a very respectable clock with an aging rate of 3×10^{-9} per 24-hr day, averaged over 30 days, and a drift of 1.5×10^{-6} over the full temperature range of 0 to 50°C. Warmup time to within 1×10^{-6} of final value is only two minutes, making a $300 battery pack a meaningful accessory.

A superior model, the 6421-L, has the crystal in a proportionally controlled oven, so the drift is a nifty 1×10^{-8} over the full temperature range. Short-term stability is 5×10^{-10} peak-to-peak per second, averaged over 120 seconds, and aging rate is the same as that of the 6421-O. This model, at $2120, makes a 9th-digit option meaningful at an additional $100.

Both models accept remote programming of time base and reset. And both deliver TTL/DTL-compatible BCD output. ■

For more information, circle 350.

Faster direct-counting counter, Beckman's 6421, measures frequency to 525 MHz and allows ratio measurements against signals from 10 Hz to 5 MHz.

High-performance DAC conquers the "glitch" problem

PROGRESS IN PACKAGED CIRCUITS

AT THIS YEAR'S WESCON Show, Teledyne Philbrick Nexus introduced a comprehensive line of digital-to-analog conversion modules. Top of the line is a new 14-bit (actually 13 bits plus sign) converter, designated Model 4001. This module offers an impressive array of performance features including controlled monotonic transition between levels and virtual freedom from glitches and overshoots. Each of these switching errors has a peak value of less than ±5 mV (compared with an LSB of approximately 1.2 mV). The settling time to within ±1 LSB is 20μs.

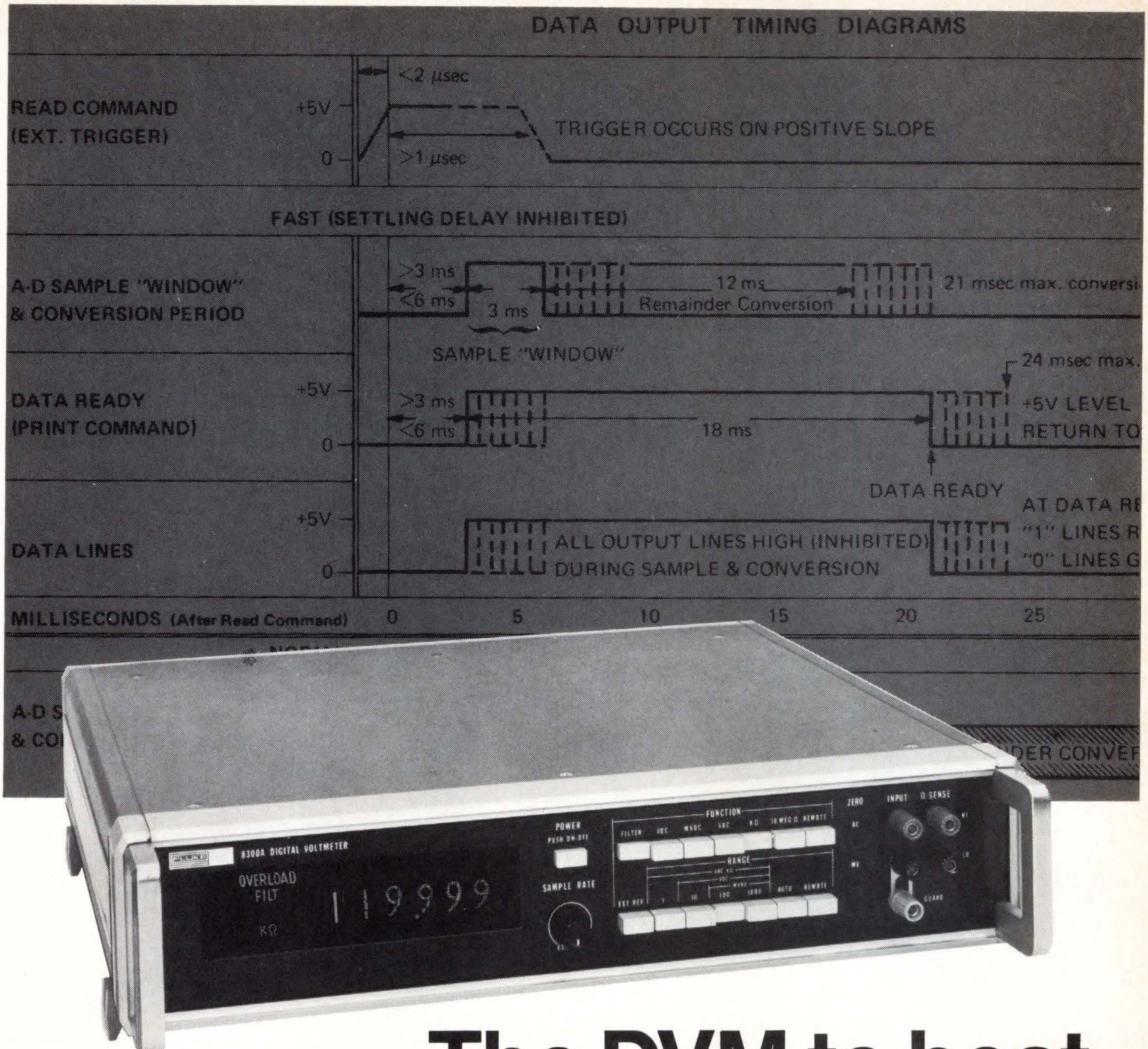
With its high resolution, moderately fast settling and freedom from large output spikes, the 4001 is well suited for a broad range of test and display applications. For example, in a system for programmed testing of semiconductors, the converter will apply the exact test voltages required, without overvoltage transients that could damage the device under test or cause severe measurement errors.

Philbrick's new DAC module isn't cheap, however. In quantities of 1 to 9, it costs $895. "Skip" Osgood, the company's Product Manager, explains that "deglitching" tends to be pretty expensive because it involves a strobed sample-and-hold amplifier and other circuits not normally included within a DAC.

Competing converters

The 4001 is priced competi-

(Continued on page 22)



The DVM to beat the system!

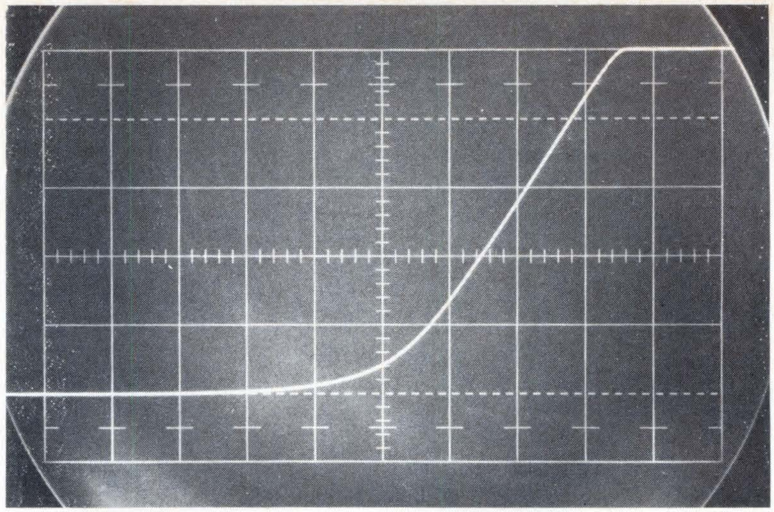
Here are 10 reasons why Fluke's 8300A is easy to use, easy to interface, and easy to program. 10 reasons why it's *the* systems digital voltmeter.

1. We blank the data output during conversion and time out to keep random signals out of the system.
2. A "device busy"/"ready" flag inhibits acquisition of readout until data is ready.
3. Programmable, on-call time-outs allow settling of analog options and auto-ranging, then call up a final conversion which is the only reading presented.
4. An automatic overload flag acts independently of the system.
5. Data may be acquired serially so that you can interface directly with an 8, 12 or 16 bit computer.
6. Because the DVM can take large overloads, problems caused by switch timing and large transients are eliminated.
7. Signal input is completely isolated from data out and remote control circuits without use of relays.
8. Fully guarded "box in box" construction gives you totally uncompromised input isolation.
9. DTL-TTL compatability.
10. High accuracy/low price... 0.005% with prices from $1395.

FLUKE®

Fluke, Box 7428, Seattle, Washington 98133. Phone: (206) 774-2211. TWX: 910-449-2850/ In Europe, address Fluke Nederland (N.V.), P.O. Box 5053, Tilburg, Holland. Phone: (04250) 70130. Telex: 884-50237/In the U.K., address Fluke International Corp., Garnett Close, Watford, WD2 4TT. Phone: Watford, 27769. Telex: 934583.

Circle 215 on Reader Service Card



Scope picture shows the 4001's controlled monotonic transitions between levels. In this picture, the two levels are zero and +10 V (full scale). The horizontal scale is 2μs per division. Glitches normally occur at the initial transition, with overshoots and ringing occurring at the final level. For the 4001, peak amplitude of glitches and overshoots are less than ±5 mV.

tively versus other converters with comparable performance. For example Analog Devices offers a 15-bit converter, the DAC-15R, which includes deglitching circuitry and sells in small quantities for $995. But, though the DAC-15R is more expensive, it has one extra bit of resolution and it settles in only 1 μs to within ±0.05%.

Other companies, for example Analogic and Phoenix Data, offer 14-bit converters that are priced in the range of $300 to $600. But these converters do not include deglitching circuits, though in some cases this circuitry is offered as an external option.

There are indications, however, that some companies are about to introduce new high-performance DACs with resolutions in the range 14 to 16 bits. Analogic will introduce a 15-bit converter that will have a settling time of 2.5 μs (to within ±1/2 LSB) and will be priced around $900 complete with output amplifier. Analog Devices is expected to introduce a 14-bit converter priced around $395. The new Analogic and Analog Devices converters will both include deglitching circuitry.

Philbrick's new low-glitch DAC measures 4.85 × 4.85 × 1 inch. It is pin-compatible with a similar unit made by Analog Devices.

Magnitude and sign

For the 4001, Philbrick uses circuitry that accepts binary magnitude-plus-sign codes. Philbrick engineers claim that, contrasted with other coding approaches such as offset binary and two's complement, the magnitude-plus-sign approach provides superior accuracy, linearity and stability for small signals. The coding technique also allows design of fast-settling circuits that are free from glitches for transitions around zero.

Another important advantage of the 4001 is its excellent power-supply-rejection ratio of ±0.005%/V (typical). This feature eliminates the need to readjust a system for power-supply variations. Unlike some competing converters, the 4001 does not need any high-voltage reference supplies, though it does need ±15 V and ±5 V.

The unit is packaged as a plug-in PC module with a handle. Overall dimensions are 4.85 × 4.85 × 1 in. Availability is from stock. ■

For more information on Philbrick's 4001, circle 352

Complete D/A converter for $29

PROGRESS IN PACKAGED CIRCUITS

Varadyne Systems (formerly Datel Corp.) has fired the latest shot in the fierce pricing battle among manufacturers of packaged digital-to-analog converters. At this year's Wescon show, the company introduced a complete 8-bit D/A converter (with built-in reference and output amplifier) that sells in unit quantity for only $29. In quantities of a hundred or more, the price of the converter, type DAC-29, falls to $25.

The DAC-29 is probably the lowest cost complete 8-bit converter on the market. At press time, the closest competitor on the basis of cost was the Precision Monolithics monoDAC-01 — a 6-bit monolithic unit that sells for around $40 in small quantities. The closest 8-bit competitor was the Analogic MP1808 — a discrete-component module with a unit-quantity price of $59.

Low tempco

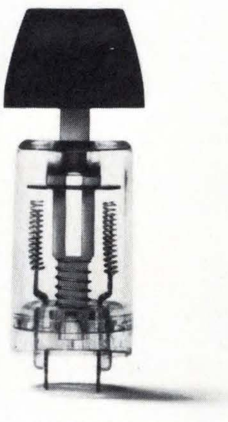
Low cost is not the only significant feature of the DAC-29. The unit's specified temperature coefficient is only 30 ppm/°C, which is lower than for most competing converters — even those with much higher price tags.

Surprisingly, Varadyne achieves the low tempco with a thick-film resistor network. Though thick films allow low-cost fabrication, most manufacturers have, hitherto, turned to thin films when they needed low temperature drift. Somehow, Varadyne's engineers have achieved a tempco for

(Continued on page 24)

Somebody had to invent a reliable, low cost mechanical keyboard switch.

Raytheon has.



A new kind of mechanical switch. From Raytheon. Ideal for computer entry or terminal display. Virtually bounce-free contacts. A ten-million-cycle life. All at a production price of less than 50¢. Isn't that something to shout about?

RAYTHEON

Raytheon Company
Industrial Components Operation
465 Centre Street, Quincy, Mass. 02169

Gentlemen: I want to hear more.

☐ Send more information. ☐ Have a Raytheon salesman call on me.

Name__________

Position__________

Company__________ Dept.__________

Street__________

City__________ State__________ Zip__________

Telephone__________

the DAC-29 that beats Analogic's thin-film MP1808 (100 ppm/°C), Beckman's thick-film Model 845 (50 ppm/°C) and Precision Monolithics' diffused-resistor mono-DAC-01 (120 ppm/°C).

Of course, total temperature drift includes errors in the reference element as well as in the ladder network. It appears, therefore, that Varadyne's engineers have managed to minimize errors in the reference, thus achieving a tempco that's governed solely by the inherent drift of the thick-film ladder. The DAC-29's operating temperature range is from zero to +70°C.

One disadvantage of the DAC-29 is that it's relatively slow — though it can still outpace many competing converters in the low-cost segment of the market. As with other low-cost converters, the speed of the DAC-29 is limited by its use of a monolithic output amplifier. The settling time is 20 μs to within the unit's rated absolute accuracy, which is ±0.2% of full scale. The linearity, also, is ±0.2%.

Binary or BCD

In addition to the 8-bit binary version discussed here, Varadyne also markets a 2-digit BCD version of the DAC-29. Input digital coding is, thus, either straight binary or 2-digit BCD for unipolar output and two's complement for bipolar outputs. All digital inputs are standard TTL/DTL logic levels. The output voltage is zero to +10 V or ±5 V,

with a maximum current of ±5 mA. The DAC-29 is packaged in a plastic case with dimensions of 2 × 2 × 0.4 inches. Pin locations are dual in-line compatible. The company currently quotes four-weeks delivery. ■

For more information, circle 342.

New direction in LSI testing

PROGRESS IN TESTING

AS CIRCUIT/SYSTEM designers began switching from discrete devices to integrated circuits, Associated Testing Laboratories found that more and more of its testing business was involving ICs. But now as medium and large-scale-integration makes testing vastly more complex and cuts down considerably on the number of ICs to be tested, Associated is looking in another direction.

"We've been testing components for years by applying various electrical stresses and corrosive atmospheres to anticipate types of failures and failure rates," explains William Luke, Jr., vice president, marketing and planning, "Why not apply the same reliability procedures to testing instruments and LSI subsystems?"

To make room for instruments? Some of the 40,000 test sockets in Associated Testing Laboratories screening facility.

Associated hopes to set up an investigative service where potential customers for IC-equipped instruments can have competitive units tested under actual or overstressed conditions. "We won't determine which instrument is better from a purely performance standpoint," says Luke, "but we will determine which one is more likely to fail or degrade and under what conditions." He also sees instrument manufacturers as a potential customer since they might want to use the test results to detect their product's weaknesses or as a sales aid in talking to customers.

The proposed instrument testing service is planned for incorporation with the company's semiconductor testing division at Wayne, N.J. ■

For a copy, circle 346

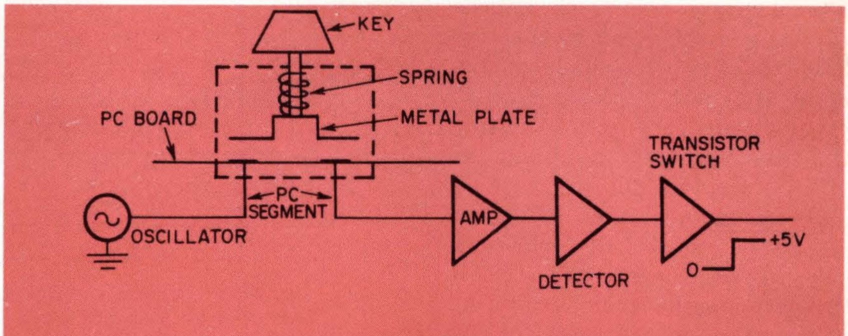
(Progress continued on page 41)

New switch in keyboard design

PROGRESS IN DATA ENTRY

STILL ANOTHER birth has occurred in the continuing keyboard population explosion. A brand new bounceless baby from Control Devices of Woburn, Mass., features: a new keyboard switch, low power dissipation and low-profile construction. The most important feature of this keyboard is its E-field or capacitance-coupled keyswitch.

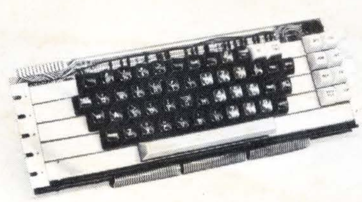
The new switch should be an extremely reliable device. It has no contacting parts to wear or bounce and passes a negligible amount of current. In addition, it has the added feature of a high signal-to-noise ratio. It seems to fall in the category of Micro Switch's Hall-effect unit, photo-electric switches and various other contactless keyswitches. The majority of keyboards in the field, however, are still using the faithful reed switch in varying forms. But, it seems as if the non-contacting types could soon change this state of affairs.



Control Device's capacitively-coupled keyswitch gives bounceless, long-life operations.

E-field coupled switch

CD's new key switch, which will not be marketed separately, works on the E-field coupling or capacitive principle. Depressing the key shown in the figure, causes the metal plate to approach two conductive segments on a PC card. One segment is fed by an oscillator and the other segment feeds an amplifier-detector-switch. If the key is down, oscillator voltage capacitively couples into the metal plate and out to the signal circuitry. The resulting input voltage is then converted to a low dc logic level. Releasing the key decreases the coupling and the circuitry returns the dc logic level to +5 V. The oscillator bar is common to all keys and each key must have its own output segment and circuitry. The key return is spring actuated.



Control Device's CDK keyboard consumes only one watt, features low-profile construction.

Keyboard features

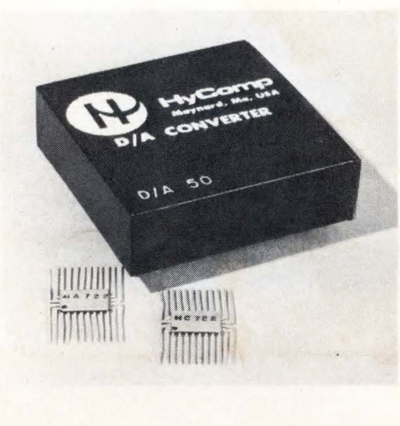
The keyboard itself requires less than a watt of power (5 V at 200 mA). TTL type logic is used for encoding and buffering. ASCII code with a parity bit is standard but other codes can be furnished. External strobe, inhibit and two-key rollover are standard. Mono, dual, tri and quad modes are available. CD plans to join Clare-Pendar and Micro Switch in the MOS-encoded board business in the near future.

Mechanically, the keyboard features a low profile (as low as 3/4 in.) and spill-proof construction. This precaution is needed since spillage is a real hazard in keyboard operation. The new switching technique also allows complete keyboard operation in a high humidity environment (up to 95%, non-condensing). Two basic board formats are offered, one for typewriter formats and one for keypunch applications. Key caps are truncated two-shot molded types.

Fully encoded keyboards sell for less than $100 in production quantities (1000 units or more).■

For more information, circle 340.

Build or buy a low-cost 10-bit DAC



PROGRESS IN PACKAGED CIRCUITS

YET ANOTHER company has joined the growing list of those offering low-cost digital-to-analog converters. The newcomer is HyComp, of Maynard, Mass. The company has taken the Fairchild μA722 and combined it with HyComp's own HC722 thin-film resistor network. The matched combination has a resolution of 10 bits and is available either as a kit that the user can assemble on his own PC board, or as a complete encapsulated module. The modular version (designated D/A 50) costs under $50 in quantities of 1000, while the unassembled kit sells for approximately $33 at the same quantity level.

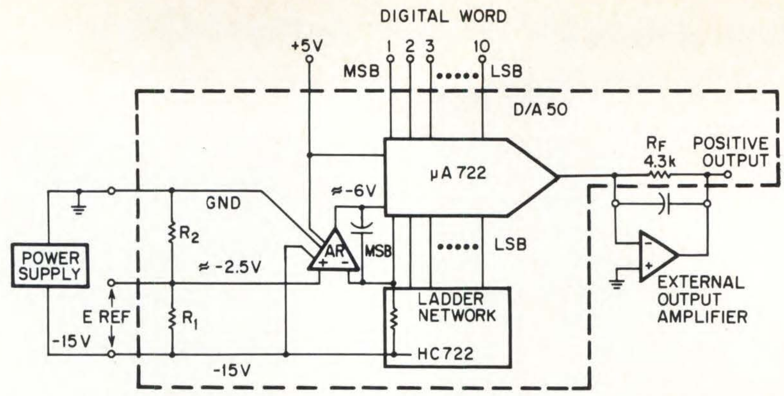
Minimizing errors

The μA722 has several well-

(Continued on page 42)

publicized shortcomings (see *EEE*, March 1970, pp. 64-65) and, for this reason, other companies (such as Precision Monolithics) have designed their own proprietary monolithic circuits that are said to offer superior performance. However HyComp decided to stay with the μA722, citing its relatively low cost and its "proven reliability."

Acording to Norman Palazzini, HyComp's marketing manager, the μA722's reference-circuit problems can be circumvented by adding an external regulator circuit. The A/D 50 module in-



Hycomp's D/A 50 consists of an VC switching network, a thin-film resistor network and a regulation circuit. Resistors R_1, R_2 and R_F are mounted on the same substrate as the ladder network.

cludes a suitable reference regulator, while the unassembled kit includes an IC op amp for the regulator along with the μA722 and HC722 circuits. The resistors for the regulator circuit are mounted on the same substrate as the ladder network. Also included within the HC722 network is a feedback resistor for an optional external output amplifier, thus ensuring good tracking over the temperature range.

Another way in which HyComp has minimized some of the μA722's errors is by carefully tailoring resistor networks to match individual IC switches. This approach also allows HyComp to trim costs by avoiding need for close-tolerance selection of the ICs.

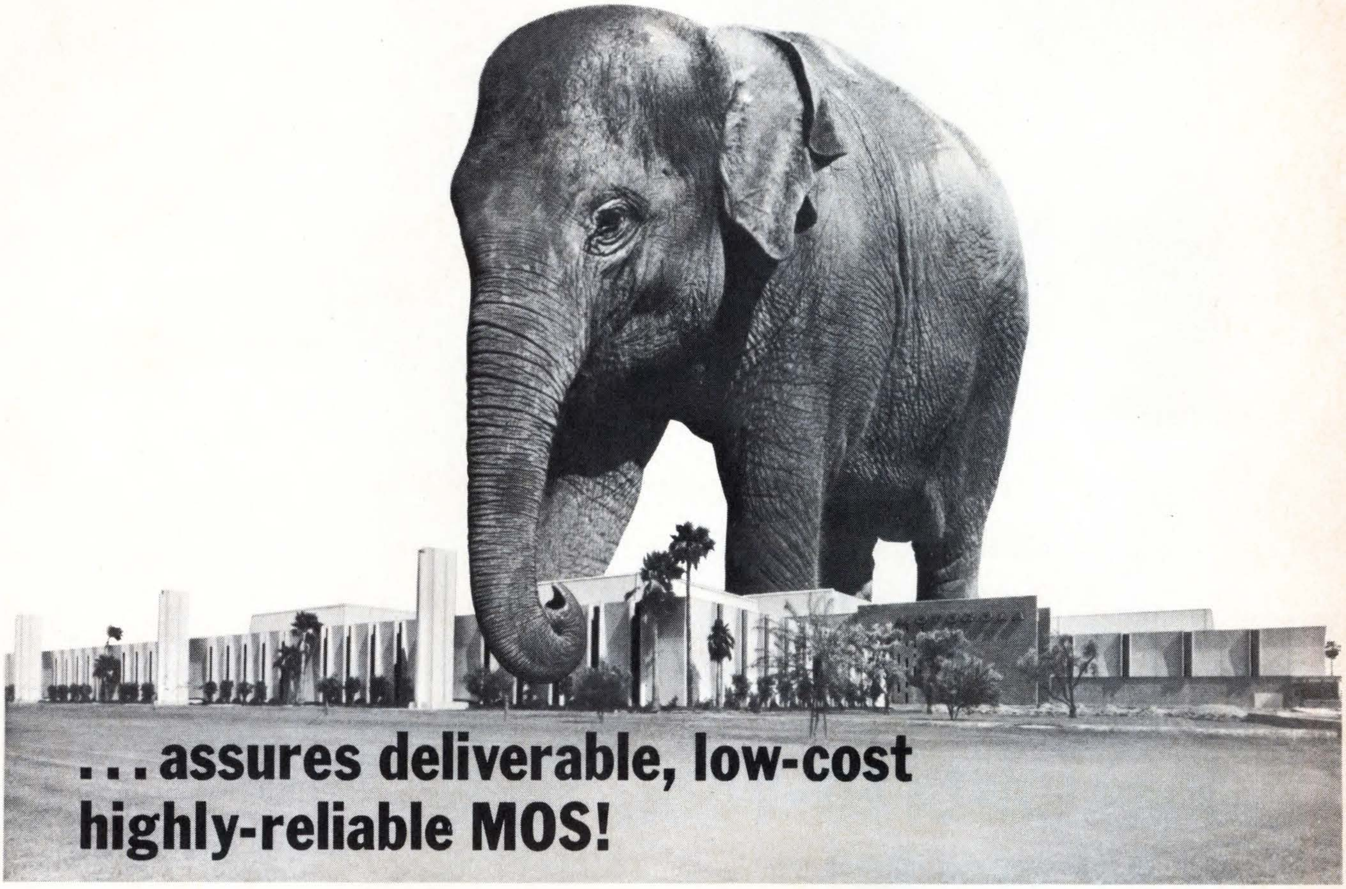
Trend to thin films

As we noted in our recent Designer's Guide on D/A converters (*EEE*, September 1970, pp. 42-46) there appears to be a current industry trend towards use of thin films rather than thick films for fabrication of D/A converters. Thin films, of course, offer the advantage of improved temperature stability versus thick films (see *EEE*, August 1970, pp. 40-44). What is surprising though is that companies like HyComp and Precision Monolithics are able to offer thin-film circuits at prices below those of competing thick-film circuits.

Perhaps the toughest competition for the D/A 50 will come from the Precision Monolithics AIMDAC-100 which uses the monoDAI-01 monolithic switch instead of the μA722 (see *EEE*,

(Continued on page 44)

Motorola's Ponderous Pachyderm Syndrome



Why Ponderous Pachyderm?

Motorola typically moves slowly and carefully into new product categories, planning, examining, and developing sure, reproducible processes before total commitment. This has been our history, and we have applied the same approach to MOS.

Motorola already offers a selection of standard MOS devices in both high threshold and low threshold P-channel MOS, matched by a growing line of Complementary MOS types. Included are gates, flip-flops, multiplex switches, memories, counters, general purpose logic elements, and dynamic and static shift registers. These will be joined before the end of the year by several Silicon-Gate MOS shift register and memory introductions to launch our capability in this significant area. And our Polycell LSI program is in full swing for the design of custom MOS. For perspective, what does the pachyderm syndrome indicate?

We were deliberate in entering the silicon transistor business. We made the commitment. Who has supplied more silicon transistors since!

We were slow with RTL and DTL. We made commitments. Who has supplied more RTL and DTL since!

We waited before committing to Linear circuits. We committed. Who has delivered more Linear circuits since!

We delayed on MOS. Then in the first six months of 1970 we increased our design capability, our production capacity, and our deliveries by 10 times. Now we are committed!

Ask us to back this up by telling us your MOS product interests. If you have a problem, we'll offer assistance. Write to Motorola Semiconductor Products Inc., P. O. Box 20912, Phoenix, Arizona 85036.

MOTOROLA MOS

—the broad line is our specialty

September 1970, pp. 22-24). Both the D/A 50 and the AIMDAC-100 have 10-bit resolution, both include internal reference regulators and neither includes an output amplifier. But there are some differences. The AIMDAC-100 is designed for the full military temperature range of −55 to +125°C, whereas the D/A 50 operates only over the range zero to +70°C. However HyComp guarantees ±1 bit accuracy over the temperature range, whereas Precision Monolithics has several versions with various temperature coefficients. Only the more expensive versions of the AIMDAC-100 would be able to provide the temperature performance of the D/A 50. Unfortunately it is impossible to make an exact price comparison because, so far, HyComp has quoted prices only at the 1000 level, while Precision Monolithics negotiates prices at this quantity level.

An important advantage of the AIMDAC-100 is that it's available in compact DIP or flatpack configurations, whereas the D/A 50 is packaged in a larger module, 2 ×2 × 0.4 inches. However, both companies will supply the unassembled individual components of their converters so that the user can assemble them to suit his own packaging requirements.

Settling time limited

HyComp specifies the settling time of the D/A 50 as 1.5 μs for the stated accuracy. Settling time is limited by the performance of the μA722. (HyComp's spec looks worse than the Fairchild spec because Fairchild specifies settling time for a lesser number of bits).

Among the other specs of the D/A 50 are a linearity of ±1/2 LSB (0.05%) over the temperature range, and a total accuracy of ±1 LSB (including reference drift) over the temperature range. The accuracy is ±1/2 LSB at 25°C.

Input logic levels are DTL/TTL compatible. The full-scale output is 2.5 mA (optional bipolar outputs available). Power-supply requirements are −15 Vdc and +5 Vdc. ■

For more information on the Hy-Comp D/A 50, circle 344

For Capacitors with GREATER RELIABILITY . . .

Choose El-Menco

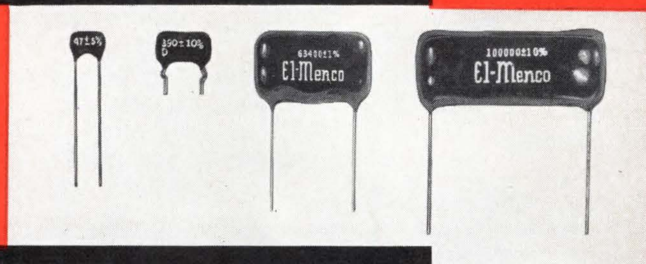
The Capacitors You Find Wherever There's Electronics!

EL-MENCO DUR-MICA CAPACITORS

Only 1 Failure Per 43,000,000 Unit-Hours!

- It has been computed that "debugged" DM30, 10,000 MMF units, when subjected to 257,000 hours of life at 85°C with 100% of the rated DC voltage applied, will yield only 1 FAILURE PER 43,000,000 UNIT-HOURS!
- DM15, DM16, DM19, DM20 . . . perfect for miniaturization and for new designs using printed wiring circuits. Also available in DM30, DM42 and DM43.
- New "hairpin" parallel leads insure easy application.

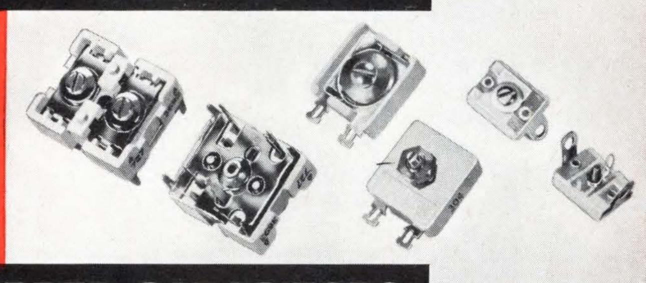
Exceed all electrical requirements of military specification MIL-C-5A.



EL-MENCO TRIMMERS & PADDERS

Design Versatility!

- Available in 350 VDC and 500 VDC as well as other test voltages.
- All bases are of low-loss steatite.
- Special lugs are obtainable for printed circuitry.
- Miniature units are available.
- Solder Lugs can be bent in any position without affecting the capacity setting due to the rigid construction.
- Various types of mounting brackets are available for all trimmers.
- Units can be constructed for special applications.

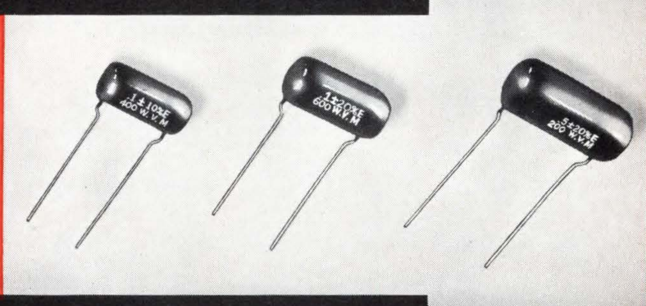


EL-MENCO *MYLAR-PAPER DIPPED CAPACITORS

Only 1 Failure in 14,336,000 Unit-Hours!

- Life tests at 105°C with rated voltage applied have yielded only 1 FAILURE PER 1,433,600 UNIT-HOURS for 1 MFD. Since the number of unit-hours for these capacitors is inversely proportional to the capacitance, 0.1 MFD Mylar-Paper Dipped capacitors will yield only 1 FAILURE PER 14,336,000 UNIT-HOURS!
- Working volts DC: 200, 400, 600, 1000 and 1600.
- Durez phenolic resin impregnated.
- Tolerances: ± 10% and ± 20% (closer tolerances available).
- Dielectric strength: 2 or 2½ times rated voltage, depending upon working voltage.
- Exceed all electrical requirements of E.I.A. specification RS-164 and military specifications MIL-C-91A and MIL-C-25A.

*Registered Trademark of DuPont Co.

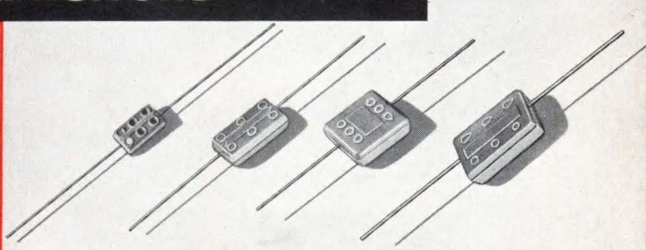


EL-MENCO MOLDED MICA CAPACITORS

Superior Performance!

- Unmatched for excellent stability, dielectric strength, high insulation resistance, extremely high "Q" and correspondingly low power factor.
- Units can be subjected to a short "debugging" life test at elevated voltage and temperature for removal of early life failures and for improved reliability.

Write for Free Samples and Booklets on Any of The Above Capacitors



EL-MENCO OFFERS A COMPLETE LINE OF CAPACITORS . . . STANDS READY TO SERVE ALL YOUR CAPACITOR NEEDS

MANUFACTURERS OF El-Menco Capacitors

THE ELECTRO MOTIVE MFG. CO., INC.

WILLIMANTIC, CONNECTICUT 06226

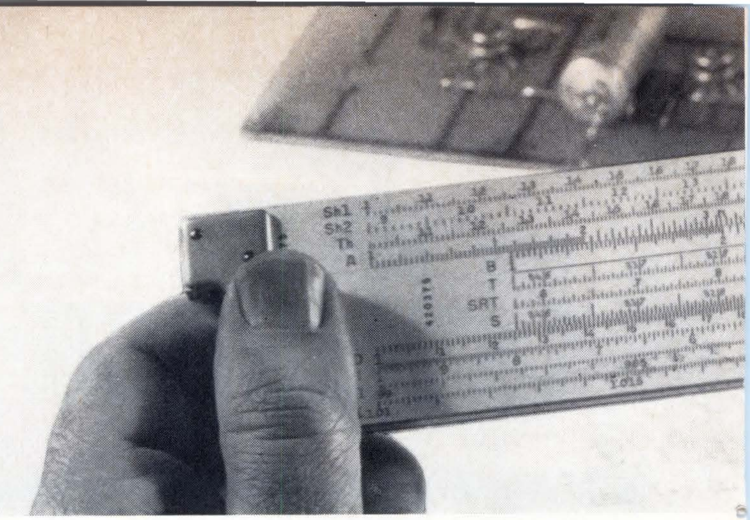
Dipped Mica • Molded Mica • Silvered Mica Films • Mica Trimmers & Padders
Mylar-Paper Dipped • Paper Dipped • Mylar Dipped • Tubular Paper

West Coast Manufacturers contact: **COLLINS & HYDE CO.,** 900 N. San Antonio Rd., Los Altos, California 94022
5380 Whittier Blvd., Los Angeles, California 90022

ALSO SOLD NATIONALLY THROUGH ELECTRONIC PARTS DISTRIBUTORS

Circle 120 on Reader Service Card

RCA Solid-State Data for Designers



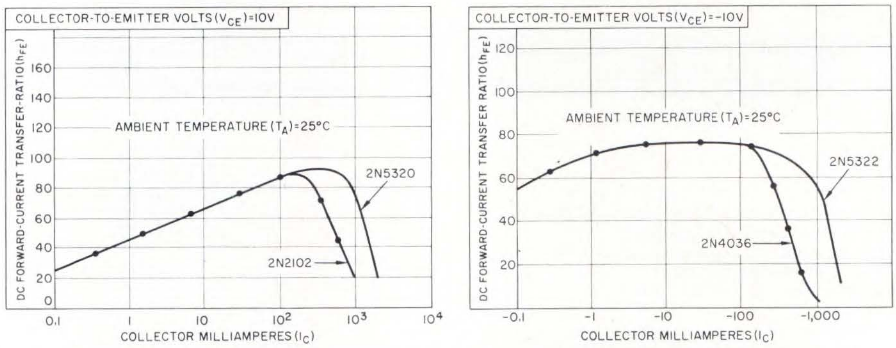
Profit makers: RCA's power transistor families

Here are two established families of RCA low-power transistors—the 2N5320 and its companion type, the 2N5322—that can help you increase profit margins from your equipment sales.

These extremely reliable devices are suitable for a myriad of general-purpose industrial applications. To name just a few: industrial controls, test instrumentation and control equipment, and power amplifier drivers.

The n-p-n 2N5320 and its p-n-p complement, the 2N5322, are double-diffused epitaxial planar transistors in hermetic TO-5 cases that feature 1 A current capability. They are big brothers to RCA's 2N2102 (n-p-n) and 2N4036 (p-n-p) transistors that have 0.5 A current capability. Examine their performance curves. You'll find they have the characteristics you need for your circuit application.

Circle **155** on Reader Service Card



TYPICAL STATIC BETA CHARACTERISTICS FOR TYPES 2N5320, 2N2102, 2N5322, AND 2N4036.

Application	MOD. or CW	Room Temperature Devices: Emitter	Laser Diode	Laser Diode Stack	Laser Array
Paper Tape Reader	CW	40736R			
Card Reader	CW	40736R			
Shaft Encoder	CW	40736R			
Keyboard	CW or CODED	40736R			
Circuit Isolator Coupler- "DC Transformer"	MOD	40736R			
Data Transmission	MOD	40736R TA7762R			
Line Finder/ Edge Sensor	CW or PULSE	40736R	TA7606, 7, 8, 9, 10, TA7699, TA7925		
Intrusion Alarm	MOD or PULSE	40736R TA7762R	TA7606, 7, 8, 9, 10, TA7699, TA7925, TA7763, TA7864	TA7764 TA7765	
Remote Control Signalling	MOD	40736R TA7762R	TA7606, 7, 8, 9, 10, TA7699, TA7925, TA7763, TA7864	TA7764 TA7765	
Voice Communications	PULSE		TA7606, 7, 8, 9, 10, TA7699, TA7925, TA7763, TA7864		
Ranging	PULSE		TA7699, TA7925, TA7763, TA7864, TA7705, TA7787	TA7764 TA7765	TA7687-92 incl.
Night Vision Applications	PULSE		All types above plus TA7867*		TA7924†

*GaAlAs—wavelengths from 800 to 880 nm

†77 K

Looking for GaAs lasers and IR emitters? RCA has the devices to meet your requirements

Gallium-arsenide lasers and/or IR emitters are now being designed into a wide range of signaling and illumination equipment. For such applications, RCA offers a broad line of lasers and emitters—well-suited to meet these requirements.

RCA injection lasers feature high peak powers, low drive currents and proven reliability. Because of their simplicity, ease of drive, and covert wavelength, they are naturals for intrusion alarms, ranging, data-link communications and secure illumination. RCA IR emitters feature small size and high efficiency. Their prefocused, high brightness beam pattern allows optimum performance in card readers, shaft encoders, short range intrusion alarms and data-link communications. Finally, RCA lasers and emitters are compatible with most photodetector systems.

Try RCA's superior GaAs lasers and IR emitters in *your* system. You'll beam!

Circle **156** on Reader Service Card

RCA Thyristors expands its triac line to 600 volts

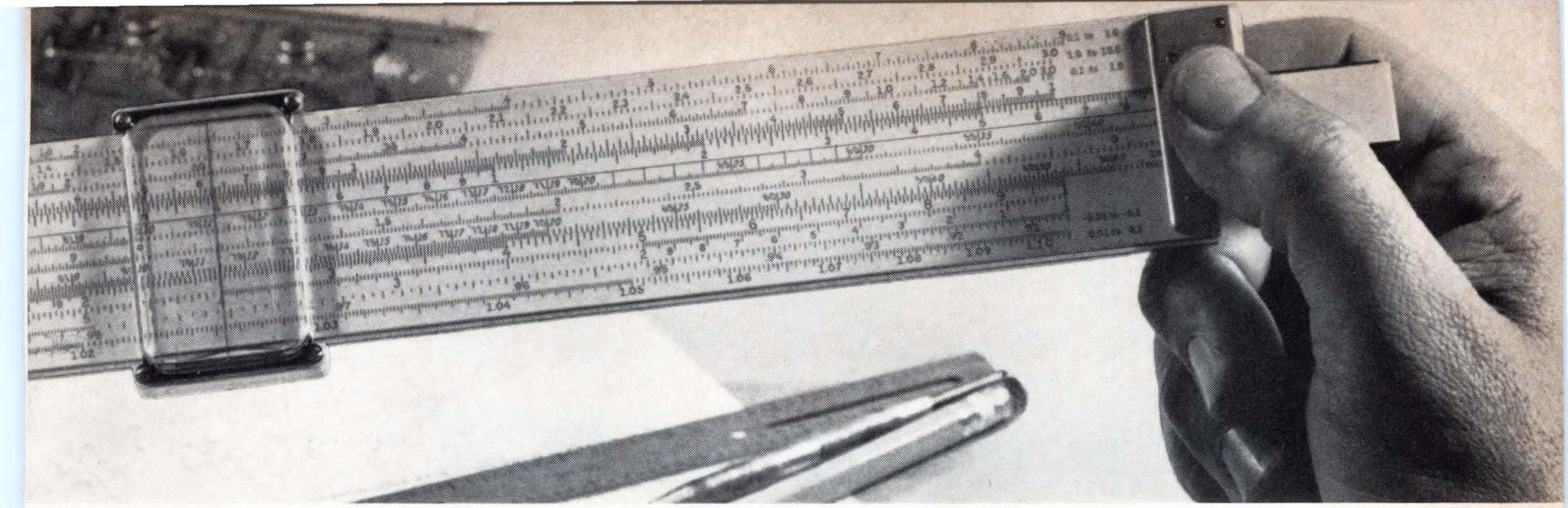
RCA announces a new line of 600 V triacs available now for industrial control manufacturers. These new triacs have a 600-V peak repetitive rating at a maximum rated junction temperature of 100°C.

In difficult industrial applications where ac power sources demand added safety margin, this group of RCA triacs can be used to assure reliable equipment operation.

600 VOLT TRIACS				
Package	10 A	15 A	30 A	40 A
Press-Fit	40795	40797	40671	2N5443
Stud	40796	40798	40672	2N5446
Isolated Stud	40801	40804	40807	40690

These new triacs (as the chart illustrates) range from 10 amperes, with availability in press-fit, stud and isolated stud packages.

Circle **157** on Reader Service Card



TA7625A: a new high power op amp

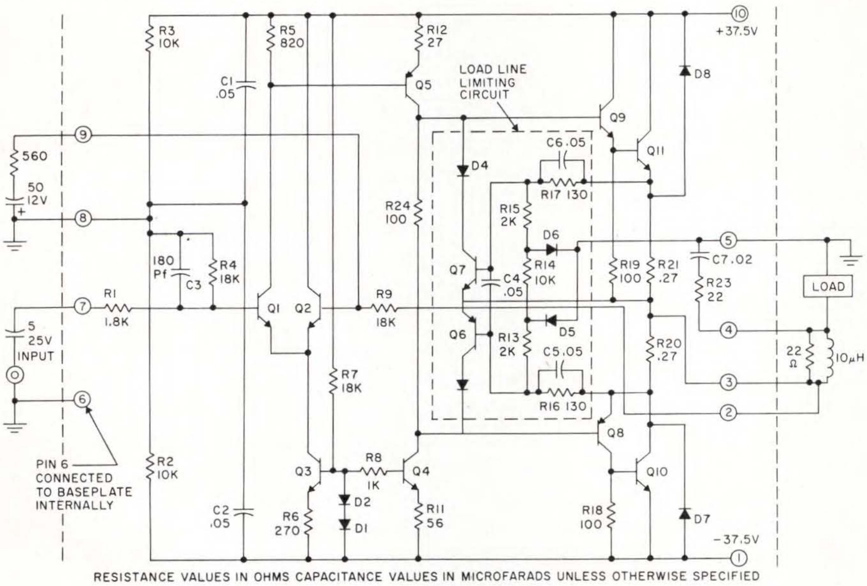
RCA's new TA7625A plastic power hybrid amplifier is capable of handling 7 amperes peak current. It is a modification of RCA's well known TA7625 linear amplifier, and thereby provides added versatility. With minor circuit changes, the TA7625A can replace the TA7625.

The TA7625A has both short-circuit protection and reactive load-fault protection. Its inverting terminals are external. Thus the feedback resistor (22 ohms across terminal 3 and 4) can be varied to minimize distortion at low frequencies.

What does this mean to the designer? It means that he is better able to use the hybrid as a current source. It also means that the TA7625A has greater capability and versatility in servo-amplifier applications, in voltage-regulator circuits, inverters, and in deflection-amplifier circuits ($V_S = \pm 37.5$ V max.).

Contact your local RCA Representative for planned price reductions.

Circle **158** on Reader Service Card



SCHEMATIC OF TA7625A HYBRID POWER MODULE.

Custom design your own 30 MHz broadband amplifier with IC's transistor array

RCA's CA3018—monolithic, four-transistor array—offers the circuit designer a best-of-both-worlds approach. Here you have the economy, compactness, and device matching and temperature tracking you expect of IC's, combined with accessibility and design freedom that normally require discrete transistors. In the CA3018, two independent transistors and two Darlington-connected transistors are housed in a 12-lead TO-5 style package.

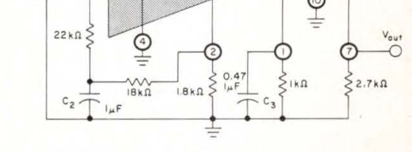
The wideband video amplifier shown here (in the schematic at right) utilizes the CA3018 to provide a 30-MHz bandwidth and a gain of 49 dB—with two feedback loops for excellent stability across the full frequency range. Gain of the amplifier is constant within 1 dB over the full −55°C to +125°C temperature range. With slide rule and breadboard you can custom-tailor this circuit to your own specifications.

RCA's CA3018 and its companion type, the CA3018A, are well suited to a variety of applications in low power systems in the dc through VHF range. The CA3018 provides a V_{BE} match of ±5 mV. In the CA3018A, V_{BE} is matched within 2 mV and performance characteristics are controlled from 10 μA to 10 mA. You can purchase the CA3018 for just 98¢, the CA3018A for $1.35 (at 1000-unit levels).

The circuit shown here may also be built with the five-transistor CA3045 in a DIC package or the CA3046 in a DIP package.

For Application Note ST-3895, "Design Ideas for RCA Linear Arrays,"

Circle **159** on Reader Service Card



SCHEMATIC OF WIDEBAND VIDEO AMPLIFIER USING THE CA3018.

For price and availability information on all solid-state devices, see your local RCA Representative or your RCA Distributor. For specific technical data, write RCA, Commercial Engineering, Section 51K/UM6, Harrison, N. J. 07029. International: RCA, 2-4 rue du Lièvre, 1227 Geneva, Switzerland, or P.O. Box 112, Hong Kong.

RCA Solid State Division

Bill Hittinger of RCA Speaks Out On The IC Manufacturer's Role

I'm concerned about all the talk of semiconductor manufacturers going into the systems business. If you were to believe some of the stories going around, you'd get the impression that most semiconductor manufacturers intend to displace their customers.

It's true that one of the problems facing many semiconductor manufacturers today is defining their area of operation. It's also true that some semiconductor-device houses now see themselves in the systems business as well as in the IC/transistor/diode business.

But it doesn't necessarily follow that there are no more big challenges in semiconductor-device development. Nor does it follow that there are few profitable device areas still to be explored. And it doesn't follow that a device manufacturer can build a system as well and as inexpensively as a systems manufacturer.

There's so much still to be done in the development of solid-state technology that semiconductor producers will have their hands full for many years to come.

There will be more sophisticated devices brought out by solid-state-device manufacturers but these will help systems manufacturers — not put them out of business.

I see the next decade as one in which the role of the semiconductor manufacturer is improving existing products and continuing the solid-state evolutionary process. Those companies that see the 70's as their conversion period from semiconductor-device manufacturing to system building may drop from the forefront in the former and never make it in the latter.

One of the real problems that now confronts semiconductor manufacturers is determining which areas to attack. Part of the problem is the need to balance requirements to keep current work going against investment for the future. And, of course, part of the problem is determining what programs are most likely to pay off in the future.

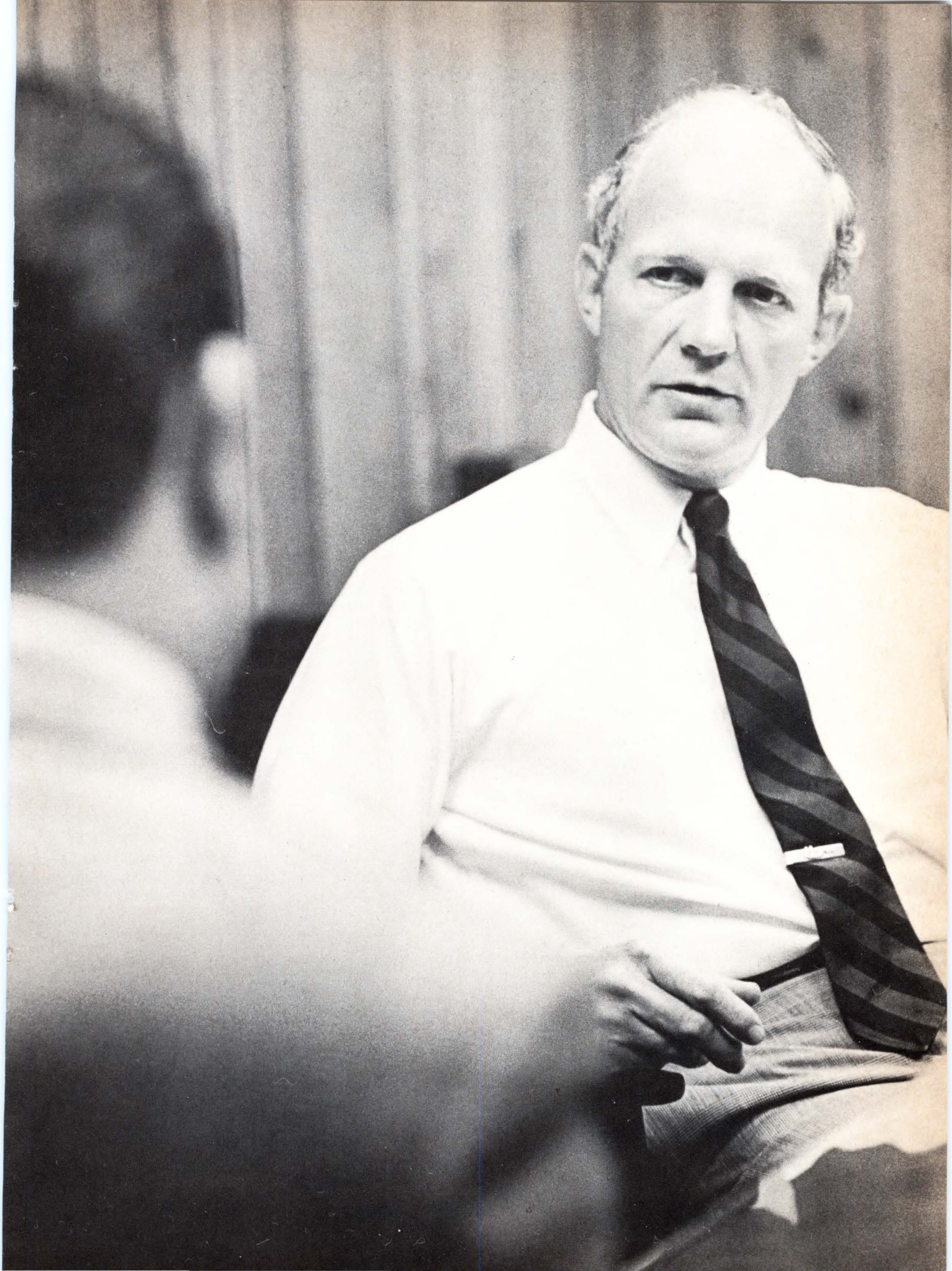
Let's examine the power-semiconductor field as an example. Here is one of the less glamorous areas of our industry, certainly not as romantic as logic and memory. But does it have a good future and is it worth an investment of key people and developmental funds?

Traditionally one thinks of power devices as discrete transistors, discrete thyristors or discrete rectifiers. Today we are moving on to power integrated devices. Reaching this stage of technology development has been accomplished through a quiet evolution lost in all the fanfare for LSI and MSI for logic and memory. But, by applying some of the same concepts used for LSI aand MSI, the cause of solid-state power has also been advancing.

Since their capabilities can be extended, power devices are going to play bigger, more important roles.

Power is here to stay and applications will be opening up not only for more powerful devices but for improved devices such as needed for use in very carefully controlled power systems where voltages must be kept at tightly prescribed levels and where high-speed transient response must be provided.

A good figure of merit for gauging progress in the power area is watts per buck. Clever innovations are being applied in building power devices and more will be coming along to raise



watt-per-buck capabilities. For example, forming unique devices by laminating silicon with heat and pressure will lead to improved power handling capabilities. Complementary pnp/npn structures will also improve performance.

Fabricating power integrated circuits, or power modules, by assembling power chips and passive components on ceramic substrates will improve the figure of merit. The semiconductor manufacturer should be highly qualified to package such components and sell them for use with semiconductor memories and other solid-state circuitry. But such a module is really a system component, maybe even a simple subsystem, but definitely not a system.

One area involving solid-state power and still wide open for exploitation is microwaves.

Here a lot has been done in the laboratory, much more than has found its way into the field. I think portions of this area are about ready to blossom — techniques now known can be applied to a variety of communications applications.

A big part of the problem has involved the cost and complexity of packaging. Getting the power from the semiconductor chip efficiently has been a headache. Designers have been bothered with reflections, impedance mismatches, heat dissipation problems and other assorted ills. Recently strip-line and coaxial packages have been making an impact; high-power micro-wave integrated circuits now are feasible.

The next step is to take advantage of beam lead-sealed junction chips to further reduce packaging complexity. Being able to come out directly from the active area of the semiconductor chip to the microwave circuit promises improvement in performance and lower cost.

If we can continue to improve packages, there's still much that can be done with silicon in the microwave region but other semiconductor materials, such as gallium arsenide, will also be getting into the picture. Also, new bulk effect devices, such as Gunn and avalanche diodes, will be making their appearance. Reliability has been a problem in this area but progress is being made.

Looking broadly at the integrated circuit field, I look forward to the day when most systems houses will have complete capability for working with semiconductor chips.

The advent of beam-leaded chips should make it possible for a natural working interface to arise between the systems house and the solid-state-device house. This division will occur at the interface between the beam-leaded device and the substrate. When this happens the areas of involvement for semiconductor-device manufacturers and systems houses should become more clearcut.

I expect that the systems house will be routinely putting down film patterns on ceramic substrates; this combination will become the equivalent of today's printed-circuit board. As you know, the systems house, not the solid-state-device manufacturer, now configures printed boards.

Thus the system designer will continue to make an impact on total design and the solid-state specialist will be able to concentrate on high semiconductor technology.

There's a story about a semiconductor-device sales manager who was unhappy about a huge transistor order brought in by one of his salesmen. He was upset because the salesman didn't find out how the transistors were to be used and didn't go after the subsystems business instead. I don't agree with this philosophy.

But this doesn't mean I believe that solid-state device makers won't be moving up in the system hierarchy. There will be situations where it'll be economical for us to supply single and multi-chip packages containing great complexities, for example, memory planes with several random-access memory chips interconnected on a substrate.

But even here we can go only so far before we reach a point where the customer knows more about the application than we do. He should be better equipped, from both knowledge and facility standpoints, to take our planes and assemble them into final memory systems. Decisions on tradeoffs on coding and decoding, inputs, outputs, power distribution and the like should be his.

As our large-scale integration and custom-processing capabilities increase, close working relationships between IC manufacturers and systems companies will evolve naturally.

Customers will come to the IC producer and say "Here's a systems job I want to do, here's how I'd like to partition my system in broad brush, now see what you can do at the chip level." If they say, "I'm willing to buy my total system from you or major chunks of it — you tell me how to do it," it's likely that both the systems house and the IC house will be in trouble. A sharing of the entire spectrum of knowledge is needed to design and build a sophisticated system. Total systems capability includes not only the hardware design but packaging of the system, development of the software and marketing of the finished product.

There's no question but that there's plenty to keep the solid-state house busy without seeking new directions in the system area and I'm not just talking about LSI and MSI.

The next decade should be one of major growth for several, of what some might consider, less sophisticated semiconductor devices — silicon controlled rectifiers (thyristors), for example. These devices have been used in consumer applications, such as blenders and drills for years, but with costs going even lower, they'll become commonplace in more applications. Light dimming controls throughout the home and office are one example. Speed controls for garden and household tools are another.

Optoelectronics offers another growth opportunity for solid-state houses. Involvement in the variety of optical products made possible by solid-state research will require extensive technological development.

Liquid crystals, for example, could very well develop into an important business. The structure of the device is simple — a sandwich is made from two pieces of glass with transparent electrodes on the facing plates and liquid crystal material inside. By appropriate configuration of the transparent contacts, made from material such as tin oxide, displays can be developed which can be viewed under any kind of lighting. They could even be programmed to form moving signs or alpha-numeric readouts.

One of the important points here is that there are device developmental areas that are more natural for the solid-state device manufacturer to go into than systems work. Technologies such as liquid crystals for display devices offer real challenges and considerable potential business.

If semiconductor-device builders really want to become systems oriented, they ought to try applying the systems approach to technological innovation.

The whole semiconductor-device process can be considered as a total system going from research right through to the marketplace. Each link should be examined and modified to keep the process functioning smoothly.

Clearly there are many areas still to be researched in device technology, there are still many problems to be licked in converting from research to manufacturing and there's a lot to keep device oriented manufacturers occupied.

Solid-state-device manufacturers will continue to bring out products of greater complexity as times goes by. But when this happens it should be because such complex products make sense from economical and technological standpoints — not because of a desire to displace their systems cutomers. **EEE**

Hittinger's Background

William Hittinger joined RCA as vice president and general manager of its solid-state division in April, 1970. He has been a pioneer in the semiconductor industry and was involved in the investigation of germanium properties before the invention of the transistor by Bell Telephone Labs.

Bill served with Army Ordnance in the Pacific during World War II and then went to work for Western Electric's tube operation in New Yok City. His next assignment moved him to Allentown, Pa., and when the transistor came along, he joined the engineering team working on its processing. His responsibility included the engineering of germanium crystal growth for production at Allentown.

Bill moved to National Union Radio, Hatboro, Pa., in 1952, to help the tube company set up a semiconductor division. He rejoined the Bell system in 1954 as a member of the solid-state development organization of Bell Labs at Murray Hill, N. J. With this group, he helped develop the intrinsic barrier transistor and, in 1956, the first diffused-junction siilcon transistor. This device went into production the following year at Allentown.

By 1960, Bill had advanced to director of the semiconductor and tube laboratory at Allentown and two years later he was appointed executive director of the electron tube and semiconductor division of Bell Labs, a position he held until 1966.

In 1966, Bellcom, a jointly owned venture of AT & T and Western Electric, installed Bill as president. Bellcom is best known for its systems engineering involvement in the manned space flight program.

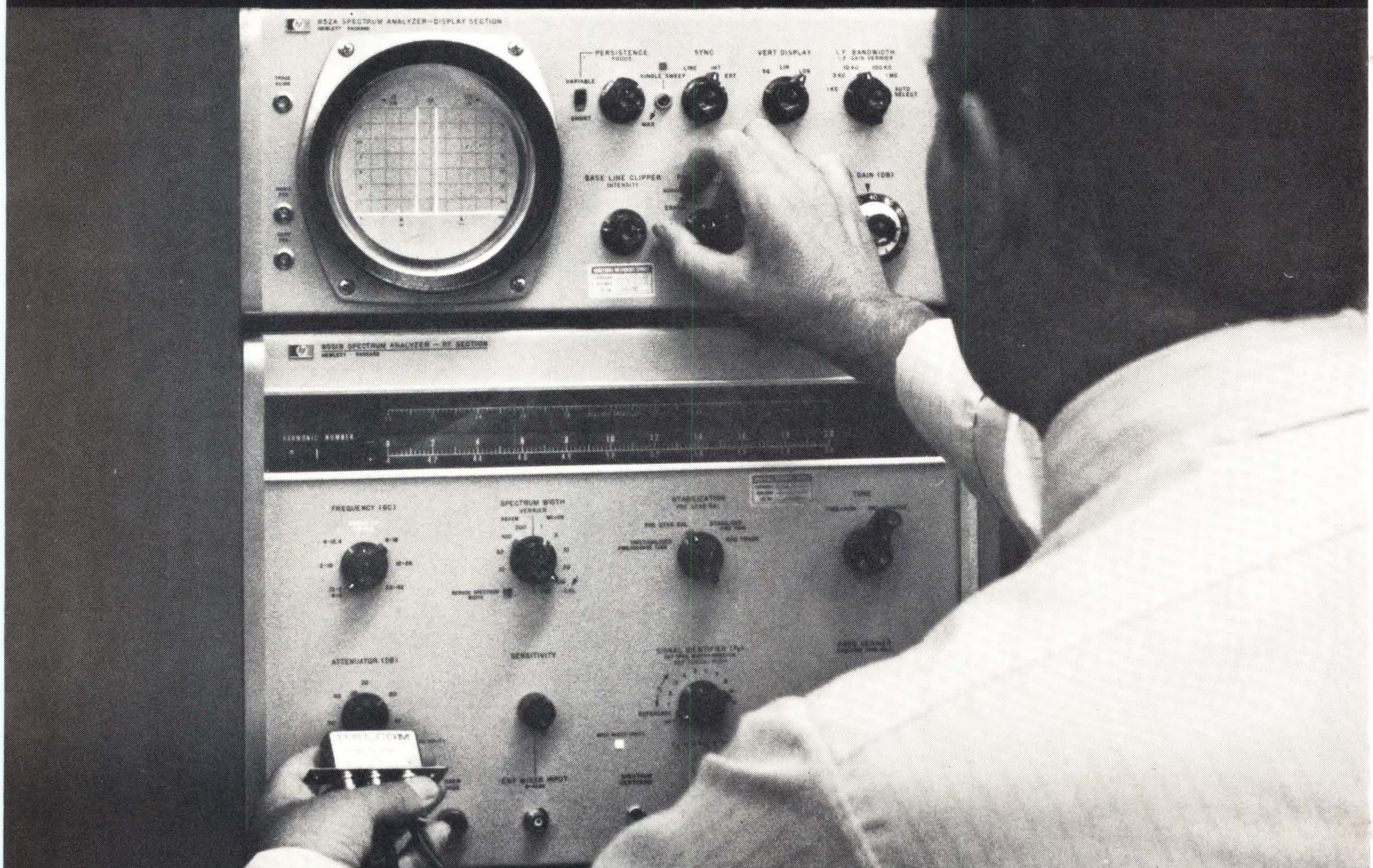
After two years at Bellcom, Bill moved into the presidency of General Instrument, his last post prior to assuming the reins for RCA's semiconductor operation.

Bill was born in Bethlehem, Pa. and grew up there, earning letters in football and track at Bethlehem High School. His quarterbacking during high school was good enough to earn a football scholarship to Lehigh University. His army career began immediately after graduation from Lehigh.

Bill's athletics are currently limited to running (not jogging), an activity he started over ten years ago, swimming and occasionally golf. He also admits to being an amateur carpenter and a classical music lover.

The Hittingers are an athletic and outdoors family. Residents of Summit, N. J., they also have a summer home in the Poconos. Bill and his wife Betty have four children Patricia 23, William 20, David 18, and Nancy 14.

EXPAND YOUR SPECTRUM ANALYZER CAPABILITY...



...AT ONLY 2.5% OF ITS COST!

Expand it with:

- Increased Sensitivity . . . 6 dB
- Reduction of Internal Spurs
- Flat Response down to 200 kHz (not 10.1 MHz)
- Flat Response up to 2 GHz (not 1.8 GHz)
- 15 db Less LO Signal at the Input Port
- 20 dB More Input Before Burn-out

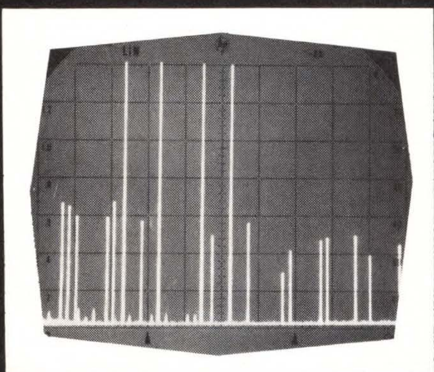
Now, all these things are economically possible with RELCOM's M1F double-balanced mixer . . . designed for use on analyzers with a 2 to 4 GHz LO and a 2 GHz IF. Just a small investment will give your instrument expanded capability to make more critical measurements.

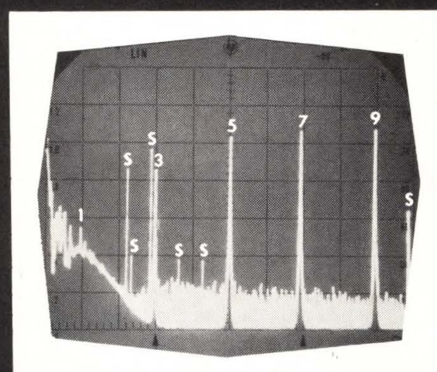
For a better idea of what this mixer can do for your analyzer, compare the following spectrum analyzer photographs.

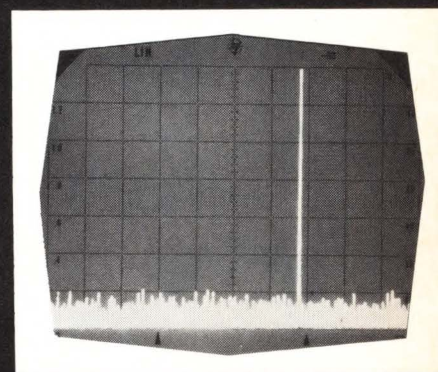
A major consideration in spectrum analysis is whether the response is real, or is internally generated. Spurious frequency components generated in the first mixer of the 8551B/851B are shown below. Where there are really only four −20 dBm input signals at 250, 350, 470, and 550 MHz, other spurious signals are present in the display.

The 8551B/851B is unspecified below 10 MHz. The numbered (in MHz) responses are −50 dBm calibrating signal inputs. Notice the low frequency response roll-off. The responses labeled "S" are internally generated spurious signals. The rise at the left of the picture shows the desensitization due to the LO feed-thru to the 2 GHz IF of the spectrum analyzer.

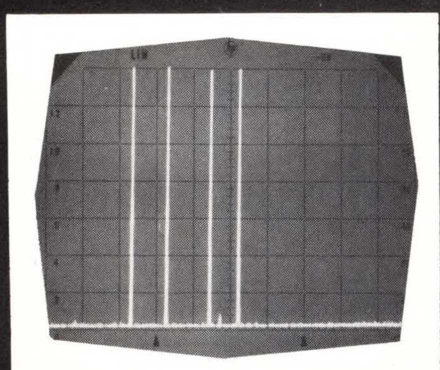
The dynamic range and sensitivity of the 8551B/851B is limited by the noise figure of the instrument. Shown below is a 600 MHz input signal at −20 dBm and a 500 MHz input signal at about −80 dBm. The settings on the analyzer are as follows: Horizontal scale 30 MHz/cm, vertical scale 10 dB/cm and IF bandwidth 10 kHz. Can you see the 500 MHz signal?

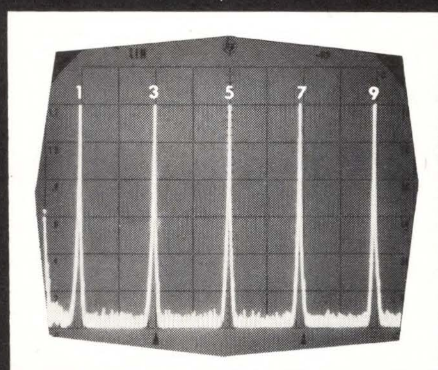


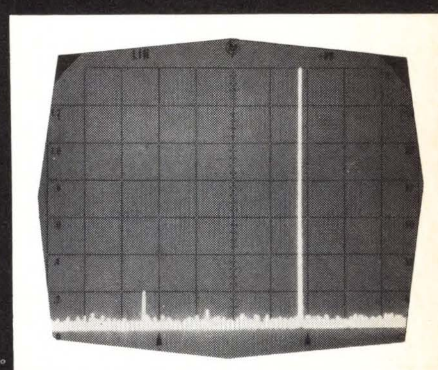




BEFORE







AFTER

With the same input signals and spectrum analyzer settings as above, substitution of the Relcom Model M1F Double-Balanced Mixer for the first mixer (single-diode) in the spectrum analyzer eliminates the confusing intermodulation products. The vertical scale is 10 dB/cm.

Same advantage apply in the 1.8 to 4.2 GHz range.

Substitution of the Relcom Model M1F Double-Balanced Mixer for the first analyzer mixer under the same conditions as above provides: (1) a *flat* frequency response in the 200 kHz to 10 MHz range, (2) increased gain and less noise for more dynamic range, (3) a drastic reduction in internally generated spurious signals, and (4) a reduction in the desensitization due to the LO feed-thru.

Substitution of the Relcom Model M1F Double-Balanced Mixer for the first spectrum analyzer mixer reveals the presence of the low-level 500 MHz signal. Reduction of the spectrum analyzer IF gain provides the same reference amplitude for the 600 MHz input. The M1F provides about 6 dB improvement in the spectrum analyzer noise figure.

Buy a Model M1F now, and see its remarkable value for yourself. We'll include applications data with delivery. If you're not completely satisfied, just return the mixer within two weeks for a full refund. Act today! Delivery from stock. Price, $275 each.

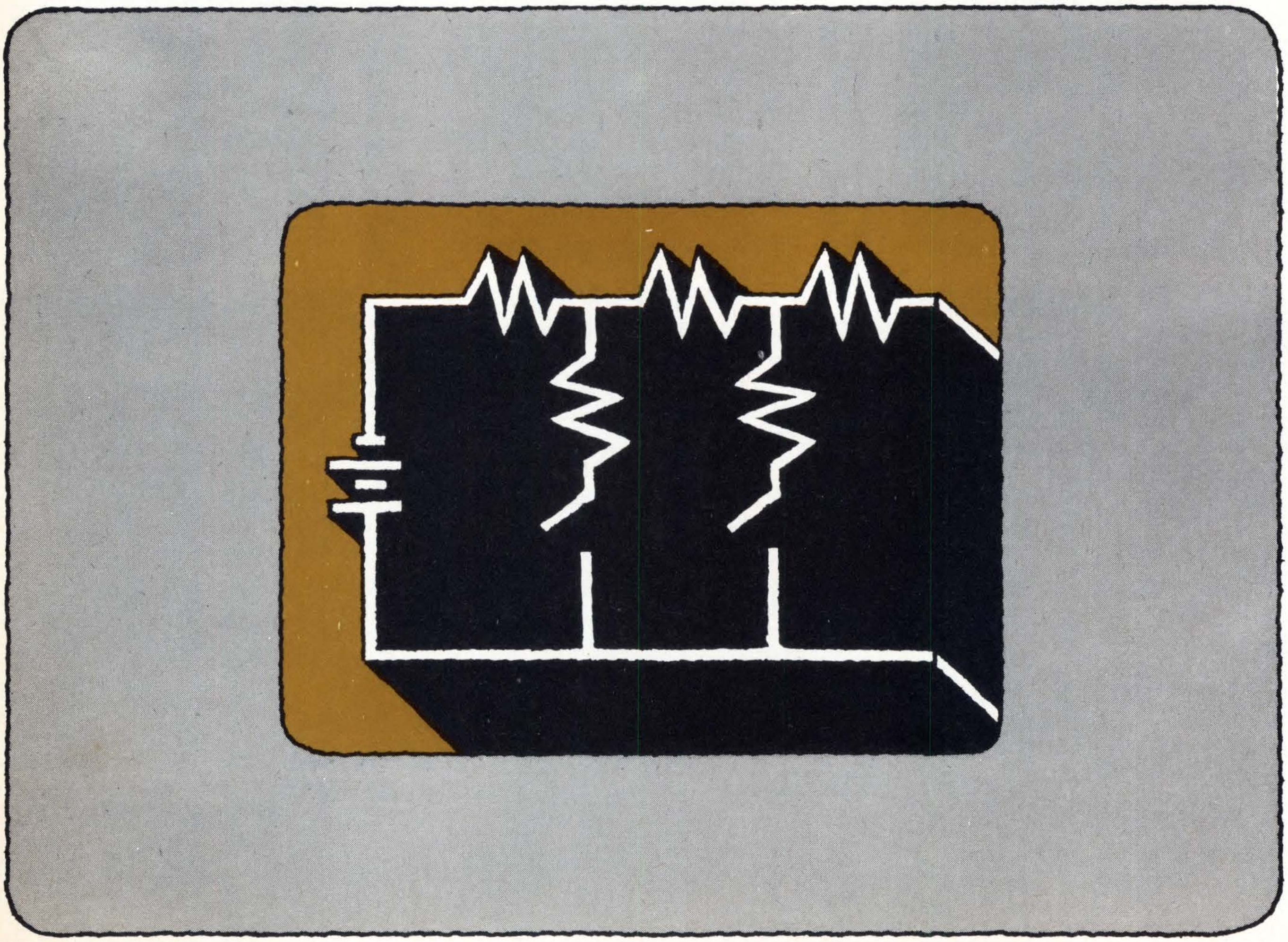
RELCOM

2329 Charleston Road ● Mountain View ● California 94040 ● Telephone (415) 961-6265 ● TWX (910) 379-6979

Circle 126 on Reader Service Card

Designer's Guide: D/A Converters

EEE
November, 1970
Number 12 Part 2



Digital-to-analog converters and their performance specifications

By Bruce K. Smith

Prices and sizes of digital-to-analog converters are shrinking. Once a quite sophisticated subsystem, the DAC now appears on system block diagrams as a routine building block. Like the flip-flop, it seems destined to vanish from the average engineer's design repertoire and to become just another rubber-stamp logic element.

Unfortunately, the overall quality of DACs seems to be declining along with their cost and size. The reason is not so much that designers and manufacturers have become dishonest, but, rather, that many of the men now designing converters have never been exposed to all the engineering subtleties. The DAC user, therefore, must either take "potted" luck, or he must learn enough about the art himself to know what to look for to match a specific application objective.

A true understanding of the nature of a device is fundamental to the achievement of device reliability. This is because *nothing* is unreliable except insofar as it fails to yield the results we expect of it. It is hoped that this article, and others in this series, will improve user understanding of DACs and thus, perhaps, create a demand for better devices.

A "four-bit" converter

It is entirely possible to build a DAC for "four bits" (50¢), or less, by hooking together four binarily related carbon-composition resistors as shown in Fig. 1. By connecting the resistor network to a four-stage binary counter ("extra-cost option") as illustrated, one can conveniently build a sixteen-step repeating staircase generator. Alternatively, the counter stages could equally well be four noncommitted flip-flops, with parallel read-in capability, thus yielding the more usual configuration of a register equipped converter.

Though the arrangement of Fig. 1 does provide digital-to-analog conversion, it has several obvious error sources. Some of these same limitations appear (to a lesser degree) in much more sophisticated instruments. Let's look at them.

Power Supply Sensitivity. When the supply voltage V_{cc} serves as a reference voltage, there is bound to be trouble. Some commercially available converters have built-in zener regulators. A simple zener is better than nothing, but this approach still leaves substantial room for improvement. Unfortunately, many DAC vendors fail to list power-supply sensitivity in their data sheets.

Switching Errors. No serious entrant in the DAC market will have switching errors (degree to which the ground and reference targets are missed) of the magnitude that can occur with, say, an IC flip-flop (for the "0" and "1" states). With DACs having resolutions of twelve or more bits, however, it becomes very difficult to hold switching errors to an acceptable level. Switching transistors must be carefully selected or specified to tight tolerances.

Output Impedance. Does the converter that you're considering have an output amplifier? If so, will it supply the required output voltage at the expected load current? Unfortunately, most popular IC operational amplifiers have very little reserve output current once the feedback requirements have been satisfied. And many new monolithic and hybrid-IC converters have low power IC output amplifiers or no amplifier at all.

Zero Offset. Our simple four-bit converter has a displacement from zero volts at zero code, but this problem is unusual in a unipolar converter. Bipolar converters, however, often have zero-offset problems. Converters designed for "offset binary" or "two's complement" codes, for instance, usually employ offsetting biases devised to place the zero at half scale. Any disparity between the half-scale code elements and the bias, due to initial tolerances, aging tolerance, or lack of temperature tracking, causes a zero-displacement error.

Author: Bruce Smith is Vice President of Advanced Development with Analogic Corp., in Wakefield, Mass.

Resolution. The resolution of a converter is defined by the number of different possibilities in its code set, independent of the accuracy of these levels. Thus, a four-bit binary converter has a resolution of one part in sixteen, regardless of whether it is constructed with five-percent carbon-composition resistors or with precision wire-wound components. As the required resolution increases, it becomes difficult to achieve accuracies commensurate with resolution. For example, for a 15-bit converter (one part in 32,768) accuracy will be inadequate regardless of the types of components chosen.

Absolute Accuracy. This DAC specification relates to the accuracy of each of the code levels with respect to the theoretical value of these levels, as compared to standards maintained by the National Bureau of Standards. Obviously, any DAC, including our simple four-bit unit, can be adjusted to yield any desired accuracy at *one* code level, such as full scale. One problem is that precision measurement against a known standard assumes that the measured voltage remains stable during the measurement. But DACs are sometimes employed in applications where command information arrives at multi-megahertz input rates. The user must make certain, therefore, that the accuracy specification relates to the actual settling time in his system, and not to a more leisurely laboratory test environment. The user should also remember that fundamental component limitations will make it impossible to achieve absolute accuracies better than about 0.01 percent, even without the additional dynamic errors.

The fine points

Anyone building our primitive four-bit converter would probably expect all of the limitations we've touched upon, even before testing it. A few others might crop up in use. Like those already noted, these additional errors are very real shortcomings that commonly occur with commercial D/A instrumentation.

A partial list of these more subtle error contributions includes the following:

Monotonicity. If the resistors in our simple four-bit converter have ten-percent tolerance, it's entirely possible that, at the code for binary seven (0111), there will be an equivalent resistance as low as 1028.7 ohms connected to the "1" logic level. If, then, the 1-kilohm resistor at the binary eight (1000) position is ten-percent high (i.e. at 1100 ohms) we will have a situation where "seven" yields a higher output than "eight."

To be monotonic, a DAC must provide a unique output for each member of its code set, and an increasing code value must result in an increasing absolute value of analog output.

Linearity. Because of the poor resistors we've used, and because of the imperfect flip-flop switching elements, it is unlikely that the steps of our converter's sixteen-state staircase will have equal height. Indeed, we have already seen how the steps can momentarily reverse direction

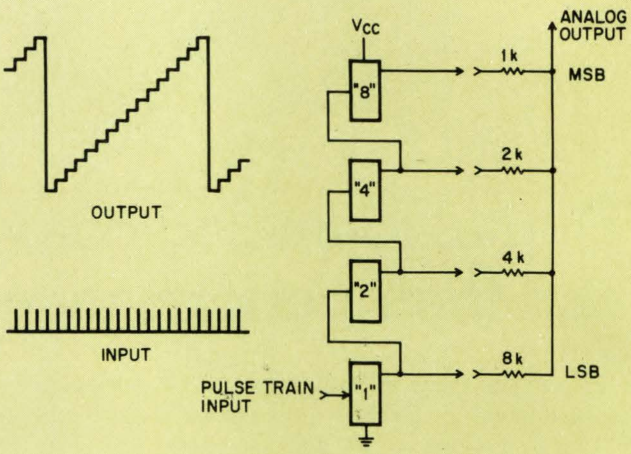


Fig. 1. Simple "four-bit" digital-to-analog converter can be connected to a four-stage binary counter. The complete circuit will generate a sixteen-step staircase.

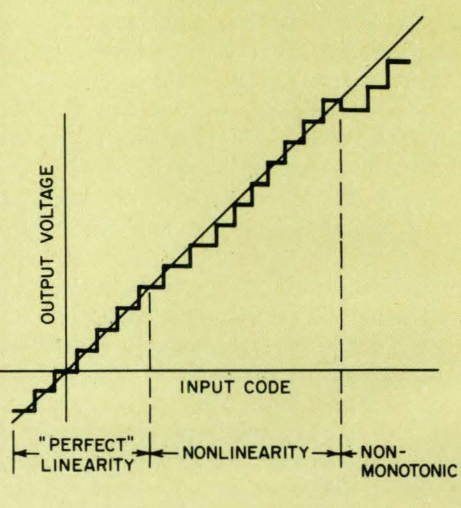
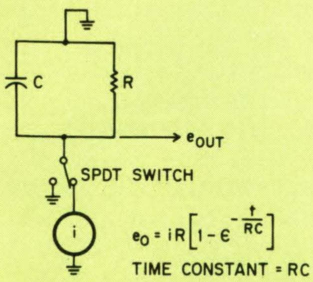


Fig. 2. This staircase output from a DAC demonstrates the meaning of the terms "monotonicity" and "linearity." The DAC is nonlinear over the middle portion of its range and non-monotonic at high outputs.



Number of time-constants	Proportion of final value (%)	Deviation from final value (%)
1	63	37
2	87	13
3	95	5
4	98	2
5	99.3	0.7
6	99.7	0.3
7	99.9	0.1
8	99.97	0.03
9	99.99	0.01
10	99.997	0.003

Fig. 3. The number of RC time-constants in the conversion networks affects the total settling time of a converter. Equivalent circuit shows the effect of a single time-constant.

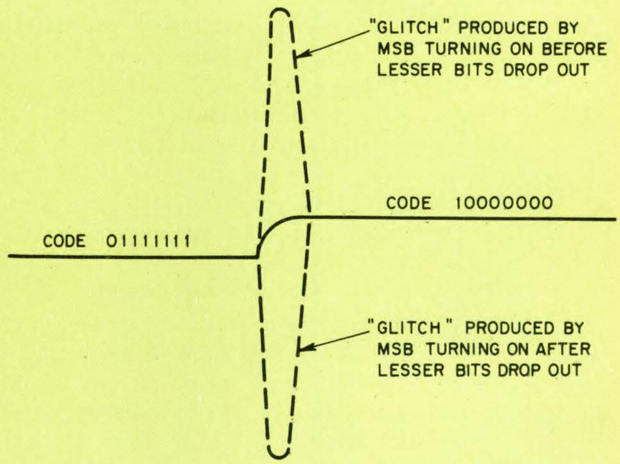


Fig. 4. "Glitches" are analog spikes produced at code transitions as a result of switch-timing discrepancies.

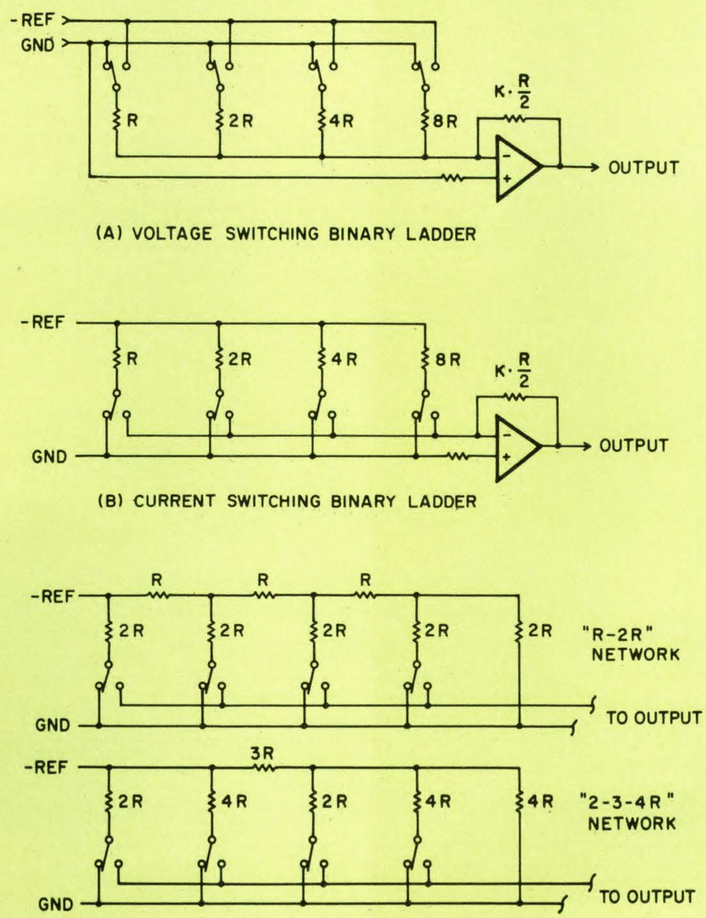


Fig. 5. Various weighting-network configurations illustrated for a four-bit DAC.

at a "major carry," (code point where several bit switches change state simultaneously).

The degree of conformity of the steps to a straight line drawn from zero to full scale is called linearity, (see Fig. 2). Sometimes, a converter that is substantially linear at low speeds becomes nonlinear as it is run faster. This is caused by imbalance in the bit time-constants.

Relative Accuracy. Frequently, DACs are used in applications where absolute accuracy has little or no importance, but where one is concerned primarily with the relationship of each of the code levels to the specific instrument's full-scale reading. Thus, relative accuracy is the only accuracy term of significance for a DAC that is used with an external reference.

Note, however, that the effects of temperature and power-supply sensitivity can often wipe out the apparent competitive advantage of a converter that offers superior relative accuracy.

Settling Time. The settling time of a DAC is the length of time required for the output to achieve its quiescent value within some stated margin (usually 1/2 LSB) following a code change corresponding to full scale or some other stipulated transition. It is a composite of many factors, including output-amplifier (if any) settling time, switching speed and the several RC time constants within the conversion network (see Fig. 3).

Some of these contributing factors can be deceptive. For example, one would be tempted to say that the analog switching speed of our four-bit unit is effectively equal to the digital switching (counting) speed of the flip-flops. However, a close examination of a flip-flop's output will reveal that the output is far from the quiescent analog level at the time when a digital change of state has just been accomplished.

The effect of the RC time-constant in our prototype is more readily calculable. It is simply the equivalent circuit resistance times the capacitance at the output. Even with the low impedances of our circuit, the time constant could easily be a tenth microsecond, or so, with only 200 picofarads at the output. Many commercial DACs employ voltage-switching networks not unlike ours, so we could reasonably expect them to have similar time-constants.

Glitches. Any transient noise spike associated with digital code changes is generally classified as a "glitch," for lack of better catch-all phraseology. In staircase generators, the usual culprit is the associated counter (such as the four-stage unit of our illustration). Quite obviously, a prerequisite for glitch freedom is simultaneity in the various bit transitions — a feature not readily achieved in a ripple-carry counter. Fig. 4 illustrates how the polarity of the glitch depends on the timing of the transitions.

The switches of a practical DAC are generally separate, identifiable, elements, rather than a part of the drive register. Being separate, they will inevitably have measurably different thresh-

Comparison of Some Bipolar Codes for Conversion Circuits

Output Range	Equivalent for Nominal ±10 V Output (12-bit Converter)	BIPOLAR BINARY CODES		
		Offset Binary	Two's Complement	Absolute Value and Sign
		Sign LSB	Sign LSB	Sign LSB
	+10.0000	Overrange	Overrange	Overrange
+FS	9.9951	111111111111	011111111111	011111111111
+FS—1 Bit	9.9902	111111111110	011111111110	011111111110
+ 3/4 FS	7.5000	111000000000	011000000000	011000000000
+ 1/2 FS	5.0000	110000000000	010000000000	010000000000
+ 1/4 FS	2.5000	101000000000	001000000000	001000000000
+ 1/8 FS	1.2500	100100000000	000100000000	000100000000
+ 1 Bit	0.0048	100000000001	000000000001	000000000001
+ Zero	0.0000	100000000000	000000000000	000000000000
— Zero				100000000000
— 1 Bit	—0.0048	011111111111	111111111111	100000000001
— 1/8 FS	—1.2500	011100000000	111100000000	100100000000
— 1/4 FS	—2.5000	011000000000	111000000000	101000000000
— 1/2 FS	—5.0000	010000000000	110000000000	110000000000
— 3/4 FS	—7.5000	001000000000	101000000000	111000000000
— FS + 1 Bit	—9.9902	000000000010	100000000010	111111111110
— FS	—9.9951	000000000001	100000000001	111111111111
	—10.0000	000000000000	100000000000	Overrange

olds than the elements which drive them, and from which they are isolated by one or more delay time-constants. Even with virtually perfect switching devices, it is practically impossible to ensure that all turn-on phenomena will coincide with turn-off phenomena, for all code changes. Lack of switch perfection, (e.g. stored charge, gate-to-drain capacity, etc.) makes the real D/A world very much a glitched one. The designer can minimize the glitches but can never completely eliminate them.

Temperature Stability. There is no fundamental restriction against use of resistors with temperature coefficients in the 500-to-1000 ppm/°C range (carbon composition), provided that all of the resistances that help determine the output level either have identical tempcos (and temperatures) or are of negligible resistance value. Unfortunately, most real-life resistance materials provide tempco spreads of appreciable magnitudes. Even etched thin-film resistor networks on a common substrate have tracking errors. Also, the resistive part of the switching device (for example, the channel resistance of FETs) often enters the picture and usually has a tempco that's much different from that of the switched resistors.

Of course, there are many temperature dependent elements in a DAC in addition to the weighting resistors. Here is a list of some of them along with their typical tempcos:

- Zener Reference Voltage: 2 to 5 ppm/°C
- FET Channel Resistance: 5000 to 10,000 ppm/°C
- Transistor Leakage: doubles every 10°C
- Transistor Beta: 0.5 to 1.0% °C
- Transistor Junction Voltages: approximately 2 mV/°C

These factors, and others, combine to render the reference supply, the output amplifier, the switches and, in short, the entire DAC subject to operating temperature. If one wishes to achieve practical conversion of 13 to 14 bits or more, it is essential to tightly control the more significant temperature dependencies within the converter.

Practical converter arrangements

So far in this discussion, we have deliberately confined ourselves to a circuit configuration that is unlikely to be found in commercial DACs. We did this partly because it provided a simple example of DAC operation and partly because we could criticize it without apparent bias against any manufacturer. Necessarily, our discussion has left many problems unsolved and some unmentioned.

In Fig. 5, we see a few of the typical resistor arrangements that are apt to appear in practical DAC networks. The circuit of Fig. 5(a) is comparable to that of Fig. 1, except that it is shown driving an operational amplifier and is configured from a negative reference to provide a positive output from the amplifier. As in our original circuit, switching results in substantial voltage changes across the resistors and poses a time-constant problem for output settling.

The same logical elements appear in the circuit of Fig. 5 (b), except that the switches now operate between ground and the null point of the op amp. Since the null is also effectively at ground, the current in each of the resistors remains constant, regardless of the switch position. Current switching effectively bipasses one important time-constant that affects settling. It also tends to simplify switch design, since all switch points are effectively maintained at the same potential.

The final two circuits, shown in Fig. 5(c), are repeating dividers. The first and more familiar circuit is commonly known as the "R - 2R" network. Of the two circuits shown in Fig. 5 (c), the "R - 2R" network has the advantage that it needs only two different resistor values. But it has the disadvantage of requiring more resistors than the other circuit. Thus the "2-3-4R" network offers an attractive compromise between complexity and resistance range. The "2-3-4R" network is particularly useful in high-precision multiplying DACs, as it minimizes the phase shift of ac reference signals.

There are myriad other "practical converter arrangements" which have been devised to meet special definitions of practicality. Some were quite impossible to implement when they were first devised mathematically, but a few of these have recently become feasible thanks to the availability of new component types and the upgrading of component performance. The reader is unlikely to encounter any of the serial or indirect converters, and is referred to more specialized texts for their descriptions.

Coding problems

More than one user of DAC modules has been surprised to discover that, while otherwise satisfactory, a purchased DAC didn't provide the positive output voltage that had been expected. Careful inspection of the data sheet, however, would reveal that this subtlety *was* specified.

Because of the trend towards short design cycles, in which a systems designer plugs standard modules into his system shortly before he ships it, "trivia" such as reversed output polarity are becoming increasingly difficult to remedy. Fig. 6 illustrates what should be expected from some common bipolar binary codes. If a manufacturer's data sheet does not provide comparable information it might be well to spell out to *him* the exact requirements.

Obviously, it is not the customer's job to write specification sheets for supposedly standard instrumentation items. It is, however, very much the job of the responsible engineer to know the kinds of specs that are important for a particular type of converter. The engineer can then ask the vendor for additional or more detailed information as needed. If the systems engineer takes the trouble to familiarize himself with DAC theory, this will pay off in on-time systems delivery, freedom from retrofit engineering, and ultimate customer satisfaction. **EEE**

the Bundle.

If you need an LSI part for your new system, bring us your circuit. In about eight weeks, for as little as $15,000, we'll deliver a working MOS/LSI circuit. That's The Bundle, NORTEC Electronics' way of helping you get your feet wet in LSI. We will even bore you with the gory details of how we do it if you like.

But ponder this: When you've bought The Bundle, you own the tooling. You have a jump on the competition. You've saved money and stand to save a lot more when you get into production by putting your parts out for bid.

And nobody will know what you're up to. We won't even ask. Interested? Write. Now.

the world's most widely traveled oscilloscopes!

TEKTRONIX®
committed to progress in waveform measurement

Customer preference has made the Tektronix 453 and 454 the world's most widely traveled oscilloscopes. The reasons are many. Here are just a few!

PORTABILITY: Features which make the going easy include—storage for accessories in a convenient front-panel protective cover; a cover to keep out rain and dust; a vertical handle position makes the carrying easy. The 453 and 454 take rugged trips in stride and arrive ready to work.

PERFORMANCE: With dual channel 1 MΩ inputs, delayed sweep, 5 mV/div, plus many other built-in performance features, you solve problems quickly in the field or in the lab.

OPERATOR EASE: The controls are human engineered to take the guesswork out of triggering, delayed sweep, and other functions—less guesswork means faster measurements.

RUGGEDIZED: Some oscilloscopes are temperamental about severe environments. Not the 453 and 454. Both meet essentially all of the important military environmental specs, without the associated extra cost.

When you make field trips, take along a field-proven oscilloscope designed to travel. Between trips, use the 453 and 454 in the lab. These ruggedized, portable oscilloscopes are designed to solve a vast range of measurement problems with *laboratory precision.* Wherever you are!

For a demonstration in your application, call your local Tektronix Field Engineer or write Tektronix, Inc., P.O. Box 500, Beaverton, Oregon 97005.

453 Oscilloscope $2050
454 Oscilloscope $2925
U.S. Sales Prices FOB Beaverton, Oregon

Available in U.S. through the Tektronix lease plan

See The Tektronix Display At FJCC

EEE Specifying Guide:

Keyswitches And Keyboards

by Jerome Lyman, Associate Editor, EEE

Clouds of confusion hide the important facts about electronic keyboards and keyswitches. The really pertinent things are hidden in a haze of terms like: ASCII, tactile feedback, 2-key rollover, elastomeric contact, tri-mode and many others. Let's lift the clouds.

Problems aplenty face the engineer who needs a keyboard. First of all, he must decide whether to assemble it with keyswitches or to buy a complete system. He will find that there are about a dozen outfits that sell individual switch modules, though some twenty companies manufacture them for their own keyboards. There are 12 different methods of keyboard switching. So let's look at the keyswitch first since it is the heart of the electronic keyboard.

Keyswitches

The most popular keyswitch until 1968 was the reed switch. It is still heavily represented in the keyboard industry. In 1968 Micro Switch brought forth its Hall-effect switch and the resulting industry reaction spawned a swarm of keyswitches. These include photoelectric, saturating-core, capacitive, elastomeric, mercury, reeds with tactile feedback and mechanical switches with tactile feedback. It is best to divide them into two classifications, contacting and non-contacting. The non-contacting types are sometimes called solid-state switches but except for the Hall-effect and optoelectronic types, this is a misnomer.

Contacting keyswitches

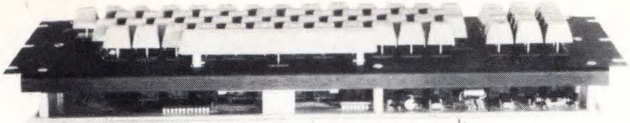
A contacting keyswitch has a physical contact that is alternately made and broken. Here we have the reed switch, the flying-magnet reed (Cherry), Unimax's magnetic-repulsion switch, the mercury-tube switch (Mechanical Enterprises), the elastomeric switch, the crossbar switch and Wild Rover's low-profile mechanical switch.

The "old reliable" of keyswitches is, of course, the reed. Depressing the plunger causes a magnet to activate a reed switch. Releasing the plunger allows a spring to return the magnet to its original position. Eight of the 21 manufacturers in our keyboard directory use reed keyswitches.

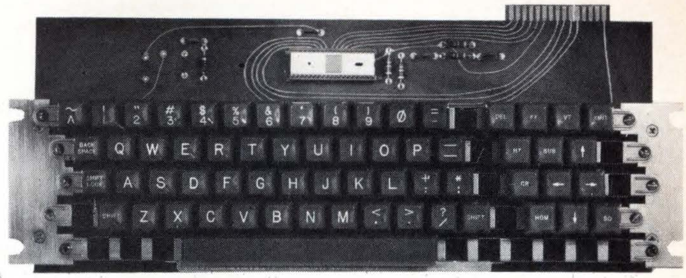
Not all reed keyswitches are the same. Cherry's, for example, uses a "flying magnet" (Fig. 1) to provide a high degree of tactile feedback. Another unusual switch, from Unimax (Fig. 2) uses a "flying magnet," but in a different way and without a reed. Here, depressing the button pushes one magnet past another. The resulting repulsion drives the second magnet up (towards the button), allowing contacts to mate. A spring under the button allows the second magnet to fly back when the button is released. Actuating this switch provides a 1-ms contact closure. So the unit is really an electromechanical one-shot.

Still another approach uses a mercury-filled tube as the contact. The unit is Mechanical Enterprises' Mercutronic switch (Fig. 3). If the key is up, a plunger finger pinches off the mercury tube. This effect removes voltage from

These are all ASCII keyboards



Cherry



Clare-Pendar

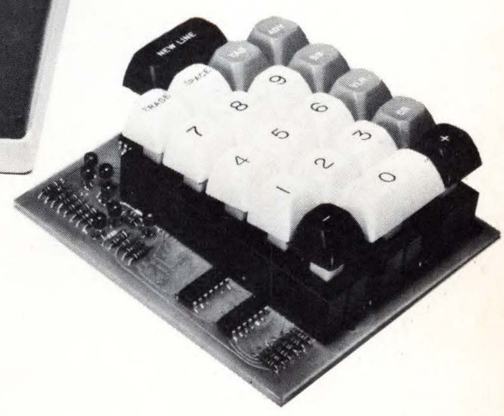
Controls Research

Electrol

Licon

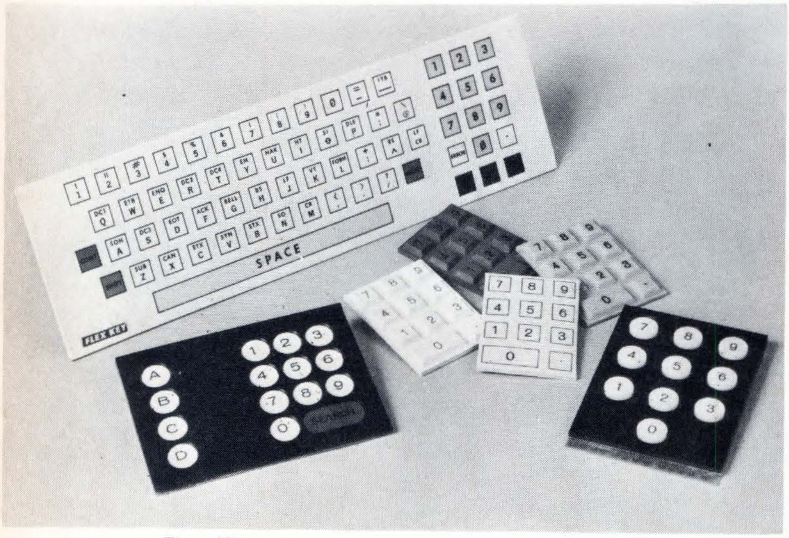
Optoelectronic-ASCII keyboard from TEC

Micro Switch keyboards with 63-key ASCII MOS encoding (foreground), 78-key ASCII DTL encoding (top), and 51 key EBCDIC MOS encoding.



Keytronic's numeric-entry keyboard has ASCII coding. This board has reed key-switches.

Low-profile keyboards from Flex Key, Wild Rover and Datanetics. The board in the rear of the Flex Key photo is an actual keyboard, not a front-panel illustration.



Flex Key

Wild Rover

Datanetics

eleven diodes mounted in the housing. Depressing the key moves the plunger finger away, permitting the mercury tube to act as a conductor. Voltage is now applied through the mercury to the common cathodes of the diodes. This switch is among the few coded types. It has zero contact bounce.

Elastomeric switches

Elastometric switches are newcomers to the keyswitch battleground. Three companies (Flex Key, Chomerics and Datanetics) have elastomeric types — but each is different. In Flex Key's version (Fig. 4), pushing down a neoprene button forces a conductive-elastomeric membrane against a contact grid on a PC board. This contact gives a relatively high-resistance, uncoded closure. However, this switch has one of the lowest profiles available.

Datanetics uses a slightly different technique (Fig. 5). Depressing a key joins the conductive plating of the diaphragm and a printed-circuit land through a hole in a dielectric separator. Here the elastomeric membrane is simply used as a spring, not as a contact.

The Chomerics switch (Fig. 6) is encoded. It's completely plastic except for the PC conductors. Unlike its competitors, it has a snap-action return. Pushing the plunger down forces a conductive elastomeric contact (silicone with a metal suspension) against encoding pads on a PC card. This action causes an encoded output and compresses two spring washers. The stored energy of the springs is used to restore the plunger to its starting point.

Non-contacting switches

The leader in this category is Micro Switch's Hall-effect device, introduced in 1968. Depressing the button moves a magnet close to a Hall-effect sensor whose output is amplified by an IC. In 1968, the output of the device was a constant dc level as long as the button was depressed. But Micro Switch didn't stand still in the face of hungry competition. The company is about to introduce a version (Fig. 7) that generates a less than 1-ms pulse. This gives Micro Switch's keyboards n-key rollover capability.

A saturating core is used by old-line switch maker, Licon, who's betting on the high inherent reliability of ferrite-core components. Fig. 8 depicts the Licon approach. The switch has a key, a plunger with self-contained magnets, a return spring, a housing and a magnet coil with dual windings. In the up position, the plunger magnets saturate the toroidal transformer, which reduces the output signal to zero. When the key is depressed, the magnetic field is removed from the vicinity of the toroid, causing it to act as a transformer. A signal can now be coupled through the transformer windings. This voltage can be rectified and used to drive IC logic.

The remaining non-contacting contenders are: Control Devices' E-coupled switch, Digitronics' photoelectric switch and TEC's optoelectronic switch. The E-field or capacitive switch is shown in Fig. 9. In this unit, depressing a plunger causes capacitive coupling between the plunger

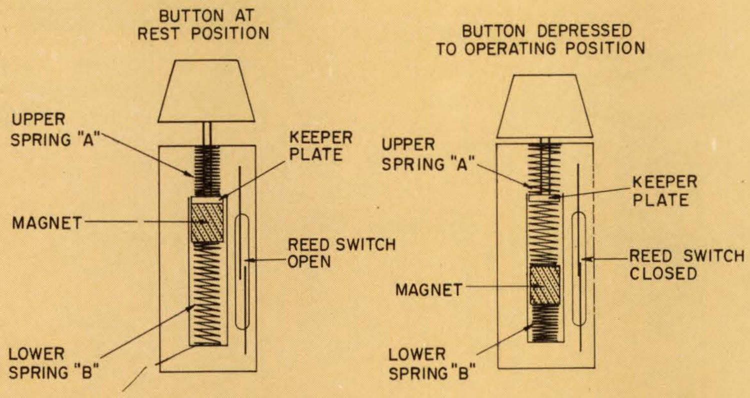


Fig. 1. Cherry's "flying magnet" keyswitch has tactile feedback and an audible click.

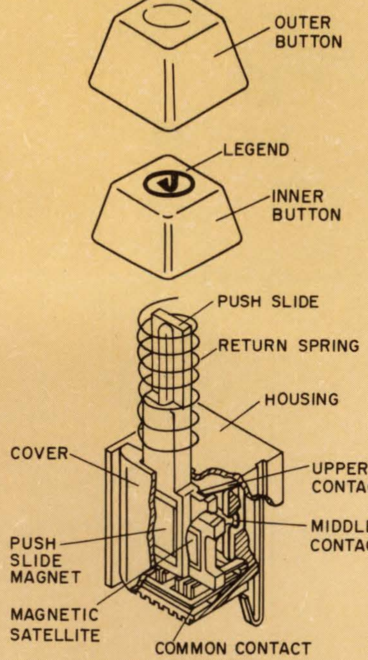


Fig. 2. Unimax's magnetic repulsion switch uses no reed but a magnetic satellite. The switch has tactile feedback with an audible click and puts out a 1 ms pulse per each actuation.

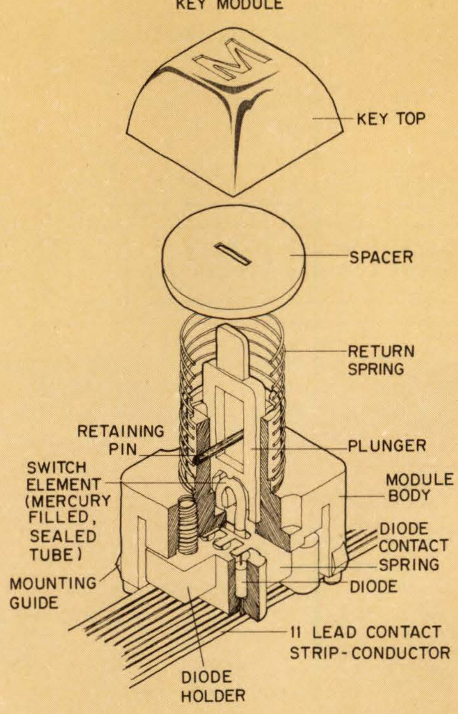


Fig. 3. This bounceless keyswitch, designed by Mechanical Enterprises, uses a mercury-filled tube as a conductor. This is an encoded switch.

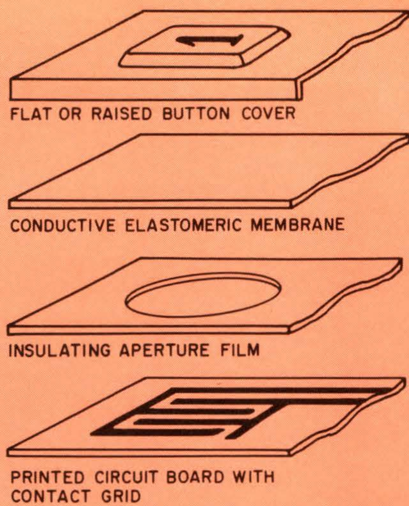


Fig. 4. This exploded view shows the novel construction of a Flex Key elastomeric keyswitch.

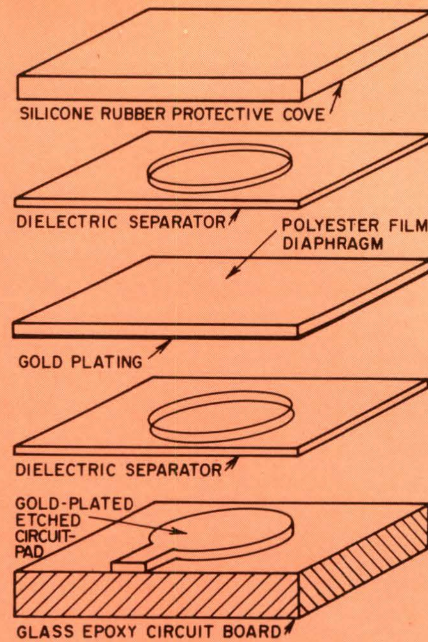


Fig. 5. In the Datanetics switch, a conductive foil and a PC land form a contact.

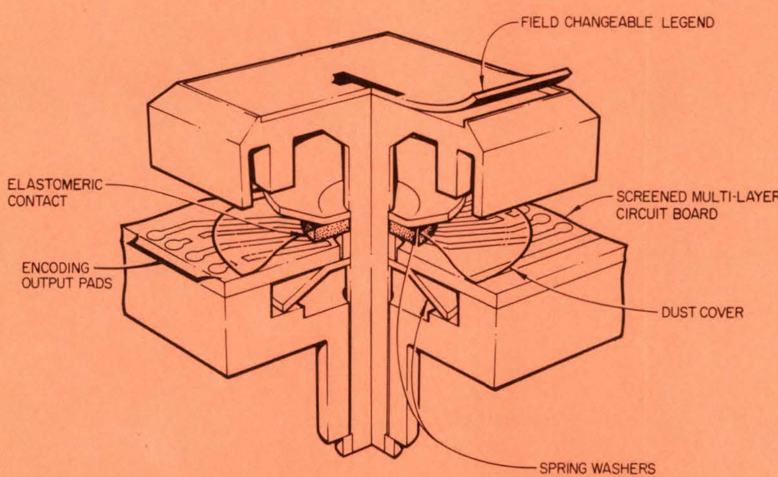


Fig. 6. The Chomerics elastomeric switch has a snap-action return and is encoded.

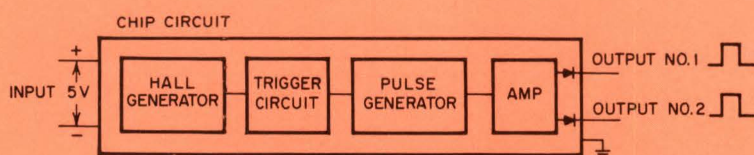


Fig. 7. Micro Switch's new Hall-effect chip now gives a momentary, less than 1-ms delay. This new design has added a pulse generator to the already existing circuitry.

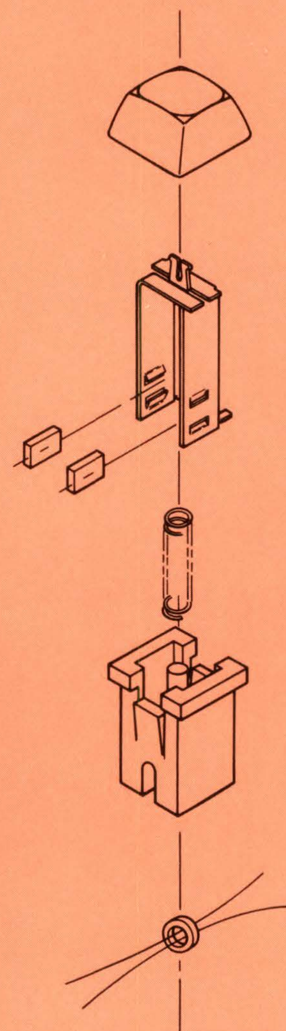


Fig. 8. A ferrite core is the heart of Licon's entry into the keyswitch arena.

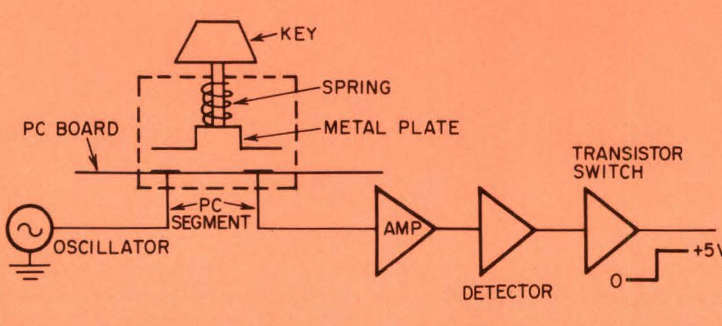


Fig. 9. This diagram depicts a simplified schematic of Control Devices' keyswitch.

plate and two conductive segments on a PC card. One of the segments is a common oscillator bus and the other contains signal-shaping circuitry for each key. The coupled signal is converted to a low dc logic level. The Digitronics keyswitch has a key-actuated shutter that interrupts light beams. The resultant light pattern is detected by photocells. This is a coded key containing up to 14 bits.

Keyswitch claims and counterclaims

The keyboard manufacturers who use reed switches claim many advantages — no stand-by power, long life, sealed contacts, easy and readily available replacement, high stability, multipurpose switching and, in the case of Cherry and Unimax, good tactile feedback. The only drawback they admit to is switch bounce, which can be minimized by keyboard circuitry.

The elastomeric newcomers also have their selling points. They claim bounceless operation, long life, low price, low profile and completely sealed or waterproof construction. However, they admit such disadvantages as high contact resistance, "different feel" (compared to an electric typewriter) and a relatively short history.

Manufacturers of non-contacting keyswitches point to other advantages — no bounce, long life, high reliability, low rfi, easy interfacing with standard logic, no degradation with time and no variation in contact resistance. The non-contacting types have two basic disadvantages. They have high standby current drain and each keyswitch has some discrete or integrated circuitry associated with it, causing a high degree of complexity.

How to specify a keyswitch

Our directory of keyboard switches points up an interesting fact. Every keyswitch manufacturer willing to sell individual switches sells only reed or mechanical types. No manufacturer of solid-state or non-contacting types is willing to sell individual switches alone. Instead, the solid-state people sell keyboards only. Therefore to specify a keyswitch, think in terms of electromechanical switches.

There really are only a few crucial specs for a keyswitch. Certain terms, like life expectancy, contact resistance and bounce have really been overemphasized. Most vendors feel that very few keyboards will experience more than a million operations in their normal life. However, if a particular application has greater than a million operations in its expected life, select your keyswitch accordingly. Switches are usually interfaced with DTL, TTL or MOS. Any competent designer can decide what the limits of contact resistance are, knowing the electrical characteristics of the logic used. Bounce, another bugaboo, is relatively simple to remove electrically (with a filter or delay).

The main specs for a keyswitch are operating force, stroke, reliability, replaceability and price.

Keyswitches interface mechanically with humans — not machines. Therefore, the touch of the switch is extremely important, so we have to watch the force and stroke.

Reliability rather than life, is another important factor. Reliability is life at a specific load whereas many "life" specs are at virtually no load.

Since the engineer who buys keyswitches is assembling his own keyboard, he needs from 12 to 128 keys per unit. If he has any sort of production run, key pricing will be vital. Switches cost 75 cents to $5.00, depending on quantity and type.

Keyboards

What is a keyboard? This question can get varying answers in this new industry. We can define three different types.

We can call the first type a keyboard array. This is simply a collection of uncoded switches for the engineer who wants to design his encoding circuitry. We can call the second type a coded keyboard array. Here, outputs are not simple switch closures, but binary-coded outputs. An example of this type is the Chomerics unit. We can call type 3 a keyboard system. This consists of a keyboard array, a coding matrix, circuitry for keyboard modes and output buffers. This type is typified by units from Micro Switch, Clare-Pendar, Cherry and Licon. The directory of keyboard manufacturers uses this system of classification.

The tactile-feedback controversy

Anybody who has ever operated a typewriter knows that he "senses" when he has hit the key adequately. He hears a click; he hears the type bar strike the paper; and, most important, his fingers tell him when he's gotten through. In an electric typewriter, this takes the form of increasing force with the increased key travel, followed by an abrupt dip in the required force. That sharp change is called tactile feedback.

The industry has three approaches to this problem. One approach involves trying to imitate the feel of the keys on an electric typewriter. Another approach ignores the problem with the assertion that it's not really important and that, perhaps, it will go away. And still another, used by most manufacturers, is a compromise between these extremes. This approach involves using a relatively large force that increases to about three ounces, but with no abrupt change in the force required.

Switches with the worst tactile feedback (or none) generally have virtually no key travel, so their proponents talk about other features (like extremely low profile).

Tactile feedback is very much a subjective matter. You can stare at curves (force-travel curves) all day long without much help. It can be a good idea to feel the switch.

Micro Switch, one of the leaders in the keyboard business, does not feel that tactile feedback is necessary. This opinion is based on three studies by Deininger and Bowen.

In an article in *Industrial Design* (May 1964), Dr. Hugh Bowen stated ". . . the dip is probably not required and may be detrimental to achieving speed on the keyboard." R. L. Deininger, in the *IRE Transactions on Human Factors in Electronics* (March 1960), reported, "Snap action, audible tones and hard bottoming in the button mechanism also did not have any appreciable effect on performance." For these reasons Micro Switch does not offer tactile feedback but rather, a 3-oz operating force, and most keyboard manufacturers go along with this approach. Nevertheless, Micro Switch and others will provide click generators to those who feel this kind of audible feedback is useful.

The two leading proponents of tactile feedback, Cherry and Unimax, go further in simulating the feel of an electric typewriter. They provide an audible click at the moment of switching.

Replaceable keyswitches?

Another area where keyboard manufacturers disagree is on whether keyboard switches should be replaceable. On the whole, reed and electromechanical switches are easy to replace. The new breed (Micro Switch, Control Devices, TEC, Digitronics) are not really replaceable. Micro Switch's Hall-effect key, for instance, must be unsoldered from a PC board.

The Mechanical Enterprises Mercutronic switch and the Chomerics elastomeric switch are secured with screws and are easy to replace. The other two (Datanetics and Flex Key) elastomeric-switch manufacturers have made almost monolithic keyboard arrays. In this arrangement the entire array must be removed in case of a malfunction.

Which button?

One of the less earthshaking controversies in the industry involves the choice of button, or keytop. The most popular type uses two-shot molding, wherein the legend is molded in the first shot and the outer body of the button is then molded around it. This makes for enormous wear resistance in the legend, but it's costly and time consuming. So if you need a special legend, you'll have to wait.

A newer approach involves one-shot molding for the button, whose top and sides are covered and protected by a tight-fitting, transparent shell. A Mylar insert, between the shell and button, contains the printed legend. This makes for a less-expensive keytop.

Another approach uses a Mylar legend label, glued onto the one-shot button, without a protective cover. In still another approach, (low profile) the legend is silk-screened on the bottom of a thick sheet of transparent Mylar.

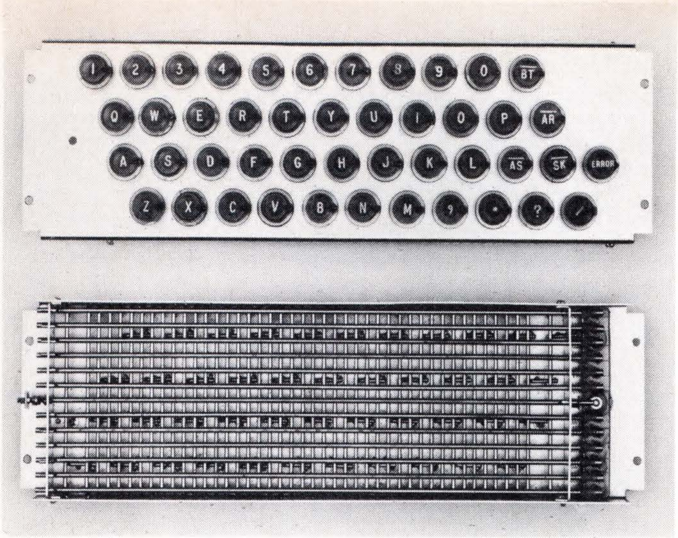
Vital keyboard specifications

It's easy to get lost in the maze of terms you find in a typical keyboard spec. These terms are a mixture of typewriter terminology, logic formats, electromechanical terms, communication coding and even a few words that are exclusive with electronic keyboards. But the biggest error engineers make in specifying boards is not on any data sheet. It's insufficient attention to to human factors. We have to ask ourselves a few questions:

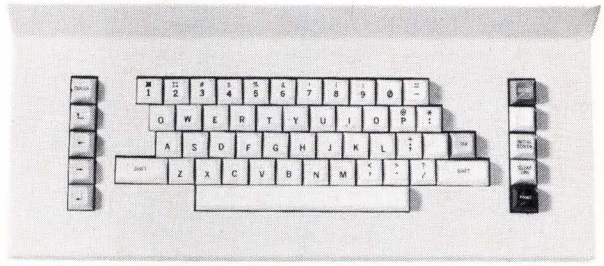
1. Is the operator skilled (typist) or unskilled (clerk, technician, engineer)?
2. Is tactile feedback required or will the common 3-oz resistance do?
3. Could a low-profile (poor "feel") board do in this application?
4. Is the keyboard layout satisfactory?
5. Will there be excessive reflection from keytops?
6. What environment will the board be operated and stored in?

Codes and modes

ASCII (American Standard Code for Information Interchange) is the most popular keyboard code and is used in graphic terminals and for interfacing with computers. It is a seven-bit code that has been adopted as a Federal Standard (USASCII).



This keyboard (Computronics) uses crossbar switching for encoding.



Raytheon uses hermetically sealed reed switches in this keyboard.

Table 1 — Directory of Keyboard Switches

Company and Reader Inquiry No.	Model	Type	Force (oz-nom)	Stroke (in.)
ALCO Lawrence, Mass 01842 **405**	RSM-41	reed	1.2	0.140
CHERRY 3600 Sunset Av Waukegan, Ill 60085 **406**	20	reed with flying magnet	2.5	0.187
CLARE-PENDAR P.O. Box 785 Post Falls, Idaho 83854 **407**	S820	reed	3	0.150
CONNECTICUT TECHNICAL 3000 Main St Hartford, Conn 06120 **408**	NA	reed	1.4	0.156
ELEC-TROL 21018 Soledad Canyon Rd. Saugus, Calif 91350 **409**	KA1001	reed	2.1	0.200
GEORGE RISK 802 S. Elm Kimball, Neb 69145 **410**	KB-01J-01	reed	2.5	0.175
MICRO SWITCH Freeport, Ill 61032 **411**	NA	reed	3	0.187
OAK Crystal Lake, Ill 60014 **412**	400	lever leaf	4.4	0.125
RAYTHEON 465 Centre St Quincy, Mass 02169 **413**	MC182B	reed	2.5	0.156
TEC 6700 South Washington Av Eden Prairie, Minn 55343 **414**	101	mechanical	2.5	0.170
UNIMAX Wallingford, Conn 06492 **415**	digital switch module	magnetic repulsion	4	0.190

Table 2 Directory of Keyboards

Company and Reader Inquiry Number	Model	Switch type	Key force (oz)	Key stroke (in.)	Kbd type	Number of keys	Operating modes	Output coding	Two-key rollover	N-key rollover
ALCO Lawrence, Mass 01842 **416**	SB-032	R	5	0.21	ka	9-12				
CHERRY 3600 Sunset Av PO Box 718 Waukegan, Ill 60085 **417**	custom	Rf	2.5	0.188	ks	52-65	1, 2, 3	ASCII-S EBCDIC-O BAUDOT-O HEX-O BCD-O	S	O
CHOMERICS 77 Dragon Ct Woburn, Mass 01801 **418**	12ES	E	2	0.080	kac	12		ASCII-S BCD-S		
CLARE-PENDAR PO Box 785 Post Falls, Idaho 83854 **419**	K353	R	2.5	0.187	ks	53	1, 2, 3	ASCII-S EBCDIC-O BAUDOT-O HEX-O BCD-O	S	
	708-106	R	2.5	0.187	ks	12-16		HEX		
COMPUTRONICS 4949 Hollywood Blvd Los Angeles, Calif **420**	H-600	Cb	5	0.060	kac	45		ASCII-S BCD-S EBCDIC-S BAUDOT-S HEX-S		
CONN TECHNICAL 3000 Main St Hartford, Conn 06120 **421**	302	R	1.4	0.156	ks	59		ASCII-S BCD-O EBCDIC-O BAUDOT-O HEX-O	S	
CONTROL DEVICES 204 New Boston St Woburn, Mass 01801 **422**	CDK	Cap	3	0.170	ks	125	1, 2, 3	ASCII-S BCD-S EBCDIC-S BAUDOT-S HEX-S	S	
CONTROLS RESEARCH 2100 S Fairview Santa Ana, Calif **423**	S6A01180	R	2	0.156	ks	56	1, 2, 3, 4	ASCII	S	
DATANETICS 2828 Spreckels Lane Redando Beach, Calif 90278 **424**	DC151	E	3	0.187	ks	64	3	ASCII	S	
	DC131	E	3	0.187	ks	49	2	EBCDIC	S	
	DC401	E	3	0.187	ka	16				
DIGITRONICS One Albertson Av Albertson, NY **425**	PK200	Pe	2-4	NA	ks	48, 64, 75	1, 2	custom	S	
ELECTROL 21018 Soledad Canyon Rd Saugus, Calif 91350 **426**	KB1007-000	R	2.1	0.200	ks	62 plus space bar	3	ASCII	S	
	DCD	R	2.1	0.200	ka	9-16				
FLEX KEY 1277 Main St Waltham, Mass 02154 **427**	DK-IM	E	2.5	.020	ka	11				
	DK-IL	E	5	.003	ka	11				

EBCDIC (Extended Binary-Coded-Decimal Interchange Code) is an eight-bit code that's very popular with IBM. It is used in key-punch and key-to-tape applications. It is second in popularity to ASCII.

Baudot is a five-bit alphanumeric code used primarily for Teletype. It is named after the inventor, a French army officer.

ASCII keyboards can have four modes: mono, dual, tri and quad. Mono-mode offers only one mode of operation, such as normal with no shift capability. Dual-mode offers normal and shifted codes (for, say, lower- and upper-case letters). Tri-mode offers normal, shift and control functions. Quad-mode offers two sets of control functions as well as normal and shift. In general, multimode refers to the assignment of more than one coded character to the same key.

2-key and n-key rollover

A term that commonly appears in keyboard specs, 2-key rollover, refers to an electronic cir-

Table 2 Directory of Keyboards

Company and Reader Inquiry Number	Model	Switch type	Key force (oz)	Key stroke (in.)	Kbd type	Number of keys	Operating modes	Output coding	Two-key rollover	N-key rollover
IDM PO Box 954 Hanover, NH 03755 **428**	ANK	R	NA	NA	ks	16		ASCII		
KEYTRONIC Bldg 14 Spokane Ind Park Spokane, Wash 99216 **429**	video terminal	R	3	0.171	ks	68	1, 2, 3, 4	ASCII	S	O
	numeric entry	R	3	0.171	ks	20	1	ASCII	S	
LICON 6615 Irving Park Rd Chicago, Ill 60634 **430**	550	Fe	2.5	0.187	ks	63 typ	1, 2, 3	ASCII-S BCD-S EBCDIC-O	S	
MECHANICAL ENTERPRISES 5249 Duke St Alexandria, Va 22304 **431**	200-0065	Hg	2.1	0.187	ks	65 typ	1, 2, 3, 4	ASCII-S BCD-S EBCDIC-S BAUDOT-S HEX-S	O	
	BCD Keyboard	Hg	2.1	0.187	ka	10-12		BCD		
MICRO SWITCH 11 West Spring St Freeport, Ill 61032 **432**	51SW5-2	H	3	0.187	ks	51	1, 2, 3, 4	EBCDIC	S	O
	63SW5-2	H	3	0.187	ks	63	1, 2, 3, 4	ASCII	S	O
	78SW	H	3	0.187	ks	78	1, 2	ASCII	S	O
	16SW3-1	H	3	0.187	ks	16				
RAYTHEON 465 Centre St Quincy, Mass **433**	custom	R	2.5	0.156	ks	55-90	1	ASCII-S EBCDIC-S	S	
TEC Box 6191 Minneapolis, Minn **434**	NA	Pe	2.5	NA	ks	47	1, 2	ASCII	S	
UNIMAX Ives Rd Wallingford, Conn **435**	NA	Mf	4	0.190	ks	custom	1, 2, 3	ASCII-S BCD-S EBCDIC-S BAUDOT-S HEX-S	S	
WILD ROVER Herbert Av Closter, NJ **436**	custom	M	1.2	0.002	ka	custom				

Keyswitch type: Cb-crossbar, **R**-reed, **H**-Hall-effect, **Pe**-photo-electric, **M**-mechanical, **E**-elastomeric, **Hg**-mercury switch, **Rf**-reed with tactile feedback, **Mf**-mechanical with tactile feedback, **Fe**-ferrite core, **Cap**-capacitive.

Keyboard type: ka-uncoded array, **kac**-coded array, **ks** keyboard system consisting of an array, coding. buffering and 2-key rollover.

Operating modes: 1-mono **2**-dual, **3**-tri, **4**-quad.
Notes: S-standard, **O**-optional, **NA**-not available.

cuit to prevent false code generation when two keys are momentarily depressed "simultaneously." The 2-key rollover feature is standard or optional on all complete keyboard systems.

But is 2-key rollover enough? A fast typist can sometimes hit three or four keys "simultaneously." Will 2-key rollover protect us from error then? No. As a result, we're beginning to see more and more keyboards with n-key rollover, an extension of 2-key rollover that allows code generation only from the first key (and not from subsequent keys until the first key has been released). Thus far, four vendors (Cherry, Micro Switch, Keytronics and Unimax) offer n-key rollover.

Price

Keyboard prices range from about $80 to $350. But the keyboard business is mostly custom and it's hard to get a firm price without firm specs. Most prices must be negotiated. **EEE**

More On "How Accurate Is

By Endel Uiga

EEE did it again. It opened the bag and let the ghost out. Let's see if it can be contained or tamed. It is by no means a simple matter because I am talking about instrument specs.

Starting with the article "How Accurate is the Accuracy Statement" in May 1969 and continuing to the Speak Out by Doug Strain in November, I find it hard to forget the countless hours of discussion and argument over the same problem with dedicated engineers working on United States Standard on Electronic Analog Voltmeters.

Specs inadequate, but needed

Let's clarify my position first. It's true that instrument specifications are somewhat limited and are an inadequate means to describe the properties, or even more, to certify the quality of an instrument. Nevertheless, a better way has not been established. To be realistic, we had better assume that specs and specsmanship will stay with us for some time.

Only one thing seems certain: there are as many ways to specify accuracy as there are committees working on the problem, or manufacturers specifying instruments. By writing this, I am sure that I am again setting the stage for arguments and different points of view. Nevertheless, this step should be taken because good arguments are needed to clarify the subject and to consolidate thinking in the field. I would like to set forth the ideas with which we agree in our committee, and which I think have merit, and which are different from the two approaches described in *EEE*'s articles.

The first, what may be called a "conservative approach," is a method where possible uncertainties of all error sources at their worst circumstances are summed to a worst case. This is then called the instrument accuracy. This approach seems a very fair one, especially to the user. He is guaranteed that his error will not exceed the accuracy limit.

First approach too costly

A deeper analysis of the situation reveals, however, that this is also a very costly approach. The environmental or external parameters which result in the maximum possible measurement error very seldom appear. Under normal use a high safety factor is implied and the full capability of an instrument is not used. When the user needs a more accurate measurement he has to choose a more accurate instrument, which invariably is more costly, even when the original instrument may have given satisfactory results under favorable conditions.

Accuracy costs money, and the cost increase is more exponential than linear. A second difficulty arises when one has to verify accuracy. A sophisticated instrument has at least a half-dozen factors contributing to accuracy. Combinations and permutations of those factors result in a considerable number of measurements if one really needs to find the maximum possible error. That is also costly!

The second approach may be called the "statistical approach." It takes into consideration the fact that the worst possible case of error combinations seldom occurs. To account for this, the error sources are considered random variables and are added in a statistical or "rms" manner. This, instead of a maximum error limit, gives an accuracy with certain confidence limits which is supposed to be used as the accuracy of an instrument.

Second approach too lenient

This approach certainly overcomes the undue conservatism of the first approach, but it leaves the user wrestling with other dilemmas. The most severe may be that the requirement of present industry will not be satisfied with the statement, "I think my accuracy is probably within these limits." I personally know several government inspectors who will not buy that. Moreover, to verify the accuracy of an instrument would be even more complicated than with the first approach. The whole history of an instrument run may have to be investigated to find the statistical distribution of error.

Finally, as stated by Dr. Thomas of NBS, the whole philosophy behind this approach is questionable. There are many measurements, especially at the very limit of the art, where the measurement accuracy is limited by precision or by some other random occurrences. This is not the case with commercial and laboratory instrumentation. The accuracy of these instruments is determined mostly by known systematic error sources with the error pattern repeating itself measurement after measurement, and even from one instrument to the other. To combine those errors in the rms manner would be inexcusable.

Third approach thorough

Let's now look at the third method of accuracy specification. This is the method which, after long deliberation, is proposed by ANSI, the American National Standards Institute (formerly USASI, United States of America Standards Institute, and earlier, ASA, American Standards Association), in its Committee C39.7 on electronic analog voltmeters. Let's call

---

Author: Dr. Uiga is product engineering manager of Boonton Electronics in Parsippany, N.J.

The Accuracy Statement"

this a "thorough approach."

It is worth mentioning that its basic philosophy agrees with IEC (International Electrotechnical Commission) Subcommittee 13C on electronic measuring instruments. It recognizes the fact that a complex characteristic, like accuracy or error pattern of an instrument, cannot be adequately described with one figure. This is not an uncommon situation. My wife recognizes this when ordering our living room carpet by two dimensions, 14′ by 22′, instead of one figure 308 sq. ft. This incidentally, would have been satisfactory for determining the price of the carpet even if the carpet received had not fit our living room.

The approach first establishes a starting point for all accuracy determination, starting with the instrument accuracy under controlled environment conditions called "reference conditions," which is a typical environment found in a standards or instrument laboratory. Typical reference conditions might be: ambient temperature, 23°C; power supply ±1% normal; relative humidity 10-55%. Accuracy achieved under those conditions is called instrument "class" accuracy and can be advertised as such.

Now it's time to hide behind the barricades because I can see the rocks, eggs and bottles whirling in my direction, and hear passionate cries, "Unfair, What good is it? Who uses an instrument under those conditions? Manufacturers' gimmicks!," etc.

This accuracy rating is not meant to be the user's available accuracy and it should be so stated loudly and clearly. Its purpose is to describe the quality class of an instrument and, more importantly, to establish a common reference plane or starting point for all measurements and calibration. It allows the user to check the instrument in Incoming Inspection and come up with the same figures as did the manufacturer without a doubt about measurement conditions. It allows comparison of the calibration between standardizing laboratories and tells the user the best possible accuracy which can be achieved with the instrument. It is useful information because sometimes, to make a highly accurate measurement, it is more economical to control the environment (in an air-conditioned room) than to buy a more accurate instrument.

To make the accuracy statement usable, the Standard proposes two additional criteria: First, the accuracy has no meaning when it is not accompanied by corresponding stability. Performing a calibration or stating an accuracy is really an attempt to predict the future. It tries to say that if an instrument is calibrated and found to be within the specified limits, future measurements, during a certain time period, are also probably within the specified accuracy limits.

To take this thought into account, Standard C39.7 sets the first additional condition of meeting an accuracy class: the stability of the instrument should be such that it stays in calibration over 500 operating hours, or at least a period of three months. Second, the effects (or "influences," as they are called in the Standard) of changing environmental parameters should be known and their magnitude should have definite limits. The Standard recognizes this situation by defining another set of environmental conditions called "normal operating conditions." These have wider limits of external parameters, like: supply voltage, ±6% of normal; temperature, 18-30°C; relative humidity, 10-75%.

Under these conditions the accuracy is allowed to deteriorate from reference accuracy by a maximum possible amount. For example: line-voltage effect, 25% of class accuracy; temperature effect, 50% of class accuracy; humidity effect, 25% of class accuracy. Thus, an instrument specified as 1% accurate under reference conditions may be a 2% instrument under normal operating conditions if all the environmental parameters deviate to the allowed extremes and the additional errors are such that they are all additive. Similar type of limits could be used to describe other parameters like linearity, noise effect, etc.

This specification approach also tries to ensure that the instrument is stable and has somewhat equal characteristics toward environmental parameters.

Two sets of figures, as described in the Standard, give an engineer a powerful tool for using the instrument to its accuracy limit. If he is working under environmental conditions in which only one of the parameters deviates from the reference value, the additional degradation of accuracy is easy to compute, more so if the manufacturer assigns a specific value to the effect instead of using maximum limits set by the Standard. It's true that the proposed approach to accuracy is more complex than we are accustomed to dealing with, but we are in an age when the simple approach sometimes doesn't work; especially when one is reaching for the moon.

Needless to say, the Standard is somewhat more extensive in that it also sets limits for "severe operating condition," describes test conditions, etc. I think, however, I have opened enough doors for arguments and counter arguments and the best thing to do is to stop, look and listen. **EEE**

Computer Microtechnology has ROMS,

MOS/LSI

RAMS, and

BIPOLAR AND MOS/LSI

REGISTERS

SILICON GATE MOS/LSI

to elaborate:

	ROMS	RAMS	REGISTERS
BIPOLAR LSI	**CM 2800** 1024-bit (128x8) high speed (50 nsec access) TTL ROM. Low power (400 mW typ.) OR-tieable outputs. Two chip-select inputs for ease of expansion. Turnaround: 4 weeks from customer's pattern to delivered parts. In 24-pin DIP. Price: under 2¢/bit in volume. **CM 2850** 1024-bit (256x4) ROM. Same as CM 2800, except comes in 16-pin DIP. **CM 2900** 1120-bit (224x5) high speed TTL character generator. Low power (400 mW typ.) 50 nsec access. Designed for 5x7 or 7x10 dot matrix; standard font for ASCII code. Customs available.	**CM 2100** 64-bit (16x4) high speed TTL scratchpad memory: access 60 nsec max.; minimum write pulse width, 35 nsec max. Fully decoded. OR-tieable outputs. Memory expandable by chip-select input. Packaged in 16-pin DIP. **CM 2150** 256-bit (256x1) TTL RAM. Fully decoded with three chip selects. (A world's first.) Easy to expand. Fast: 74 nsec typ. High speed chip select makes it pre-addressable. Low fan-in. In 16-pin DIP.	WHO NEEDS 'EM?
MOS/LSI	COMING SOON: 1024-bit 2048-bit 2240-bit 2560-bit 4096-bit	**CM 2400-Series** 4096-bit (4k x 1, 2k x 2, 1k x 4) read/write multi-chip memory module. Best of both MOS and bipolar worlds. TTL input and outputs. Static operation; no refresh needed. Operates asynchronously with minimum support electronics. In 26-pin DIP. **CM 1101** 256-bit (256x1) MOS read/write memory. Speed: 1 μsec access. OR-tieable outputs. Fully decoded. Price: less than 5¢/bit in volume.	**CM 1402** Quad 256-bit dynamic shift register. Low power: .1 mW/bit at 1 MHz. DTL and TTL compatible. Operates up to 5 MHz clock rate. Uses low-threshold silicon gate technology. In 16-pin DIP. **CM 1403** Dual 512-bit register. Same features as CM 1402, packaged in low-profile 8-lead TO-5. **CM 1404** Single 1024-bit register. Same features as CM 1402. In low-profile 8-lead TO-5.

For information about any of our ROMS, RAMS, or REGISTERS, circle the bingo card number or call us collect at (408) 736-0300, (617) 891-0002, or (714) 835-8323. For delivery, call our distributor in your area: Kierulff, K-Tronics, F-J-R Electronics, or Schley Electronics. Computer Microtechnology, Inc., P.O. Box 7050, Sunnyvale, CA 94086.

National m popular devi Signetics and put together.

What do we mean by popular? We mean popular: National makes all the bipolar digitals, linears, hybrids, transistors and J-FETS most companies use most of the time. And we make them in all the popular packages.

Who determines our line? Our customers. Primarily systems designers. Guys with common needs and custom needs. We fill the common needs with the devices we all know and love. And, we find a way to turn custom problems into more common solutions. Which means we wind up with most of the devices you're most likely to put on your own parts list.

Which makes us the logical first stop when you've got a new list of parts to buy.

Or, if you already have a good first source, give us a shot at seconds.

When you use National **National.** as a second source, you don't have to shop around for a third source.

akes more ces than TI, Fairchild

- Bipolar Digital Circuits
  - TTL
    - 54N (T.I.)
    - 74N (T.I.)
    - 54LN (T.I.)
    - 74LN (T.I.)
    - 74H (T.I.)
    - 54J (T.I.)
    - 54L (T.I.)
  - MSI
    - Popular 7400 (T.I.)
    - Popular 9300 (FSC)
    - Popular 8200 (Sig.)
  - DTL
    - 830 (Mot)
    - 930 (FSC)
- Linear
  - Amplifiers
    - 703 (FSC)
    - 709 (FSC)
    - 741 (FSC)
    - 747 (FSC)
    - 748 (FSC)
    - CA3028 (RCA)
  - Comparators & Sense Amps
    - 710 (FSC)
    - 711 (FSC)
    - SN5520 Series (T.I.)
    - SN7520 Series (T.I.)
  - Regulators
    - 723 (FSC)
- Hybrids
  - SH2001 (FSC)
  - SH2002 (FSC)
  - SH2200 (FSC)
- Discrete Devices
  - Jan TX types
  - Industrial (T.I.)
  - Consumer (Mot)
  - J-Fets (Mot)

To be a good second source, you have to be a good first source.

A Simple Frequency-Difference Detector

by John D. Campbell

In some frequency comparators, two signals are mixed and the difference frequency is counted or measured. However, with this approach the sign of the frequency difference is lost. The circuit described here gives both magnitude and sign of the frequency difference. Though less accurate than many digital-counter types of frequency comparators, it is much simpler. Also, in many applications, such as afc and servo circuits, its direct analog output is advantageous. With one input frequency constant, the circuit may be used as a discriminator, even at audio and subaudio frequencies. These frequencies are often prohibited to a conventional discriminator because of the cumbersome transformer required.

Theory and equations

The block diagram of the frequency-difference detector is shown in Fig. 1. Two independent one shots produce equal, constant-width, constant-amplitude pulse at repetition rates equal to their respective input frequencies. The dc component in the output of each one shot is proportional to its input frequency. The combined difference amplifier and low-pass filter yields a filtered dc output proportional to the difference frequency.

Author: Mr. Campbell is a Research Associate in the Highway Safety Research Institute at the University of Michigan in Ann Arbor.

The dc component in the output of each one shot is

$$E_1 = V_{p1}\, t_{p1}\, f_1 + V_{ce(sat)1} \qquad (1)$$

and

$$E_2 = V_{p2} t_{p2} f_2 + V_{ce(sat)2} \qquad (2)$$

$V_{ce(sat)}$ is the collector to emitter saturation voltage of the output transistor of the one shot. Other quantities are defined in Fig. 1. If the one shots are identical, all corresponding quantities in Eq. 1 and 2 except f_1 and f_2 are equal, but in practice small differences may exist so each is written explicitly. The practical circuit is shown in Fig. 2. The dc output of the operational amplifier is:

$$E_o = A_2 V_{p2} t_{p2} f_2 - A_1 V_{p1} t_{p1} f_1 + A_2 V_{ce(sat)2} - A_1 V_{ce(sat)1} + V_{os} \qquad (3)$$

where $A_1 = R/R_1$ and $A_2 = R/R_2$ are respectively the inverting and noninverting dc gains of the op amp, and V_{os} is the output offset voltage of the op amp. When the input frequencies are equal, the output should be zero. Thus

$$E_o = (A_2 V_{p2} t_{p2} - A_1 V_{p1} t_{p1})\, f + A_2 V_{ce(sat)2} - A_1 V_{ce(sat)1} + V_{os} = 0 \qquad (4)$$

The last three terms are constant with respect to pulse width, amplitude and frequency and their

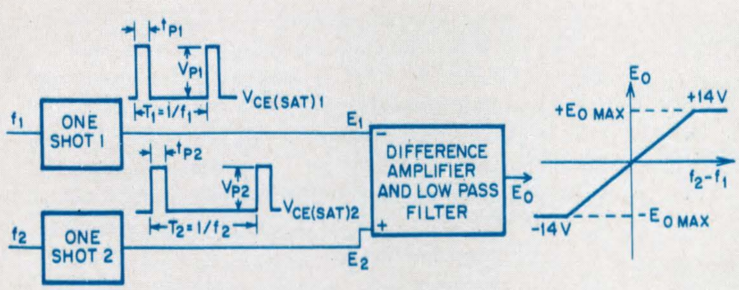


Fig. 1. Block diagram and characteristics of frequency-difference detector.

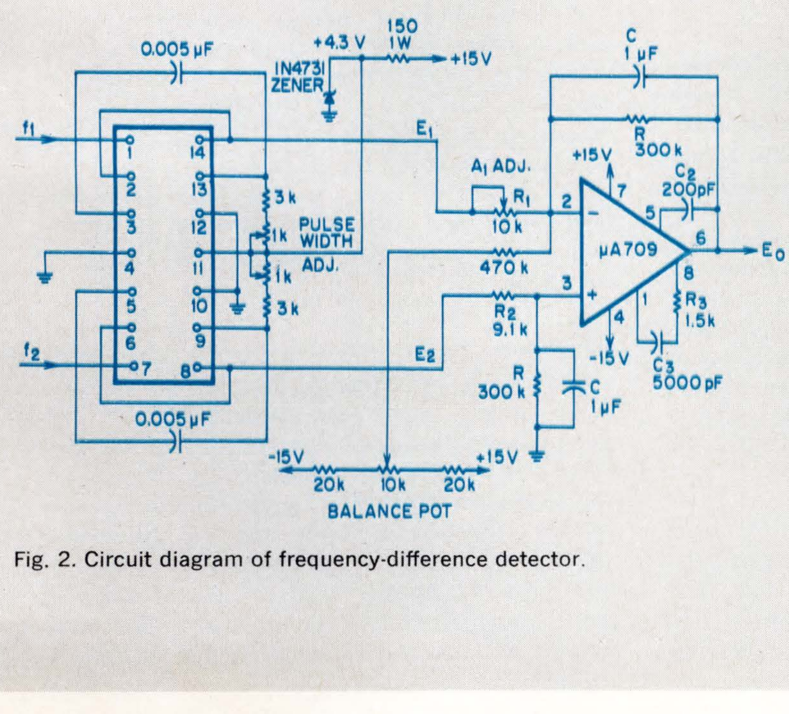


Fig. 2. Circuit diagram of frequency-difference detector.

sum can be set to zero by adjusting V_{os} with the balance pot shown in Fig. 2. The first term can be set equal to zero for all frequencies by adjusting one or more of the six quantities (A_2, A_1, V_{p2}, V_{p1}, t_{p2}, or t_{p1}) to obtain $A_2 V_{p2} t_{p2} = A_1 V_{p1} t_{p1}$. In Fig. 2, A_1, t_{p1} and t_{p2} are adjustable.

Simple alignment

To balance the detector the same signal is applied to both inputs and then

(1) the one shot outputs are adjusted to desired equal pulse widths,

(2) A_1 is adjusted (by pot R_1) to obtain minimum output-voltage variation when the signal is varied over the input frequency range, and

(3) the balance pot is adjusted to obtain $E_o = 0$.

With the detector balanced its dc output is

$$E_o = A\, V_p\, t_p\, (f_2 - f_1) \tag{5}$$

where $A = R/R_2 \simeq R/R_1$, V_p and t_p are the nominal design values.

Frequency-range limitations

Assuming $R_1 = R_2$, which is approximately the case when the detector is balanced, the transfer function of the difference amplifier/low-pass filter is

$$E_o\,(s) = \frac{R}{R_2}\,\frac{1}{(RCs + 1)}\,[E_2\,(s) - E_1\,(s)] \tag{6}$$

The high frequency break point of the low pass filter, $f_{3dB} = 1/2\pi RC$, should be at least a decade below minimum frequency applied to either input of the detector to give a reasonable output ripple. The filter attenuation increases 6dB/octave at frequencies greater than f_{3dB}.

At high frequencies where the one-shot duty cycle approaches one, the pulse width decreases due to one-shot recovery time. The pulse width is decreased about 1% at a duty cycle of 0.2 and about 10% at a duty cycle of 0.5. Thus detector nonlinearity at high frequency due to one-shot recovery is less than 1% if the pulse width is selected to give a duty cycle of less than 0.2 at the maximum input frequency.

Design equations and example

Designing the detector is straightforward. Determine V_p from the one-shot circuit data. For the circuit of Fig. 2, $V_p = 2$ volts. Select t_p, the pulse widths of the one shots, to give a duty cycle of 0.2 at the maximum input frequency, i.e., $t_p = 0.2/f_{max}$. Select $A = R/R_2$ such that $E_o = A\, V_p\, t_p\, (f_2 - f_1)$ is less than the op amp saturation voltage at the maximum frequency difference. Then select C to give the desired high-frequency break-point, $f_{3dB} = 1/2\pi RC$. Resistor $R1$ (and thus R_2) should be 6 kΩ or larger to prevent excessive amplitude unbalance of the one-shot output due to loading of the one shot connected to the op amp inverting input. Values of R_1 much greater than 10 kΩ also should be avoided to minimize variation of V_{os} with temperature.

The component values shown in Fig. 2 are for an input-frequency range of 10 Hz to 10 kHz and a maximum frequency difference of approximately 10 KHz, with the following results:

$V_p = 2$ V, $t_p = 0.02$ ms, $A = R/R_2 = 33$, $f_{3dB} = 0.53$ Hz,

$E_o = AV_pt_p(f_2 - f_1) = 1.32 \times 10^{-3}\,(f_2 - f_1)$ volts.

The detector characteristic should be linear to about 1% for $(f_2 - f_1) \leq 10$ kHz. With the same signal applied to both inputs and with the detector balanced, the output should remain within about 20 mV of zero as the signal is swept from 10 Hz to 10 kHz. At the maximum frequency difference of ±10 kHz, $E_o = \pm 13.2$ V or 0.8 volts less than the μA709 saturation voltage of ±14 V. Resistor R_3 and capacitors C_2 and C_3 are the manufacturer's recommended frequency-compensation elements for the μA709.

Sensitivity limitation

With appropriate changes in one-shot pulse widths and op-amp gain, the circuit may be used at input frequencies greater than 100 kHz and at sensitivity as high as 1 V/Hz. Of course, at high sensitivity the frequency-difference bandwidth is decreased because of the op-amp saturation limits.

The circuit operates well on square, sine and triangular input waveforms provided the amplitude is sufficient to give positive triggering of the one shots.

Applications

The frequency-difference detector can be used in afc circuits and, more attractively, as a discriminator with electrically variable center frequency and bandwidth or sensitivity. The center (or reference) frequency can be supplied from a voltage controlled oscillator and the difference-amplifier/filter can be operated at low gain followed by an amplifier with electrically variable gain. A gain-control voltage applied to the latter would then cause the bandwidth and sensitivity of the discriminator to change. EEE

Products Of The Month

Semiconductors

Boldface numbers following each product refer to those you can circle on the reader inquiry card for further information.

MOS 512-bit RAM, RM53L, includes 9-bit address word decoder, current-mode data output, chip disable function, and multiple data bus interconnect. Chip enable function makes possible expansion of system word capacity. Operation time, 425 ns; access time, 250 ns. 24-lead DIP. AMERICAN MICRO-SYSTEMS. **299**

Bipolar 64-bit RAM, RAM0064, with Schottky-clamped transistors. Access time, 35 ns. Organized as 16-word by 4-bit array with full decoding. Power dissipation, 6 mW/bit. Compatible with DTL, TTL. Open collector output for "Wired-OR" expansion. Power supply, 5 V; write pulse width, 25 ns; output current, 16 mA; input current, 1.6 mA. 16-pin DIP. $25.60 (100-999). HARRIS. **300**

Read-write silicon-gate MOS IC, 1103, said to be priced below cores. Max access, 390 ns; 1024 by 1 organization. $38.90. INTEL. **301**

Content-addressable 128-bit memory, TMS4000-JC, organized as 16 8-bit words. Three possible modes of operation. Two normal RAM modes, CAM mode. CAM interrogation time, 250 ns. Dissipation, 200 mW. 40-pin DIP. $20.10. (100-999). TEXAS INSTRUMENTS. **302**

Dynamic 1024-bit shift register, SRO-301, requires four-phase clock system. Frequency, 10 kHz to 1 MHz. Typ diss, 75 mW. Voltage rating 30 V. Round can 10-lead TO-100. NRMEC. **303**

MOS dual 100-bit static shift register, N2010K, shift rates to 3 MHz. Typ propagation delay, 200 ns. Requires two 28-V clock phases, two dc supplies. $4.00. SIGNETICS. **304**

MOS dual 100-bit shift register, V002, can operate to 2 MHz over full mil temp range. Dissipation typ 1mW/bit at 2 MHz. Single-phase clock. Round-bottom 10-lead TO-100. $3.75 (100 up). VARADYNE. **305**

Associative memory, MμL4102, 35-μs match time. Organized into four 4-bit words, each with its own address line. By wire-ORing match outputs from four 4102 memories, user can create 4-word by 16-bit associative memory. Write enable capability. Uncommitted collector outputs for expansion. 24-pin DIP. $50 (100-999). FAIRCHILD. **306**

MSI family, 9200 series, replace units originated by Fairchild. Series includes 9210/16 counter with 75 mW typ diss, 13 MHz counting speed, 9200 4-bit register, 9216 4-bit counter. $3.95-$9.75 (100 up). ADVANCED MICRO DEVICES. **307**

Programmable 2560-bit dynamic ROM, TMS2300JC, organized as 256 words by 10 bits/word. Access time, 750 ns. Can be custom programmed.. Compatible with DTC, TTL. 24-pin DIP. $19.80 (250-999). TEXAS INSTRUMENTS. **308**

Driver, commutator, switch, D125BK, G115BK, G123BK, for industrial temp range applications. D125BK 6-channel driver performs amplification and dc level shifting between low-level logic and MOS FET switches. D125BK, $8.25; G115BK, $9.75; G123BK, $6.90 (100 up). SILICONIX. **309**

Instrumentation op amps, SS725, C, replacements for 725 and 725C. Input offset voltage, 0.5 mV max; input offset current, 5 nA max. CMRR, 120 dB; offset voltage drift, 1 μV/°C max. DIP, TO-99 or flatpack. $7.50, $25 (100 up). PRECISION MONOLITHIC. **310**

Second-source op amp line, AD101A, 201A, 301A, 741, replace National Semiconductor, Fairchild devices. Five versions of 741 available. $3.45 for 301A, 741 ranges from $3.05 to $5.95. ANALOG DEVICES. **311**

Small-signal pnp transistors, 2N3634-7, replace relays in high-voltage switching applications. Max collector current, 1 A; switching speed, 400 nA; dissipation, 1 W. 2N3634,5 have 140 V ratings; 2N3636,7 have 175 V ratings. $6 to $12 (100-999). FAIRCHILD. **312**

Rf power transistor, 2N5918, overlay device. Output, 10 W and 8 dB min gain at 400 MHz. Emitter-ballasting re-

sistors. Voltage rating, 60 V; diss, 10 W; collector current, 750 mA. Formerly dev type TA7367. RCA. **313**

IMPATT diodes, 5082-0430 series, generate 100 mW with 3% eff in 5-14 GHz range. Devices require dc power source supplying 80-120 V at 25-40 mA. Sample circuits available three packages. $14. HEWLETT-PACKARD. **314**

Rf power transistors, MM1522-3, amplify to 175 MHz. Power output, 90 W at 150 MHz, as class C amplifier. Voltage ratings, 65, 100 V. Strip-line package. $43.50 (100 up). MOTOROLA. **315**

(Continued on page 84)

This Month's ICs

Read-write 512-bit MOS memory. AMI. **299**
Schottky-process 64-bit bipolar RAM, $25.60. HARRIS. **300**
Read-write 1024-bit silicon-gate memory, $38.40. INTEL. **301**
Content-addressable 128-bit memory. $20.10. TEXAS INSTRUMENTS. **302**
Dynamic 1024-bit shift register. NRMEC. **303**
Dual 100-bit static shift register, $4.00. SIGNETICS. **304**
Dual 100-bit dynamic shift register, $3.75. VARADYNE. **305**
Associative bipolar 16-bit RAM, $50. FAIRCHILD. **306**
MSI counter/shift register family, $3.95. ADVANCED MICRO DEVICES. **307**
Programmable 2560-bit ROM, $19.80. TEXAS INSTRUMENTS. **308**
MOS drivers, commutators, $6.90. SILICONIX. **309**
Instrumentation op amps, $7.50. PRECISION MONOLITHICS. **310**
New op-amp second-source line. $3.05 up. ANALOG DEVICES. **311**

This Month's Transistors and Diodes

Small-signal pnp solid-state relays, $6.00. FAIRCHILD. **312**
Overlay rf emitter-ballasted transistor. RCA. **313**
IMPATT diodes, $14. HEWLETT-PACKARD. **314**
Rf power transistors, $43.50. MOTOROLA. **315**
Plug-in long-lead thermistors. VICTORY ENGINEERING. **316**
Adhesive-mounted thermistor. FENWAL ELECTRONICS. **317**

Thermistors, new series, plug-in and lead-mounted packages. Thin-film 25-micron device. Chopping rate on free-standing units flat to 7.5 Hz. Fall off about 3 dB at 10 Hz. Noise level, 5 μV typ. VICTORY ENGINEERING. **316**

Thermistors, H49, H36, for temperature sensing applications. H49 is adhesive mounted for surface temperature measurement or control. H36 is for liquid sensing. FENWALL ELECTRONICS. **317**

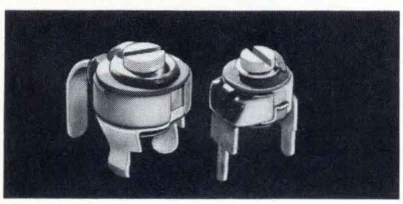
Capacitors

Bondable hybrid-capacitor chip, U-15, for solder or wire bonding. 50 × 50 mils at base and 60 mils high. NPO 5 to 200 pF ±10%, BX 200 to 4000 pF ±20% and AW 4000 to 12,000 pF +80-20%. AMERICAN COMPONENTS. **220**

Monolithic-capacitor elements, Stable-K, with a capacitance range from 10 pF thru 2 μF in seventeen sizes starting from 0.050 × 0.050 × 0.050 in. Max cap change ±15% over −55 to 125°C. Standard electrode is silver with gold, palladium silver and platinum gold available. REPUBLIC ELECTRONICS. **221**

Low-cost dipped tantalum capacitor, GS, with rugged plug-in construction. Full rated V from −55°C to +85°C. C/V range is 0.47 μF at 50 V through 330 μF at 6 V. Cylindrical case range from 0.175 to 0.400 in. diameter by 0.350 to 0.750 in. height. DICKSON. **222**

Miniature ceramic-trimmer capacitor, 9300, with extremely linear tuning and

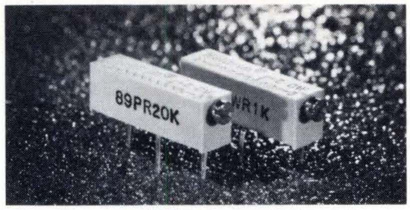


a high resistance to shock and vibration. Cap range 1.7 pF to 50 pF. Dielectric strength 250 V. Printed circuit mount. $1.90 to 18¢ each. JOHANSON. **223**

Resistors

Thick-film resistor networks, with tempco matched to 10 ppm. R to 1% tolerance. ΔR over 1000-hr life at 85°C, is less than 1%. In dual in-line, conformal coating or epoxy-molded packages. CAL-R. **216**

Low-cost trimmers, series 89, with a new low profile, 0.250 in. high. 10Ω-2 MΩ. 15-turn units with special tempco



of ±50 ppm/°C in the 100Ω-100 kΩ range. Std tempco 100 ppm/°C for 100Ω-2 MΩ range. 3/4-in. rectangular unit with pin spacings of 0.200 in. and 0.100 in. 0.75 W at 25°C. $1.35 (1-9 qty). BECKMAN. **217**

Tera-ohm resistor, 102, with a semiconductive glass resistive element. 10^8 to 10^{11} Ω. Tolerances 25% and 10%. Tempco −0.3%/°C −270° to 200°C. 0.13 × 0.040 dia. Goldplated leads. $8.00 (1-24). ELTEC INSTRUMENTS. **218**

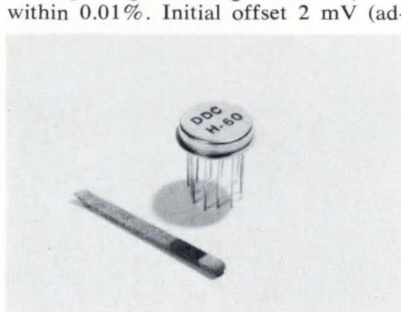
Low-cost film resistor, MK132, for high-density packaging in large volume printed-circuit applications. Units are 0.29 in.^{2} × 0.095 in. Resistor is non-inductive and rated at 1/2 W at 105°C. R from 100 Ω to 5 MΩ. −55°C to +150°C. Tempco 50 ppm/°C. Std tol 1% with tol to 0.1% special order. CADDOCK ELECTRONICS. **219**

Packaged Circuits

Price change

BELL & HOWELL has reduced prices by as much as 25 percent on its line of hybrid IC op amps. Also, the company is now marketing the amplifiers itself instead of through other circuit manufacturers. **270**

Fast-settling hybrid op amp, H60, in TO-8 package. Settling time 0.5 μs to within 0.01%. Initial offset 2 mV (ad-



justable to zero with external pot). Slew rate 200 V/μs. Unity-gain bandwidth 25 MHz. Open-loop dc gain 100 dB. Voltage drift 20 μV/°C. Full-power output frequency 2 MHz. Rated output ±10 V at 10 mA. Operating temp −55 to +85°C. Common-mode voltage range ±10 V. CMRR 90 dB at ±5 V. $125 (1-9). Stock. DDC. **271**

Hybrid FET-input op amps, 8500 series, in four different versions with offset-voltage tempcos from 25-75 μV/°C and bias currents from 10-50 pA. Open-loop gains from 20,000 to 50,000. Input impedance 10^{11} Ω. Output current 10 mA. Operating temp −25 to +85°C. Low-profile encapsulated package with height of 0.2 in. GPS. **272**

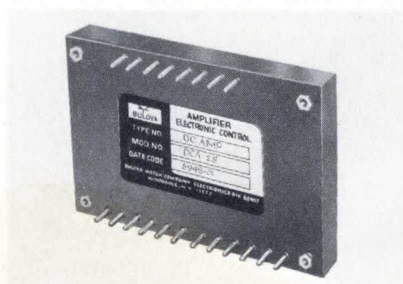
Fast FET-input op amps, 152 A/B/C, in differential configuration for inverting or non-inverting applications. Slew rate 100 V/μs. Unity-gain frequency 15 MHz. Settling time 0.4 μs to within 0.01%. Overload recovery time 0.5 μs. CMRR 10,000. Gain 400,000. Drift 10 μV/°C (152C). Bias current 20 pA. 1.125 × 1.125 × 0.5 in. From $30 (100 up). Stock. DYNAMIC MEASUREMENTS **273**

High-voltage FET op amp, 1957, with output-voltage range of ±100 V at 10 mA. Unity-gain frequency 1 MHz. Full-output frequency 20 kHz. CMRR

60 dB with input of 40 V pk-pk. Unit withstands input of 200 v pk-pk without damage. Encapsulated module 1.8 × 2.4 × 0.6 in. Under $40 (production qty). MELCOR. **274**

Low-cost chopper amplifier, 233, in compact encapsulated module, 1.5 × 1.5 × 0.4 in. Small-signal bandwidth 500 kHz. Full-power response 4 kHz. Maximum votage drift 1, 0.3 and 0.1 μV/°C for "J," "K" and "L" versions, respectively. Current drifts 2, 1 and 0.5 pA/°C. Can be used with input resistors up to around 100 kΩ without deterioration in circuit performance. Prices in 1-9 qty: $45 ("J" version), $54 ("K") and $75 ("L"). Stock. ANALOG DEVICES. **275**

Compact dc power amplifier, DCA25, to drive torque motors, servo motors, valves, deflection coils and other devices with up to 25 W. Claimed "low cost" but vendor didn't quote price.



Can be used with external transistor bridge to boost output power to 300 W. Current limiting prevents demagnetization of torque motors and provides short protection. BULOVA. **276**

Encapsulated dc servo amp, MA-5, to drive dc torque motors with voltages

(Continued on page 86)

Varadyne D/A and A/D converters. In volume. In stock. Now.

(Single Quantity)

(Single Quantity)

$29

SPECIFICATIONS

ELECTRICAL

Digital Inputs

Resolution .... 8 binary bits or 2 digit BCD

Coding .... Parallel data in the following formats:
Straight binary (unipolar output)
BCD (unipolar output)
Two's complement (bipolar output)

Data inputs .... DTL or TTL compatible, positive logic.
Loading: one standard TTL load
IL max. = 1.6 ma @ VIN = 0.4V

Update rate .... 5MHZ typical, but voltage output limited by output amplifier setting time

Analog output (@25°C)

Accuracy .... ±0.2% of FS ±½ LSB

Output voltage ...... 0 to +10V FS (connect Pin 15 to Pin 14)
±5V FS (connect Pin 15 to Pin 13)

Output current .... ±5 ma

Output loading .... 2K ohms for 0 to +10V output or 1K ohms for ±5V output, in parallel with 1000 pf

Output setting time .... 20 μsec to ±0.2% of FS (typ.)

Output voltage resolution .... 40 mV for eight binary bits
100 mV for 2 digit BCD

Linearity .... ±½ LSB

Temperature coefficient ± 50 pp m/°c of FS

Long term stability .... ±0.05%/YR

Reference source ..... Internal

Input power requirements .... ± 15VDC @ ±20 ma

Operating temperature range .... 0°c to + 70°c

Storage temperature range .... 55°c to +85°c

Size .... 2" L x 2" W x 0.4" H plug-in module

Weight .... 2 oz.

ORDERING INFORMATION: DAC-29- 8B — 8 BINARY BITS
8D — 2 DIGIT BCD

$89

SPECIFICATIONS

ELECTRICAL

Inputs:

Analog input voltage range .... 0V to +10V FS, (Ground Pin #2)
±5V FS (Pin #2 floating) Binary only

Input impedance .... 5K ohms shunted by 10 pf

Outputs:

Parallel output data .. Up to 8 parallel lines of data held until next conversion command
Vout ("0") < +0.8V
Vout ("I") > +2.4V
Each output capable of driving up to 6 TTL loads

Coding .... Straight binary (unipolar input)
2 digit BCD (unipolar input)
Offset binary (bipolar input)

End of Conversion.... Conversion status signal.
Vout ("0") < +0.8V Conversion complete
Vout ("I") > +2.4V during conversion
Loading up to 6 TTL loads

Performance:

Resolution .... One part in 2^n (resolution 8 binary bits or 2 digit BCD)
(n = number of binary bits)

Accuracy .... ±0.2% of FS ±½ LSB

Long term stability...... ±0.05%/YR

Temperature coefficient .. ±50 ppm/°c

Encoding time .... 8 binary bits — 200 μsec total
2 digit BCD — 100 μsec total

Reading Rate .... 8 binary bits — 5000 samples/sec. max.
2 digit BCD — 10,000 samples/sec. max.

Input Power Requirements .... +15 VDC, ±0.5VDC @ 20 ma
15 VDC, ±0.5VDC @ 12 ma
+ 5 VDC, ±0.5VDC @ 75 ma

Operating temperature range .... 0° to +70°c

Storage temperature range .... 55°c to 85°c

Size .... 2" W x 3" L x 0.4" H

Weight .... 4 oz. max.

ORDERING INFORMATION: ADC-89- 8B — 8 BINARY BITS
8D — 2 DIGIT BCD

36 OTHER A/D AND D/A MODELS TO CHOOSE FROM. WRITE FOR OUR FREE 24-PAGE CATALOG.

VARADYNE SYSTEMS
A DIVISION OF VARADYNE INC

1020 TURNPIKE ST., CANTON, MASSACHUSETTS 02021 · (617) 828-6395

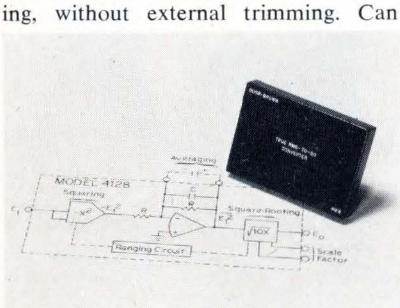
Circle 127 on Reader Service Card

up to 52 V. Operates from 60-V dc supply. Peak output power 25 W. Can be boosted to 300 W using external transistor bridge. Encapsulated module, 3 × 2 × 0.4 in. Mounts on PC board or on external heat sink. Current-limiting circuit prevents motor demagnetization. Short protected. Can be connected as voltage or current amplifier. Gain determined by external resistors. $295 (1-9). 2 wks. INLAND CONTROLS. **277**

State-variable active filters, 3704 (dc to 5 kHz), 3705 (dc to 50 kHz) and 3706 (dc to 500 kHz), with independently adjustable center frequency, Q and gain. PC-mtg module, 2 × 1 × 0.5 in. Operating temp −55 to +85°C. Simultaneous bandpass, low-pass and high-pass outputs. Fourth op amp included for utility, $87 (3704 in 1-2), $189 (3705 in 1-2), $295 (3706 in 1-2). Stock. OPTICAL ELECTRONICS. **278**

Active low-pass filters, AF3L and VF3L, with Butterworth, Bessel or Papoulis responses. 3-pole multiple-negative-feedback circuits. AF series are complete and have 100-kΩ input impedance and unity dc gain. VF series need external resistors to set input impedance and gain. Both series have cutoff frequencies from 10 Hz to 30 kHz, operate from ±15 Vdc supply and are packaged in epoxy modules, 2.4 × 1.5 × 0.625 in. $39. Stock to 4 wks. TESTRONIC DEV LAB. **279**

True rms-to-dc converter, 4128, in encapsulated module, 3 × 2.1 × 0.4 in. Solid-state circuitry eliminates need for matched thermocouples and other expensive components. Accuracy ±.5% of full-scale ±0.5% of reading, without external trimming. Can

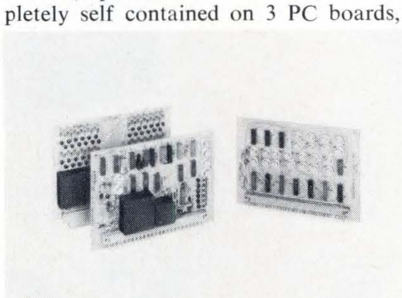


be improved to ±0.1% f.s. ±0.1% rdg with external trimming. Has built-in low-pass filter with time constant of 0.5 s. External capacitance can increase averaging time-constant. Input impedance 5 kΩ. Output ±10 V at 5 mA. $145 (1-9). Stock (small qty). BURR-BROWN. **280**

8-bit A/D converter, ADC-89, using new digital integrating circuit. Overall accuracy ±0.2%. Tempco ±0.005%/°C. Full-scale input can be unipolar (0 to +10 V) or bipolar (±10 V). Input impedance 50 kΩ. Output coding can be straight binary (unipolar input) or two's complement (bipolar inputs). Digitizing speed 5 kHz (200 μs). Suitable for asynchronous operation. TTL/DTL compatible. Operating temp 0 to +70°C. PC-mtg package 2 × 3 × 0.4 in. DIP-compatible pinning. $89. 4 wks. VARADYNE SYSTEMS. **281**

Analog circuit modules, A160 (high-impedance multiplexer expander), A161 (high-impedance multiplexer with output buffer), A162 (high-impedance multiplexer with decoder), A163 (high-impedance multiplexer with decoder and buffer), A164 (constant impedance multiplexer expander), A165 (constant-impedance multiplexer with output amp), A166 (multiplexer with decoder), A167 (constant-impedance multiplexer with decoder and output amp), A260 (dual amp), A460 (sample-and-hold module), A461 (buffered sample-and-hold circuit), A660 (12-bit multiplying DAC), A860 (12-bit dual-slope integrating ADC), A861 (unipolar high-speed ADC) and A862 (bipolar high-speed ADC). DIGITAL EQUIPMENT. **282**

Compact lightweight S/D converter to accept 3-wire synchro inputs and convert them to 12-bit parallel digital word (expandable to 13 bits). Completely self contained on 3 PC boards,

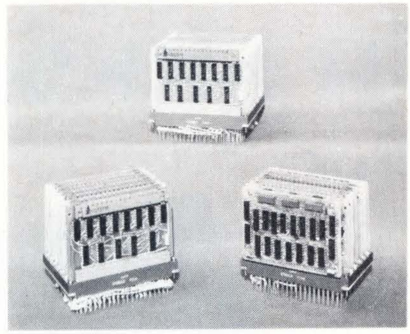


each 4-1/2 × 6-1/2 in. Accuracy ±1 LSB (0.0879°). TTL/DTL compatible. Available in industrial or military versions. Input impedance 50 kΩ l-l. Tracking-type circuit uses tapped toroidal transformers. ASTROSYSTEMS. **283**

Sample-hold modules, SHAIII (100 μs transient settling time) and SHAIV (10 μs transient settling time), for long hold times with good accuracy. Full-scale output ±10 V at 10 mA. Droop 10 mV/s (accuracy 0.01% when holding ±10 V levels for 100 ms). Input impedance 100 MΩ. Drift 10 μV/°C. DTL/TTL compatible. Gain unity ±0.005%. Max transient amplitude ±7 V (SHAIII) or ±200 mV (SHAIV). Sample-to-hold settling time 10 μs for both units. Aperture time 50 ns (plus 10 μs settling time). Hold-to-sample recovery time 130 μs. Encapsulated module, 2 × 1-1/8 × 0.4 in. $95 (SHAIII) in unit qty) and $120 (SHAIV in unity qty). Stock. ANALOG DEVICES. **284**

Compact 13-bit DACs, BDAC series, to accept BCD inputs. Accuracy ±0.025% f.s. Settling time 7 μs. Short-circuit proof output of ±10 V at 5 mA. Separate power and analog-signal grounds provide 60 dB rejection of inter-system ground noise. Tempco ±0.002% f.s. per °C. Built-in output amplifier and reference element. External-reference versions available. PC-mtg module, 2.6 × 3.1 × 0.4 in. $400 (for operating temp of −55 to +85°C and qty of 1-9) or $250 (for operating temp of 0 to +70°C and qty of 1-9). Stock to 3 wks. DDC. **285**

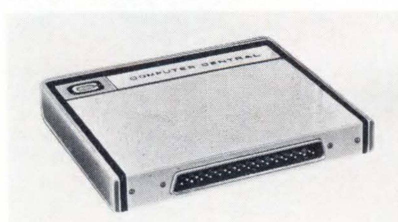
Prewired logic-card assemblies, Monibloc, consisting of group of DTL or TTL logic cards pre-wired to perform some specific function. Available systems include binary-to-BCD converters, BCD-to-binary converters and 8-channel multiplexers with A/D converter



and all necessary timing. Prepackaged and pretested. Compatible with manufacturer's existing hardware line. 2 wks. MONITOR SYSTEMS. **286**

70-MHz counter cards, 622 (decade counter), 623 (presettable up-counter), 624 (up-down counter) and 625 (presettable down-counter), with speeds to 6 ns. Non-saturated current-mode ECL ICs. Plug-in PC boards, 4.5 × 3.16 in., with gold-plated ground-plane construction. Complete with non-loading 50-Ω coaxial test points and standard 44-contact gold-plated edge connector. $150 (623) to $246 (625). 4-6 wks. DATA TECHNOLOGY. **287**

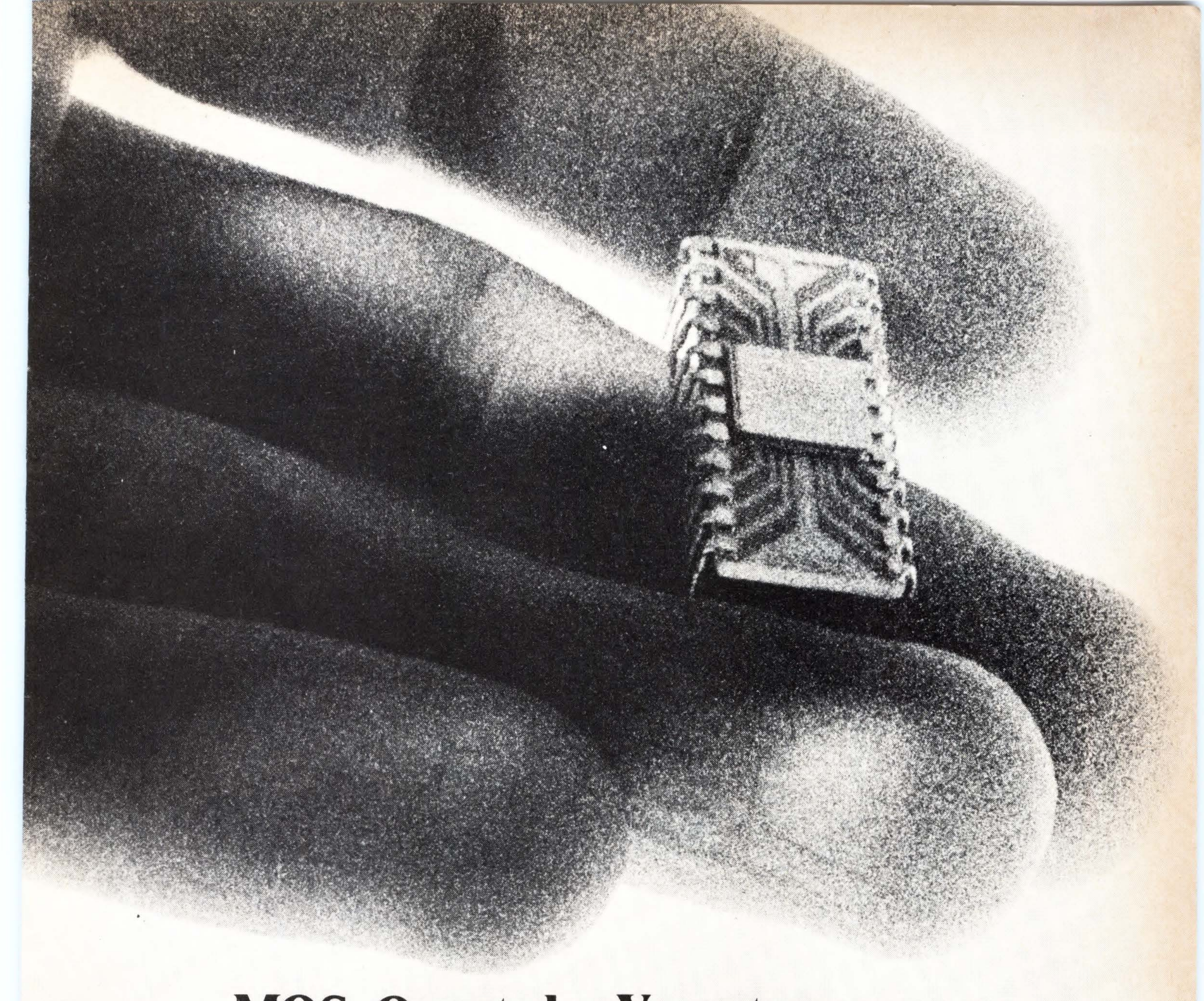
Digital-comparator module, 711, consisting of digital summing junction with analog output. Computes difference between 2 parallel input numbers and converts difference to proportional analog voltage. For use in digital-feedback servo systems having optical encoders or synchros (plus S/D



converters) for position measurement. Dynamic range 1 MHz. Certified linearity. Operating temp 0 to +70°C. Compact module, 4-1/4 × 5-1/2 × 7/8 in. Compatible input range extenders and encoder electronics available. Output range ±10 V. From $295 (7-digit version) to $790 (13-digit version). COMPUTER CENTRAL. **288**

Core-memory system, ExpandaCore 18, packaged in rack-mountable 5-1/4 in. enclosure. Incorporates "closed-cooling" system that protects against dirt without use of fan filters. Memory capacity 16,384 × 18 bits. Available in 4-k version which is expandable in 4-k increments by adding additional storage boards. Full-cycle

(Continued on page 88)



MOS. Ours today. Yours tomorrow.

We're there. Just like you. Up to our oxides in MOS technology. In active production, meeting demand with give-a-damn delivery.

Example: our MOS Read Only Memories, built for extraordinary flexibility in design. Ready for logic-programming to your specs, right on the chip. Just slap a truth table onto a deck of IBM cards and turn us on.

Our 24-pin ROMs don't settle for dinky single-line chip-select either. You can control 1 to 8 devices through our three chip-select terminals—a three-line binary coded function strictly exclusive with us. Access time, 550ns. Power dissipation, 150mW.

Optional output programming too: either bare drain or MOS pull-up resistor. Turn-around time from receipt of deck to delivery, competitive, of course.

Example: a salt-of-the-earth dynamic Random Access Memory. Completely characterized, in high volume MOS production longer than any similar device. Anywhere.

A remarkable RAM. With five chip-select inputs, permitting expansion to 8K—a capability ours alone. And unique 2.5 milliamp outputs for fast, inexpensive sensing. Fully decoded. Cycle time, 650ns. Access time, 400ns.

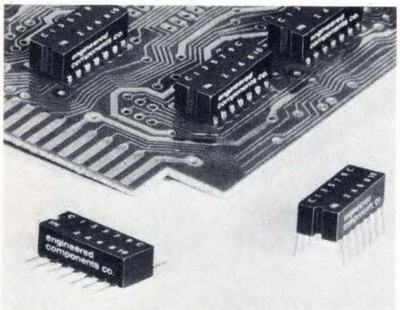
2410 Series	256x4 Static ROM	16-pin Ceramic DIP
2420 Series	128x8, 256x4 Static ROM	24-pin Ceramic DIP
2430 Series	256x8, 512x4 Static ROM	24-pin Ceramic DIP
N2301	256-bit Dynamic RAM	24-pin Ceramic DIP

In-depth applications info available. In person. Just call George Rigg (408) 739-7700, and let's discuss it man to man. Data sheets and price lists for the whole MOS batch, ready too. Along with our ROM Selection Chart, listing ten option combinations. Call and let George do it too, or write Signetics Corporation, 811 E. Arques Avenue, Sunnyvale, California 94086. A subsidiary of Corning Glass Works.

Signetics

time 1 μs. Access time 350 ns. Operating temp 0 to +50°C. $4065 (for basic 4-k system without power). 90 days (units with power) or 60 days (units without power). CAMBRIDGE MEMORIES. **289**

Lumped-constant delay lines, DIP series, in true 14-pin dual in-line packages. Choice of 3 impedance ranges, 50 Ω, 100 Ω and 200 Ω. 224 different basic versions. Can be tapped to 1-ns increments. Choice of lead styles: radial lead or axial lead. Lines can be cascaded to provide delays up to 1500 ns. TTL compatible. High delay-to-



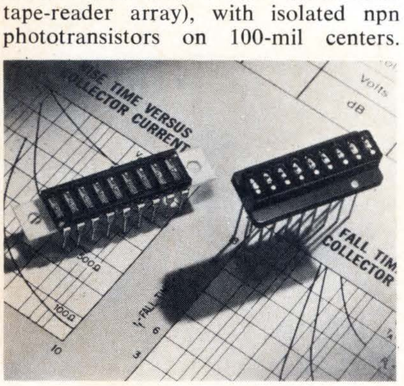
risetime ratios. Compensated for optimum pulses response. From $8 to $15 in small qty. Stock to 3 wks. ENGINEERED COMPONENTS. **290**

Miniature synchro bridge, SB-M-11, to accept 3-wire synchro signals and convert them to 2-wire analog voltage representing synchro position. Claimed "smallest and least expensive synchro bridge ever offered." Accuracy 20 sec of arc. Applied voltage 90 V l-l. 0.44 × 0.5 × 1.75 in. $100 (small qty). Stock. THETA INSTRUMENT. **291**

Mixer-pre-amp circuits, DM series, with discrete- component or hybrid-IC amplifiers. Beam-lead Schottky diodes. Typical specs: Frequency range 1 to 12 GHz. Rf-LO isolation > 20 dB. I-f bandwidth 10 to 200 MHz. Rf to i-f gain 20 dB. Noise figure 8 dB (S band). Input vswr 2:1. Output +6 dBm. Size 2 in.^{3}. From $595. 30 days. RHG ELECTRONICS. **292**

Photo-detector amplifiers in TO-5 cases. Peak sensitivity 2.5 × 10^4 V/W/cm.^{2} Bandwidths to 10 MHz. Detectors and pre-amplifiers can be matched to customers' requirements. MICRO-ELECTRONIC SUBSYSTEMS. **293**

Phototransistor arrays, STA71 (9-position array) and ST/A72 (dual-inline tape-reader array), with isolated npn phototransistors on 100-mil centers.



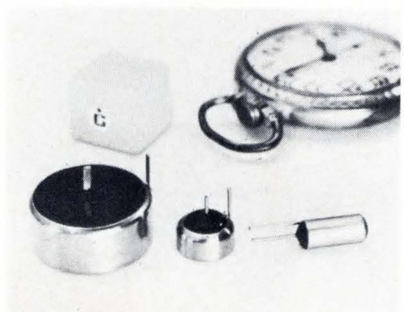
TTL/DTL compatible. Collector dark current 100 nA per cell. Radiometric sensitivity 150 μA/mW/cm.^{2} Luminous sensitivity 7.5 μA/fc. Light current rise and fall times 3 μs each. Stock. SENSOR TECHNOLOGY. **294**

Monolithic crystal filter with center freq of 99 MHz. 1-dB bandwidth 20 kHz. Insertion loss 3 dB. Ripple 1 dB. Max attenuation 50 dB. Package similar to HC-18U but with height of 0.34 in. McCOY. **295**

Switches & Relays

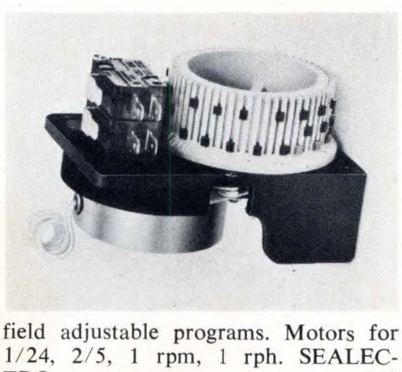
Solid-state TDR with screwdriver adjustment of 1- to 10-s delay, on or off delay, form-A or form-B static load contacts for continuous 3 A 115 V 60 Hz. Isolated load and timing circuits. Transient protection to ±1400 V 100 μs. Front-panel pushbutton for quick test, with neon showing proper operation. TEMPO. **258**

Solid-state timer with energy-storage device allowing one-shot or repeat-



cycle timing from 10 to 10^5 seconds (in four modules, each with 100:1 timing range). Operates from + and −5 V. Repeat acc ±5% for fixed temp and supply voltage. +5-V output standard (into 2 kΩ), others optional. 0 to 70°C standard. Timing adjustable with low-value external resistors to 390 kΩ. 2.3 cu in. GOULD IONICS. **259**

Drum-timer/programmer, LCT, for up to 60 on/off cycles per revolution per channel. Two independent channels with 15-A snap-action switches. Quick,



field adjustable programs. Motors for 1/24, 2/5, 1 rpm, 1 rph. SEALECTRO. **260**

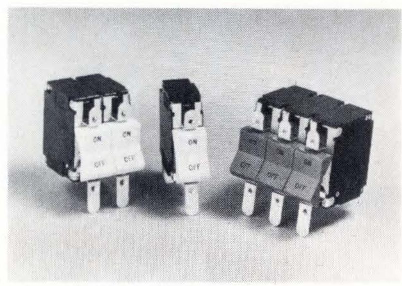
Repeat-cycle timer with each switching circuit controlled by serrated wheels with rise and drop tabs that contact actuator that operates spdt snap-action switch for 5 to 95% timing cycle. Combination rise/drop tabs for pulsed outputs. To 10 switch circuits. EAGLE SIGNAL. **261**

Ultra-sensitive relay, PYZA, with pull-in from as low as 70 μW. 1-A 110-V 60-Hz form K (spdt center off). Polarized coil for switching to either contact depending on direction of current flow. 100-Hz switching speed. PC mount. BARBER-COLMAN. **262**

Low-level reed relays, CR300, with 0.1-μV differential thermal offset for 5% duty cycle, 1 μV for 100% duty cycle. Copper shield acts as shield and thermal conductor. To 200 samples/sec as multiplexer. Copper leads avoid thermocouple error in copper-copper connections. 1-ms pull-in, 0.5-ms release. 1, 2 or 3 form A. From $10.40 (1-9). COMPUTER PRODUCTS. **263**

Multi (!) pole transfer switch, Centipole, with single modules for 50pdt or 100pdt. Five modules can be ganged for 500pdt. Max torque 5 lb-in. per 100 poles. 50-mΩ max initial contact resistance. Switch 0.5 A 30 Vdc. −40 to +85°C. Manual or solenoid operation. DAVEN. **264**

Circuit breakers, JC, in line expanded to include 2- and 3-pole models. Rocker handle for setting breaker on or off. 20 mA to 30 A, to 65 Vdc or



250 V 60 or 400 Hz. Different ratings available on different poles. HEINEMANN. **265**

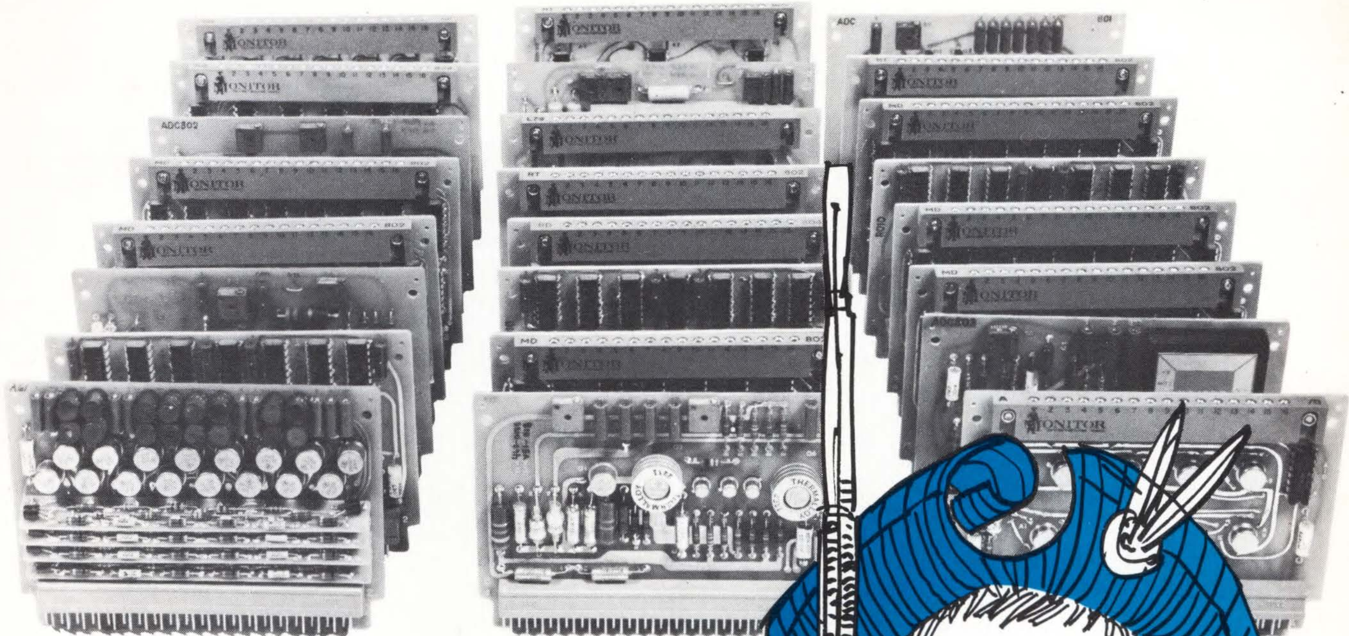
Proximity reed switch with form-B 0.4-A 100-Vdc 3-W contacts. Actuation by proximity (calibrated from 75 to 150 mils) to ferrous material or small external magnet. Industrial, commercial and consumer grades at $2.42, $2.20, $2.10 (500-999). McCLINTOCK MATRIXES. **266**

Open-frame solenoids, SA-L, with coils for 3 to 400 Vdc. Many forces. Adjustable strokes. To 100°C operation. $1.75 to $3.80 (1000-up). TEC MAGNETICS. **267**

Momentary pushbutton switches with form-A contacts for 1 A 28 Vdc/115 Vac, 0.5 A 250 Vac. 10-mΩ initial contact resistance. 10^{10}-Ω IR. C&K. **268**

4-lamp lighted pushbutton switches and word indicators, 12H, to meet Mil-S-22885/15, /16, dpdt or 4dpdt. Momentary or alternate action. Front-panel lamping and legend change

(Continued on page 90)



Shape Up! With Monitor's Analog Army

CHECK THIS ROLL CALL!

- **A/D & D/A CONVERTERS**
- **MULTIPLEXERS**
- **SAMPLE & HOLD AMPLIFIERS**
- **OP-AMPS**

They're all veterans of the analog wars. We've got regiments of Multiplexers to engage your inputs. Our Sample and Hold captures them for our A/D'S. You can muster 90 variations of A/D'S (up to 12 bits) on a MONILOGIC card! And for reinforcements we have D/A Converters, D.C. Amplifiers and Low-Level Amplifiers.

FOR FURTHER INFORMATION WRITE OR CALL

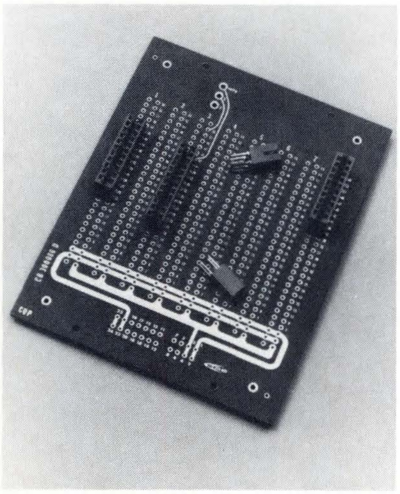
PHONE 215-646-8100
Fort Washington, Penna. 19034
TWX 510-661-1520

MONITOR SYSTEMS
an AYDIN company

without tools. Common or split ground for lamp circuits. 5 A 125/250 Vac 30 Vdc. $7 (production qty). MASTER SPECIALTIES. **269**

Packaging/Hardware

Modular PC edge connectors, Mod-Con, requiring inventory of only two different parts. End sections have four contacts, centers have six. Contact tails and connector bodies push fit as

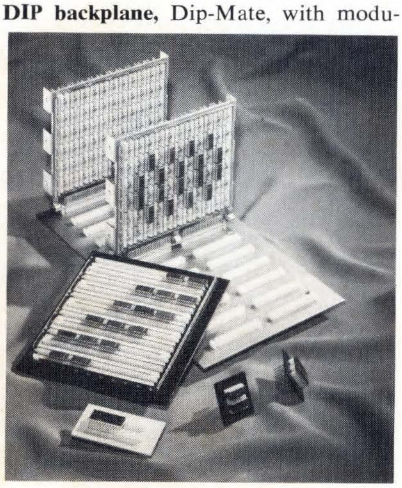


unit into 3/32 to 1/8-in. mother board with plated-through holes. Contacts, of gold-plated phos bronze, on 150-mil centers with 200 mils between rows. Two- or three-level Wire-Wrap tails. SAE. **245**

Modular PC edge connectors with center sections having 2, 3, 4, 8 or 16 dual-readout positions; end sections, with or without card guides, having 5 positions. Contacts on 125-mil centers. Wire-Wrap tails. FABRI-TEK. **246**

Ceramic-substrate connector for MSI/LSI mounted on 1 × 2-in. substrate. Card guide positions critical side of substrate. DAP or phenolic body with 40 BeCu contacts on 50-mil centers, 100 mils between rows. Dip-solder contact tails for PCs up to 125 mils thick. WINCHESTER. **247**

DIP backplane, Dip-Mate, with modu-



lar DIP connectors mounted in base plate containing solderless voltage and ground planes. Base plate can hold daughter plate mounted at right angle. MALCO. **248**

DIP backplane, 4401, to accommodate 92 14-pin and nine 16-pin DIPs on 14.65 × 3.95 in. surface. Wire-Wrap sockets in 3/16-in. copper-clad G-10 with V_{cc} plane on one side, ground plane on the other. 50-pin connector at end. $178. DATA TECHNOLOGY. **249**

Tiny 50-Ω coax connector, Ridgelok, of 3-piece construction. Max contact resistance 8.3 mΩ at 3 A. Four fit in area required by two BNCs. Positive lock. MICRODOT. **250**

Test-bath liquid, FC-48, for thermal shock tests with reduced fluid loss. Pour point −80°F. Boiling point +345°F. Clear, colorless, non-flammable. Dielectric strength 35 kV across 0.1-in. gap. 3M. **251**

Hot-pressed ferrite for mag-tape heads with high definition short gaps allowing very wide frequency response, low S/N ratio and 10 times life of conventional metal heads. MATSUSHITA. **252**

Heat-sink washers of hard-anodized aluminum for power semis. 400-V rating in 20-mil thickness. High abrasion and corrosion resistance. Withstands 250-hr salt spray. 9¢ (1000-up) for TO-3 style. THERMALLOY. **253**

All-alumina MSI/LSI packages in various styles including 42-lead flatpack, 40-lead plug-in edge package, 40-lead wide-base DIP, narrow-base DIP with 24, 28 or 40 leads. COORS. **254**

Beryllia substrates, AlSiMag 794, with 1741 BTU in./hr/ft^2/°F at 25°C, 230 V/mil at 60 Hz, 10^{14} Ω-cm at 25°C. Dielectric constant 6.9 at 25-100°C at 1 MHz, DF 2 × 10^{-4} at 25-100°C at 1 MHz. 10-30 mil thickness, 10-μin. flatness as fired. AMERICAN LAVA. **255**

Keyboard buttons, 56, two-shot molded of SAN copolymer. 10 standard colors

for legend and body. Outside dimensions 0.716 in. square, 0.477 in. high. LICON. **256**

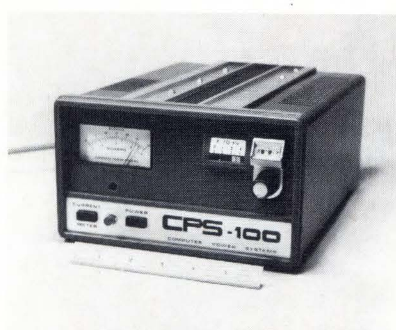
Low-profile, panel-mount fuseholders, 348000 for 3AG and indicating-pin fuses, 378000 for 8AG. 3/16 in. above panel. Snap into 5/8-in. square hole in 1/32 to 1/8 in. panel. Thumb pressure on square cap opens or snap-locks holder. LITTLEFUSE. **257**

Power Supplies

Automatic voltage regulator, 1592 Variac, with an accuracy as tight as 0.25%. Electromechanical regulator controls the rms characteristics of its output waveform. Regulates 120- and 230/240-V, 50 and 60-Hz lines with rated outputs up to 10 kVA and transient-correction rates as high as 50 ms/V. Has remotely selectable output voltage and can be used in 2 and 3-phase configurations. $525. GR. **229**

Fuel cell, for producing dc power by electrochemically combining hydrogen obtained from ammonia with oxygen from ambient air to form water. Uses a phosphoric acid matrix electrolyte. Noiseless with no noxious fumes with operation in the 20 W to 2 kW range. Unattended service for 6 months. For nav beacons, μw repeater stations, radio transmitters and monitoring control systems. ENGELHARD. **230**

Stable high-voltage lab supply, CPS-100P and CPS-100N, with voltage



variable from 0 to 30 kV at 0.5 mA. Regulation 0.001%. Ripple 200 mV pk-pk. Drift 0.005/hr. Short-circuit proof and arc-proof. Half-rack width. 5-1/4 in. high. $1725. CPS. **231**

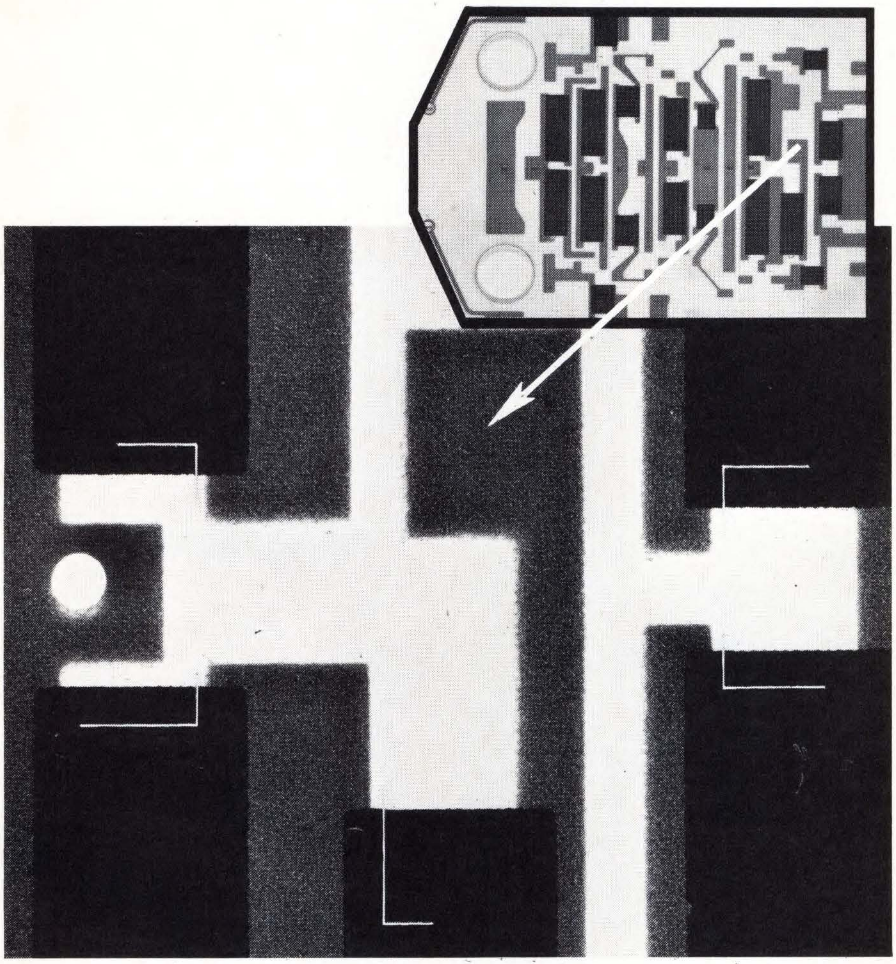
Miniature power supplies, 5P1 and 3.6P1, for operating directly from 115 Vac, 50-400 Hz. 5P1 provides 5 V at 500 mA and 3.6P1 provides 3.6 V at 500 mA. Accuracy of 1% and line and load reg of 0.15%. Short-circuit protection. 1-1/2 × 1-1/2 × 1 in. Weigh less than 3 oz. PC mount. $62.50. PALOMAR ENGINEERS. **232**

Miniature multiple output supply, HM3-5152, with ±15 V and +5 V outputs. Linear supply with no switching to make RFI or spiking. 250 mA rating at ±15 V and 2 A for the +5 V at 71°C base plate temp. Reg 0.25% for line and load each. Ripple 0.25% pk-pk. Foldback current limiting on all outputs and overvoltage protection on the 5 V output. 2-13/16 × 5-1/4 × 3-1/2 in. Operates from 105-130 V, 60 Hz, $72.00 (100-249 qty). HUDCO. **233**

High-performance inverter, 2050, with isolated dual 15-volt outputs from a single 28-volt source. Max load current 50 mA. 0.5%-line reg and 1.5%-

(Continued on page 92)

ESI takes the hit and myth out of laser resistance trimming:



Inset at top is full size thick film chip with 19 resistor L-cut trims, which do not show to the naked eye. Enlarged photo (approx. 8.5X magnification) shows detail of laser cuts.

Anyone who has looked into trimming resistors by laser knows: It has been a hit and myth affair.

The many variables that affect speed, accuracy and repeatability are not only difficult to control, they have been tough to classify. Film pastes, resistor or network configurations, cutting geometry, mechanical handling, laser parameters, bridge measurement capabilities, interfacing, noise . . . all affect the trimming process directly and hence design of the trimming system.

At ESI we have taken three major steps to overcome these problems and are passing these benefits on to you with the sale of each system:

1) We have developed a complete family of systems to provide flexibility in trimming resistors from 1 Ω - 10 MΩ. The speed of the system depends upon accuracy required:

   a) A **high speed,** low accuracy (0.1% and below) system, which employs a computer-controlled, continuous tracking bridge for closed-loop production at 5,000-10,000 trims/hr.

   b) A **medium speed,** low accuracy (0.1% and below) system for low-cost research or pilot production (500-5,000 trims/hr.).

   c) A **high accuracy** (0.1% to 0.001%), medium-speed system that can be either closed loop computer controlled or semi-automated by limited memory. Here a measure/predict/trim, measure/predict/trim sequence is used.

2) In our test laboratory we have developed an extensive collection of data on paste variables, component handling techniques and effective cutting geometries. Specifications of the tracking bridges were determined by trimming a wide variety of thick film pastes using many aspect ratios over the complete range of resistance/square values. Lower precision cylindrical resistors were spiraled, thick films were L-cut and "top-hats" trimmed. Both YAG and CO_2 lasers were used.

   For thin films the measure/predict bridges have been used to cut loops and trim tabs on a wide variety of networks. These bridges are also being used in production to adjust tantalum nitride resistors by trim anodization.

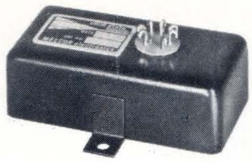
3) We have assumed total responsibility for delivery of an operating system to your production or lab floor. The measurement subsystem and laser must be properly chosen to meet your particular application. Connection scanner, Q-switch, laser optics, table speed, table travel and resolution are all variables which must be tailored to your requirements.

For a no-nonsense discussion of the tradeoffs in laser trimming, get in touch with our special systems group via Ed Swenson or Bob Conway.

ESI Model 20 computer-controlled laser trimming system is used to test pastes and cutting geometry in our laboratory.

e|s|i®

Electro Scientific Industries
13900 N.W. Science Park Dr.
Portland, Ore. 97229 • Ph. 503/646-4141



load reg. Ripple 1%. Operates over a mil-type environment. 7/8 × 1-5/16 × 2-9/16 in. MELCOR. **234**

Test Equipment

Broadband phasemeter, 305, with a direct reading accuracy of better than 0.1° over the full 360° range. Freq. range 5 Hz to 10 MHz. Angle ranges 0° to 360° and 0° to ±180° automatically selected. Operator adjust-

ments, none. Readouts: analog, digital or panel meter at option of user. Size: 3-1/2 in. high × 17 in. wide × 16 in. deep. DRANETZ. **235**

Flat-bed X-Y recorder, XL-683, with alternate X-t operation. X-function drives recorder pen across the chart, Y-function drives low-inertia chart beneath the pen. Chart span is 250 mm/axis. Alternate X-t operation, with optional selection of 1, 2, 3 or 10 chart speeds is std. Accuracy ±0.25% of either span. Span response time, 0.5 sec on X-axis and 0.7 sec on Y-axis. Automatic gain and damping. Chart speeds available for X-t mode from 2 cm/hr. Dimensions 17-3/4 × 17-5/8 × 6-3/8 in. $1570. LEEDS & NORTHRUP. **236**

7-channel monitor, MS5220A, with up to seven self-contained, dual input dc-10 MHz oscilloscopes in only 3-1/2 in. of panel height. Common power supply. Each scope has own controls. Bandwidth dc-10 MHz. Input sensitivity 0.1-10 Vrms/in. Acc (vertical) ±3% f.s. Sweep rate 10 Hz-1 MHz. Sweep linearity 3% f.s. Power dissipation 50 W. $2995. VU-DATA CORP. **237**

Semi-automatic digital teraohmeter, 9520, for the measurement of high resistance in the range of 10^7 to 10^{15} Ω. No manual balancing required — operation is completely automatic. Measuring V of 1, 10 and 100. Measurement time, 1 to 100 seconds. Accuracy and resolution are 0.1% and 0.02% respectively at a measuring current of 1 pA. BCD output optional. $2500. GUIDELINE INSTRUMENTS. **239**

Low-cost digital multimeter, LX-2, with portable battery operation. BCD output and remote program options. Automatic range and polarity selection and 4 automatically selected ranges of ac and dc V from 100 μV to 1000 V. R from 100 mΩ to 1.250 MΩ. Multi-function ratio-measurement mode (dc/

dc, ac/dc, Ω/dc) and switchable 60 dB input filter. Reading speed 500 ms. $795 base price. NON-LINEAR SYSTEMS. **238**

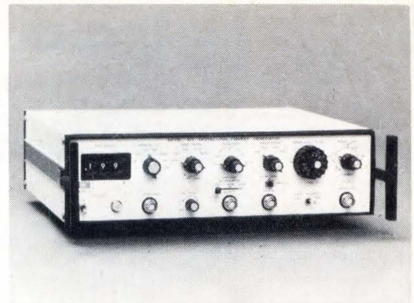
Single-pulse generator, BG-1, for flip/flop clocking, setting and resetting Gives a single negative pulse 1-μs long for every depression of push-button switch. No power required. Can be used with TTL, DTL, RTL, ECL and MOS. Overvoltage protection. Will not double trigger. 5/8 in. dia × 6 in. long. $19.50 (qty 10-25). CONCEPT ELECTRONICS. **240**

Self-powered IC tester with a clip probe and a flexible cable for in-system

testing of both 14 and 16-pin dual-in-line TTL or DTL ICs. Cable length is 24 in. Displays logic states of all pins simultaneously. Tester lamps are on for logic highs and off for logic lows. $120. EMCEE ELECTRONICS. **241**

Pseudo-random pattern generator, 112, for testing digital transmission equipment for telephone line communication or telemetry. Provides selectable bit rates of 1.2 kHz, 2.4 kHz, 4.8 kHz and 9.6 kHz. Freqs determined by 9.6 kHz crystal oscillator. Pattern length programmable in binary steps from 1024 to 524,688 bits. Data and clock outputs. Signal characteristics are Mil-Std-1888. $950. DIGITAL PRODUCTS CORP. **242**

Waveform generator, 127, with digital frequency dial and VCF and sweep operations. Freq 0.1 Hz to 3 MHz. Produces sine, square, triangle, ramp, pulse and sync waveforms. Modes: run, gate, triggered, burst, pulse and sweep. Sweep from 100 seconds to 10 μs. In pulse mode, pulse duration and rep rates are variable. Sine distortion 0.25% over audio range. Output 10 V

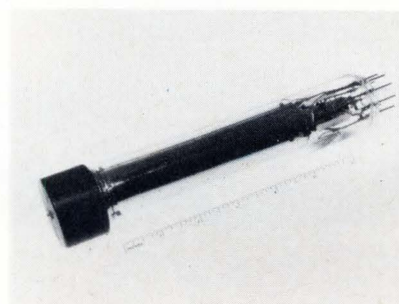


pk-pk into 50 Ω. 60-dB attenuation. ±10-V variable dc offset. Floating output and a variable phase start-stop for triggered and gated waveforms. 12-1/2 × 3-1/2 × 10-1/2 in. $645. EXACT ELECTRONICS. **243**

MOS driver, G720, for use as a clock or data driver. 5 Hz to 10-MHz rep freq. Delay and width 50 ns to 200 ms. Risetime 1 ns/V with a 100-pF load and two buffered trigger outputs. Can be driven externally from 0 to 10 MHz and will accept DTL/TTL compatible data input from word generators. Remote probe drives 100 pF with risetime of 1 ns/V. Front-panel 10-turn control adjusts output from −5 V to +15 V and from −30 V to 0 V. $495. E-H RESEARCH. **244**

Display Devices

1.5-inch diameter storage tube, SP5105, for video storage, computer output buffers, and information processing systems. Utilizes a monolithic-silicon-array target which provides resolution



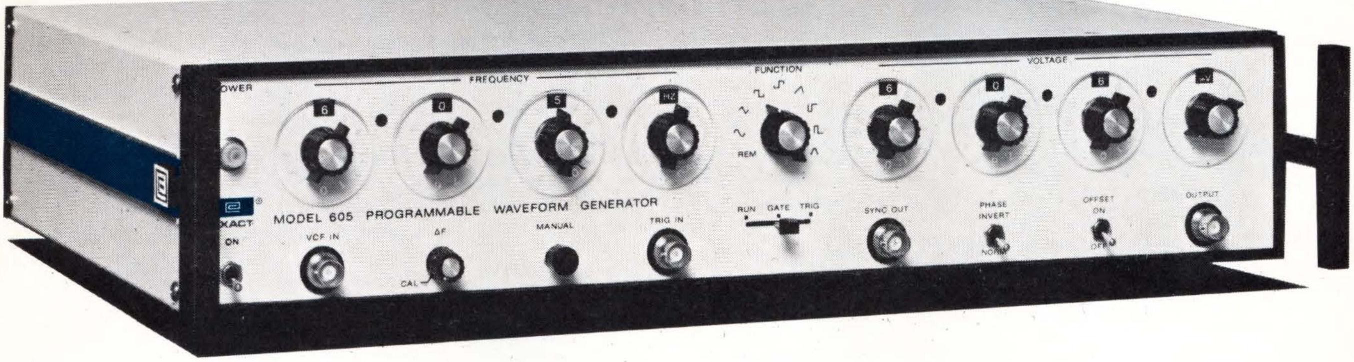
better than 1000 lines. Retention times in excess of 12 min for gray scale and over 1 hr for black and white. Images can be held for more than a week with beam off. SYLVANIA. **224**

Low-cost 3/4-inch CRT, Y4028, with electrostatic deflection for commercial and industrial applications. Miniature flat faceplate with P-1 phosphor. 3.75 in. length. Anode voltage 1000-2000 V. Deflection sensitivity 230 Vdc/in./kV. Reading capability from a distance of 50 ft. GE. **225**

Caption modules, 711, for displaying math signs, symbols or words. Lighted area may present single message or be divided into 2, 3, 4, or 6 areas that are individually switchable. Designed to

(Continued on page 94)

SYSTEM SOURCERY



EXACT announces a programmable waveform source designed for trouble-free system interface

- **Remote or local programming of frequency, waveform, amplitude, trigger, gate, D.C. offset and phase.**
- **Produces sine, square, triangle, ramp, pulse . . . symmetrical about ground or with programmed D.C. offset. Programming trigger or gate modes produces single-shot or burst output.**
- **Programming inputs compatible with DTL, TTL, contact closure.**
- **Frequency range 0.001 Hz to 1.1 MHz (usable to 0.0001 Hz).**
- **Voltage controlled frequency (VCF) with 1000:1 ratio.**
- **Two models . . . Model 605 with remote and local programming . . . Model 606 with remote programming only.**

Exact's Model 605 and 606 Programmable Waveform Generators are designed for use with the most advanced automatic test systems. Commanded by any standard digital logic, they can produce the waveforms needed to drive high speed systems without disturbing the integrity of the system itself.

Trouble-free system interface is accomplished by several design features. Programming and signal grounds are isolated for flexibility and safety. Less than 1 milliamp of sink current (less than 1 TTL load) per programming line eliminates the need for buffers. And, up to 50 volts can be applied to programming lines without damage.

The Model 605 (shown above) can be programmed remotely or by front-panel local controls. The operator can program all functions remotely or all locally, or he can program some remotely and some locally. All front panel connectors are paralleled at the rear for added convenience. The Model 606 is identical to the 605 except it is programmed remotely only.

Call or write Exact for a demonstration of these versatile generators. Or circle the reader service number for complete specifications.

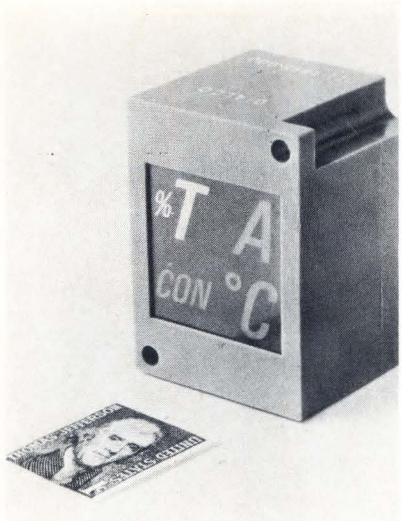
Model 605 (remote/local programming) $1,450
Model 606 (remote programming only) $1,250

Waveform generators from $295

EXACT electronics, inc.®

Box 160
Hillsboro, Oregon 97123
Telephone (503) 648-6661

A subsidiary of
Vector Management Corp.



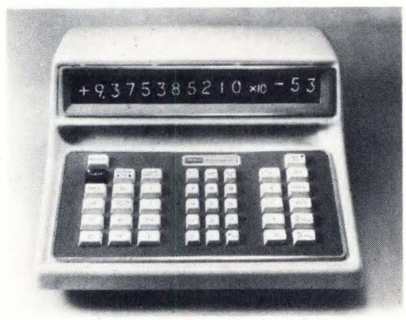
provide error-free reading at over 30 ft. Incandescent lamps of 5, 6 and 14 to 16 V. Lamp life 100,000 hrs. average. DIALIGHT. **226**

Digital-position readout, 360, for use with optical encoders to provide electronic digital display of machine tool coordinates. Readouts use plug-in MSI ICs and display linear or angular displacement to ±199.9999. In the event power fails, readout locks up at all zeros and power loss annunciator lights. Single qty $1,250. ITRON. **227**

4-1/2 inch edgewise meter, 1140, with five times the sensitivity of similar devices. 1.2-in wide. Standard ranges to 200 μAdc or 10 mA ac. May be stacked horizontally or vertically. Bar-type pointer and 4-in. scale. Shielded movement. SIGMA. **228**

Data Handling

Programmable electronic calculator, Statistician 911, for statistical calculations and other mathematical problems. Calculates factorials of integers from zero to 69 with single keystroke. "Sigma keys" allow accumulation of values into two different registers. "Incrementer key" allows counting and incrementing by fixed number from an initial value. Other single-key calculations include $|x|^y$, $\sqrt{x^2 + y^2}$, f(x), ln x, e^x, int x, sin x, cos x and arcs. 26

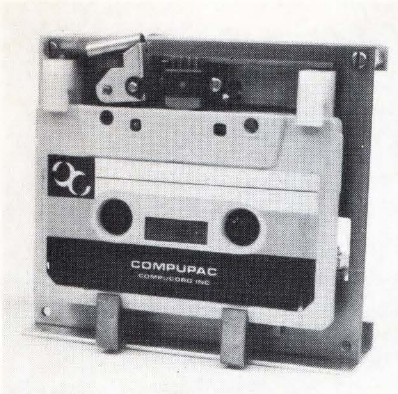


stored constants (100 optional). 85 program steps (256 optional). $3,780. 60 days. CINTRA. **318**

Alphanumeric data display, consisting of data controller (HDC) and data monitor (HDM). Displays data on TV monitor with local character generation and refresh memory. Available for character capacities of 128, 256 or 512. Accepts inputs from Teletype line, data set, keyboard or other digital devices. Optional interface equipment available. Parallel or serial entry for full-screen updating in 13 ms. HDM available with 6-in. or 9-in. display Under $760 (qty 1000). Available late 1970. HUGHES. **319**

Cartridge tape recorder, DPM-511, to log up to 35 days of continuous digital data for subsequent computer analysis. Cartridge similar to popular cassettes but larger. Companion reproducer (DPM-521) plays back complete cartridge in 2 min. Cartridge (MRC-100) contains two flanged bearing-mounted reels, tape guides, pinch roller and reel braking. $3,400 (DPM-S11), $2100 (DPM-521), and $30 ((MRC-100). 3M. **320**

Digital cassette recorder, Compudette 110DC, for battery operation. Draws only 150 mA while recording data. True bit-by-bit incremental capability. Write speeds to 300 steps/s. Rewind speed 30 in./s. Packing density 100 bits/in. 4.5 × 3.8 × 2.6 in. Optional

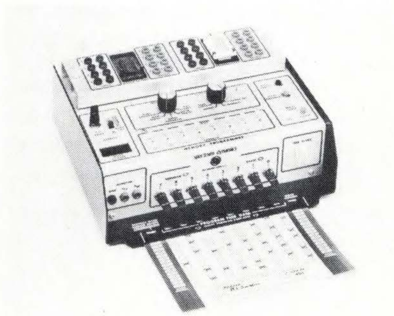


electronics available. COMPUCORD 321

Digital cassette deck, CAS-10, with variable speed and bi-directional read/write under dual capstan control. Optical sensing of beginning-of-tape and end-of-tape. Also includes sensors for cassette-in-place and file protect. 3 variable speed motors with Hall-generator feedback control. Electrodynamics braking. Independent solenoid-operated pinch rollers. 4-11/16 × 4-1/4 × 7 in. 4 1/2 bs. $300 (sample qty without electronics). $125 (1000 up). 6 wks. AURICORD. 322

Incremental digital cassette recorder, 400T, for communications and time-share applications. Automatically interchangeable Baud rates of 110, 150 and 300. Different rates can be used for record and playback. EIA (RS-232) and standard Teletype interfacing. Serial input/output. Patented recording system with data strobed onto tape by optical positioning clock coupled to stepper motor. MOBARK. 323

Field programmer, 402, for programmable read-only memories such as those made by Harris Semiconductor and Motorola. Manual or automatic programming and verification. Instrument addresses ROM chip with binary-coded data, sets outputs for desired logic and applies the required electrical signals for programming. Address-section capability 512 words. Accommodates many different device packages including 16-pin DIP, 24-pin DIP

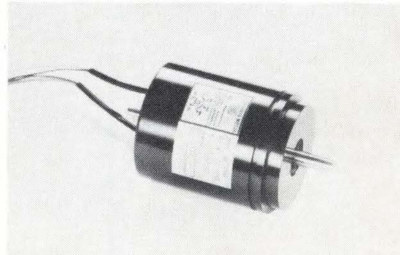


and 24-lead flat pack. Separate tester checks semiconductor parameters of ROM. 12 × 10 × 5 in. $945. Stock to 6 wks. SPECTRUM DYNAMICS. 324

Special Products

Tiny dc torque motor, NT 0716, with volume of 1 in.³ Peak torque 7 oz-in. Continuous shaft power output 10 W. Acceleration rate 53,000 rad/s.² Electrical time constant 0.36 ms. Weight 3 oz. Low cogging at low input currents. INLAND MOTOR 296

High-torque stepper motor, 020-030 in size 20 (2-in. dia) case. Stall torques 35 oz-in. Typical running torque 12



oz-in. Bi-directional responses at rates to 350 steps/s. Step angle 15°. Variable-reluctance design. IMC MAGNETICS. 297

Digital-output pressure transducer consisting of thin-film transducer, comparator, ladder network and complete logic circuitry in package of similar size to conventional analog transducers. Choice of fittings and output connectors. STATHAM INSTRUMENTS. 298

New Books

Theory of Nonlinear Control Systems. Nicolai Minorsky. McGraw-Hill. 324 pp + index. $16.50. ☐ Interpretation of Russian work on stability analysis and corresponding design technique of interest especially to advanced theoreticians.

Basic Electric Circuits. Donald P. Leach. Wiley. 597 pp + appendices and index. $9.95. ☐ Fine introduction for technician or student. Organized with review questions, glossaries, etc.

Circuit Theory: An Introduction to the State Variable Approach. Ronald A. Rohrer. McGraw-Hill. 301 pp + appendix and index. $14.50. ☐ Classical network theories in state variable terms.

Electronic Power Supplies. Joseph Grabinski. Holt, Rinehart and Winston, Inc. 216 pp + index. $3.95 (paperback). ☐ Very basic info for use in technical institutes, junior and community colleges.

Thin-Film Transistors: A new Approach to Microelectronics. Andrew C. Tickle. Wiley. 137 pp + index. $9.95. ☐ First book devoted to theory, methods of fabrication and analysis and circuit techniques of transistors fabricated by thin-film deposition techniques. Frequent comparisons to MOS.

Wave Generation and Shaping. Leonard Strauss. McGraw-Hill. 757 pp + index. $16.50. ☐ Extensive revision of a fine text on pulse circuitry with new additions including material on FETs, digital and linear ICs.

Maintainability: Principles and Practices. Benjamin S. Blanchard and E. Edward Lowery. McGraw-Hill. 331 pp + index. $12.50. ☐ Simply written, primarily for classroom use or managers interested in maintainability principles and techniques.

Automatic Data Processing: System/360 Edition. Frederick P. Brooks, Jr. and Kenneth E. Iverson. Wiley. 444 pp + index. $14.50. ☐ College text applying theoretical material on data processing in terms of IBM's System 360 Computers.

Electrons in Metal Semiconductors. Denis Greig. McGraw-Hill. 156 pp + index. $13.50. ☐ Coherent and useful comparison of metal vs semiconductor characteristics following physics review of bond structure, kinetic theory and scattering.

Logic Circuits. N. M. Morris. McGraw-Hill. 179 pp + index. $13.50. ☐ Systems approach to engineering logic emphasizes Karnaugh map method of logic reduction.

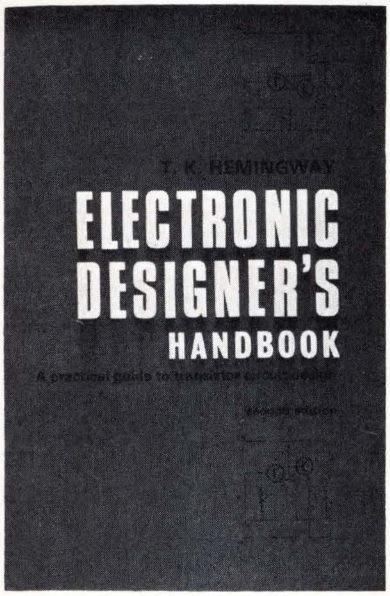
Computer Programs for Computational Assistance in the Study of Linear Control Theory. James L. Melsa. McGraw-Hill. 129 pp. $3.95. ☐ A series of eight digital computer Fortran programs which permit one to carry out the analysis, design and simulation of linear control problems. The practicing engineer will find this book to be valuable as a design and analysis aid.

Integrated Electronic Systems. Edited by Nick Holonyak, Jr McGraw-Hill. 463 pp + index. $16.95. ☐ Thorough discussion of integrated circuits from the system standpoint.

Information Transmission, Modulation and Noise. Mischa Schwartz. McGraw-Hill. 664 pp + index. $14.50. ☐ Revised and expanded second edition of a fine treatment of this subject with added emphasis on digtial communication and optimization techniques.

SAVE $2.00

on this special Prepublication Offer!



- **Brand-New & Updated**
- **16 BIG Chapters**
- **304 Fact-filled Pages**
- **Over 300 illustrations**
- **Handsome Hardbinding**

CONTENTS

Part 1: BASIC CIRCUITS

Semiconductor Diode Properties
The Transistor: D. C. Characteristics
The Transistor as a Switch
Transistor T-Equivalent Circuit
Linear Sweep Circuit
Constant-Current Circuits
Practical Design of Simple Amplifiers
Negative Feedback
D. C. Amplifiers

Part 2: SPECIAL CIRCUITS

Complementary Circuits
Wide-Range Voltage-Controlled Oscillator
Ultra-High Gain in One Stage
The Transistor Pump
The Transistor Cascode

Part 3: USEFUL TECHNIQUES

Bootstrapping
Prototype Testing

EVERYONE INVOLVED IN CIRCUIT DESIGN SHOULD HAVE THIS PRACTICAL GUIDE

ELECTRONIC DESIGNER'S HANDBOOK:

A Practical Guide to Transistor Circuit Design

BRAND-NEW UPDATED SECOND EDITION

By T. K. Hemingway, Author of Circuit Consultant's Casebook

Very probably the best book on transistor circuit design ever written for the practicing circuit designer.

The new edition of this well known and widely used book brings in the latest developments in transistor circuit design. Apart from the changes and additions to the text, this second edition will be particularly welcomed for the approximately 80 diagrams that have been updated and revised.

This up-to-date handbook provides a complete reference on transistor circuit design, to the depth required for practical engineering design. Part 1 gives extremely helpful, detailed coverage of the transistor used as a switch, and as a small-signal amplifier, as well as circuit operating principles and consideration of transistor parameters in practical design. The designer will find Part 2 of particular value for its description of several unusual circuits and the straightforward discussion on how novel designs can be synthesized and modified to serve in a number of practical applications.

The content is specifically intended to show the reader how to design his own circuits. As opposed to presenting superficial knowledge of a great number of circuits, specific circuits are presented and analyzed in detail so that the reader, armed with the underlying design techniques, can apply them in developing his own specific circuits.

Part 1 describes examples of the design of circuits, and shows how to simplify the theoretical analysis process which leads to practical designs. Typical values of transistor parameters are used in step-by-step examples of how to design basic circuits, with emphasis on the importance of developing circuits which are independent of parameter variations and ambient temperature changes. The Chapters on linear sweep and constant current circuits provide information not normally found in books on transistor circuit design. Part 2 shows how unusual circuits can be designed and given practical form. This section will be of special interest to designers looking for data they can draw upon to develop new and unique circuits. Again, the coverage is in much greater detail than is usual in a book of this type. Part 3 discusses the practical difficulties encountered in the design and testing of prototype circuits, offering many useful hints for solving a number of problems rarely mentioned in other books. Much of the math has been relegated to the appendix, where justification will be found for the expressions and approximations used. This book is specifically oriented to serve the needs of the practical design engineer, whether he be an "apprentice" or an "oldtimer." It shows how a designer's mind really works to achieve a satisfactory circuit. 294 pps., 304 illus.

FREE — 10 DAY EXAMINATION "Electronic Designer's Handbook" is published to sell at $9.95 but you can order now at the Special Price of only $7.95 . . . at our risk . . . for 10 day FREE examination. SEND NO MONEY! Simply fill in and mail NO-RISK coupon below for this indispensable volume!

OTHER HELPFUL BOOKS FOR ELECTRONICS ENGINEERS

Circuit Consultant's Casebook: Another practical guide of value to anyone involved in any phase of circuit design work — from theory to actual breadboard performance. This book is written for the circuit designer who encounters difficulties either in conceiving a suitable circuit configuration to meet a required specification or in obtaining optimum performance from a newly designed circuit. The content is divided into two main sections, the first dealing with important factors on how to avoid design faults, and the second on how to meet preconceived design specifications. Among the subjects dealt with in Part 1 are DC conditions, protection, microcircuit usage, dynamic effects, system defects, and errors in testing. Part 2 concentrates on methods of meeting specification requirements not readily achieved by standard circuits. In certain cases a simple modification to a standard circuit configuration is shown to be sufficient; in others a novel approach is given. The well-written text is mostly non-mathematical and can be followed by anyone who has a basic knowledge of circuit design techniques. You'll find the text and illustrative material most informative, and the countless examples and problem solutions — worked out in minute detail — of enduring practical value. 224 pps., 114 illus. Hardbound.
Order #288 .... **Only $9.95**

Solid-State Circuit Design & Operation. A unique and informative guide to semiconductor circuit analysis and design of value to practicing design engineers. Containing numerous practical circuits designs, along with the solutions to a variety of basic circuit development problems, this all-encompassing work delves into operational problems frequently encountered in everyday design work. Encompasses biasing techniques, amplifier circuits, pulse and switching circuits, computer logic using digital ICs, with many circuit design examples (including DTL TFL) and a discussion of basic AND-OR/NAND-NOR functions. A similar treatment is given operational amplifiers. 272 pps., 140 illus.
Order #508 .... **Only $9.95**

Electronics Reference Databook: This reference book is much more than a simple collection of tables, formulas, graphs, equations, etc. Rather, it contains an abundance of helpful information — specific guidance in the use of data, using as examples numerous problems associated with every level of interest — from electronics theory (formulas, laws) to measurements, and circuit design. Unlike most other data books, information here will enable you to use data available from many other sources; also, it tells how to develop additional data on your own. 232 pps., over 100 illus.
Order #488 .... **Only $7.95**

Electronic Circuit Design Handbook: New Third Edition. A carefully-planned reference source of nearly 600 tried and tested circuits, selected from thousands submitted by distinguished engineers. This detailed compilation of practical design data is the answer to the need for an organized gathering of proved circuits—basic and advanced designs that can easily serve as stepping stones to a needed configuration for busy design engineers, that can be adapted or modified to serve specific needs. 19 big sections cover circuit designs for control, regulation, protection, filtering and suppression, comparison, amplification, oscillation, alarm, counting and timing, testing and measuring, power supplies, detection and sensing, display and readout, gating and logic, relay and switching, and signal generation. 384 pages, $8\frac{1}{2}$ x 11".
Order #T-101 .... **Only $17.95**

FET Applications Handbook: New 2nd Edition. For anyone needing practical design data on FET circuits, here is the most current and comprehensive guide available today. Prepared by some of the most capable men in the industry, the content covers FET types, parameters and characteristics, and operational modes. Of immediate value to anyone looking for new ideas and unique circuit applications. Illustrated with over 250 circuit drawings and graphs. Appendices contain often-needed design data and charts. 352 pps.
Order #240 .... **Only $14.95**

PUBLISHER'S GUARANTEE

Put the information in these books to work for you for 10 days. If they don't prove to be worth several times their cost, return them and we'll cancel invoice.

NO RISK COUPON—MAIL TODAY

TAB BOOKS Blue Ridge Summit, Pa. 17214
Please send me .... copies of "Electronic Designer's Handbook" at the Special Prepublication Price of only $7.95.
Also send me: ☐ T-101 ☐ 240 ☐ 288 ☐ 488 ☐ 508
☐ I enclose $........
☐ Please invoice on 10-day FREE trial

Name........
Company........
Address........
City........ State........ Zip........
SAVE POSTAGE BY REMITTING WITH ORDER! EE-117

New Literature

Capacitors, resistors, transistors, filters, pulse transformers in 76-pg Sprague catalog. **440**

Coax connectors in 148-pg ITT Gremar handbook. **441**

IC op amps and D/A converters in Precision Monolithics 26-pg short form. **442**

DPMs and other digital-display modules in Instrument Displays 6 pager. **443**

Test equipment and transducers in B&K 40 pager. **444**

Active filters in 6-pg Analog Devices analysis. **445**

Microwave circuit modules in GE 16 pager. **446**

Kilowatt class S amplifiers in Instruments, Inc. 4-pg tech article. **447**

Trimmer pots in Weston 6 pager. **448**

Ferrites in Ceramic Magnetics 16-page applications guide. **449**

Metal-plate connectors in 40-pg Elco design handbook. **450**

Liquid coolant and leak tester in 22-pg 3M brochure. **451**

IC concepts and circuit applications in four Fairchild tech articles. **452**

CRTs in Westinghouse 20 pager. **453**

Graphic recorders in Valtec 8 pager. **454**

Electronic hardware in 36-pg Atlee catalog. **455**

Magnetic transducers in Pickering file holder. **456**

Printing calculators in Wang 8-pg catalog. **457**

Paddle-handle switches in C&K data. **458**

Attenuators, filters, switches in 80-pg RCL catalog. **459**

Analog panel meters in Jewell 12 pager. **460**

Precision motors and air movers in Instrument Systems 40-pg catalog. **461**

Multilayer ceramic capacitors in handsome 28-pg Electro Materials catalog. **462**

Rack/panel connectors in new Bundy 32 pager. **463**

Swept impedance measurements in HP 6-pg app note. **464**

Tin-oxide resistors in 16-pg Corning design guide. **465**

Jacks, plugs, patch panels, associated hardware in ADC 16 pager. **466**

Epoxies for hybrid circuits in Epoxy Technology data. **467**

Emi shielding materials in Metex 28-pg short form. **468**

Stepper motors, controls in 40-pg IMC design guide. **469**

10-bit BCD cermet resistor array in Beckman data. **470**

Primerless high-strength RTV silicones in GE data. **471**

Computer-aided hardware design in 24-pg Standard Logic brochure. **472**

Dc supplies in 64-pg Trygon handbook and catalog. **473**

Piezoceramic transducer materials in Gulton 28-pg catalog. **474**

Mag heads in Nortronics 8 pager. **475**

Indicators and lamps in Leecraft 12 pager. **476**

TTL Schmitt applications in 8-pg TI app note. **477**

NTC thermistors in Senistron 8-pg tech article. **478**

Power conditioning in Wanlass 18-pg data handbook. **479**

Rotary solenoids in 32-pg Ledex catalog with design and applications information. **480**

DIP-packaged LC filters in ESC 12 pager. **481**

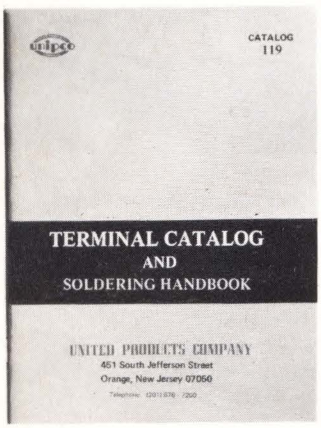
Abrasive-jet machining in 16-pg S. S. White brochure. **482**

Dc supplies in Technipower 62-pg catalog with terms, definitions, thermal data. **483**

Unusual Literature

Terminal Catalog and Soldering Handbook
United Products

Unless you like to read page after page of part numbers and their Mil-spec or competitive equivalents and unless you enjoy studying some ten dozen drawings of terminals, you'll find most of this 68-page catalog less than fascinating.



Tucked in the middle, however, there's an 18-page handbook on soldering, and this should prove more interesting. Even within the handbook, drawn in part from material published by Kearfott, Raytheon, AIL and NASA, there is a good bit of material that isn't terribly enlightening. One may suspect, for example, that rather few engineers will feel they've learned a lot from statements like, "A single poor solder joint makes an assembly unreliable," or "A neat and orderly work area contributes to quality work . . ." Nor should photographs of "A Quality Work Station" and "A Cluttered Work Station" prove highly instructive.

Nevertheless, there remains a great deal of information that can prove extremely valuable to anybody responsible for manual soldering. There are dozens of seemingly minor procedures and tricks of the trade that can prevent poor solder joints which, as many of us have learned, can be agonizingly difficult to track down — even in a breadboard.

If studying the 18-page handbook within this catalog can prevent even a single poor joint, the few minutes spent can be repaid amply.

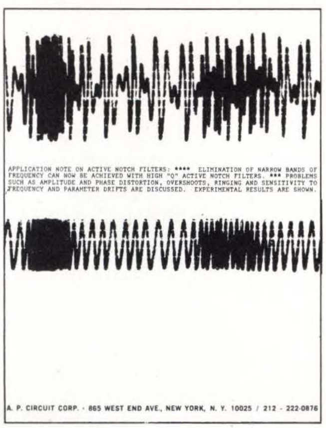
For a copy, circle **404.**

Active Notch Filters
A. P. Circuit

This is a very businesslike app note. The author wastes no time getting to the matter at hand.

He starts at a run — defining a generalized notch filter in terms of a three-terminal black box with a voltage transfer function and a frequency response. He discusses the applications of such a black box, shows typical waveforms it can provide, then moves into its LC and Twin-T passive-circuit implementations.

At this point, he points out that the ideal notch filter does not exist in nature. Carefully and methodically, he discusses



the limitations of real filters and shows how their performance departs from the ideal.

He provides equations that reveal the components that contribute to imperfections in response. He analyzes amplitude and phase distortion, frequency drift and attenuation change then, in the process, he discloses an important advantage of active filters — their ability to vary rejection bandwidth.

Finally, he shows the all-important — and deceptive — influence of filter Q. He concludes by showing the tradeoffs involved in designing around a high-Q notch filter.

For a copy, circle **402.**

CIRCUIT DESIGN AWARD PROGRAM

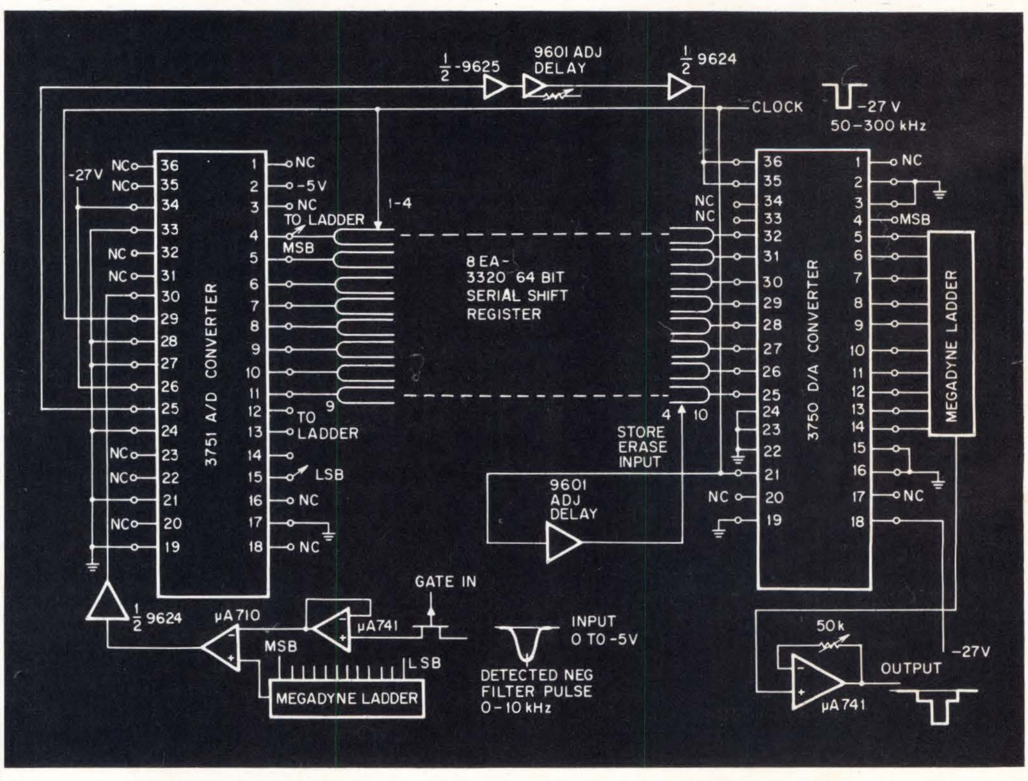
UNUSUAL CIRCUITS ☐ Designed by EEE's readers ☐ For use by EEE's readers ☐ Voted on by EEE's readers.
Your vote determines the winner of the monthly $100 U. S. Savings Bond. All monthly winners are finalists of this year's $1000 U. S. Savings Bond grand award. All other circuits published each month win a $25 U. S. Savings Bond consolation award.
VOTE NOW . . . The ballot is on the reader inquiry card.
Submit your own circuit, too. Mail entries to Circuit Design Program Editor, EEE, Mactier Publishing Corp., 820 Second Ave., New York, N. Y. 10017.

EEE readers have voted Karl Karash winner of the $100 Savings Bond for September. The winning circuit design is "Gain-programmable amplifier." Mr. Karash is with Raytheon in Sudbury, Mass.

A digital boxcar generator

Circuit Design No. 603

by **John J. Contus**
Hughes Aircraft
Culver City, California



MOS TECHNOLOGY HAS made possible monolithic A/D and D/A converters and serial or dynamic memories. These LSI type ICs with their small size and low power, are used here in a precision digital boxcar generator. The conversion time of this circuit is in the medium to slow speed range but its accuracy is much greater than corresponding analog types.

The schematic shows a digital sampler using a Fairchild 3751 A/D, A Fairchild 3750 D/A, and a Fairchild 3320 64 bit circulating shift register. In addition to the shift register, the 3320 contains logic for loading, recirculating or erasing its information. A parallel stack of eight 3320s is used to store

(EEE cannot assume responsibility for circuits shown nor represent that they are free from patent infringements.)

64 × 8 bits in the memory mode. Any one of the 8 bit levels may be selected for readout by proper clock domain selection. In the same manner, the recirculating loop can be opened momentarily for erasure of some or all of the information.

The 3751 A/D samples the analog input continuously and feeds a digitized output to the 3320 serial memory.

The holding registers of the 3750 D/A are gated by the delayed end of conversion pulse of the 3751 A/D. By extending this delay, storage capabilities can be increased by adding additional serial registers. ■

Tunnel diode minimum pulse-width detector

Circuit Design No. 604

by Richard W. Fergus
Argonne National Laboratory
Argonne, Illinois

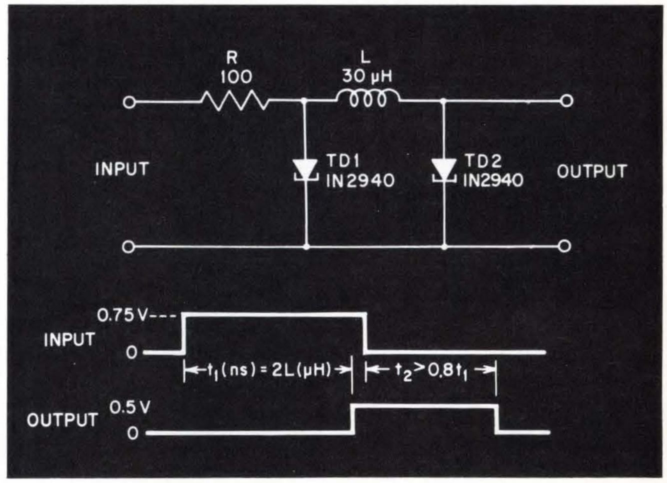
MINIMUM PULSE-WIDTH detectors have often been designed around IC monostables, UJT oscillators and discrete monostables. The circuit illustrated uses tunnel diodes for this purpose and has the advantage of being extremely simple, pulse-powered, predictable and fast.

Referring to the schematic, the input pulse current thru R will switch the tunnel diode (TD_1) to a high voltage state. In this state TD_1, becomes a a relatively constant charging voltage source for the inductor. The constant voltage across the inductor (TD_2) in its low voltage state) causes an inductor current that increases linearly with time. If the input pulse is shorter than the selected minimum width, the inductor current will not reach the level necessary to switch TD_2. If the pulse is longer than the selected minimum width, the inductor current will increase and switch TD_2 to the high voltage state. At the termination of the pulse, TD_1 will return to its low voltage state but TD_2 will remain in the high voltage state until the inductor current decays below the TD_2 valley current. The tunnel diode switching characteristic provides precise resolution (estimated at one nanosecond) while the charged inductor forces a minimum output pulse width. The circuit will not generate a partial output for a borderline pulse width.

The input pulse amplitude must provide a current through R greater than the sum of the valley and peak currents of the tunnel diodes. The minimum pulse width is a linear function of the inductance and is approximately the product of the inductance and TD_2 peak current divided by TD_1 peak voltage. For the circuit shown, this reduces to

$$t \approx 2L \text{ or } 60 \text{ ns.}$$

where t is in nanoseconds and L is in microhenries. ■



This pulse-width detector uses a minimum of components but operates at high speed.

Electronic dipstick

Circuit Design No. 605

by Larry Svelund
Sr. Assoc. Engineer
IBM Los Gatos, Calif.

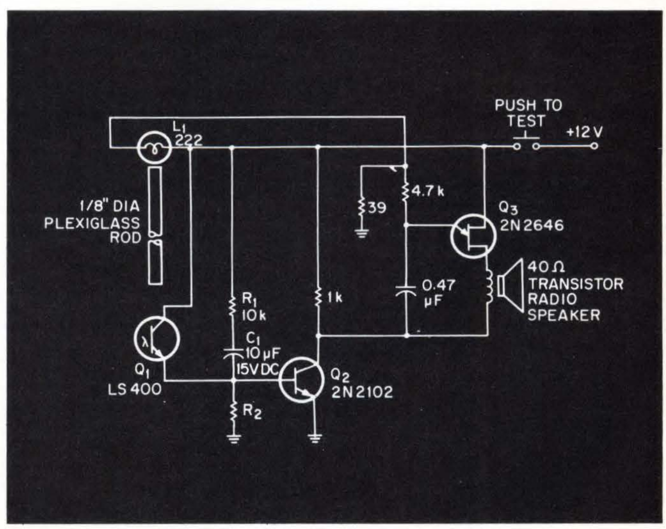
THIS CIRCUIT CHECKS crankcase oil level from the driver's seat. A plexiglass rod is attached to the dipstick and used to conduct light from lamp L_1 to the crankcase. This light is sensed by phototransistor Q_1 which is mounted at the "add oil" mark of the dipstick, about 1/2 in. below the bottom of the rod.

Depressing the test switch charges C_1 and saturates Q_2 for a short time. This activates the unijunction oscillator circuit of Q_3 and a short audio tone is heard. This verifies that the circuitry is functioning properly and that lamp L_1 is not burned out.

If the oil is low, light from the plexiglass rod is sufficiently attenuated so that the phototransistor's resistance will be high. After C_1 charges, Q_2 will turn off.

When oil is low, sufficient light reaches Q_1 to lower its resistance enough to keep Q_2 saturated after C_1 charges. In this case, a continuous tone will be heard as long as the switch is depressed.

The value of R_2 should be determined experimentally. A nominal value is 5kΩ. The plexiglass rod should be polished on the end near Q_1 for greatest light transmission and should be wrapped in foil for minimum light attenuation. The other end should be in contact with the lens of the lamp. Secure the phototransistor and the rod to the dipstick with RTV potting compound or high temperature shrinkable tubing. The sides of the dipstick may have to be filed to allow the assembly to fit in the dipstick hole. ■



Electronic dipstick uses phototransistor and plexiglass rod as sensors. A continuous tone signals a low oil level.

Current sources improve amplifier slew rate

Circuit Design No. 606

by William Peterson
ITL Research
Northridge, Calif.

DIFFERENTIAL AMPLIFIERS SUFFER from slew-rate slow down when driving capacitive loads. This effect is due to the RC-time of their collector networks. By replacing the resistive collector network with a constant current source, a substantial improvement in slew rate is realized. Fig. 1 illustrates a typical improvement. The circuit illustrated in Fig. 2 demonstrates the use of a npn constant-current network in a typical deflection amplifier.

From Fig. 2, we see that the circuit is a symmetrical differential amplifier, Q_1 and Q_3 are identical current sources. The network forming Q_1's current source is Q_1, CR_1, Q_7, R_6 and R_8. Transistor Q_7 is used as a 6.2 V zener diode. This equivalent zener has an extremely low impedance and will maintain 6.2 V with only a few μA of current. CR_1 compensates for V_{BE} drifts of Q_1, therefore, the voltage drop across R_8 is essentially 6.2 V. R_6 supplies the current for Q_7 and base drive for Q_1.

Under large output conditions the current variation through R_6 is maximum, since the entire signal appears across R_6. However, Q_7 maintains a 6.2-V constant drop due to its low dynamic impedance. Since this voltage appears across R_8, the current through R_8 is a constant. The only dynamic current variation under large-signal conditions is the current through R_6. The output impedance into the collector of Q_2 is close to 100 k. ■

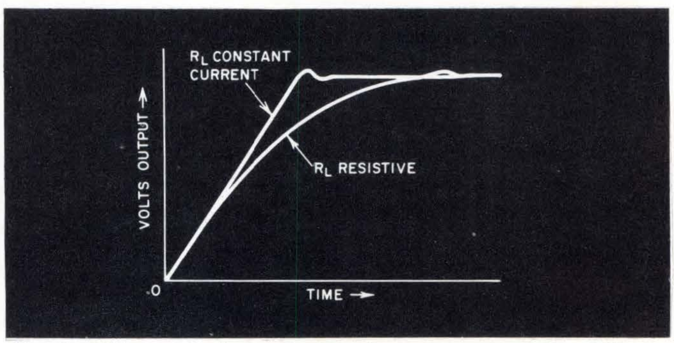


Fig. 1. This graph shows the transient response of the differential amplifier with and without the constant-current load.

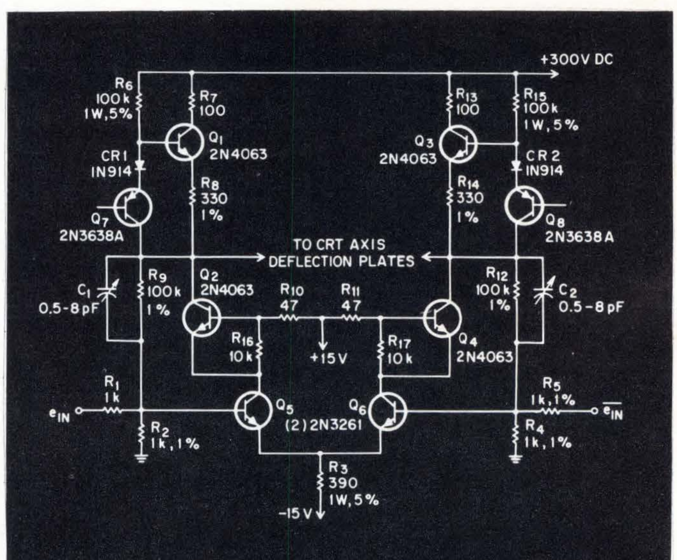


Fig. 2. This is the circuit of a high-voltage deflection circuit with current sources as output collector loads.

Sales Offices

NEW YORK
820 Second Ave., New York, N. Y. 10017
Gerald Hoberman 212-661-0450

NEW ENGLAND
41 Stevens Lane, Cohasset, Mass. 02025
Donald Kennedy 617-383-0029

MID-ATLANTIC
820 Second Ave., New York, N. Y. 10017
Richard Millar 212-661-0450

SOUTHEAST
Ken Fairleigh Associates, P. O. Box 3956, Charlotte, N. C. 28203
Kenneth F. Fairleigh 704-366-1434

MIDWEST
612 No. Michigan Ave., Chicago, Ill. 60611
Thomas F. X. Carter 312-642-3774

SOUTHWEST
1245 East Walnut St., Pasadena, Calif. 91106
Lawrence C. Papp 213-795-1528

WEST COAST
LOS ANGELES: 1245 East Walnut St., Pasadena, Calif. 91106, Los Angeles 213-684-0590
Pasadena 213-795-1528
Lawrence C. Papp
Burt Underwood

SAN FRANCISCO: Thompson & Healey, Inc. 1111 Hearst Building, San Francisco, Calif. 94103 415-362-8547
Jules Thompson
William J. Healey

JAPAN
Nippon Keisoku, Inc., P. O. Box 410, Central Tokyo, Japan 535-6614
Yoshi Yamamoto

SALES ADMINISTRATOR
Sally Ann Morley

PRODUCTION

Arline G. Jacobs, Manager
Rosalind Leifer, Assistant

Advertising orders and contracts should be sent to EEE, 820 Second Ave., New York, N. Y. 10017

Printing materials should be shipped prepaid to EEE, c/o Brown Printing Co., 307 Second St., Northwest, Waseca, Minn. 56093

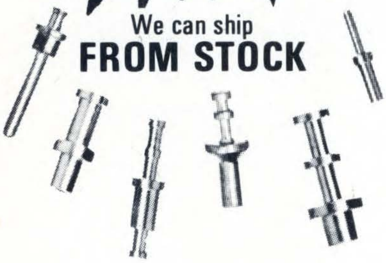
MARKETING DEPARTMENT

Lorraine de Camille, Marketing Services Manager
Irene Chervin, Research and Circulation Manager

Advertiser's Index

PIN/TERMINAL HEADACHES?

We can ship **FROM STOCK**



The
CONCORD

equivalent of almost any: LERCO • USECO, or CAMBION BRASS SOLDER TERMINALS and PINS PLUS...PRINTED CIRCUIT, MS STD., Mil-T-55155, Fed. Spec. Nos. & Crack Proof Terminals.

"We completely manufacture everything we sell."
Certified Plating to ALL MIL-Specs.

CONCORD ELECTRONICS CORPORATION
37 GREAT JONES STREET • NEW YORK, N.Y. 10012
(212) 777-6571 TWX 710-581-4930

Circle 145 on Reader Service Card

NEW!

• High Performance • Low Cost • Precision

D. C. TORQUE MOTORS

ONLY $10.40 ea. 100 lots — $13.50 ea. single units

Specifications:
- Peak Torque — 1.1 oz.-in.
- Torque-Inertia Ratio — 65,000 rad/sec.
- Torque Constant — 2.1 oz.-in./A
- Velocity Constant — 16mv/rad/sec.
- Voltage Rating — 12 volts

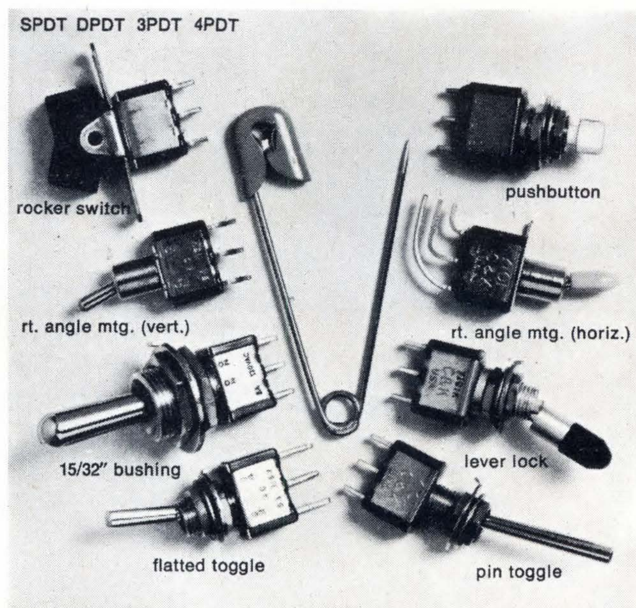
Applications:
- Cassette Tape Drives
- Film Transport Drives
- Servo Controls
- Potentiometer Drives

Our new catalog lists over thirty motors, tachometers, power amplifiers, and power supplies. Request your copy today!

MICRO MO ELECTRONICS, INC.
3691 Lee Road
Cleveland, Ohio 44120
Phone (216) 752-5599

Sudbury, Ma., 01776
Phone (617) 443-8959

Circle 148 on Reader Service Card



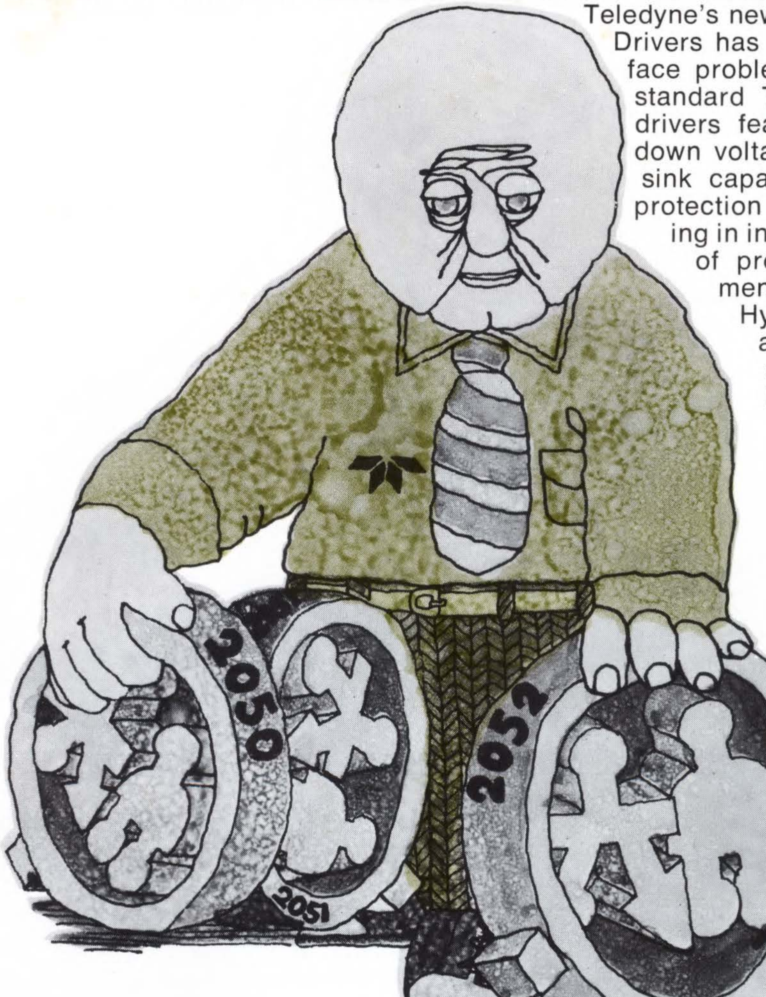
8 tiny, new additions to our family.

There they are – in a proud family portrait.
And like all C&K subminiature switches,
they're competitively-priced and Made-in-America.
Ask for our new catalog.

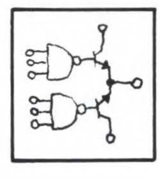
C&K COMPONENTS, INC.
103 Morse Street, Watertown, Massachusetts 02172
Tel: (617) 926-0800

Circle 149 on Reader Service Card

TELEDYNE SEMICONDUCTOR HAS A NEW LINE OF 100V HYBRID DRIVERS FOR YOUR TTL INTERFACE PROBLEMS



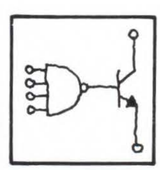
Teledyne's new line of 100V Hybrid Microcircuit Drivers has been designed to solve all interface problems where output capabilities of standard TTL gates are exceeded. These drivers feature a maximum output breakdown voltage of 100V with 250 mA current sink capability. Our 100V rating provides protection against voltage transients, resulting in increased reliability and elimination of protection circuitry. As a replacement for Discrete Components, the Hybrid Microcircuit Drivers reduce assembly problems, save space and optimize performance at a better price.



2050 CE

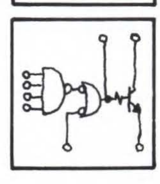
Dual Hybrid Microcircuit Driver

- ☐ Separate or Parallel Operation
- ☐ 500 mA current sink capability



2051 BE

Single Hybrid Microcircuit Driver



2052 BE

Hybrid Microcircuit Driver

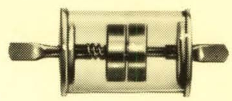
- ☐ Latching Capability
- ☐ Replacement for 40V - 2001 Hybrid Lamp Driver

TELEDYNE SEMICONDUCTOR
1300 Terra Bella Ave.
Mountain View
Calif. 94040
Phone (415) 968-9241
TWX: (910) 379-6494

TELEDYNE FIELD SALES OFFICES: Palo Alto, California (415) 321-4681 • **Hawthorne, California** (213) 772-4551 • **Anaheim, California** (714) 635-3171 • **Dallas, Texas** (214) 357-0259 • **Des Plaines, Illinois** (312) 299-6196 • **Westwood, Massachusetts** (617) 326-6600 • **Lutherville, Maryland** (301) 825-1920 • **Little Falls, New Jersey** (201) 256-8557 • **Wappingers Falls, New York** (914) 297-4316 • **Winter Park, Florida** (305) 647-7813 • **Dayton, Ohio** (513) 298-7207 • **Liverpool, New York** (315) 622-2021 • **Wiesbaden, Germany** 370243 • **Hong Kong** K 207764.

"ZERO" Reaction Time

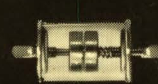
clip transients...

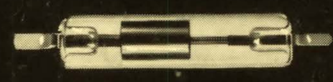


with the New Uni-Imp Voltage Surge Protector

- **Impulse Ratio** .... **1.1 to 1**
- **Trip Voltages** .... **550V to 15kV** **(constant up to 50 kV/microsec.)**
- **Life** .... **greater than 5,000 shots @ max. rating**
- **Follow-on Current** .... **Compatible with normal relay closure times**

Now it is possible to protect sensitive components, even semi-conductor equipment, against voltage transients without concern for the rate of voltage rise. The "zero" reaction time of Signalite's new Uni-Imp is only one of its many unique features. Others including its Bi-Polarity, immunity to di/dt restrictions, infinite leakage resistance, are described in a new data sheet.





AVAILABLE UPON REQUEST Detailed Data Sheet . . . on Signalite's Uni-Imp Zero Reaction Time Voltage Surge Protectors.

Signalite

Division of General Instrument

1933 HECK AVENUE, NEPTUNE • NEW JERSEY 07753
(201) 775-2490