Low-power, low-cost lasers, both gas and semiconductor, have moved out of the laboratory and onto the production line. They are finding wide use in areas like data processing, construction, communications and education. For assistance in using this new class of lasers more effectively, turn to the special report on p. 24.
Do you face a make or buy decision on power supplies?

Announcing Lambda's new 85W negative power hybrid voltage regulator

85W, -5.2V, 5A

$35 ea. (in quantity)
$20 ea. (in quantity of 100)
$18 ea. (in quantity of 1000)

also available

62W positive power hybrid voltage regulators
62W, 5V, 3A

$25 ea. (in quantity of 1)
$14 ea. (in quantity of 100)
$11 ea. (in quantity of 1000)

85W positive power hybrid voltage regulators
85W, 5V, 5A

$30 ea. (in quantity of 1)
$18 ea. (in quantity of 100)
$15 ea. (in quantity of 1000)

100,000 hours MTBF demonstrated

Regulation: 0.2% line
0.2% load
Ripple: 2mV RMS

WHETHER YOU MAKE OR BUY...

SEND FOR 1973 POWER SUPPLY CATALOG AND APPLICATION HANDBOOK
If you're a systems designer stuck with the use of discrete or electro-mechanical timing devices, you should investigate Exar's new monolithic timing circuits.

The XR-220 and XR-320 generate precise pulses and delays variable from one microsecond to one hour, using a single external resistor-capacitor combination to determine the time, 2RC. They are excellent for monostable or self-triggering timing pulse generation, linear sweep generation, and for pulse-width or pulse-position modulation timing. By combining two or more circuits, you can create an infinite variety of sequential and delayed timing cycles.

These Exar circuits are the only ones in hermetic DIP packages, and the only circuits which accept inverted or non-inverted inputs, and have outputs which are inverted or non-inverted, of high or low level.

You can buy the XR-320 for as little as $1 in 100-up quantities. It operates from 0 °C to 75 °C and has a guaranteed accuracy of 5%. The XR-220 is our prime device, with accuracy guaranteed to 0.5%, selling for $6.50 at 100-up. An XR-220M MIL version operates from −25 °C to 125 °C and sells for $10.

Call or write for more information on these new Exar products. Ask for Bill Seibert: Marketing Manager.
Here’s the perfect DAC-ADC team for your closed loop system

These Burr-Brown Digital-to-Analog and Analog-to-Digital converters are designed to work as an ultra accurate team. Both units have 16 bit resolution, the DAC has guaranteed monotonicity and the ADC has no missing codes. This makes them ideal for your process control, instrumentation, data logging and other closed and open loop systems. They are self-contained in 2" x 4" x 0.4" modular packages.

The ADC 100 features maximum linearity error of only 0.005% and a maximum accuracy drift as low as 5 ppm / °C. The unit is available with BCD or binary coding and unipolar or bipolar inputs. The binary units have pin programmable resolutions of 12, 14, or 16 bits, while the BCD units offer 4 digit or 4 digit plus sign coding. Conversion time is just 30 msec. Optional card-mount and rackmount packaging is available. Unit price is $225.00.

The DAC45 has a linearity error of only 0.003% and a maximum linearity drift of ±1ppm/°C. The unit is TTL/CMOS compatible and accepts 16 bit binary or 4 digit BCD input codes at transfer rates as high as 20 kHz. Conversion speed is just 5usec for a .6mV step. Optional card-mount and rackmount packaging is also available for the DAC45. Unit price is just $325.00.

FOR COMPLETE TECHNICAL INFORMATION, use this publication’s reader service card or phone Burr-Brown.

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Cover: Photograph by William A. Welch and Kent K. Sutherlin shows the replaceable read-only memory portion of Optical Data System Inc.'s storage and retrieval Holoscan system.
SWITCHING REGULATOR

<table>
<thead>
<tr>
<th></th>
<th>$V_{CEO}$</th>
<th>$V_{EBO}$</th>
<th>$V_{CE(SUS)}$</th>
<th>$h_{fe}$ @ 1 MHz ($V_{CE}=10V, I_C=200mA$)</th>
<th>$h_{FE}$ ($V_{CE}=5V, I_C=10A$)</th>
<th>$V_{CE(SAT)}$ @ 5.0 A</th>
<th>$I_C$ @ 75°C</th>
<th>$P_T$</th>
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<tbody>
<tr>
<td>DTS-1010</td>
<td>120V</td>
<td>7V</td>
<td>80V</td>
<td>12</td>
<td>200</td>
<td>1.8V</td>
<td>10A</td>
<td>100W*</td>
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<tr>
<td>DTS-1020</td>
<td>120V</td>
<td>7V</td>
<td>80V</td>
<td>12</td>
<td>500</td>
<td>1.5V</td>
<td>10A</td>
<td>100W*</td>
</tr>
</tbody>
</table>

*100 percent tested at 2.5A, 40V.
The Kokomoans now give you Darlington Switching Power.

Use a Darlington in place of an ordinary transistor, and you'll realize an additional magnitude of gain plus increased switching power. Use a Delco silicon power Darlington (DTS-1010 or DTS-1020) and you'll also realize a gain in dependability.

Delco’s Darlington are triple diffused mesa units housed in copper TO-204MA cases and built for ruggedness. The design gives them high energy capability—the ability to handle surges of current and voltage simultaneously. They are ideal for switching inductive loads in circuits subject to transients or fault conditions.

Design a switching regulator circuit around a Delco Darlington or use it in any 60-100 volt application to reduce circuit size, weight, and cost. In addition, the Darlington space saving feature allows you more design flexibility. Unlike an ordinary transistor, it’s only energy-limited, not beta-limited. You can exploit its full energy capability in your circuit.

Call your nearest Delco distributor. He has them in stock and he’s got the data on high energy switching for small spaces.

For details on the switching regulator circuit, ask for Application Note 49.

Delco Electronics

Division of General Motors Corporation.
Kokomo, Indiana

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ONTARIO • Scarborough • Lake Engineering Co., Ltd. (416)-751-5980
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El Segundo, Calif. 90243, 514 Coral Circle, (213) 640-0443.
Kokomo, Ind. 46901, 700 E. Firmin, (317) 459-2175 (Home Office).

INFORMATION RETRIEVAL NUMBER 6

ELECTRONIC DESIGN 2, January 18, 1973
Our Bill Shuart doesn't work for Power/Mate.

Bill is the Power/Mate Quality Assurance Manager and he has 34 supervisors and perfectionists under him. They also work for you. The result is unexcelled and consistent quality that we at Power/Mate are genuinely proud of.

Bill does a lot more than making sure our products are produced in accordance with his high standards of workmanship. (He wrote the book on that too.) Bill has developed a series of courses for all our employees on soldering techniques and workmanship standards.

He oversees the continuing MTBF studies (by computer of course) and worst case calculations on all our power supplies to insure the long life and trouble free performance you should expect.

He has developed a thermally cycled burn-in rack in which we subject all of our power supplies for 24 hours before shipment to insure there are no premature field failures.

He oversees the random sampling of all production-run power supplies. These are subject to a continuous night and day life test . . . for your continued assurance of a long-lived trouble free product.

We could go on . . . but we at Power/Mate are glad he works for you. That's why we can give a five year no-holds warranty.

Bill Shuart
Power/Mate Quality Assurance Manager

THE NEW
POWER/MATE CORP.
514 S. River Street, Hackensack, N. J. 07601/ Phone (201) 343-6294
TWX 710-990-5023

INFORMATION RETRIEVAL NUMBER 7
A cheer for less work

I like most of your editorials, because they’re novel and punchy. But the one in the Nov. 9, 1972 issue—"Get Enriched (If Not Rich) With Those High Flyers"—smelled too much of 19th-century optimism and the Protestant work ethic.

The editorial message was: "Get involved in a fledgling company. You’ll work like hell. You probably won’t get very rich. But the experience will be enriching.” The trouble with this message is:

1. There are too many electronics companies right now, and they’re competing for scarce business. A more optimum situation is the auto industry with four companies producing all the cars (more optimum for the men in the industry).

2. If 25 hours a day of work does not make you very wealthy, it is to be shunned.

3. Hard work of the sort done by fledgling company executives is not at all enriching (except monetarily); it serves to produce ulcers and coronaries, which are to be shunned.

There’s a new movement in America that your editorial is blissfully ignorant of. It’s the movement for less work and a better quality of life, with more leisure time. It’s a movement that professes:

1. A man should not be married to his career.

2. America has so much excess productive capacity, that people should work fewer hours, not more. (This produces the four-day work week, which is gradually gaining acceptance.)

3. A man’s work should be emotionally rewarding. If it’s not, he should change his work if at all possible.

Like any other industry, electronics has its share of freaks, who thrive on grueling, exhausting, unnerving work. If your editorial is aimed at these few freaks, why print it? If it’s aimed at the rest of us also, then please change the tune. It’s out of key with the second half of the 20th century.

Robert Bruce, MSEE
15 Johnstone Road
Great Neck, N.Y. 11021

Wire-AND advice draws a complaint

In Dwight H. Sawin’s discussion of wire-AND (“Use the Wired-AND and Implied-OR,” ED 20, Sept. 28, 1972, p. 76), he very mistakenly says that up to 10 open-collector TTL gates can be wired together with no adverse effects. He goes on later to state that the wire-AND configuration is not only hazard-free but also provides a significant savings.

The problem with this reasoning is that it assumes unfortunately that the real world ends at the designer’s bench. If those who utilize wire-AND connections only for package-count-savings had the onerous task of troubleshooting this design in production, or had the profit responsibility for field repairs, they would find another approach. Only when no other avenue is available does the TTL open-collector, wire-AND connection provide any real savings. The near impossibility of isolating a failure to the bad IC when several are wire-ANDED runs up test costs far exceeding any imagined savings of low-cost, standard TTL

(continued on page 11)
GENERAL AUTOMATION SAYS BUY DEC
If you're shopping the minicomputer market for raw hardware at rock bottom cost, it's hard to know where to stop. With more than two dozen price lists to choose from, it can get confusing. And time consuming.

We're here to make it easy for you. Buy DEC.

When you cut through all the claims, DEC's priced as low as anyone else. And they have built a business fulfilling the needs of the low-end iron buyer.

We make low cost hardware too. And if you're price shopping, you'll find us competitive. But raw iron is not our primary business.

The cheapest machine vs. the cheapest solution:

Sure, our goal is to save you money too. But our long suit is squeezing these savings out of your total systems cost rather than off of our price list. So if you need more from the machine or the company that sells it to you, we recommend us. General Automation.

Take the world's most powerful minicomputer, for instance.

The General Automation SPC-16. The SPC-16 possesses the most powerful instruction set you can buy in a minicomputer today. Think about that. The most powerful. As a result, the SPC-16 does more things in less time. It will actually reduce the total cost of your system.

Depending on your specific needs, you can choose from six different models in the SPC-16 family. Each backed by the best software and peripheral capability in the business. There's another very important reason why you should buy from us.

It's called involvement.

All the other big mini manufacturers today are touting the fact that they're "end-user oriented" or that they're now "in the systems business."

We've been doing exactly that for more than five years now. And it's nice to see that others have begun to recognize our leadership.

We learned a long time ago that the only way to really help our customers in solving their systems problems was to fully understand those problems.

So we got involved with our customers. Both end-users and OEMs. Listened attentively. Learned a lot. Got answers. And wound up building systems to solve some very tough, very complex problems.

Emissions analysis and electrical test systems for the nation's largest automobile manufacturers.

Production machine control systems for some of the biggest companies in the machine tool business.

Telecommunications and message switching systems for the world's leading telecommunications companies, to name just a few.

In short, we've built our company and our reputation by offering answers, not just iron.

Who's it gonna be?

Actually, we've made your choice fairly simple.

If all you need is raw minicomputer hardware at a "rock bottom" price, we recommend DEC.

If you'd like something more—from a mini with more oomph to the total solution of a complex systems problem—we recommend us. General Automation.

Our phone number is (714) 778-4800.

Or write:

1055 South East St., Anaheim, Calif. 92805

General Automation
Introducing the Fluke 8100B. At $595, you’ll wonder how we did so much in a 4½ Digit Multimeter.

The new version of Fluke's most successful DMM, Model 8100B, gives you the most value for your money ever offered in a quality digital voltmeter.

With a basic dc accuracy of 0.02%, the Fluke 8100B measures ac and dc volts in four ranges from 100 microvolts to 1200 volts and resistance from 100 milli­ohms to 12 megohms. With an optional ac/dc current shunt accessory, it measures from 10 nanoamperes to 12 amps in six switched ranges.

Features include an active 2-pole switchable filter and automatic polarity indicator. All functions are push-button selectable.

For $100 extra, a rechargeable battery pack can be added to give the user complete portability with up to eight hours continuous operation. Other options include RF and high voltage probes, switched ac/dc current shunts, data output and a ruggedized case. Demonstrated MTBF is over 10,000 hours, to make the instrument the most reliable available. The 8100B has tough environmental specs to ease your workload. Fully backed by Fluke's no-nonsense 12-month guarantee and service policy, here's an instrument that will meet your greatest expectations.

Call your local Fluke sales engineer for a demo and details. In the contiguous U.S., get his location by dialing our toll free number, 800-426-0361. Otherwise, address one of the locations listed below.

packages. I shudder to think of 10 gates wired together.

Jesse Pipkin,
Product Manager,
Digital Circuit Testing
Hewlett-Packard
5301 Stevens Creek Blvd.
Santa Clara, Calif. 95050.

The author replies

While Mr. Pipkin does make a good point, from the standpoint of reliability diagnosis, there are two sides to the discussion. The comment in the article concerning wiring 10 open-collector TTL gates together with no adverse effects refers to adverse electronic effects, if read in context. Specifically, it refers to the disastrous results suffered when "totem pole output" TTL gates are wired together.

Furthermore the article offers a general technique that may be applied when any logic family is used to reduce the package count. Likewise power consumption and size are also reduced. Granted, trouble-shooting in large equipment is difficult enough without wire configurations; however, in an extremely simple, high-volume production article, it may be that discarding the faulty circuit entirely is the best course of action economically.

Dwight H. Sawin 3d
University of Idaho
College of Engineering
Office of the Dean
Moscow, Idaho 83843.

Who makes that cassette transport?

In our FOCUS report on digital cassette and cartridge recorders (ED 18, September 2, 1972, pp. 40-46) we showed a picture of a three-cassette peripheral unit offered by Data General for use with its Nova minicomputers. In the caption, however, we failed to mention that the cassette transports were developed and manufactured by Redactron Corp. The cassette transport was developed originally for Redactron's editing typewriter system and is currently being used by other firms in typesetting uses.
Take signal sources for example...

You can't see the automated testing and the other manufacturing advances that help lower the price of HP's quality signal sources. But you sure can see the versatility and extra performance you get for your money. From the simplest function generator to the most capable synthesizer, HP technology has brought the price of quality way down.

Brand New Function Generator 3311A shows what a performance plus you get from this technology in action. Priced at only $249, it adds sweep capability and a separate high-power pulse output to the usual sine, square and triangular wave outputs. Sweep it over any 10 to 1 span within its 0.1 Hz to 1 MHz range. The pulse output drives up to 20 TTL loads. Note that price again. It's 15% lower than its nearest major competition.

Wide Range Function Generators 3310A/B deliver general-purpose waveforms with extended low-frequency response. These 0.0005 Hz to 5 MHz instruments equip you with a linear very-low-frequency ramp, in addition to sine, square, triangle and pulse waveforms. Prices are a modest $595 for the 3310A, and $735 for the 3310B that also provides free-run, single-cycle and multiple-cycle operating modes.
Lowest Cost Frequency Synthesizers 3320A/B bring you synthesizer quality for as little as $1,900. You get 1 part in $10^6$ frequency resolution over the entire 0.01 Hz to 13 MHz range. Also, on the 3320B, HP’s thermopile control of amplitude level gives 0.01 dB level resolution. If precise amplitude setting and calibration aren’t required, get the 3320A for $1,900. Or, get both frequency and amplitude precision in the 3320B for $2,550 (add $595 for full ASCII programmability). How’s that for a blend of quality, performance and low price!

Top-of-the-line Automatic Synthesizers 3330A/B have a built-in “brain” that lets you avoid tying up a computer. They’re like the 3320A/B, only these can be programmed to automatically sweep their frequency spectrum (and, on the 3330B, its precision amplitude level). With the 3330B you’re getting a synthesizer, a sweeper, a marker generator, a counter, a programmable attenuator, a built-in controller and a precision level generator—in other words a lab-in-a-box—for just $6,000. Or, cut that to $5,100 for the manual-amplitude-control 3330A.

Whatever your needs in signal sources, satisfy them with one of HP’s technology-leader instruments. They’re packed with more capability than ever before—and priced lower, too. For more information on the entire family of HP signal sources, contact your local HP field engineer. Or, write Hewlett-Packard, Palo Alto, California 94304. In Europe: HPSA, P.O. Box 85, CH-1217 Meyrin 2, Geneva, Switzerland. In Japan: Yokogawa—Hewlett-Packard, 1-59-1, Yoyogi, Shibuya-Ku, Tokyo, 151.
ACROSS THE DESK
(continued from page 11)

... And more ways to convert temperature

With respect to temperature conversion (see "A Foolproof Method to Convert Temperature," ED 17, Aug. 17, 1972, p. 7), I would like to suggest an approach that requires only the remembrance of the number 18 instead of any of the C/F or F/C conversion equations.

We all know that water freezes at 0° C, which equals +32° F. For each 10° increase/decrease of C, there is an 18° increase/decrease of F.

Therefore: +10° C = +50° F, +20° C = +68° F and +30° C = +86° F (note that, fortuitously, 86 is the reverse of 68), etc., -10° C = +14° F, -20° C = -4° F, etc.

Also, for each 1° increase/decrease of C, F increases/decreases 1.8° for interpolating.

Using this approach, you can do most of the conversions mentally. I forgot the 5/9, 9/5, +32, -32, etc., 50 years ago.

Julius Bernstein
118 Rosedale Rd.
Yonkers, N.Y. 10710

The Aug. 17 issue includes a good method of Fahrenheit/Celsius conversion, but James W. Wrenn could have indicated the background for the use of the "40." It might have made the system a little easier to understand. Simply, both Fahrenheit and Celsius scales are exactly equal at -40° ( -40° C = -40° F ). Therefore if the known scale is brought to a new origin at -40° (add 40 to a positive degree value) and then converted by the 5:9 ratio of the size of each degree, and finally the 40 subtracted out to get to the 0° level of the new scale, the job is done.

This method described by Mr. Wrenn is so much more logical and understandable, yet is almost never mentioned in the schools.

Robert Fabris
Research Specialist
Systems Integration

Lockheed Missiles & Space Co., Inc.
Sunnyvale, Calif. 94088.

Correction

In a recent product feature introducing Motorola’s dual-tracking voltage regulator, the MC1468 (“Improved Op Amp Regulator,” ED 19, Sept. 14, 1972, p. 169) some erroneous statements crept into a comparison with Raytheon’s RC-4194 dual-voltage regulator. To set the record straight, we note the following:

- Both ICs usually require six components (two resistors and four capacitors) for ±15-V operation. However, Motorola’s regulator can deliver ±15 V with just the four capacitors; the two resistors are needed only to limit load current. For output voltages other than ±15-V, the Motorola IC requires two extra components, while Raytheon’s general-purpose device can still operate with six external components.

- Prices for commercial-temperature-range versions in quantities of 100 up and in a TO-66 package are $3.90 for Raytheon’s 4194 and $3.75 for Motorola’s 1468. In 10-pin metal packages, the MC1468 sells for $2.50 (100-999), while Raytheon has a 14-pin DIP version of its regulator for $2.66 (100-999).

For additional information on Raytheon’s 4194, see “Dual-Tracking Voltage Regulator Extends Operating Range to 90 V,” ED 8, April 13, 1972, p. 97.

Correction

In the article “Can’t Decide Which Instrument to Buy?” (ED 24, Nov. 23, 1972, pp. 162-163), the instructions are garbled in one of the bottom blocks at the left of the Frequency Considerations chart (p. 162). As published, the instructions say: “Consider FG or Digital Dial and RC Osc (To 10 MHz).” They should say: “Consider FS or Digital Dial FG and RC Osc (To 10 MHz).”
Nobody can match Allen-Bradley's resistor cost

...on the board.

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

Paying the lowest price doesn't mean you're getting the lowest cost. Many fixed resistor brands lose their identification in the PC board cleaning process. Some don't have true colors to begin with. Or the color bands darken and become illegible from the heat produced in normal usage. The result is costly identification errors. Contrast this with the bright, crisp identification of Allen-Bradley's specially formulated paints. Baked on to resist aging, rough handling and solvents. Why gamble with questionable quality that can lead to unforeseen costs? Learn the facts. Ask your nearest A-B distributor for our free booklet, "7 ways to tell the difference in fixed resistors." Or write Allen-Bradley Electronics Division, 1201 South Second St., Milwaukee, Wisconsin 53204. Export: Bloomfield, New Jersey 07003. Canada: Allen-Bradley Canada Ltd., Galt, Ontario. United Kingdom: Jarrow, County Durham NE32 3EN.
AccurSystem™ back panels from Winchester Electronics offer you the bottom-to-top versatility and reliability you need from one manufacturer. To give you the cost/performance target you’re after.

Just consider the three basic AccurSystem offerings...

On the bottom, AccurFrame®, AccurPlate™ and AccurPlane™ back panels are available ready for automatic or semi-automatic wire-wrapping with accurate, reliable terminal alignment. Or, they will be shipped already precision-wrapped to your specifications.

AccurFrame and AccurPlane back panels accept Winchester Electronics HW Series edgeboard connectors on grids of .100 x .200 and .125 x .250; and our DW’s with .125 x .125 spacing. AccurPlate back panels accept our PW Series connectors for grids of .100 x .200 and .125 x .250; or, PDW’s with .125 x .125 spacing. Plus all three types accept our RW Series input/output connectors on either a 100 or .125 grid with wrapable contacts.

On the top, we can give you .100 or .125 contact spacing.

Many AccurSystem back panels feature field replaceable contacts.

AccurSystem is a proven, total interconnect solution to suit your design requirements. Exactly, even if it includes ground/voltage planes or ground bussing. You’ll call it a beautiful bottoms up story, too. Because any way you go, the AccurSystem means you can order precisely the back panel you want. AccurSystem. Developed by Winchester Electronics with your total needs in mind. Put our full scope of innovative ideas and practical knowledge to work for you, now. Winchester Electronics Division, Main Street & Hillside Avenue, Oakville, Conn. 06779. (203) 274-8891. Or, for discrete connectors, contact your local authorized distributor.
This Eight-Bit D/A Converter Does So Many Things... So Simply

Here Are Just A Few

Ever since we introduced the “basic” D/A converter, the MC1406 monolithic six-bit multiplying D/A, we’ve been getting requests to apply the same approach to an eight-bit type. By popular demand, then, here is the MC1508, a monolithic eight-bit multiplying D/A that’s versatile, simple to use, and inexpensive.

The MC1508’s flexibility is rooted in its simplicity. System requirements determine the voltage reference to be used, from simple zener to sophisticated IC. The op amp is chosen to meet the desired speed, accuracy and output range.

Choose among four variations covering a broad range of performance requirements. MC1508L-8 and MC1408L-8 provide worst case relative error of ±0.19% and full eight-bit accuracy. The MC1408L-7 and the MC1408L-6 have seven and six-bit accuracy, respectively, with eight-bit resolution. All four versions have a fast typical settling time of 300 ns, reference current slew rate of 4 mA/μs, and an extended output voltage swing of +0.5 V to -5 V. The non-inverting digital inputs are both TTL and CMOS compatible. Operating temperature ranges are -55 to +125°C for the MC1508 and 0 to +75°C for all MC1408 versions.

Prices (100-999) are in a class by themselves, with the MC1508L-8 naturally top priced at $8.50, the MC1408L-8 in the middle at $5.95, and the MC1408L-6 carrying a low $3.95 tag. Get full information by using the reader service number, or write to Motorola Semiconductor Products Inc., Box 20912, Phoenix, Arizona 85036.

*This approach does not result in a 16-Bit D/A Converter.

MOTOROLA LINEAR
—Serving a greater range of analog designs
Kertron’s “KS Series” of fast switching power transistors are continually finding new applications as requirements for greater efficiency demand faster $T_{on}$-$T_{off}$ times. The KS devices have been successfully used to power the Laser diode. They also replace mechanical and solid state circuitry for DC to DC converter (chopper) circuits. The Kertron KS series has also been successful in driving “LED displays” as well as switching power supplies and switching regulators.

The Kertron factory is in full compliance with the requirements of MIL-Q-9858A, and Hi-Rel assembly and processing is in accordance with MIL-S-19500, MIL-STD-750, MIL-STD-202 or any customer special requirement.

Kertron offers you 150 types of fast switching power transistors plus capability to produce for you the neatest little package for your own special requirement. Quality at Kertron is a serious business and quality gives you the assurance of optimum transistor performance without overspecifying your requirements. Check the chart below for your number and, if perhaps, it is not there, call us or write.

**SELECTED SAMPLES**

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**Contact Kertron Incorporated for Information and for name of Local or Overseas Representatives.**

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**INFORMATION RETRIEVAL NUMBER 19**

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**ELECTRONIC DESIGN 2, January 18, 1973**
NASA aims to hold the line with a $3.4-billion budget

NASA spending in calendar 1973 is expected to remain in stationary orbit. The budget for fiscal 1973 was $3.4-billion, and the total for fiscal '74 is expected to stay at this level. Even if it drops slightly, spending for calendar 1973 won't be affected too much.

The main effort will be the space shuttle, which the agency will push along as quickly as it can, albeit cautiously. The big fear is that Congress might quash the whole thing if something big went wrong. Except for a few items that will have to be bought for test purposes, almost all the work on electronic portions of the shuttle will be studies and analyses, says Ronald V. Murad, chief of avionics and ground systems for the shuttle program.

"This year, we'll put the finishing touches on our over-all avionics development plan," Murad says, "making phase-development schedules to tie in with the over-all program milestones. We will also study, with prime contractor North American Rockwell, the types of subcontractors we want."

Other action in the shuttle program this year will include the following:

- The Massachusetts Institute of Technology will begin systems analysis for guidance, navigation and control and performance monitoring. And IBM will begin an analysis of software design.
- Intermetrics in Cambridge, Mass., will begin developing the higher-order language, called Hal, for the shuttle computer, and later will develop the compiler. A computer will be selected by July.
- Honeywell will begin an analysis of the flight-control system and American Airlines an analysis of the problems of maintenance.

"We will also be firming up plans for a shuttle avionics integration laboratory to be located in Houston," Murad says.

The emphasis in unmanned satellites continues to be for better sensors and instrumentation in the spacecraft to relieve the cost and size of equipment on the ground, according to a spokesman for NASA's Goddard Spacecraft Center in Greenbelt, Md.

Needed are sensors to monitor the earth's resources. Atmospheric and water-pollution monitors are being developed, but "as soon as we've gained some experience with them, we're going to want to improve them," the spokesman said.

Ocean color-monitoring sensors are needed, along with other instrumentation to look at the earth.

An example of the kind of sensor Goddard wants is a microwave instrument for the Nimbus meteorological satellite that will pierce clouds to measure the thermal emission characteristics of the earth. By interpolation, measurements can then be calculated for the temperatures at various altitudes below and above the cloud formations.

"We're asking sensors and instrumentation to do more and more," the spokesman pointed out, "and consequently they're costing more." Because of this, Goddard is asking industry to use existing technology wherever possible, rather than pushing to new, expensive approaches.

Balancing out the cost increase for NASA sensors is a decrease in money needed for ground-tracking facilities, which were recently upgraded and will be adequate for the next few years. Over-all spending at Goddard will remain at about $500-million a year.

The biggest activity in the continuing exploration of the planets this year will be work on Viking, which is to orbit and land on Mars in 1975. NASA and the Jet Propulsion Laboratory will continue work on the camera, the line scanners, instruments to determine the atmospheric composition and pressure, and the nuclear-electric power generator for the lander.

The second Pioneer spacecraft will lift off in April to fly by Jupiter. It will be powered by a nuclear-electric engine. In October, Mariner will take off, powered by solar cells to fly by Venus and Mercury. Both craft will carry radiometers, spectrographs and imaging systems.

NASA's aeronautical work is picking up this year. Efforts are under way to reduce aircraft noise and airway and airport congestion. For noise abatement, a two-segment landing approach is being studied that would require a steeper descent to the final glide slope. Such a technique would require area navigation systems in all planes.

A STOL avionics program is under way to provide a short-takeoff-and-landing plane to operate in bad weather in a conventional aircraft terminal area. An automatic landing system is being developed for a VTOL (vertical take off and landing) plane. And improvements are being sought for landing conventional planes in bad weather.

A standard predicted for instrument interface

A de facto standard for the interface of programmable instruments will soon be in effect in the U.S., possibly by this summer. So says Robert Faulks, vice president of engineering for the General Radio Co, in Concord, Mass., and chairman of the U.S. Advisory Committee on Instrument-Computer Interfaces, which he helped form.

The standard is being considered for adoption by the International Electrotechnical Commission, the Scientific Apparatus Makers Association, the IEEE and other groups.

If the standard is adopted users of instrument systems will be able to interconnect a variety of instruments—such as signal generators, multimeters, recorders, card readers and computers—simply by plugging in cables. Any of the connected instruments could control or
feed information to up to 14 other connected instruments.

All manufacturers of programmable or systems-oriented equipment would have to conform to the interface or risk incompatibility between their equipment and that of other manufacturers.

The interface system—as initially proposed—is identical to one designed and developed by Hewlett-Packard, and described in its Journal, Vol. 24, No. 2, Oct., 1972. Basically it is a byte-serial, bit-parallel system in which each multiple-bit byte of information is transmitted in parallel and bytes are transmitted serially.

Only 15 lines are required: Eight are reserved for data input/output, three for data transfer control and the remaining four for general bus management.

However, the data-transfer-control portion, called the three-wire handshake, is proprietary to HP. Thus its adoption would require licensing agreements with HP. Don Loughry, corporate interface engineer for HP—and one of the developers of the interface—states that HP will certainly license the technique and make it available to everyone. But the details of the license have yet to be worked out.

Faulks feels that whatever form the interface takes, it will be substantially completed by this summer, although not yet officially adopted. This means, Faulks explains, that there will be very little risk of substantial changes after this summer, and that he'll be confident in recommending that General Radio go ahead with the interface hardware. Other companies, he continues, will probably also follow suit.

Minicalculator to become ‘major market’

The enthusiastic acceptance of the pocket calculator last year is continuing to build at a healthy pace, boosting the miniature electronic device into “one of the hottest consumer markets around—and one in which the Japanese are not yet ready to compete”—according to panelists at the “Outlook 73: Calculators” session of the Winter Consumer Electronics Show in Chicago this week.

“The U.S. market will absorb eight to 10-million units,” according to Herbert Barnett, national marketing manager of Commodore Business Machines, Santa Clara, Calif. “The rest of the world will take another two million.”

Both Barnett and Robert Beachler, vice president of operations for Craig Corp., Compton, Calif., predict that most of the 1973 crop of small calculators will cost the consumer from $59 to $69.

Variations of the pocket calculator expected to appear this year include a slightly larger, more versatile desk-top minicalculator to cost from $69 to $74, Barnett predicts, and calculators with expanded memories for from $100 to $120.

The next big development in the minicalculator line, though not expected before 1974, will be a true electronic desk-model printing calculator with standard vertical printout, says Commodore Business Machine’s Barnett. The only one available now, which is built by Canon, prints out a non-conventional horizontal serial form similar to ticker tape.

The reason the U.S. won’t have to contend with Japanese competition right away is “because they are a year behind the U.S. in their technology,” Barnett says. “There’s only one chip manufacturer in Japan.”

Users demand and get higher reliability ICs

Increased pressure by manufacturers for more reliable integrated circuits at lower costs has spawned efforts by a number of companies to meet their demands. Signetics’ program is called Supr Dip, Texas Instruments has REL II, National Semiconductor calls its program Test, Motorola has Sentry and Raytheon also has a strong program.

The users desire for guaranteed, factory-made reliability, according to Richard Kramer, National’s manager of reliability engineering, is to avoid the expense of having to inspect ICs as they are bought. More important, Kramer notes, is the time and money wasted in reworking printed circuit boards where faulty ICs are used. Also, manufacturers have to worry about warranties and servicing, both expensive and time-consuming.

To overcome these problems, says Kenneth La Barbera, marketing manager for Signetics, Supr Dip was initiated, which resulted in a new category of IC that falls in between the military and commercial devices, both in cost and performance. For an additional 5 to 8¢ per IC, a customer can get a plastic device that has a guaranteed AQL (accepted quality level) of 0.15%, has undergone several visual inspections, thermal shock and electrical and high temperature functional testing.

The program has been so widely accepted, reports La Barbera, that “we plan to come out with a new version of it—Supr Dip II.”

National Semiconductor also plans to come out with a new version of its Test program this quarter.

Texas Instruments’ distributing arm, TI Supply, has just introduced its high reliability REL II program, which in addition to performing additional tests, provides for a 168-hour power burn-in to eliminate devices that fail early. It provides devices with an AQL of 0.25% and costs an additional 25¢ per unit.

Motorola Semiconductor is about to introduce its Sentry program for consumer ICs. It differs from some of the other efforts in that its main emphasis is on meeting critical environmental requirements.

News Briefs

The American Stock Exchange in New York City has an infrared transmission system that carries transaction data from the roof above the exchange floor to a computer complex two blocks away. The system, which now handles 5400 characters a second, may be expanded to carry 25,000 this year.

A publishing company, Gannett of Rochester, N.Y., has invested more than $2.5-million in R&D on a system for producing printing plates through multiple laserbeam applications. The process would eliminate the need for a photographic negative, line-casting machines or other metal composition procedures.
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OPTOELECTRONIC DETECTOR LINEUP

L15A SERIES
- hermetic phototransistor
- packaged for printed circuit board mounting

L15E SERIES
- hermetic phototransistor
- sensitive, fast switching
- for detector arrays

L14A SERIES
- hermetic phototransistor
- 3 µsec turn on, turn off

L14F SERIES
- hermetic photodarlington
- typical 3 µsec turn on

L14T SERIES
- PNPN photo switch

L14D SERIES
- photodarlington configuration
- high sensitivity

L8, L9 SERIES
- hermetic photosensitive SCR
- switches 1.6 amp

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OUR NO. 1 GOAL:
TO MAKE GENERAL ELECTRIC YOUR BEST BUY
The low-cost, low-power laser: It’s here, there, everywhere

Some six or seven years ago laser designers convinced the construction engineer to lay aside his $5 ball of string and try using a gas laser for making straight lines. The helium-neon laser, with its pencil beam of light might cost a little more, but it is more accurate, saves time and requires fewer people to do the job.

After the construction industry discovered this, a host of new industries joined the laser club, and more than 100,000 low-power, low-cost, CW helium-neon lasers have been sold—lasers with a power output of 5 mW or less and costing less than $750. Some sell for as little as $40 in large quantities.

Competition appears

Low-power lasers are high-power business today, and prospects are that the major growth still lies ahead. The result has been the rise of new laser types and a growing applications struggle between competitors.

About two years ago a low-cost gallium-arsenide semiconductor injection laser became commercially available.

Not able to emit a pencil-like beam, and therefore not suitable as a “straight edge” for alignment jobs, the semiconductor injection laser is finding applications in short haul communications, military ranging devices, security systems, special illumination for battlefield imaging systems and in many jobs in the laboratory.

Ranging in price from $9.60 to $950, more than 50,000 low-cost gallium arsenide semiconductor injection lasers have been sold, says RCA’s product marketing manager for the devices, T. J. Grabowski in Lancaster, Pa.

A third laser, which appeared commercially about four years ago and has sold close to 1000 units, is the helium cadmium. Not quite “low cost” but getting close to that goal, this gas laser emits a blue (4420 A) or ultraviolet light (3250 A) that has attracted users who need to write on emulsions and films.

Its advantage over the HeNe laser is that available photosensitive papers are more sensitive—faster—in the blue-green region than in the red, thus making the HeCd laser handler for writing than the HeNe. The HeCd has a big advantage over the Argon laser, because it’s cheaper and has better photosensitive paper available for its blue light than the Argon does for its green.

In the jockeying for market position, helium-neon laser has proved it can do far more than define straight lines for highway construction, bricklaying, tunneling, the laying of pipes and—when beamed through a rotating prism—the building of ceilings. HeNe lasers are also being used in the following applications:

- Alignment work. Engineers are using the lasers to align gun positions and antennas on ships and align wheels and other points on automobiles. And now that the devices have become so inexpensive, they are even being bought by small auto-repair shops where damaged car and truck bodies are straightened.
- Testing and precise measurements. Glass and sheet-metal manufacturers find HeNe lasers useful for nondestructive testing—for blemishes as large plates pass down a production line, for example. The lasers are also used for making flow and machine-tool distance measurements, for gauging thickness, for positioning automated machines, for inspecting large prisms and lens and for optical tooling operations.
- Scanning. The gas lasers scan production lines to keep quantitative records on output. And they can read bar-code patterns on packages and letters and on supermarket products at the checkout counter, adding up totals and keeping inventories.
- Data processing. Lasers for character recognition for computer readouts “will eventually dwarf the laser market provided by the construction industry,” says Philip H. Vokrot, manager of market planning for lasers at RCA’s Electronic Components Div. in Lancaster, Pa. And Richard Roemer, manager of laser product sales at the Hughes
NEW, UNIQUE LOW COST BUILDING BLOCKS WITH BUILT-IN RECTIFIER, FILTER, REGULATOR AND OVP.
25 models, 5 power packages, up to 30v, up to 18a. Direct electrical connection to a transformer and mounting to a heat sink completes a quality d.c. power supply that meets your specific needs at the lowest possible cost.

OTHER EXCLUSIVE FEATURES:
- Regulation: Line/Load ±0.075%
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No need to add external components.

CUSTOM DESIGNS
Also these new standard sub-modules are ideally suited for custom designs at low costs and fast delivery. Custom designs are standard practice at Powertec.

SUB-MODULES OUTPUT RATING CHART AND PRICES.

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<th>5V to 6V</th>
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Typical ordering information for 5V: 1.0A, Model 22A-100; and 12V, 6.8A, Model 22D-300, etc.
*Consult factory for prices at other quantities.
Aircraft Electronic Dynamics Div. in Torrance, Calif., says: "A single customer might need tens of thousands of such units a year."

- Communications. Gas lasers can carry large amounts of information, audio and video, and they have an excellent potential for short-haul data links, says R. A. Jeuch, engineering leader for RCA's Gas Laser Development in Lancaster, Pa. He points out the advantage of using a laser link at a football stadium to transport television signals to a transmitter van. "At a big game, 25 miles of cable might be needed," he notes. "At $1 a foot for cable, a laser would do the job for far less money."

Other applications for the HeNe laser include holographic recording for checking filed data—such as the validity of credit cards (see cover photo)—spectroscopy, particulate sampling in a pollution detection device, ranging systems and optical displays.

"Two applications with promising futures are noncontact printing and, in the home entertainment field, video playback systems to be used with home television sets," says Hughes' Roemer.

**How HeNe lasers are made**

The fundamental ingredient in most helium-neon lasers is a tube that is rugged and stable and can be mass-produced. Hughes and Spectra-Physics in Mountain View, Calif., have both substantiated tube lifetimes of more than 15,000 hours.

The tubes are, with a few exceptions, of a coaxial design—one of the key breakthroughs that took the laser out of the laboratory and into the field. Developed and patented by Hughes, the coaxial construction resulted in a rugged, smaller tube. Another breakthrough, developed by Bell Telephone Laboratories, was the cold cathode-ray tube, which cut the need for heaters and permitted the use of an inexpensive power supply.

Some manufacturers offer tubes that are environmentally sealed in aluminum cylinders with end caps and flexible power cords, ready for operation. The cylindrical configuration of the laser heads permits easy mounting in clamps, V-blocks, rings and other hardware.

Permanent factory alignment of the output beam so it is concentric with the cylindrical mounting surface simplifies alignment of the laser relative to other components in the user's system.

The HeNe laser comes both as a neat and complete package, including power supply, or in components for the original-equipment manufacturer (OEM) to put together. At present most OEMs prefer to buy components and put them together. However, the trend, according to Marc Eliason, vice president of marketing of C W Radiation, Inc., in Mountain View, Calif., is toward assembly of custom packages by the laser makers for OEMs.

"In the future the OEM will know more what he wants and will tell us what the complete package is to be," Eliason says.

Hughes foresees demand for complete systems, including the laser power and optics.

At present there is a wide variety of laser ruggedness that the OEM can choose from. There are units for construction work that are protected from dust and heat and vibration and there are less rugged lasers for use in laboratories.

Available HeNe lasers operate in various modes. One is the TEM_00 mode, which offers the greatest concentration of light in the exact center of the beam. There are also random modes, which concentrate the light anywhere in the beam. According to Hughes, approximately 95% of OEM orders specify TEM_00. One reason is that this mode has roughly half the beam.

(continued on page 28)
The low-fat lasers. Now they come in rugged new packages, too.

We already streamlined the product, giving you all the minimum daily OEM requirements at a low, fat-free price.

Now we've gone to work on the packaging.

We've encased our bare-bottle helium-neon lasers in cylindrical metal packages and added them to our line of low-fat lasers.

The new models offer one or two milliwatts of polarized or unpolarized output power. They come with flying leads and an internal ballast resistor and have the output beam precision aligned with the 10½" package.

We've built unusual tube ruggedness into these new models. With package construction that allows the lasers to be used in systems without worrying about high-voltage exposure or mounting directly to a glass surface.

These units come at low-calorie prices, too. Available in minimum quantity of 10, from $139.95 each and from $99.95 a unit in lots of one thousand. With them, you get an 18-month, no-hour limit OEM warranty.

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For complete information, write: 3100 W. Lomita Blvd., Torrance, CA 90509.

U.S.A. and Canada
A sampling of the low-cost, low-power lasers available

### Helium neon lasers

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<td>Self-contained, weather-proof, detachable laser heads. Packaged systems.</td>
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<td>Contact: Marc Eliason</td>
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<td>Vice President</td>
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<tr>
<td>Hughes Aircraft</td>
<td>1 to 5 mW</td>
<td>6328 Å</td>
<td>TEM\textsubscript{00}</td>
<td>Polarized Unpolarized</td>
<td>12 V dc</td>
<td>Laser and power supply separate. Complete laser or components.</td>
<td>$40 to $280</td>
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<tr>
<td>Electron Dynamics Div. Torrance, Calif. 90509</td>
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<td>Contact: Dick Roemer, Sales Mgr.</td>
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<td>Eric Hass, Asst. Sales Mgr.</td>
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<tr>
<td>Metrologic Instruments</td>
<td>0.5 to 5 mW</td>
<td>6328 Å</td>
<td>TEM\textsubscript{00}</td>
<td>Polarized Unpolarized</td>
<td>12 V dc</td>
<td>Complete lasers or tubes.</td>
<td>$87 to $275</td>
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<td>Contact: Larry D. Adams Program Manager</td>
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<td>RCA</td>
<td>1 to 5 mW</td>
<td>6328 Å</td>
<td>TEM\textsubscript{00}</td>
<td>Polarized Unpolarized</td>
<td>12 V dc</td>
<td>Power supply separate or combined.</td>
<td>$110 to $440</td>
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<td>Contact: F.H. Yokrot</td>
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<td>Spectra-Physics</td>
<td>0.5 to 5 mW</td>
<td>6328 Å</td>
<td>TEM\textsubscript{00}</td>
<td>Polarized Unpolarized</td>
<td>115 V ac</td>
<td>Laser and power supply separate or combined.</td>
<td>$99.50 to $675</td>
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<td>1250 W, Middlefield</td>
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<td>Contact: Ron Elchesen</td>
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### Helium cadmium lasers

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<tr>
<th>Manufacturer</th>
<th>Power Range</th>
<th>Wavelength</th>
<th>Modes</th>
<th>Output</th>
<th>Power supplies</th>
<th>Packaging</th>
<th>Price range</th>
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<tr>
<td>Coherent Radiation</td>
<td>1 to 10 mW</td>
<td>4416 Å</td>
<td>TEM\textsubscript{00}</td>
<td>Polarized</td>
<td>12 V dc</td>
<td>Components or complete laser.</td>
<td>$1600 to $1750</td>
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<tr>
<td>Metrologic</td>
<td>3 to 25 mW</td>
<td>4420 Å</td>
<td>TEM\textsubscript{00}</td>
<td>Polarized</td>
<td>115 V ac</td>
<td>Complete laser.</td>
<td>$780 to $1080</td>
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<tr>
<td>RCA</td>
<td>5 mW</td>
<td>4416 Å</td>
<td>TEM\textsubscript{00}</td>
<td>Polarized</td>
<td>108 to 132 V ac</td>
<td>Complete system.</td>
<td>$1725 to $2125</td>
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### Semiconductor injection lasers

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<tr>
<th>Manufacturer</th>
<th>Peak Power</th>
<th>Wavelength</th>
<th>Output</th>
<th>Configurations</th>
<th>Power supplies</th>
<th>Packaging</th>
<th>Price range</th>
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<tr>
<td>Laser Diode Labs</td>
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<tr>
<td>Contact: Robert Gill Vice President</td>
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<tr>
<td>Diodes</td>
<td>4 W to 60 W</td>
<td>GaAs</td>
<td>Unpolarized</td>
<td>Discrete diodes Stacks Arrays</td>
<td>28 V dc Pulse generators and converters.</td>
<td>Laser and power supplies separate.</td>
<td>Discrete diodes $9.60 to $95</td>
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<tr>
<td>Stacks</td>
<td>25 W to 175 W</td>
<td>GaAIAs</td>
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<tr>
<td>Araryrs</td>
<td>60 W to 1000 W</td>
<td>GaAIAs</td>
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<tr>
<td>GaAs</td>
<td>9040 to 9050 Å</td>
<td>GaAIAs</td>
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<td>at 27 C</td>
<td>8000 to 8700 Å</td>
<td>GaAIAs</td>
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<tr>
<td>RCA</td>
<td>1 W to 1000 W</td>
<td>GaAs</td>
<td>Partly polarized</td>
<td>Discrete diodes Stacks Arrays</td>
<td>Power supply not provided.</td>
<td>Transistor type packaging.</td>
<td>Discrete diodes $10 to $100</td>
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<tr>
<td>Electro Optics Products</td>
<td>1 W to 50 W</td>
<td>GaAs</td>
<td></td>
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<td>25 W to 100 W</td>
<td>GaAIAs</td>
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<tr>
<td>Lancaster, Pa. 17604</td>
<td>25 W to 1000 W</td>
<td>GaAIAs</td>
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<td>Contact: R. Swarbrick</td>
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(continued on page 30)
Economy: First Class

SIGNETICS LINEAR. First with phase locked loop! First with the universal IC timer! First with the Schottky-clamped comparator! Plus a solid line of standard-busters in between.

Class tells. In vastly extended design capabilities. In pared down device costs and function consolidation. Old shoe linear gets the boot at Signetics. We never leave well enough alone. And from this commitment has come industry-shaking innovations. Spectacular enough to set new technological standards. Practical enough to expand your options without penalizing system design, compatibility or efficiency. But with so much versatility built in, the flexibility of each component reduces circuit count.

Phase Locked Loop. The world’s first PLL devices eliminated tuned circuits altogether when Signetics put complete systems on a chip. Operating from dc to 30 MHz, our PLL invention has proved extremely versatile—useful for AM and FM demodulation, frequency multiplication and division, or frequency sensing (tone decoding). With no precision components required. Signetics ships the broadest PLL product line available anywhere: circuits 560, 561, 562, 565, 566, 567 now on the shelves.

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527/529 High Speed Comparator. A real two-in-one breakthrough, still another Signetics first. The fastest, least cantankerous voltage comparator to hit the market when introduced last year. The biggest improvement in comparators since the 710 (300% faster). By incorporating Schottky technology into 527/529, both high speed and precise input characteristics are maximized. Offering users a new generation of sense amplifiers as an alternate application of these devices. When it comes to industry standards, Signetics linear shapes them up before we ship them out. So much so, they evolve into new circuits—pin-compatible but considerably enhanced. So versatile, you can stock fewer parts yet accomplish a great deal more, while lowering total board costs.

592 Video Amplifier. Primarily applied as a magnetic head preamp for also file read circuitry. Pin-for-pin with 733, but offering more refined performance and versatility. Proven useful for high frequency bandpass or highpass filtering because no matched passive components are required. So, less parts are needed—both inventory and board work costs go down.

531/536 Op Amps. Salt of the earth, economy-minded op amps for generalized performance requirements. The 536 FET input Op Amp easily replaces the lower end of the modular op amp market without penalty, and saves up to 50% cost. Low-price 531 High Slew Rate Op Amp is priced under competitive devices, but functions more than adequately over most standard requirements.

540 Power Amplifier. Out-performs common power drivers with extra high speed. This Class AB audio amp on a single chip is economy-priced, but saves still more on unnecessary associated components. Output power limiting delivers total power protection and still allows smaller output transistors: less cooling is required.

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Fill us in on Signetics economical first class linear devices. Please send:
 [] PLL Applications Book
 [] Linear Handbook, Vol. No. 1

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<td>Title</td>
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<td>Company</td>
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<td>Telephone</td>
<td>Signetics Corporation, A subsidiary of Corning Glass Works.</td>
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Electronic Design 2, January 18, 1973
Where the semiconductor works

The semiconductor injection laser emits a wide beam of light rather than a pencil beam, and its emission is pulsed rather than continuous. It's surprisingly small—the size of a transistor—and it's finding many uses, particularly in short-distance operations. The applications include these:

- Intrusion alarms. Gallium-arsenide lasers are taking the place of tungsten bulb and filter systems in both military and industrial security systems. When an intruder enters the beam, he reflects light that triggers an alarm. The advantages of the laser system are lower cost, lower power drain and smaller, less detectable systems.

- Communications. Diode lasers are good for short-haul communications—between buildings, for example. And for secure communications for the military, infrared systems are finding application.

- Ranging. The military is buying small diodes for use as altimeters for helicopters, for range-finders to zero in on enemy tanks and similar targets, and for proximity fuses. In the latter applications, when the laser determines that a shell or missile is within a predetermined distance of its target, it explodes the weapon.

- Data processing. Although this application is still in its early stages, Robert Gill, vice president of Laser Diode Laboratories in Metuchen, N.J., sees the semiconductor laser being used as a device for computers.

RCA's 15-diode linear array provides a peak power output of 75 W.

Other applications that RCA and others foresee include real-time readout of holograms, collision avoidance for automobiles, traffic control, weapon simulation and "ceilometers" for measuring the altitude of clouds.

The trick for the OEM in choosing the right semiconductor laser is to order only the power he really needs, Gill says. "Engineers often ask for more power than they need," he notes.

The OEM has a wide variety of semiconductor injection lasers from which to choose. There are single-diode injection lasers, stacked diodes and diode arrays. They are made with gallium arsenide and emit in the 9040-to-9050-Å range.

Gallium-aluminum-arsenide injection lasers are also available for use with near-IR-sensitive (8000 to 9000 Å) image intensifiers and photomultipliers.

The single diodes have a peak power range from 4 to 60 W. The stacks from 25 to 60 W, and the arrays from 60 to 1000 W. Single diodes are suitable for voice communications over short range. Stacks, which consist of two or more diodes in a stack, emit more power and are suitable for voice over longer links and for intrusion alarms. To illuminate a battlefield target for an IR or TV image converter, the array might be used; it consists of diodes placed side by side and connected by wires.

Though young, and not inexpensive, the helium cadmium laser is also gathering a following because of its ability to do the following:

- Write on photosensitive paper. The applications include information storage, particularly on film; in-flight recorders and data processing readout devices.

- Detect pollutants. Some particles are detected more easily by wavelengths in the blue region than in the HeNe's red.

- Display in full color. By use of a single 4416-Å beam to excite red, blue and green fluorescence, a full color display can be achieved.

- Conduct experiments in spectroscopy. New research in the fluorescence of microscopically small samples is possible, as are new studies of excitation and decexcitation processes of triplet states in organic molecules.

The HeCd laser is usually packaged with its power supply. The total package measures 30 to 40 inches in length and 6 by 6 inches on the sides.

The most inexpensive HeCd laser on the market, Metrologic's ML 442, emits a continuous beam of coherent deep blue light (4420 Å). The beam is randomly polarized and provides a 20-mW output in the TEM_00 mode. The integral mirrors are permanently aligned.

Design features include the laser's use of single isotope cadmium, a diffusion chamber for minimizing noise, and all-fused quartz-glass, sealed optics.

The tube has a directly heated tungsten matrix cathode with long life emission. Warm-up time for the laser is five minutes.

RCA offers a HeCd unit for $1725. Hughes and Coherent Radiation are doing custom work in this field, and Hughes will soon announce a commercial line.
The GI book

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INFORMATION RETRIEVAL NUMBER 24
Defense spending is expected to increase slightly this year—by $4-billion for fiscal 1974, if the Defense Dept.'s recommendation goes through. A total of $80-billion is being sought. But because operating and personnel costs are also rising, it's unlikely that there will be any increase in research and development money.

Only two things would be dramatic enough at this time to cause a war-weary Congress and nation to increase arms spending significantly: a total breakdown of the SALT talks with the Soviet Union, which are intended to curb the arms buildup on both sides, or involvement in another war.

R&D and procurement will continue for what is considered to be the nation's fixed triad of strength: bombers (the B-1), Minuteman land-based ICBMs, and submarine-launched ICBMs.

**Army stressing versatility**

Big Army programs include development of a large transport helicopter, a new attack helicopter, the ground-to-air SAM-D missile and a new tank.

Spending for ground and ship-based radar from the middle of 1972 to July, 1974, will exceed $1-billion, according to a study by Frost & Sullivan, a New York-based market research firm.

Radar work is under way for the two Safeguard antiballistic missile sites, for the defense of Minuteman sites and for over-the-horizon radars.

The Army has assigned a high priority in 1973 to the improvement of surveillance techniques, electronic warfare, command and control systems and communications.

**Air Force looking ahead**

The Air Force's Airborne Warning and Control System (Awacs) and Advanced Airborne Command Posts will both go into the advanced development stage this year.

The Air Force will continue efforts to reduce the risks associated with over-the-horizon backscatter radar. It plans to develop automatic tracking and air traffic control for tactical aircraft, a new generation of highly reliable airborne uhf radios, other avionics and landing systems, including a new ground-control approach system.

Also, there will be increased emphasis on the survivability of weapons and equipment exposed to electromagnetic pulses and electromagnetic radiation. Tests are to be made after the development of electromagnetic simulation techniques. New techniques in information transfer systems will be explored, as well as advances in low-frequency communication and base security sensors.

**Navy aiming to economize**

For the Navy, the trend in ships is toward more inexpensive ones. Work will also continue on the DD 963 destroyers. Also in the works for 1973 is a fleet communications satellite system and a cruise missile to match the Soviet's Styx missile.

The Office of the Director of Defense Research and Engineering will attempt to overcome a number of technological deficiencies this
Our new model 38 series.

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*Prices subject to change without prior notice.
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Controlled and isolated by a reed relay, these solid state AC switches provide a modern means for interfacing DC logic signals and AC-powered loads such as motors, relays, solenoids and lamps. Expected life exceeds 1 million operations so they are especially suited to highly repetitive applications.

Switching capabilities range from 1.7 to 20 A rms, 60 Hz depending upon type of package and mounting method. All have a 1 Form A (SPST-NO) "contact" as well as an internal RC network that provides dv/dt suppression. All feature the inherent long life and the ability to switch high inrush loads that characterize thyristors.

ECT Series. Steady-state rms current ratings (at 25°C) range from 2 to 20 amperes depending upon the method of mounting. Coil voltages are from 5 to 48 V DC. Power requirements are 290 mW for 120V, 60 Hz operation and 450 mW for 240V, 60 Hz. .250" quick-connect terminals are standard with .187" and .205" also available.

EBT Series. The solid-state "contact" is designed to carry a maximum load current of 7A rms, 60 Hz at 25°C ambient. This series provides the convenience of octal plug-in terminals and may be mounted in a socket having screw terminals.

JDB Series. This fully-encapsulated, low-profile (.350" height) hybrid will switch 1.7A AC loads. It is being used in modern machine tool controls, food packaging equipment and similar applications requiring DC input and AC output switching.

EKU Series. Rated at 7 amperes, 60 Hz at 25°C, the EKU is housed in the versatile KU-style case and has .187" quick-connect terminals. It may be mounted direct to a chassis or in a socket having screw, solder or printed-circuit terminals. A wide variety of P&B relays and solid state time delays are housed in this same case.

For complete information, call your local P&B representative or Potter & Brumfield Division AMF Incorporated, Princeton, Indiana 47670. 812 385 5251

*Like to try your hand at solving the puzzle shown above? Ask your P&B representative for one.

Solving switching problems is what we're all about.
year, according to Edwin N. Myers, staff specialist in electronics sciences. Among them are these:

- Microwave tubes. "We got overcommitted in solid state microwave devices, and they won't do all we want them to do," Myers explains. "Meanwhile our laboratories dropped out of the tube business, as did much of industry."

Wanted are tubes with high average and peak power, more bandwidth—into the millimeter-wave region—and more efficiency. A typical application is for countermeasures equipment. "We're looking for new ideas and new techniques to push on into the millimeter regions," Meyers says. "We haven't seen many new tube structures, so it appears that the answer will be based on conventional designs. But we'd like to see some breakthroughs."

- CMOS. The high-density package capability of CMOS interests the military, as does its low power consumption, but the devices must first be hardened against radiation.

- Semiconductor technology beyond silicon—"something to give us additional advantages in terms of speed and better infrared detectors," Myers says. "Gallium arsenide isn't the answer now, because there is no MOS technology feasible in the III to IV groups of the periodic table. What must be found is some compatible insulating material similar to silicon dioxide. We're encouraging our research people to tackle these problems."

- Magnetic bubbles. The Pentagon sees a limited military application for magnetic bubbles as replacements for tape recorders in unattended places. "For high-speed work, however, bubbles are too slow," Myers concedes.

- A nonvolatile memory—one that isn't wiped out when the power fails. The memory being used now is plated wire, "but the power consumption is too great and it is large and heavy, especially for space or airborne use," Myers points out.

- Amorphous semiconductor memories. They're being studied but have not yet been fully checked out, Myers reports. Receiving the most attention is the MNOS (metal nitride oxide semiconductor) memory. "They're attractive but there are still questions on their vulnerability to fatigue," Myers says. "If you design it for more than $10^9$ write cycles, the device wears out. This limits the program very badly. Until we solve the fatigue problem, the MNOS is not a very likely candidate for a true random-access memory."

- Far infrared. Imaging by infrared—including airborne forward-looking infrared (Flir)—has a big future in the military for night-viewing vehicles, sights for weapons, such as the TOW missile, and hand-held thermal viewers. An infrared imaging system gives a picture as good as that produced by television, and it does not require any light.

- Acoustic surface-wave devices. Basically signal-processing devices that work in the low microwave range, these devices, which are about the size of an IC, could replace pulse-compression filters in radars, delay lines and signal correlators. There are, however, still some technology problems. "We need materials that are uniquely tailored to the acoustic-wave needs to eliminate the need for a constant temperature," Myers notes. "Now, performance characteristics change with the temperature."

- Display techniques. "This spring," Myers says, "we're going to decide on the kind of large flat display we think is best and then put a lot of work into it."

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Industrial electronics becoming 'a way of life'; manufacturers see a year of growth ahead

Industrial electronic-equipment sales are climbing and are expected to continue to do so through 1973. This welcome observation is shared by most producers of the equipment and is based on inquiries and proposals received by them late last year.

"We expect a 10 to 20% increase in sales over 1972," says Donald Law, General Electric's manager of numerical-control operations in Waynesboro, Va. "The increase will be more in overseas sales than domestic, because Europe was slower to pull out of its recession than was the U.S. Domestic sales began to pick up in 1972 and will continue to increase, whereas in Europe they are just beginning to move."

There are several other reasons for the over-all growth. With business in the U.S. much improved, electronics manufacturers are finding that automation equipment built for one industry—automotive or metal-working, for example—has application in other industries, such as textiles, chemical, wood-working and processing. Controls are getting smaller, smarter and cheaper. And people are losing their fear of working with sophisticated equipment. "It's become a way of life, and they're buying it," says Donald Chace, industrial product development manager for the Digital Equipment Corp. in Maynard, Mass.

Allen-Bradley in Cleveland is looking for a wider market for its computer-controlled system, which was introduced at the Machine Tool Show in Chicago last September. William Ware, the company's marketing manager for industrial controls, reports that inquiries have come in for systems for a wide variety of applications: warehousing, transfer lines, automatic assembly operations and the supervision of programmable controllers. The company is building systems now that will both supervise programmable controllers and control other aspects of the manufacturing operation at the same time.

Controllers on the move

Programmable controllers have moved out of the factory and into the gas and oil fields, says Edward Holmes, electronics production
manager for Cameo, Inc., in Houston, Tex. Controllers are turning up in well-production facilities and pipelines, and Cameo plans to extend the memory capacity of its current line.

Analog gas-flow computers are also gaining among gas-distribution companies, as are supervisor control systems. "Because of the energy shortage, people have to do a better accounting job of what's sold and what's available," Holmes says.

He also foresees an over-all upsurge in sales of electronic equipment for the petroleum industry because of an anticipated increase in exploration.

The trend in industrial controls is toward the use of more and more minicomputers and microcomputers—"toward the computer on a chip," Allen-Bradley's Ware says. "This development work will be under way this year," he continues, "with hardware expected in 1975 or 1976."

MOS and LSI are reducing the size and complexity of minicomputers, and programmable controllers are becoming more sophisticated. "Eventually there'll be a boom in small controls for industrial tools, similar to the one now for the hand held electronic mini-calculators," Ware says.

Computerized numerical control (CNC) is expected to continue its lead over direct numerical control (DNC), says Allen Bradley's manager of product planning for numerical controls, L.O. Rexrode, in Highland Heights, Ohio. For the distant future, however, the company is developing a DNC system, he says.

**Hardwire vs softwire systems**

Law of GE says the mix in demand for hardwired vs softwired systems will depend on how much the customer has been influenced by advertising. He sees a place for both systems. "Hardwired systems will continue to have a place," he says, "until softwire can be reduced to a chip—until the computer on a chip arrives. In many cases it's better to have hardwire than to have to reprogram software in a minicomputer. Advertising this year may influence some people to buy softwire when they really need hardwire."

Within the automation equipment itself more electronic components will be used. A programmable solid-state interface will replace relay logic in Allen-Bradley's 4000 NC series, and DEC's Chace says that this year solid-state controls will make the biggest inroads to date into relays.

"Solid-state controls," Chace says, "will extend from the lowest level of factory automation up the hierarchy through the higher ones. This trend is coming into vogue very quickly." The reason: Solid-state controls allow machines to operate faster and offer longer life.

"Solid state is coming of age this year in all kinds of industrial equipment," says Robert A. Morgan, marketing manager for the Industrial Systems Div., at Westinghouse Electric in Buffalo, N.Y. "One example is SCRs, which will go into adjustable speed and adjustable-frequency drive equipment—ac and dc motor controls.

"Installing SCRs in heavy machinery, some of it as large as excavation machines for open-pit mining, means going back to the drawing board. "We're also using more cycloconverters for applications such as peak-power energy-storage systems and for load-compensation requirements."

A combination of solid-state rectifiers and converters is opening the door to a number of applications, such as fans and pumps, Westinghouse is finding.

Wesinghouse agrees with other manufacturers that there is a good immediate future in computerized numerical control but not much for direct numerical control. ■ ■
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Data current as of December, 1972

*swift /'swift / adj.... quick to respond: READY

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English firms have recently sold more than $700,000 worth of electronic equipment to Communist bloc countries, including the Soviet Union and mainland China. Seven numerical-control systems for machine tools, valued at $400,000, have been sold to the Soviet Ministry of the Radio Industry by the Survey & General Instrument Co., Ltd., of Kent. Each system consists of an x-y coordinate table, a television camera, a television monitor and a tape-punching machine. Radio and telecommunications equipment worth $300,000 for use in Chinese radio and telephone factories has been ordered from Marconi Instruments, Ltd., in Herts.

A medical data link between the Royal College of Surgeons, London, and an exhibition center 1-1/2 miles away recently demonstrated the feasibility of bedside consultation and diagnosis by and with doctors located at a distance. Analog data taken from a demonstration patient at the exhibition center were sent over telephone lines to the college. At the school, the data were analyzed by computer and the results transmitted back along a digital communications link to a visual display unit at the patient's bedside. Also in use was the CRT Viewphone developed for telephones by the British Post Office Telecommunications unit. With the Viewphone the "surgeon" at the bedside could study X-ray charts and other graphics located at the college.

Custom-fabricated LSI arrays are now low-cost enough for low-quantity requirements, says Ferranti of England. Where development costs for LSI in small quantities were previously prohibitive, the English manufacturer has introduced a standard uncommitted logic array of 200 cells. Using the collector-diffusion-isolation technique licensed from Bell Telephone Laboratories, these arrays are prepared and held in stock as a semi-processed unit, complete except for the final aluminum interconnections. Only the final metallizing layer is needed to make each cell operational and to provide connections to external input and output circuits and power.
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Army to improve its electronic camouflage

The Army is looking for industry help to improve its electronic camouflage and countersurveillance techniques. The research and development program will involve sophisticated techniques of disguising, blending and simulating Army weapons and their signatures, so they cannot be detected by ultraviolet or acoustic surveillance. The Army's Mobility Equipment R&D Center is searching for firms with experience in advanced computer-simulation techniques as well as broadband signature analysis and simulation, including visual, infrared, radar and acoustic modes.

AIA plan spurs talk of SST revival

A source of resuscitation for the supersonic transport program may be contained in a proposal by the Aerospace Industries Association. The AIA is asking the Civil Aeronautics Board, which is drawing up legislation to help airlines finance aircraft purchases, to add a provision for Government loans to companies doing R&D in the commercial aircraft field. Developments such as the SST and short-take-off-and-landing (STOL) craft would be candidates for loans from a $3-billion fund in the AIA plan. Although considerable opposition to such a proposal could be expected in Congress, the AIA hopes to sell the idea on the basis that the U.S. is losing out in the world aircraft market to foreign, government-financed ventures.

Ash appointment stirs Senate countermove

Legislation will be introduced in Congress to require Senate confirmation of Presidential appointments for the post of director of the Office of Management and Budget. The move is a result of criticism of President Nixon's appointment to the job of Roy L. Ash, former Litton Industries chief executive. Critics, noting Litton's problems with cost overruns and schedule slippage in its shipbuilding program for the Navy, question whether Ash will perform any better as a Government manager. However, under the present law, Congress has no say in the matter. Attempts to cut funds for Litton's Landing Helicopter Assault (LHA) and DD-963 destroyer programs are expected when new budget proposals come before Congress in the spring.

One Navy procurement official—Gordon Rule, a civilian—testified before a joint economic subcommittee chaired by Sen. William Proxmire (D-Wis.) that the LHA contract should be terminated for default on
Feb. 28, when the Navy is scheduled to make the next decision on the program. As a result of his testimony, Rule was transferred from his job by high Navy officers.

More storm clouds for F-14 program

The Navy's troubled F-14 aircraft program may face its biggest challenge from the powerful House Appropriations Committee, which with its Senate counterpart, are ultimate keepers of the Federal purse. The committee strongly criticized Navy management of the program last year, and some members were reported to be "extremely disgusted" over the service's inability to bring the contractor, Grumman Corp., into agreement on its contract. Unless the Navy does a super sales job explaining why it needs the F-14, the committee may well seek to cancel the program, sources say. The committee asked the Navy to study the possibility of adapting the Air Force's F-15 fighter, now being developed by McDonnell Douglas, but it met a wall of Navy resistance.

Capital Capsules: The National Science Foundation is pushing a program to encourage research in optical communications. Some 20 grants have been awarded to support basic studies, mostly in aspects of laser communications. . . . The Labor Dept. says it has placed 6000 professional people in new jobs through its Volunteer Engineers, Scientists and Technicians (DEST) program. The effort was set up 18 months ago to help those who had lost jobs in the defense and space fields. . . . The Electronic Industries Association estimates that U.S. electronics sales last year reached a record $29.8-billion, almost $2-billion more than in 1971. Within that total, the EIA says, the communications and industrial electronics segment grew 10% to about $12.2-billion, consumer electronics reached $6-billion, and defense and space stayed at about $11-billion. . . . NASA wants scientists to propose instruments and experiments that can be carried on the Large Space Telescope system planned for launching in the early 1980s. Such instruments as photometers, polarimeters, astrometric instruments, infrared detectors and very high dispersion spectrographs are possible candidates. . . . The Army is planning a new research program on the biological effects of microwave radiation exposure. It will contract for experiments to simulate field exposures of both continuous and pulsed microwaves. . . . The Commerce Dept. has appointed an ombudsman to help businessmen who need assistance in their dealings with the Federal Government. He is Thomas E. Drumm Jr., Special Assistant to the Secretary of Commerce. . . . A new standard that will spell out how much vibration can be tolerated by humans in aircraft, transit systems, ships and near ground machinery of all types is nearing completion after 10 years of preparation at the American National Standards Institute. . . . The Army Combat Developments Experimentation Command is looking for a day and night, passive real-time imaging system sensitive to wavelengths from 0.4 to 10.6 micrometers and capable of reproducing scenes during bright daylight and overcast night at ranges of 5 kilometers or more. . . . A joint State-Federal survey in seven states has found serious shortcomings in safety practices in the use of potentially dangerous lasers in high school and college science classes. A laser operating with a power output of 2 mW has been reported to have produced a burn in the retina of a human eye, according to the Food and Drug Administration in Washington.
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Selling is a dirty word.

Compared with the major shows in Europe, ours in the U.S. are flops. Exhibits are dull; papers are duller; and attendance shrinks. At least in New York, show management has traditionally been slow to improve the show, though it's been zealous in policing it to see that no holy rules are violated. Some of these rules, exhibitors tell me, are perfectly asinine. One, for example, allows miniskirted girls to stand at the booths—but not sit down.

This year a new show management, imported from WESCON, is valiantly trying to pump new life into IEEE Intercon. For a start, the directors shifted the exhibit days to Tuesday through Friday, March 27 to 30, dropping the traditional Monday opening. This should help those who can't break away from the office on Monday. (The technical sessions still start on Monday, but not till 2 p.m.) The directors and Intercon manager Don Larson have planned other innovations. Some will no doubt help the show, others won't. But at least they have the guts and imagination to try things. They're not just watching the shows disintegrate.

It's likely that one of the toughest nuts will be a legal one. An exhibitor is not allowed to sell at the show, lest IEEE's tax status be endangered. So maybe we need to fight for new tax legislation. The furor created when Fluke sold some multimeters at WESCON would be hard to picture in Europe. The Europeans are more sensible. They design their shows for selling and buying in a convivial atmosphere. Exhibitors there commonly provide a space where a visitor can sit with a company's engineers, enjoy a drink and something to eat, and discuss business. He can talk about technical specifications, delivery schedules and prices. And he can write an order. WRITE AN ORDER. What a horrible thought. At American shows we act as if writing business at a show is degrading, as if it's an imposition on an engineer to sell him something. We act as if he builds computers, television sets and communication systems with equations—and never dirties his hands with semiconductors, resistors, relays and test equipment.

Our loftiness and stupidity make our shows duller. While we try to preserve dignity, the Europeans keep looking for new ways to add sparkle, excitement, interest and usefulness. Are we smart enough to learn from them? I think so. The new IEEE Show management is intent on making this year's show a great one. It deserves our support, encouragement and thanks. I look forward to seeing you at the show.

GEORGE ROSTKY
Editor-in-Chief
Use current-mode IC amplifiers. New quad versions replace conventional op amps, while avoiding dual-voltage supplies and lowering the cost and package count.

Because conventional operational amplifiers need a dual power supply—typically ±15 V—this often poses a problem for system designers. Many systems are designed to operate from a single-power-supply voltage. If an op amp is used with the single supply, limited output voltage swings and unwanted common-mode offsets will probably result. In addition other important performance characteristics may be degraded.

One solution to these problems is provided by a new type of IC amplifier which has a current-mode input stage and can provide characteristics similar to those of conventional op amps while operating from a single power-supply line.

Amplifiers embodying this technique are already commercially available in quad versions—with four amplifiers in a single 14-pin DIP—from two manufacturers. National Semiconductor's version is designated LM3900, while Motorola has a version, the MC3401, which is very similar but not an exact replacement. Other companies are expected to provide alternative sources in the near future.

Both ICs can operate, with little change in performance, from a single voltage supply over a wide range of supply voltages. For the LM3900 the operating range is +4 to +36 V, while the MC3401 spans +5 to +18 V. The output voltage in both cases can swing from nearly ground—typically about 0.1 V—to about 80% of the power-supply voltage.

While, strictly speaking, not op amps, the new amplifiers can do the job of op amps in the vast majority of cases. The basic current-mode operation, therefore the name “Norton” amplifier, is a departure from conventional designs. Instead of using a voltage-differential input, the Norton amplifiers operate on differences in the input currents to their inverting and noninverting inputs. Many biasing advantages are thus realized. Also, because currents can be passed between the two input terminals, some unusual applications are possible. If external, large-value

2. A differential input, using a current-mode of operation, is achieved with a "current-mirror" circuit.

output current divided by $\beta^2$, where $\beta$ is the current gain per device. For an output current of 10 mA, the input current is $-1\mu A$, if $\beta^2 = 10^4$.

Input current can be reduced by the addition of a transistor to achieve a $\beta^2$ current reduction. If the output transistor, $Q_1$, is converted to a Darlington pair, the peak-to-peak output-voltage swing is reduced. If, on the other hand, the input, $Q_2$, is made into a Darlington pair, the dc voltage level present at the input would be undesirably doubled.

However, a lateral pnp transistor, $Q_3$, while neither reducing the output voltage swing nor raising the input voltage, provides the additionally needed $\beta$. Note that the collector of $Q_3$ is connected directly to the output terminal. This bootstrap arrangement reduces the loading at the high-impedance collector of transistor, $Q_6$.

Current mode provides balanced input

The gain stage of Fig. 1 has only an inverting input. But a general-purpose amplifier requires

3. The complete amplifier uses transistors $Q_6$ and $Q_7$ as current-source loads.

4. The Norton amplifier’s open-loop gain is about 10 dB more than the popular 741 op amp above 1 kHz.
A single regulated bias circuit built into the chip provides biasing currents for the four Norton amplifiers.

An equivalent circuit for the amplifier helps in arriving at first-order designs.

Both an inverting and a noninverting input. Since the gain-stage input operates in a current mode, a noninverting input can be provided by the addition of a current drain-off (current-mirror) circuit to subtract or drain off current from the inverting input terminal (Fig. 2). The input common-mode voltage of the input terminals is maintained at only one diode drop above ground. Thus by the use of appropriate input resistors, there is almost no upper limit to the level of externally applied common-mode input voltage. This is especially useful in comparator applications, where high-level common-mode voltages are present. The inherent input biasing at both inputs—since each input self-biases at \(+V_{BE}\)—eliminates the need for an external common-mode biasing voltage network. Further, input summing can be performed at the relatively low impedance level of the input diode.

An amplifier stage complete with current-source loads, \(Q_1\) and \(Q_2\), is shown in Fig. 3. Since the circuit is simple, four of these amplifiers can be put on a single chip. The bias source for voltage \(V_b\) on \(Q_1\) causes the current—nominally 200 \(\mu A\) in the LM3900—to change with temperature. This action provides first-order compensation for the \(\beta\) variations of the output transistor, \(Q_1\). Transistor \(Q_2\) (in the LM3900—not present in the MC3401) provides class-B action together with \(Q_3\) under large-signal conditions.

Figure 4 compares the LM3900's open-loop frequency response with a typical 741 op amp. The curve shows that the 3900 provides an additional 10 dB of open-loop gain for all frequencies above 1 kHz.

Regulated supply does the biasing

A single bias circuit (Fig. 5) in the 3900 serves all four amplifiers. The regulator circuit insures that only small changes in bias current occur as the supply voltage changes. Thus the open-loop gain changes only slightly over the wide power-supply range, and it is almost independent of the effects of temperature.

A single resistor, \(R_5\) in Fig. 5, controls the power consumption of the whole chip and establishes the conduction of transistor \(Q_{10}\) in the bias supply. The emitter current of \(Q_{10}\) biases the \(Q_1\) output current sources of all four amplifiers at points \(V_o\) (Fig. 3), and the collector current of \(Q_{10}\) biases the \(Q_1\) current sources at points \(V_p\).

When power is turned on, the biasing circuit transistors \(Q_{20}, Q_{30}\), and \(CR_c\) conduct, thus starting the bias circuit. Current flow through the reference diodes \(CR_c, CR_a, CR_b\), and \(CR_c\), then turns off \(Q_{20}\), and current through the amplifier circuits thus depends mainly on the \(V_{BE}\) of \(Q_1\), divided by \(R_5\). Power-supply current drain is then essentially independent of the power-supply voltage.

The multi-emitter transistor, \(Q_{17}\), clamps negative input voltages at each of the eight input
If the RL IOk is not in place, the circuit will not work. The circuit requires an RL IOk to function correctly.

Designing with the amplifiers

Though these amplifiers can be used instead of a standard op amp, a new design approach is needed. An equivalent circuit for a Norton amplifier is shown in Fig. 6. Both the plus and minus inputs are clamped by diodes, so they can be no more than one-diode drop above ground. Thus the input common-mode voltage at the input terminals is inherently restricted to within a few hundred millivolts of 0.5 V. Therefore, to apply current-mode amplifiers to operate with a voltage-mode input, the external voltages must first be converted to currents by use of series resistors. The use of external input resistors can extend the range of externally applied common-mode inputs almost without limit.

Let's analyze the ac-coupled inverting amplifier of Fig. 7a to see how a typical Norton amplifier such as the 3900 is used in a circuit. Figure 7b is an equivalent circuit that includes the biasing current path.

First, consider the dc biasing paths and make a dc analysis. The output quiescent voltage, V_o, is

\[ V_o = V_o^- (I_b + I^+) R_2 \tag{1} \]

and

\[ I^+ = \frac{V^+ - V_D^-}{R_3}, \tag{2} \]

where

\[ V_D^+ \approx V_D^- \approx 0.5 \text{ Volts} \]

and

\[ I_b = \text{bias current} (30 \text{ nA}) \ll I^+. \]

Also, take \( A_i = 1 \)

and \( V^+ \text{ (max)} = V_{cc} \) (power-supply voltage).

If Eq. 2 is substituted into Eq. 1,

\[ V_o = V_D^- \left( I_b + \frac{V^+ - V_D^+}{R_3} \right) R_2, \tag{3} \]

which is an exact expression for \( V_o \). But since \( V_o \gg V_o^- \) and \( V^+ \gg V_D^+ \), we can simplify Eq. 3 to provide a quick design relationship:
When used as a dc amplifier with a single power supply, the Norton amplifier is not as precise as a standard op amp with a split supply. However, single-polarity inputs and noninverted outputs down to zero volts can be readily accommodated with the common-mode input biasing resistors $R_2$ and $R_3$ and offset adjustment $R_4$. This circuit is adequate for most noncritical applications.

A bandpass amplifier with a $Q$ between 10 and 50 can be constructed with two amplifiers. The circuit uses only two capacitors. Resistors $R_1$ and $R_2$ set the bias so that the output voltage of the amplifiers approaches $V_\text{cc}/2$. To do this, resistor $R_2$ is chosen to equal twice $R_1$, and $R_3$ is chosen to equal $R_1$ and $R_4$ in parallel. The value of the constant $K$ is selected for either control of the spread of resistor values or for optimization of final gain.

For $10 \leq Q \leq 50$, $1 \leq K \leq 10$

For biasing:

\[
R_5 = 2R_1,
\]

\[
R_4 = R_5/(R_6 + R_7)
\]

Gain:

\[G = \sqrt{Q \cdot K}\]

Example:

Requirements: $Q = 25$, $f_0 = 1$ kHz

Select for convenience: $C_1 = C_2 = 0.1 \mu F$, $K = 3$

Then solve for $R_1$ through $R_7$: $G = 15$ (23 dB).
The Norton quad-amplifier group makes an economical choice for audio mixing and channel selection. Three of the amplifiers summed into the fourth is a convenient arrangement. Individual amplifiers can be turned off when a dc control signal is applied to the plus input. The positive voltage, $v^+$, unless shorted by switches $S_1$, $S_2$, and $S_3$, saturates the respective amplifiers and they pass no signals.

For: $Q \geq 50$
Let: $C_1 = C_3$ (for convenience)
$R_1 = R_2 = R_4$
$R_1 = R_1 (2Q - 1)$
$R_3 = R_1 = 1/\omega C_1$

For biasing: $R_i = R_i = 2R_s$
Example: $Q = 50$
$V_{cc} = 1 \text{kHz}$
$G = 100$
(40 dB)

A distinctive symbol used

Note the new amplifier symbol that is used in Figs. 7a and 8 to represent this class of current-mode amplifiers. This symbol is recommended to avoid confusion with the standard op amp, since Norton-amplifier operation is quite different in many respects. The current-source symbol between the two inputs represents the new mode of operation. It signifies that current is removed from the minus input terminal. And the current-arrow symbol on the plus input lead indicates that this terminal operates as a current input. This new symbol is thus helpful in both clarifying the behavior of the circuits described here and in doing your own design work.

Armed with an understanding of the internal

$$V_o \simeq \left( \frac{R_s}{R_3} \right) V^+. \quad (4)$$

And, if $R_s$ is made equal to $2R_3$, then $V_o \simeq \frac{V^+}{2}$

The latter result shows that the output can be readily biased to one-half of the power-supply voltage, so that the full peak-to-peak swing can be made symmetrical and almost equal to $V_{cc}$.

This simple dc model is adequate for designing switching circuits.

Design procedure for ac amplifiers

What happens to ac signals? Since the circuit behaves as a standard op amp with its plus input grounded, the closed-loop voltage gain, $A_{v(CL)}$, is:

$$A_{v(CL)} = -\frac{V_o}{V_{in}} \approx \frac{R_3}{R_1}$$

The procedure for designing an ac-coupled inverting amplifier consists therefore of first selecting $R_1$, $C_1$, $R_2$, and $C_0$, as for a standard op amp. Then $R_s$ is made equal to $2R_2$. Note that $R_s$ is the only additional resistor needed to complete the biasing requirements. This simplicity contrasts with the complications encountered in dealing with large common-mode voltages when trying to bias standard op amps for operation from a single power supply.

A practical ac amplifier design with remote voltage-controlled gain is shown in Fig. 8. For maximum gain, $C_R$ is cut off and the current through $R_2$ and $R_s$ provides a bias to set the quiescent output of the amplifier approximately $0.6 V_{cc}$. For minimum gain, $C_R$ is turned on, and only the minimum bias current through $R_s$ enters the input to set the quiescent output at approximately 0.3 $V_{cc}$. The bias is thus automatically varied to accommodate a large output swing when the gain is set to maximum. The signal swing required for gain control varies from 0 V for minimum gain to less than 10 V for maximum gain.

A bandpass filter with a $Q \geq 50$ can be built with three amplifiers. The resulting increase in over-all open-loop gain also reduces the effects of component variations.
Sinewave oscillator using Norton amplifiers achieves amplitude stability and waveform purity. It uses a two-amplifier, RC active filter that requires only two capacitors. A third amplifier controls the gain around the filter. The fourth amplifier compares the sinewave amplitude to a dc-reference voltage and averages the difference. The values selected for $R_{15}$ and $R_{16}$ provide first-order temperature compensation for both CR and the internal input diodes. The peak magnitude of the output sinewave is automatically regulated at twice the reference voltage, $V_{ref}$.

Free-running staircase generator uses all of the amplifiers on the quad chip. Amplifier A1 provides the input pulses that generate the staircase wave via resistor $R_1$. Amplifier A2 integrates and holds the pulses. Amplifiers A3 and A4 provide a combination comparator one-shot multivibrator function. Resistor $R_4$ samples the staircase output voltage and compares it with the power-supply voltage ($V^+$) via $R_5$. When the staircase output exceeds approximately 80% of $V^+$, the one-shot provides a 100-µs pulse. This pulse resets the integrator $A_5$ via $R_3$.

Squarewaves are generated when capacitor $C_1$ charges and discharges via $R_1$ between limits that are established by resistors $R_{2i}$, $R_3$ and $R_4$. When $V_0$ is low, current through $R_1$ is low and can be neglected. Therefore $R_2$ and $R_4$ control the point at which the output starts to rise. When $V_0 \approx (R_2/R_4)V^+$, positive feedback via the plus input and $R_4$ triggers rapid output rise. The other trigger point, with $V_0$ high, occurs when $V_0 \approx (2R_2/R_4)V^+$.

An integrator configuration generates triangular waveforms. Current through $R_1$ produces the negative-output slope. When the input to the second amplifier drops below the trigger point set by $R_5$ and $R_6$, current through $R_2$ produces the positive output slope. If $R_2 = 2R_5$, the output waveform will be symmetrical.

The design of Norton amplifiers let's look at some specific applications. Brief outlines of some typical circuits will demonstrate the versatility of the new quad-amplifier ICs and show how their design ground rules differ from those for standard op amps.

The circuits are categorized into three groups —analog circuits, signal generators and analog-to-digital interface circuits. Because of diversity of possible applications, few generalized design principles can be given, other than those already presented.

Though most of the applications described use the amplifiers in a linear mode, Norton amplifiers can be safely overdriven well beyond saturation and used in a wide range of logic circuits in addition to the a/d interface circuits shown.
Analog-to-digital interface circuits

**Hysteresis may be designed into a comparator** to form a Schmitt-trigger circuit. The circuit can be made either inverting or noninverting. The lower switch point for the inverting circuit is determined by the amount of current flowing into $R_2$. And since the output voltage is low, current through $R_1$ can be neglected. As the input current, $I_1$, drops below $I_2$, the output starts to switch to the high level. Positive feedback via $R_2$ rapidly drives the circuit to saturation. With $V_0$ high, additional current, $I_2$, is driven into the plus input through $R_3$. Therefore the input current, $I_1$, required to switch $V_0$ down is increased by the amount needed to overcome this additional current. Thus the circuit has different trigger point for high and low outputs—a hysteresis effect.

**One-shot circuit uses only one amplifier**. Resistor $R_2$ tends to keep the output in the low-voltage state. A positive voltage at the trigger input sufficient to overbalance the current through $R_2$ causes the output to switch to the high-voltage state. Resistor $R_3$ latches the amplifier in the high state until capacitor $C_1$ charges from near ground to a voltage that forces current into the negative input that is almost equal the current into the plus input. At this time the circuit returns to the low state.

Each amplifier can be thought of as a super transistor with a $\beta$ of 1,000,000 (25-ua input produces 25-mA output current). The amplifiers also have a noninverting input feature capable of providing positive feedback that can create sharp trigger points and hysteresis for Schmitt and one-shot circuits. Finally, the low-input currents allow the design of timing circuits with small capacitors and large resistors.

Of course, where the application demands unusually high performance, the designer may be forced to use a more expensive specialized op amp unit. This happens when very wide bandwidths, very high slew-rates, greater gain, very high input or very low output impedances are required. Also, the single source limits dc inputs and outputs to single-polarity excursions.

**Norton amplifiers operate as inverting comparators.** To insure proper operation, the reference voltage must be larger than the internal $V_{BE} \simeq 0.5$ V. But there is no upper limit as long as the input resistors are large enough to limit the input currents to under 200 $\mu$A.

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Although the single-ramp technique for a/d conversion is both simple and economical, the accuracy obtained seldom exceeds 1%, or eight bits. By introducing a calibration cycle, along with the normal measurement cycle, the designer can reduce errors to as low as 0.01%, allowing 4-1/2-digit operation without a drastic increase in circuit complexity. The technique, for which a patent is pending, also has many other possible applications in low-cost digital instrumentation.

The converter uses alternate Measure and Calibrate cycles to reduce the measurement error. A known analog input is measured, and the resulting digital number is compared with the correct answer. If this digital number is not correct, the converter is automatically adjusted so the correct answer will be produced. Since the calibration cycle is interlaced with a cycle that measures the unknown analog voltage, compensation for all but the most rapid variations in converter accuracy is provided.

This conversion method requires close tolerance in only one area—the reference voltage used in the calibration cycle. This voltage must be maintained to within $\pm \frac{FS}{2^{(n+1)}}$,

where $n$ is the number of bits of accuracy if $\pm 1/2$ least-significant-bit (LSB) accuracy is to be expected. Voltage FS is the full-scale reading of the converter.

As the converter is primarily intended for use in a DVM and suitable readout devices require a BCD signal, a BCD counter is employed to count the clock pulses. In a BCD counter the most-significant-bit (MSB) is zero until a decimal count of eight is reached. At a decimal count of ten, the MSB returns to zero. Therefore the calibration point is chosen at 80% of full scale, and a reference voltage of exactly 8 V is used. The converter will lock on to, and correct for, error conditions in which either greater or less than an 80% of full-scale count is obtained before the ramp voltage crosses the reference voltage and stops the count.

Basic converter counts clock pulses

The ramp a/d converter uses a linearly rising voltage ramp to convert an unknown voltage into an equivalent time interval. This time interval gates a portion of the output of a clock oscillator. The number of cycles of the oscillator passed by the time gate constitutes a digital number proportional to the unknown voltage. The train of pulses is normally converted to a more usable number system, such as binary, BCD, Gray, etc.

Figure 1 shows the single-ramp a/d converter in a simple form. In general, some time is required for recovery of the ramp after each use, as well as for whatever digital operations may be

required to produce the required type of digital word. Therefore timing gates are needed to separate the various operations. Fig. 1a includes a simple arrangement to accomplish the desired gating, and Fig. 1b shows typical waveshapes. Let's now consider the operation of the various components in the block diagram.

The ramp generator consists of an operational amplifier with a capacitor, C, in its feedback path. The input is from a constant-amplitude sweep voltage through a resistor, R. Because the

2. Comparator drift is minimized by use of a two-comparator scheme shown (a). The count begins (b) after the ramp crosses the level set by $A_1$, and it ends when the level of $A_2$ is reached.

op-amp input terminal remains at virtual ground, the current through $R$ is constant. This current is available to charge $C$, resulting in a linear ramp voltage. It is important that the ramp be linear, because this is the only significant source of error not corrected by the converter's calibration cycle. An op-amp IC performs the comparator function indicated in the block diagram. Its output is high when input 2 exceeds input 1, and low (clamped near ground) otherwise. The gate and clock generators provide the wave shapes shown. The AND-gate output is high when all its inputs are high.

Ramp and clock errors limit accuracy

The simple a/d converter of Fig. 1a works extremely well if only a few bits of accuracy are required. However, as more accuracy is demanded, various errors begin to appear. These tend to fall into two major classifications: those associated with the ramp and those caused by clock inaccuracies.

There are two types of ramp errors, other than nonlinearities: those related to slope and those related to starting time. If the ramp starts late, fewer than the correct number of counts will be included. Also, if the slope of the ramp is too steep, it will reach the unknown voltage too soon and, again, the pulse count will be too small.

Comparator voltage offset and delay have effects similar to errors in ramp starting time. If the ramp voltage must exceed the unknown voltage by a given amount to change the state of the comparator, the gate will close late, and too many counts will be included. Likewise comparator propagation delay will cause too many counts to be indicated for a similar reason.

Somehow, ramp-delay errors must be minimized and made to behave predictably with environmental variations. A frequently used method is to start the ramp below the zero-reference voltage (Fig. 2). Then the timing gate is opened when the ramp crosses the zero reference and closed when it crosses the unknown voltage.

The two crossings are detected by identical comparator circuits and should therefore track
each other well. Delays and nonlinearities associated with ramp start-up are also eliminated by this technique. But one problem is created by this technique: It is very difficult to synchronize the clock with the opening of the timing gate, because the gate opening is an analog event not related to the clock. This nonsynchronization can result in a 1/2-LSB error if the gating occurs during the rise time of a clock pulse. With practical clock speeds and standard logic families, this error will normally occur less than 1% of the time.

The clock frequency, of course, has the same effect on count correctness as ramp slope does: If the clock is too slow, it will not produce a sufficient number of pulses during the gate interval. Variations in the clock frequency can be made small by use of a crystal or other high-Q, frequency-determining device.

**Calibration cycle controls ramp slope**

Errors caused by improper ramp slope or improper clock frequency are closely related and are compensated for in the calibration cycle. Both types can be compensated for if the ramp slope is adjusted properly, and this is easy to do. The problem is to determine the direction and amount of change required—that is, to derive an error signal.

A trial-and-error method determines the required direction of the ramp-slope change. The known analog reference voltage is converted to a digital number, and the resulting value is observed. If the digital output is too high, the error must be increased, and vice versa.

A block diagram of the calibration scheme is shown in Fig. 3. As explained earlier, the voltage reference is selected to be exactly 80% of the full-scale value of the converter. In a BCD counter the MSB is switched only once during the full-scale count—at exactly the 80% value. The comparator is switched to the reference voltage during this cycle. The MSB of the BCD output number is examined once during the calibration cycle by ANDing it with pulse E. The presence of a logical ONE during pulse E indicates that the ramp slope is too shallow, while a logical ZERO indicates the opposite. Since the error voltage is only present during the E pulse, a way must be provided to store the ramp-speed control-voltage value during the absence of this pulse.

In the system shown an op-amp integrator is used as a sample-and-hold circuit. The capacitor
and charging-resistor values are selected so the resulting error control voltage will correct the ramp slope by an amount corresponding to LSB/4. Error pulses are supplied only when the gated count is too high—MSB equal to ONE. Control in the other direction, toward a shallower ramp slope, is provided by the fixed negative bias.

**Timing and control circuits complete the design**

The circuit diagram of a converter using the calibration system just described is shown in Fig. 4. Counters and latches are in Fig. 5. To avoid the necessity for precision parts in the loop, a potentiometer is used to allow adjustment of oscillator frequency. This control is set so that no more than 10,000 counts can be passed in the calibration cycle during the time the ramp, no matter how shallow, reaches the 8-V reference.

From here the ramp-error control signal will always be of the correct polarity to increase the ramp slope, until 8000 pulses have been counted. This occurs at the moment when the ramp crosses the 8-V reference; at this point the loop will lock.

The error input to the integrating amplifier, A_e, is single-ended—that is, error pulses are supplied only when the gate count is too high, control in the other direction being provided by a fixed bias. With no error pulses, the derived error-control signal to A_e drifts slowly positive, while with continuous error pulses it moves in negative steps at the same average rate.

Timing and gating functions are derived from an oscillator (or from the 60 Hz line) by a sequence of dividing and decoding operations. The ramp generating signal (Fig. 6) occurs at 1/4 the oscillator frequency. Two other signals, an enable pulse and a reset pulse, are generated by decoding the divider wave shapes. The enable pulse, during the calibrate mode, is designated E_e and gates the error signal into the sample and hold. In the measure mode, this pulse is called Display Enable and it latches the digital equivalent of the unknown analog voltage into the output display.

The reset pulse occurs immediately following the enable pulses, and resets the counters to zero. The trailing edge of the reset pulse also triggers the Cal/Meas signal, the longest of the converter. Within the period of the ramp signal, comparators A_3 and A_4 control the duration of the timing gate in a manner similar to that shown in Fig. 2. The clock pulses are counted only during the timing gate period.

The error control voltage changes rapidly during the E_e pulse and drifts slowly between pulses. With large errors, such as might be present for a short time when the unit is first turned on, a staircase error wave shape will be produced, but at near zero error the MSB error-decoder output will be toggling between a plus and minus value to produce a sawtooth wave. This toggling during the calibration cycle has no effect on the measuring cycle, because the ramp slope is only being shifted by an amount corresponding to LSB/4—less than the resolution of the converter.

**More features can be added**

The converter so far described cannot distinguish between a negative input voltage and zero input. It gives a zero output for either. To correct this, additional circuitry is required. If a zero or negative input voltage is applied, we note that in the Measure mode a Stop pulse is generated before or simultaneously with the Start pulse—in other words, no timing gate is generated. In this case, input polarity can be
5. The converter output is available as four BCD digits. The Enable signal latches the measured voltage into the output display during the Measure mode. This section also supplies the MSB for ramp speed control.

reversed with a relay. If no timing gate is present during the following Measure mode, as would be the case with zero input, the input should again be reversed. Hence, with an exactly zero input, the input relay is reversed once each Cal/Meas cycle, and the plus-and-minus sign likewise alternates at the cycle rate.

The circuitry to accomplish the above polarity sensing is implemented as follows (Fig. 4): Polarity is indicated by a J-K flip-flop, FF1, connected so that it will change state every time it receives a negative-going pulse. The timing-gate signal is connected to its input, so each occurrence of a timing-gate signal will trigger FF1. Use of the negative-edge triggering assures that the flip-flop will not trigger until the end of the Timing Gate—that is, after the measurement is completed. Thus the flip-flop triggers when the ramp crosses either the unknown or the Reference voltage level.

During converter operation flip-flop FF1 changes state at the end of each measurement of a positive voltage. The Timing Gate, which is always present during the Calibrate cycle (because the reference voltage is always positive), returns FF1 to its original state, ready for the next measurement. However, if the input is negative or zero, the Timing Gate will be present only during the Calibrate mode, so the state of FF1 will alternate with the mode.

A second J-K flip-flop, FF2, is connected to FF1 in such a way that its state is forced to be the same as that of first flip-flop at the time of the Display-Enable pulse. With two flip-flops connected in this way, the polarity relay (and readout) will be activated only when the unknown input is either negative or exactly zero voltage.

Another optional feature is the use of the 60-Hz line frequency to synchronize the system. This improves the appearance of the display when a digital readout is used, since the voltage under measurement frequently has a small 60-Hz component. When the sampling rate is synchronized with this "hum," the reading is always taken at the same point in the hum wave shape, so the last digit is less likely to fluctuate. The actual reading obtained is, of course, the input voltage at this instant and may not be the rms value of the input signal plus hum.

When the converter is operated at a 60-Hz rate, only about seven corrections per second are made. In a 4-1/2-digit system, LSB/4 is only 1/40,000th of full scale, so if each correction is LSB/4, the correction rate is only 0.0175% per second. Therefore, if the initial error should happen to be 10% of full scale, it will take about 10 minutes for the system to stabilize. This time can be reduced by synchronizing a higher frequency oscillator to the line frequency and using its output to operate the converter.

Another desirable refinement is the use of a potentiometer to vary the offset of one of the comparators. This provides a zero-offset adjustment for the instrument and allows the output to read zero for a nonzero input, a condition sometimes desirable when the input comes from a transducer. Provision for this adjustment also allows the use of a less precise operational amplifier, such as the MLM301A, instead of expensive precision comparators.
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<td>S/D or R/D</td>
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<td>400Hz</td>
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<td>400Hz</td>
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Design versatile d/a converters by using constant-current sources. Custom components are not needed to obtain devices for special applications.

Designing "one-of-a-kind" digital-to-analog (d/a) converters presents a formidable problem to the designer. If, for example, the input code is unusual, a suitable off-the-shelf converter may be unobtainable or prohibitively expensive. Yet a completely new in-house design may also involve high expenditures and long delays. What's needed is a versatile conversion technique that lends itself to special applications.

A d/a converter designed with constant current sources can handle a wide range of requirements. Almost any type of digital input coding can be accommodated. Precision resistive ladder networks are not needed, so no time is spent waiting for delivery. Also, most commercially available resistive-weighting networks are restricted to binary inputs.

In a constant-current d/a converter, the outputs of all the current sources are connected by a common bus to a constant-impedance load. Each source is individually adjusted so it supplies a steady current value that is equal in weight to the input data bit that controls it. For example, the converter shown in Fig. 1 uses a weighting factor of "one unit equals 1 mA" and the output voltage is developed across an impedance of 1000 Ω. But any other weighting factor and load impedance can be chosen. Extra digits can be added to this type of converter if additional sources are used. But, of course, there is no reason to design and build a five-digit d/a converter when the output of the analog device has only two-digit resolution.

Design the switched current source

The heart of the constant-current converter is the current source shown in Fig. 2. The characteristics of the field-effect transistor (FET) and the value of the source resistor, R_s, determine the value of drain current, I_D, flowing through the device. The value of V_GS required for a given I_D can be found with the formula

\[ V_{GS} = V_P \left(1 - \sqrt{I_D / I_{DSS}}\right) \]

where: V_GS is the required gate-to-source voltage for the FET,

\[ V_P \] is the pinchoff voltage of the device,

\[ I_D \] is the required drain current, and

\[ I_{DSS} \] is the zero-bias drain current of the transistor.

The value of R_s is then R_s = V_GS/I_D.

Since device parameters vary considerably from their published specifications, it is wise to use a potentiometer with a total resistance of twice the calculated value of R_s instead of a fixed value. This insures that the required I_D can be obtained, and it allows the precise adjustment required for accurate calibration of the current source.

The selection of the V_cc for the current sources is very important for proper operation of the converter. It must be large enough to insure that, even with the converter inputs and output at almost full scale, there is enough voltage to keep the least-significant-bit (LSB) current source operating in the constant-current region. A sure way to determine this value is to add the full-scale voltage needed at the current-source output

1. The design concept for a two-digit BCD-to-analog converter. The analog output voltage goes from zero for an input code of (0, 0, 0, 0 - 0, 0, 0, 0) to 9.9 V for a code of (1, 0, 0, 1 - 1, 0, 0, 1).

Jon L. Turino, Test Equipment Engineer, Xerox Corp., El Segundo, Calif. 90245.

Electronic Design 2, January 18, 1973
2. The heart of the d/a converter is the current source (a). A variable resistance (b) is preferred so that each constant-current source can be adjusted exactly to the required values.

PARAMETERS:

- \( V_{BE(SAT)} \approx 0.5V \)
- \( V_{CE(SAT)} \approx 1.0V \)
- \( I_{CBO} \approx 0.05mA \) (MAX)
- BETTA \( \approx 50 \) (MIN)

\[ V_{cc} + 20 \text{ V dc} \]

3. Complementary transistors, \( Q_1 \) and \( Q_2 \), are used in a combination, level-shifting and saturated-switch circuit. A true input (4 V) causes \( Q_1 \) and \( Q_2 \) to saturate, thereby turning on the preset current source \( Q_3 \).

This method of selecting \( V_{cc} \) will insure that there is adequate drain-to-source voltage (\( V_{DS} \)) across each FET. For example, assume that the circuit of Fig. 1, with a full-scale voltage of 9.9 V at the top of \( R_m \), requires a \( V_{GS} \) of 5 V for the 0.1 mA output. The \( V_{CC} \) supply should then be \( (9.9 \text{ V} + 5 \text{ V}) + (0.25) \cdot (9.9 \text{ V} + 5 \text{ V}) = 18.6 \text{ V} \). In practice, a well-regulated voltage of 18-20 V dc will work satisfactorily.

Interface with the logic levels

With the current-source values and components selected, the remaining part of the circuit to be designed is the input-switching interface. This interface must take the digital input levels and cause them to turn the individual current sources either fully on or fully off. Since the required interface depends on the specific digital device connected to the converter input, no hard and fast rules can be made for its design. An example, however, should serve to point to the concepts.

Suppose the interface logic levels are 0.5 V maximum for a ZERO (saturated collector-emitter junction) and 4.0 V minimum for a ONE (a pull-up resistor connected to +5 V dc). A circuit suitable for converting these levels to an on-off control for the current source is shown in Fig. 3. The design procedure starts with the value of the collector current of \( Q_2 \) and works back to the input terminal with some rules of thumb.

First, select the \( I_c \) of \( Q_2 \) as 16 mA—that is, twice the value of the current source output. (Although no more than 8 mA will flow in the circuit, this rule insures that there will always be enough base current applied to \( Q_2 \) to cause saturation.)

Next, find the \( I_b \) of \( Q_2 \), using the minimum \( \beta \) of the transistor. For this example, assume a minimum \( \beta \) of 50, so that \( I_b = 0.32 \text{ mA} \). Select \( R_4 \) so that less than one-half of the \( V_{BE(SAT)} \) of \( Q_2 \) can be dropped across it when the \( I_{CBO} \) of \( Q_1 \) is at its maximum. Then if

\[
(V_{BE(Q2)}\,_{SAT} = 0.5 \text{ V} \\
\text{and } (I_{CBO})_{Q1} = 0.05 \text{ mA})
\]

\( R_4 \) should be 0.25 V/0.05 mA = 5000 \( \Omega \).

Next the value of \( R_3 \) can be selected. It should drop \( V_{ee} = (V_{BE(Q2)}\,_{SAT} - (V_{CBO})_{Q1} = 18.5 \text{ V} \) at a current of 0.37 mA (\( I_b \) of \( Q_2 \) plus the current through \( R_3 \)). Its value is then 18.5 V/0.37 mA, or 5000 \( \Omega \). Using the value of 50 for the \( \beta \) of \( Q_1 \) and a required collector current of 0.74 mA (again we have multiplied the required collector current value by a factor of 2), we see that the base current of \( Q_1 \) should be approximately 0.015 mA. The value of \( R_3 \) should be chosen to drop five times \( h_{fe} \) at \( V_{BE(SAT)} \), so its value should be \( R_3 = 0.5 \text{ V}/0.075 \text{ mA} = 6700 \text{ \Omega} \). A resistor with a standard value of 6.8 k\( \Omega \) should be close enough. The value of \( R_4 \) can then be calculated. It should drop 4 V - 0.5 V = 3.5 V at a current of 0.09 mA. The value is 39 k\( \Omega \).

The schematic of the final version of the two-digit BCD-to-analog converter is shown in Fig. 4. Although a precise dc circuit design procedure may be used when the interface circuits are designed for a specific application, the use of the assumptions and rules of thumb previously discussed insure that the transistors are off when the input is low and on when the input is high.

Calibrate with external voltages

All that remains is the calibration of the converter. This is done very simply. First, connect all input terminals to a +0.5 V source and adjust the offset control of op-amp A, for zero output voltage (pin 6). Then connect each input indi-
4. The complete two-digit BCD-to-analog converter requires only the appropriate power supplies and a simple calibration routine. A Minus signal from the input device actuates the relay to allow bipolar operation.

 individually to a +4.0 V source and adjust the current-source potentiometers to give the proper output voltages at pin 6 of the op amp (8 V for Units position 8 and 0.4 V for Tenths position 4, etc.).

The output of the converter can drive most analog devices directly. If more driving power is required, it can be obtained in the usual ways (such as with a complimentary-symmetry stage).

Semiconductor-device selection is not critical. The switching portion of the circuit is designed for worst-case operation. A large amount of negative feedback regulates the current-source portions. FETS are used as current-source elements to achieve design simplicity and a low parts count. The total cost of the components comes to only $45.

Measurements show that the circuit has a zero drift of less than 0.1 mV from 15 to 50 C. Linearity is better than 0.5%, and the overshoot when codes are changed is less than 1%. The maximum spike duration is less than 50 µs, which is much too fast to disrupt the indications of most analog devices.

The only critical voltage is the $V_{cc}$ for the current sources. This must be regulated so it does not fall below the minimum required voltage. Only the minimum value is important; an increase of 25% affects the converter output by less than 1%.
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Multiplexer technique solves X-out-of-Y bit pattern-recognition

Straightforward application of Boolean techniques becomes unwieldy when the logic designer needs a pattern of X true bits from a field of Y bits. A technique that uses digital-multiplexer ICs easily yields solutions for any range of X and Y. And it is especially useful when Y exceeds six, as often happens with error-correcting codes.

A multiplexer with N addressing (select) bits can produce all Boolean products of N variables. A ONE output results when the selected input line also equals ONE. The input lines are labeled as the decimal equivalent of the N addressing bits. For example, the select addresses of 011, 101 and 110 each produce a ONE output if input lines 3, 5, and 6 are all ONES, as shown for Z.

In this case, a ONE output is produced when two out of the three bits are ONES. Similarly, the inputs can be wired so as to recognize one out of three and three out of three ONES on the select lines.

A three-of-six pattern detector where, X = 3, Y = 6 and N = 3, is shown in the schematic. The output is true whenever three, and only three, of the six inputs are true. The technique used is to work from the output backwards, providing one level of multiplexers for every subset of N = 3 input variables.

If Y, Y, Y = 000 the three-of-three input to the final multiplexer will be selected. Hence the final output will be ONE if Y, Y, Y = all true.

If Y, Y, Y = 001, 010, or 100, thereby selecting inputs 1, 2 and 4, then the output will be true only if two of the other variables Y, Y, Y = are true.

If Y, Y, Y = 011, 101 or 110 (3, 5, 6), then the output will be true only if one of the other variables Y, Y, Y = is true.

When variables Y, Y, Y = 111 (7), the output will be true only if none of the other variables is true.

In the first level the presence of none-of-three, one of three, two of three, and three of three true variables must be detected. Single gates will detect none of three (000) and three of three (111) patterns; multiplexers economically detect one of three and two of three patterns. Note that only one polarity of the Y variables is required.


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Analog divider simplifies ac ratio meter and yields ±0.2-dB measurement accuracy

An ac ratio meter simplifies frequency-response measurements by determining the output-to-input voltage ratio at any given frequency. The circuit shown measures the voltage ratio to within 0.2 dB and has a parts cost of hundreds of dollars instead of the thousands that commercial units cost.

The circuit consists basically of an analog divider and two peak detectors. The latter converts the ac voltages, \( V_1 \) and \( V_2 \), to proportional dc magnitudes at the input to the divider. A readout device such as a DPM, indicates the ratio \( V_2/V_1 \) from the output of the divider.

The simple op amp peak detectors shown work adequately at audio frequencies. An uncompensated op amp should be used and preferably should have wide bandwidth.

If capacitors \( C_1 \) and \( C_2 \) have large values, the op amps should be current-limited at their outputs, to prevent damage when the capacitors charges toward the peak input voltage.

With the components shown, the ratio meter exhibits a frequency response of ±0.2 dB from 20 Hz to 20 kHz, provided the inputs to the divider are near their full-scale value of 10 V. The dynamic range is 0 to -40 dB, ±0.2 dB, under the constraint that \( V_0 \approx 10 \) V, and that 10 V ≧ \( V_N \) ≧ 0.1 V.

The inputs \( V_o \) and \( V_N \) to the divider must be scaled so that \( V_o \) is more than 1 V. This limits the divider error to ±0.1 dB but restricts the dynamic range to -40 dB. Scaling amplifiers used before the peak detection will extend the dynamic range to ±60 dB.


CIRCLE NO. 312

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Analog sorting network ranks inputs by amplitude and allows selection

An analog circuit automatically selects the Mth largest signal in an arbitrary set of N analog inputs. The N analog inputs are ordered from lowest to highest value

\[ V_{1R} < V_{2R} < V_{3R} \cdots < V_{nR}; \]

and the Mth member of the sorted sequence is chosen. Thus,

\[ V_0(M) = V_M \]

where M is a variable parameter selected by the designer and R denotes sorting. In the special case, where, for example, \( N = 3 \) and \( M = 2 \), we have a mid-value selector. In another case where \( N \) is odd and \( M = (N + 1)/2 \), the \( V_0(M) \) represents the median input voltage.

An arbitrary number of voltages, \( N \), are connected to the noninverting inputs of N op amps (Fig. 1). Each amplifier output is connected to a
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single diode in a cluster of \( M \) diodes. The diodes then select the largest voltage from among the next \( M \) amplifier output, where \( 1 \leq M \leq N \).

A diode OR-gate circuit, with one input per cluster, causes unity gain feedback of the lowest cluster voltage, \( V_0 \), to the input amplifier inverting terminal bus. \( V_0 \) is the minimum of \( V_{J1} \) through \( V_{JN} \).

Circuit operation can be explained mathematically as follows: Assume (without loss of generality) that \( V_1 < V_2 < \cdots < V_N \). Let \( E_i \) and \( V_{Ji} \) denote the \( i \)th op-amp output and diode voltage respectively, for \( 1 \leq i \leq N \). Also let \( V_D \) be the forward drop of any single diode. Then, \( V_0 = \min (V_{J1}, V_{J2}, \cdots, V_{JN}) + V_D \). Also \( V_{Ji} \) is defined by the diode clusters \( V_{Ji} = \max (E_1, E_{i+1}, \cdots, E_n, E_{i+2}, \cdots) - V_D \), where \( M \) terms are included in the parenthesis. Since all of the op-amp inverting inputs are common, we have

\[
E_1 < E_2 < \cdots < E_N.
\]

Substituting into the above, we get,

\[
(V_{J1}, V_{J2}, \cdots, V_{(N-M+1)}, V_{JN}) = (E_M, E_{M+1}, \cdots, E_N, E_N) - V_D
\]

and so \( V_0 = E_M \) which implies that \( V_0 = V_M \) by virtue of the feedback.

The constant-current sinks (1N5305) are chosen to draw twice the current of the constant-current source (1N5297). This will cause equal currents through the two active diodes and thereby equalize the diode voltage drops. Resistors can be used instead of the diodes. But there will be a reduction of dynamic range and a loss of the exact diode forward-voltage cancellation.

Input voltages to almost \( \pm 15 \) V can be handled with reasonable accuracy. The circuit also features high input impedance, low output impedance and low input-to-output offset.

\[\text{Dennis R. Morgan, General Electric Co., Electronics Laboratory, Syracuse, N.Y. 13201.}\]

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8-bit d/a converter module settles to 0.4% within 15 ns

Computer Labs, 1109 S. Chapman St., Greensboro, N.C. 27403. (919) 292-6427. See text.

Computer Labs, known for high-performance analog-to-digital converters, has entered the low-cost, miniature converter field. The company's first entry in the low-cost arena is a modular line of 12 ultra-fast current-output d/a converters, with resolution of either eight or 10 bits. The MDS/815 is the fastest of the new units, with a settling time of only 15 ns to 0.4% of full scale (1 LSB). It costs $109 in unit quantities.

Two other eight-bit units are available, with settling times of 30 ns and 50 ns, respectively, to 0.4% of full scale. These are designated the 830 and the 850. Accuracy of the eight-bit units is adjustable to ±0.2% (1/2 LSB).

In addition three 10-bit converters are offered—the 1020, 1040 and 1080—with respective settling times of 20, 40 and 80 ns to 0.1% of full scale. Accuracy of the 10-bit units is adjustable to ±0.05%.

Any of the converters can be ordered as the MDS Series, with a temperature coefficient of ±30 ppm/°C, or—for an additional $20—as the MDP series, with a tempco of only ±15 ppm/°C. All units operate from −20 to +75 C.

With 15-ns settling time, the MDS/MDP 815 appears to be the fastest eight-bit modular d/a converter available today. One example of a competitive unit is Datel Systems DAC-HI Series, which comes in either eight or 10 bits, settles to ±0.1% of full scale in 25 ns and has a tempco of ±15 ppm/°C. The eight-bit DAC-HI costs $149. Another example is the Analog Devices MDA-10F, a 10-bit converter with a settling time of 40 ns to 1/2 LSB.

But it must be pointed out that most companies specify settling time to 1/2 LSB for a full-scale change in the input code—that is, all ONEs to all ZEROS or vice versa, Computer Labs, on the other hand, measures settling time for the major-carry input code transition, in which the MSB switches out of phase with all the other bits.

Correction accuracy is within 99.8%, bw is 10 MHz and slew rate is 40 V/µs in both horizontal and vertical axes. The plug-in module measures 3.5 × 2.5 × 0.87 inches.
Nonlinear low-pass filter exhibits zero phase shift

Response of the nonlinear filter to a 10-V, 800-µs noise pulse riding on a 3-V pk-pk, 200-Hz sinusoid (top trace). The output of the filter is shown at bottom. The center trace is the response of a single-pole, linear low-pass filter to the same input. The nonlinear filter has no phase shift, while the linear filter gives a 45-degree lag.

Non Linear Filters, P.O. Box 338, Trumball, Conn. 06611. (203) 268-6308. $100 (1-9); $70 (100s); 30 to 60 days.

Engineers working in digital communications, spectroscopy, voice communication and music reproduction are often plagued by phase-delay distortion and noise spikes. Impulse noise cancellation networks, phase-locked loops and other complex techniques are usually used to reduce such noise. Now, a fledgling company, Non Linear Filters, has come up with an encapsulated 2.56 × 2.56 × 0.8-in. module that appears to eliminate noise spikes more effectively than previous methods.

The device-designated the Model 1P—is an active, nonlinear low-pass filter that attenuates frequencies above its corner frequency. This in itself is obviously not earthshaking. What is different, however, is the fact that the device introduces virtually no phase shift either above or below the corner frequency. Thus spikes and other types of noise are reduced without phase-delay distortion.

The user selects corner frequency—up to 10 kHz—of the nonlinear filter by adding two nominally equal capacitors. The capacitor values in microfarads (C) are determined by division of the number 1.7 by the desired corner frequency in Hertz. The dV/dt of the input is then limited to 1.65/C—the maximum slew rate of the device. Also, three external resistors determine the transfer function.

The Model 1P requires a nominal supply voltage of ±15 V at 20 mA. Over the operating range of 0 to 70 C, the unit's input bias current is 3 nA, and input-to-output offset voltage is 750 mV maximum. The linear voltage region of the filter is confined to ±11 V for both input and output.

Input resistance, from dc to 100 kHz, is a minimum of 2.7 kΩ, while output resistance is 1 Ω max. Voltage gain of the device is nominally 1, but it can vary from 0.8 to 1.2. Both input and output are protected against short-circuits.

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INFORMATION RETRIEVAL NUMBER 53
Heat Generation and Temperature Control

That's right. Hot wire heating elements and bimetallic thermostats can be replaced with one simple solid state device. No exotic circuitry. No expensive transistors or SCR's. Few, if any, additional components.

Murata's Posistors provide both heat and temperature control for small appliance applications with heating requirements up to 100 watts. What's more, when higher heating capacities are required, Posistors may be utilized to provide smooth, stepless and extremely accurate temperature control.

Want to learn more? Write today for Murata's complete technical specifications.
Card printer/punch handles 96 columns

Model 9640 is a fully buffered printing punch with an optional card-reading capability. The standard unit features a 2000 card input hopper and three output stackers. It can punch or print 96-column cards at the rate of 120 to 240 cards/min., depending on the number of positions used. At the lowest speed, four rows of 32 positions each can be printed. A stacker overflow condition can be handled automatically or via programming, thereby eliminating the need to halt operations for card unloading. A field installable 1000 cards/min. read-before-punch option is also available. The additional cost is $850. OEM quantity discounts are available for the Model 940.

Buffer matches slow devices to fast channel

Models 7132 are a series of terminal buffers for mating printers such as TTYs with high-speed data links. The buffer units contain 4000-character memories and all the circuits and controls required for editing, automatic transmission, answer-back and control hand-shaking. Modules are available for memory capacity expansion.

The "Dip-Clip" is specially designed to allow the attachment of test probes to 14 or 16 lead DIPs. The unique patented design greatly reduces the possibility of accidental shorting while testing live circuits. Numerous test probes may be quickly connected for hands-free testing.
Stereo IC with all functions on chip, simplifies quadraphonic decoding


Matrix systems have been put on chips for the decoding of CBS SQ four-channel systems—Motorola’s MC1312 and MC1313 series. They are the first ICs to contain all the circuitry to drive the four channels, with their preamps and power amps, from two-channel program sources. And these devices conform to specifications for decoding quadraphonic records produced by some of the largest record companies.

Available in 14-pin TO-116 plastic packages, the new ICs consist of two preamps and two all-pass networks of the Wein bridge form. External resistors can be connected between pins 2 and 11 and 3 and 14 to permit blending the four-channel outputs for enhancement of center-front to center-back separation (see diagram).

The quadruphonic signal results from the matrixing of four channels into the two through a special encoder. The two matrixed channels, right total (RT) and left total (LT)—obtained after record is played on conventional stereo—are then processed through the decoder and the four original channels are recovered. The circuit consists of two preamps that receive LT and RT signals. The preamps each feed two all-pass networks to derive two pairs of quadrature signals. The four signals are matrixed to yield left front, left back, right front and right back (LF', LB', RF' and RB') output signals.

The resistive arms of the Wien bridge all-pass networks are realized in the IC, but the RC arms are formed by external components. The user can choose values for these components within certain constraints.

With the components shown, bandwidth of 100 Hz to 10 kHz is provided, together with a phase ripple of ±8.5%.

Four models are available: MC1312, MC1313, MC1312P and MC1313P. Harmonic distortion in the latter two is typically 0.1% and 0.25%, and they have average input impedances of 3 MΩ and 1.8 MΩ. Signal-handling capability is at least 2.0 V rms for the MC1312P and 0.8 V rms for the MC1313P. The MC1312 is designed for home-entertainment systems and for operation from 0 to 75°C with VEE = 20 V, while the MC1313 is designed for automotive use at VEE = 12 V and a temperature range of −40 to 85°C.

The only system similar to the CBS SQ is the Electro-Voice EV-4, which uses the EV8-7743 decoder chip. The latter is designed specifically for that system.

CIRCLE NO. 259


A set of pROMs enables an MCS-4 microcomputer prototype to assemble programs for itself. The four pROMs (AO-740, 741, 742 and 743) plug into the prototyping board (SIM4-01 or SIM4-02) and perform all the functions of a Fortran IV assembler, eliminating the need for a general-purpose computer. The pROMs translate symbolic assembly language into bit patterns suitable for entry into the microcomputer's control ROMs. The assembler accepts input source text from a teletypewriter on each of two required passes.
VECTROL

“CUBE-PAC”
a new
dimension in
SCR POWER CONTROLLERS

offers low cost
high performance

Keep pace with the needs of today’s modern control systems. The unique CUBE-PAC VPAC 500 Series Power Controller, with options, allows the user to custom tailor the VPAC 500 to meet specific requirements at a significantly lower cost than competitive units without options. Measuring only 9” x 6¾” x 5”, this compact unit provides: phase control – 0 to 100% output • SCR protection • clipping network and hard firing gate pulse • soft start • single phase and three phase, 30 thru 80 amps • back-to-back SCR output. Options include: current limiting • voltage/current regulation • manual, current, offset and gain adjustments. Request Bulletin 3105.

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0007 Clock Driver
0009 Dual Clock Driver
0032 FET Operational Amplifier
0033 High Speed Buffer
0034 Level Shifter

Coming in 1973:
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For prices and data sheets on these and other high-quality thin-film microcircuits and resistor networks, please write or call collect: Yutaka Tonai
there's no such thing as "custom standard" but we come close.

ICs & SEMICONDUCTORS

Op amp upgrades LM118

Advanced Micro Devices Inc., 901 Thompson Pl., Sunnyvale, Calif. 94086. (408) 732-2400. $19.95 to $22.95 (100 parts).

The Am118, a high slew rate, internally compensated op amp, offers the highest stability rating in the industry, according to the company. The Am118, which is pin compatible with the like-numbered circuit from National Semiconductor, has a phase margin of 35° and less than 2 dB of peaking at unity closed-loop gain. Other features (all typical) include slew rate of 70 V/µs, input offset voltage of 2 mV, input bias current of 120 nA and offset current of 6 nA. The device has a 15 MHz small signal bandwidth and operates over ±5 to ±20-V range.

CIRCLE NO. 261

Dual voltage translator replaces DM7800

Texas Instruments Inc., P.O. Box 5012, M/S 308, Dallas, Tex. 75222. (214) 238-3741. SN75180: $2.40 (100 parts); stock.

A dual voltage translator, designated the SN55/75180, is a second source IC to the DM7800/DM8800. This device can interface from standard TTL or DTL voltage levels to those levels associated with high impedance junctions or MOSFET-type devices. The SN55 version (for −55 to +125 C temperature applications) replaces the DM7800 while the SN75 version (for industrial temperature range applications) replaces the DM8800.

CIRCLE NO. 262

Schottky TTL clock comes in DIP

Vectron Laboratories, Inc., 121 Water St., Norwalk, Conn. 06854. (203) 853-4433. 4-6 wks.

The CO-238 crystal oscillator, available in a 14-pin DIP, can drive Schottky TTL circuits at frequencies to 100 MHz. It operates from 5 V dc and drives 10 TTL loads. The standard CO-238 provides stability of ±0.0025% over 0-70 C. Options include the MIL range CO-238-2 with stability of ±0.005% over the −55 to +125 C and the high stability CO-238-3 with stability of ±0.0003% over 0-50 C.

CIRCLE NO. 263

Radio circuit arrives on a chip


The ZN414, a ten-transistor circuit fabricated with Collector Diffusion Isolation techniques, provides the basis for a complete AM radio circuit. It operates from 1.1 to 1.8 V and requires only battery, earphones and antenna plus a tuning capacitor and two decoupling capacitors to form a radio. Other features include output of typically 30 mV rms, current of 1 mA and harmonic distortion of ≤1%. The ZN414 operates over the temperature range of 0 to 70 C and is available in a 3-pin TO-18 package.

CIRCLE NO. 264

ELECTRICAL ENCLOSURES

Hoffman

FREE-STANDING

NEMA 12 single door; single door, dual-access; two-door, dual-access. Versatile mounting panel and relay rack angle arrangements. EMI/RFI shielding optional.

CONSOLES, CONSOLETS

Nearly 2 dozen models with a large variety of accessories. Sturdy 14 gauge steel construction. All-welded seams, gasketed doors, oil tight. NEMA 12. EMI/RFI shielding optional.

INSTRUMENT ENCLOSURES

Oil-tight. 12 standard sizes, 6 x 6 x 4 to 14 x 12 x 6. 14 gauge steel, continuously welded seams. No holes or knockouts. Gasketed covers. Optional interior mounting panels.

Your needs for instrument enclosures vary widely and delivery is important. That's why there are Hoffman distributors strategically located throughout the U.S.A. Offering precision-built enclosures of all different sizes and shapes. With factory backup on all catalog items. NEMA 12 and JIC type electrical/electronic enclosures, including pushbutton boxes and wireway. We also do custom fabrication. Write for catalog and name of nearest distributor.

Hoffman

ELECTRICAL ENCLOSURES

Hoffman Engineering Company
Division of Federal Cartridge Corporation
Anoka, Minnesota Dept. ED 212

INFORMATION RETRIEVAL NUMBER 60

Electronic Design 2, January 18, 1973

84
ECL 1024-bit memory uses isoplanar process

Fairchild Camera and Instrument Corp., Semiconductor Components Group, 464 Ellis St., Mountain View, Calif. 94040. (415) 962-3816. $100 (25-99); 6-8 wks. (large qty.).

An ECL 1024-bit RAM—the industry's first, according to the manufacturer—is fabricated with Fairchild's Isoplanar process. Designated the 95415, it features a 45-ns access time and is packaged in a standard 16-pin ceramic dual-in-line package. It has power dissipation of 0.5 mW/bit and an uncommitted collector output for simple memory expansion.

CIRCLE NO. 265

Low-cost op amp settles in guaranteed 1 µs

Teledyne Philbrick, Allied Dr. at Route 128, Dedham, Mass. 02026. (617) 329-1600. P: See text; stock.

A guaranteed settling time of 1 µs to 0.01% at a price of $7.50 (100 up) are the key features of the Model 1324, a monolithic IC op amp fabricated with standard triple-diffused processing techniques. Other features of the 1324 include excellent bandwidth and slew rate (10 MHz and 35 V/µs, respectively), freedom from latch up and TO-100 packaging with 715-compatible pin-out.

CIRCLE NO. 266

Silicon-on-sapphire kit for advance designs


Designers can now build their own integrated circuits using silicon-on-sapphire (SOS) technology with a “do-it-yourself” kit. Called an Instant SOS Kit, the package includes a set of photomasks, instructions and sufficient p-type and n-type SOS wafers for building p-channel, n-channel, deep-depletion and complementary circuits. And these can be built right on present solid-state production lines, according to the manufacturer.

CIRCLE NO. 267
Plug-ons extend versatility of DMM measuring system

Hewlett-Packard has expanded the capabilities of its snap-on DMM measuring system with three new additions: the 34750A, a 5-1/2-digit mainframe display; the 34703A multifunction module, and the 34722A preamp/ammeter module.

The line now includes six possible instrument combinations, each made up of a top display module and a bottom function module. Any of the six combinations can be converted to portable operation by the addition of a center battery-pack module. Or a BCD output package can be added as a center module to provide printout information.

Except for the additional digit, the 34750A LED display is similar to its 4-1/2-digit predecessor. The second new module—the 34703A multifunction snap-on—can be used with either the 4-1/2 or 5-1/2-digit display, as can its older counterparts, the dc voltmeter and multimeter plug-ons.

The 34703A snap-on measures resistance (four-wire measurement), dc voltage and dc current. Six voltage ranges from 10 mV to 1000 V are provided, as well as six current ranges from 1 µA to 100 mA and eight resistance ranges from 1 Ω to 10 MΩ. Full autoranging of the functions is provided, or the user can step through ranges merely by pushing a button. In most cases autoranging is completed within 250 µs. And if the user manually selects an improper range, the unit flashes the correct range annunciator LED.

In addition the 34703A can troubleshoot itself. When the user flips the function switch to the test position, the ROM-based logic controller interrogates its own circuitry for proper operation.

Specifications of the unit include an input resistance of 10 MΩ on dc volts; 10 kΩ on the 1-µA range, decreasing to 1 Ω on the 100-mA range; 100% overrange, except for 20% overrange on the 1000-V range; and 120-dB CMR on dc volts. Accuracy holds for 30 days at 23 C and depends on both the range setting and the particular display used.

Some representative accuracy figures are: ±0.04% of reading ±0.01% of range for the 10-V through 1000-V ranges and with a 4-1/2-digit display; ±0.25% of reading ±0.025% of range for 10-mA and 100-mA ranges and for the 5-1/2-digit display; and ±0.04% of reading ±0.01% of range for 10 Ω through 1 MΩ and for the 4-1/2-digit display.

The third new module, the 34722A preamp/ammeter, goes in the center of the assembled instrument, and it can increase the sensitivity of the older voltmeter and multimeter plug-ons and provide current-reading capability. Its preliminary specs include a preamp gain of 10 for ac and dc volts and current ranges (ac and dc) from 100 µA to 1 A. The full-scale insertion loss is 100 mV.

The 34750A display and the 34703A V/I/meter cost $550 each, with first deliveries scheduled for March. The 34722A has not been priced yet and will be available at a later date.

Spectrum analyzer has variable persistence

Systron Donner Corp., Microwave Div., 14844 Oxnard St., Van Nuys, Calif. 91409. (813) 786-1760. $2600; 60 days ARO.

A spectrum analyzer mainframe with a variable persistence CRT display is now available from the Microwave Div. of Systron Donner Corp. The S/D Model 711 variable persistence display unit offers a persistence range of 300 ms to 100 s. In addition, the Model 711 can store an image for up to six hours, or be used in a conventional, nonstore mode. The unit uses plug-in tuning modules covering the audio, video and baseband frequency ranges.
Best buy power module for op amps

± 15 V (tracking) @ 400 ma...$85

Line/load regulation of ±0.1% and ripple of ±1.5 mv. 3.4"H x 5.1"W x 5.1"D. Order Model TD 15-40. For 1.0 amp outputs, specify TD 15-100. Price $125. Other great buys are available to power balanced loads drawing from 25 ma to 8.5 amps. Three day shipment guaranteed. Five year warranty.

Acopian Corp., Easton, Pa. 18042
Telephone: (215) 258-5441

INFORMATION RETRIEVAL NUMBER 63

When we talk about reliability, we put our money where our mouth is.

With a full one-year warranty!

At first glance, our Model 36 looks about the same as most other 3½-digit DPMs (it even fits in the same panel cutout as the AN2532). But that's where the similarity ends:

RELIABILITY: In plain language, ours works better and keeps on working longer than theirs. To back up this promise, our Model 36 comes with something you don't get with theirs: a full service, one year warranty covering parts and labor!

PRICE: Our Model 36 sells for less than $100 in 100-piece quantities, and gives you a lot more for your money.

PERFORMANCE: Ours outperforms theirs. Check our Model 36 specs and features: 0.05% accuracy, 50 ppm/°C stability, 7-segment Sperry non-blinking planar display. Small size, 2.0"H x 3.5"W x 2.8"D. Lower power drain, less than 3.5 watts. Ultra-high input impedance, >1000 megohms. Standard models include autopolarity, automatic blanking and programmable decimal point at no extra cost.

DELIVERY: Ours can be delivered to meet your production schedules. Why wait for theirs?

WANT MORE REASONS TO BUY OURS? That's easy—just drop us a line or give us a call.

New NL-8051 from NATIONAL ELECTRONICS

- Segmented Phosphor Display
- Low Cost
- Low Power
- Direct Drive from MOS

INFORMATION RETRIEVAL NUMBER 64
MORE!

new

V-PAC* POWER SOURCES for

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Now, use standard +5v source to power your linear IC's. Simplify design, reduce system volume, eliminate extra power supplies, reduce manufacturing costs, with V-PAC power sources.

Operate from 7 to as many as 35 of these types from a single V-PAC source: 709, 741, 710, 711, 720.

Less than a third cubic inch, standard DIP pin configuration, V-PAC sources can be mounted on half-inch center cards with other components.

<table>
<thead>
<tr>
<th>TYPE:</th>
<th>VA 12-12</th>
<th>VA 15-15</th>
<th>VA 12-6</th>
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<td>+15 -15</td>
<td>+12 -6</td>
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Write or call for full specifications.

WEST: 213-843-5200 513-761-5432
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505-298-1875 803-288-4450
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206-747-9424 305-941-5544

EAST: 5325 Glenmont, Houston, Texas
77036 • 713-666-3261
Europe and the Far East: TISCO (TI Supply Co.)
TWX: 910-881-1739 • TM, Reliability, Inc.

CIRCLE NO. 270

application notes

Counter/display

The MK 5002 P MOS four-digit counter decoder is described in an eight-page application note. The note contains information on using the unit, display interfacing, cascading the 5002 (eight-digit application) and annunciator applications. Mostek Corp., Carrollton, Tex.

CIRCLE NO. 270

Stepping motors

A 60-page Stepping Motor Handbook describes types of stepping motors and their characteristics, drive circuits, use of power amplifiers, heating considerations, operating modes and typical applications. Sigma Instruments Inc., Braintree, Mass.

CIRCLE NO. 271

Polarimeter, saccharimeter

Technical Bulletin 371 describes the general applications, features, accessories and operating principles of laboratory, precision and high-precision polarimeters and saccharimeters. The generation of a half-shade using polarizing and Lippich prisms is described. Rudolph Research, Fairfield, N.J.

CIRCLE NO. 272

Lead

"Lead . . . As A Modern Design Material" describes properties, forms and design applications of lead. The uses of lead for soldering and ceramics are also discussed as are lead's lubricating qualities and its solid-state properties. The eight-page booklet includes a listing of the forms in which lead is available. The booklet concludes with a listing of the physical, thermal, low-temperature, electrical and mechanical properties of lead. Lead Industries Association, Inc., New York, N.Y.

CIRCLE NO. 273

C-V plotting

An illustrated, 10-page technical note, TN-102, discusses the advantages of the lock-in amplifier technique in C-V and related semiconductor measurement analyses. The note includes three sets of curves illustrating typical C-V and capacitance derivative plots made with the lock-in technique and a set of block diagrams illustrating typical measurement setups. Princeton Applied Research Corp., Princeton, N.J.

CIRCLE NO. 274

CMOS ICs


CIRCLE NO. 275

Laser trimming

"Functional Trimming: Discussion of a Problem, Description of a Solution" by Daniel Abenaim details the laser's contribution to the coming-of-age of functional trimming, wherein circuit-component values are adjusted for optimum total-circuit performance rather than to individual prescribed values.

The paper describes the advantages of functional trimming, compares the laser with other trimming methods and illustrates one functional laser trim system. General Radio, Concord, Mass.

CIRCLE NO. 276

IR optical materials

"Kodak IRTRAN Infrared Optical Materials," a 52-page book, describes the selection, application and production of these materials. It also explains uses at discrete wavelengths in the infrared portion of the spectrum. In addition to photographs, diagrams and tables, the book also contains a comprehensive section of transmittance curves, a bibliography and a computation worksheet. Eastman Kodak Co., Kodak Apparatus Div., Rochester, N.Y.

CIRCLE NO. 277

ELECTRONIC DESIGN 2, January 18, 1973
**Solderless wrap terminals**

Nurl-Loc Wire-Wrap Terminals, used in packaging panels for integrated circuits, feature a knurled cylinder which permits material flow for a better bond, increasing torque resistance and preventing twisting during the wrapping operation. Electronic Molding Corp.

**Terminal clamps**

A tipping-type terminal clamp consists of only two pieces—the screw and a coined clamp plate—and provides virtually identical load on two different size wires. Called Teeter Terminal, it comes in the following sizes: 4-40 × 9/32-in., 6-32 × 5/16-in. and 10-32 × 3/8-in. A fourth size will be added soon. Elco Industries, Inc.

**Solder pads**

Tin-plated and flux-coated donut pads offer solderability for PC board construction or repair applications. The pads are etched copper on 2.5-mil epoxy glass film backed with a pressure sensitive adhesive and quickly laminate to any circuit board. They are available in five sizes from 0.062 × 0.025 in. up to 0.250 × 0.040 in. and each size is packaged in precisely spaced multiple rows. Circuit-Stik.

**Test panel**

Mounted in a test panel are samples of nylon Heyco hole plugs, snap bushings, universal bushings, strain relief bushings, miniature bushings, open/closed bushings, terminal bushings and snub bushings. Data relative to sizes available and typical applications are included. Heyman Manufacturing Co.

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**NEW POCKET-SIZE LAB POWER SUPPLIES**

**PRECISE, PRESET VOLTAGE SOURCES START AT**

$39.00

<table>
<thead>
<tr>
<th>3-WIRE AC LINE</th>
<th>CORD</th>
<th>INPUT ISOLATION</th>
<th>50 Meg</th>
<th>MINIATURE SIZE</th>
<th>2.5&quot; W × 4.5&quot; L</th>
<th>1.25&quot; H</th>
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<th>Protected Indefinitely</th>
<th>ON-OFF TOGGLE SWITCH</th>
<th>6-Amp Cap.</th>
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**SINGLE OUTPUT**

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**DUAL OUTPUT**

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<td>D152</td>
<td>±15.0</td>
<td>200 mA</td>
<td>$69</td>
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**REON VARIABLE RESISTORS MEET OR EXCEED MIL-R-94 SPECS**

- 1/2" Conductive Plastic RV6 TYPE Variable Resistors
- SINGLE UNIT HOUSING Construction Provides Humidity Seal at NO EXTRA COST!
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- UNIQUE PERIMETER COOLING arrangement permits 3 WATT commercial rating without INCREASE IN SIZE!
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These low cost commercial variable resistors are QC checked to MIL specs (noise, temp cycling, etc.)

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INFORMATION RETRIEVAL NUMBER 69
Data conversion

A fold-out data-conversion short-form catalog features a line of data converters. Analog-to-digital and digital-to-analog converter specifications are arranged for quick selection by key parameters. Also included in the two-color brochure are accessory modules. Teledyne Philbrick, Dedham, Mass.

CIRCLE NO. 320

Status indicator

LED and resistor construction have been integrated in a solid state status indicator which is described in a data sheet. The indicator is designed in a mini-DIP size flat pack for PC board mounting and is compatible with DTL or TTL logic. Eldema Div., Genisco Technology Corp., Compton, Calif.

CIRCLE NO. 321

Instrument rentals

A catalog features an expanded line of instruments offered on a rental basis from General Electric. The catalog lists the nationwide network of rental agencies and inventory centers. Related services performed include measurement consulting services, environmental quality testing and instrument repair and calibration. GE, Schenectady, N.Y.

CIRCLE NO. 322

Precision resistors

Technical Bulletin R-700 describes V and M series of low-cost precision resistors that are direct replacements for wirewounds. The bulletin shows in detail the design and construction of the radial lead (V series) and axial lead (M series) configurations. Drawings are used to show how the V-53 series can occupy approximately 1/8 the board space of its wirewound equivalent. Data and performance specifications are presented. Vishay Resistor Products, a Div. of Vishay Intertechnology, Inc., Malvern, Pa.

CIRCLE NO. 323

Push-button switches

A full-color, 12-page catalog with an accompanying color-coordinating kit describes and illustrates push-button rotary switches. The switches come in green, red, yellow, blue, white and grey. Janco Corp., Burbank, Calif.

CIRCLE NO. 324

Impulse generators

Two data sheets describe three impulse generators. Singer Instrumentation, Los Angeles, Calif.

CIRCLE NO. 325

Component recorders

The Flying Spot component recorders, for producing pattern, plot or picture records, are described in a 16-page catalog. The catalog contains specification information. Featured applications contained include frequency-spectrum analysis. Recordings of "whistlers" i.e. low radio-frequency enaminations from lighting and other electromagnetic phenomena of interest in communications studies are clearly illustrated along with recordings of ionospheric back scatter made during long range communications studies by radar in real time. Alden Electronic & Impulse Recording Equipment Co., Inc., Westboro, Mass.

CIRCLE NO. 326

Modular terminal blocks

A complete line of modular terminal blocks, terminal strips and specialty items is described in a 12-page, quick-reference catalog. Drawings and photos illustrate the features and design of these products. Product categories are: control and power circuit terminal blocks, high-capacity terminal blocks; test terminals; fuse terminals; compensating terminals; slide-on connection terminals; ground terminals; micro terminals and a complete line of terminal strips. Applications, material specifications, ratings, accommodating wire sizes, mounting dimensions and physical dimensions are also included. Electrovert Inc., Mount Vernon, N.Y.

CIRCLE NO. 327

Precision decade capacitor


CIRCLE NO. 328

Line printer

Features of the Model 200 line printer are described in a six-page brochure. Included are detailed specifications on font sets and codes; the use of the multifont buffer and font belt to provide increased speed, interface information and forms handling capabilities. Iomec, Inc., Digitronics Div., Southboro, Mass.

CIRCLE NO. 329

Vacuum equipment

A catalog of vacuum equipment includes data sheets and prices on all current products. The catalog presents vacuum pumps, hardware, systems and accessories. In convenient loose-leaf form, the catalog documents equipment for high vacuum and ultra-high vacuum work. Other products described are processing equipment for semiconductor manufacturers, evaporation and sputtering equipment, leak detectors, gas analyzers, Marshall furnaces and surface analysis instruments as well as vacuum flanges, valves and gauges. Varian Vacuum Div., Palo Alto, Calif.

CIRCLE NO. 330
Prototypes of precision snap-action thermostats from Elmwood, widely specified for quick, reliable response; proven industrial and military performance record. Environ. expos. –65° to 550°F; narrow or wide diff.; rated to 15 amps. Elmwood Sensors, Inc. (401) 781-6500. TWX 710-381-6413.

**INFORMATION RETRIEVAL NUMBER 182**

Dietzgen's new 12-digit electronic slide rule does even more than your slide rule. All trig. and exponential functions—including hyperbolics and natural log—with a single function key. Converts degrees, minutes, seconds to decimal; degrees to radians or vice versa. Dietzgen Corp., 2425 N. Sheffield, Chicago, 60614. (312) 549-3300.

**INFORMATION RETRIEVAL NUMBER 185**

Thin-Trim® variable capacitors are designed to replace fixed tuning techniques. Applications include crystal oscillators, CATV amplifiers, communication and test equipment. Series 9410 has high Q's with five capacitance ranges from 1.0 - 4.5 pf to 10.0 - 50.0 pf. Johnson Manufacturing Corporation, Boonton, N. J. (201) 334-2676

**INFORMATION RETRIEVAL NUMBER 183**

400 Ideas for Design, Vol. 2, Edited by Frank Egan. Ready to borrow, modify, or adapt, the top recent contributions to Electronic Design's popular "Ideas for Design" column range from amplifiers to switching circuits. 288 pp., illus., cloth, $11.95. Circle below for 15-day examination copies. Hayden Book Co., New York, N.Y. 10011.

**INFORMATION RETRIEVAL NUMBER 186**

Unique dip switches. Positive BREAK BEFORE MAKE slider action. Self cleaning contacts. Wide variety of styles stocked all with standard 16 lead configuration. For low cost communication, computer, machine tool programming, etc. Technical Lit. ACI, 8 Ave., Conshohocken, Pa. 19428. (215)-828-6240.

**INFORMATION RETRIEVAL NUMBER 188**

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Practical Relay Circuits, by Frank J. Oliver. Time-saving guide classifies relays by function, presenting a rapid overview of the circuits that can solve the problem at hand. 384 pp., illus., cloth, $14.95. Circle below for 15-day examination copies. Hayden Book Co., New York, N.Y. 10011.

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CIRCLE NO. 331

Stereoscopic television

A four-page illustrated technical paper surveys various three-dimensional television systems and describes the company's system which optically converts normally flat closed-circuit television to 3D. Stereotronics Television Co., Sherman Oaks, Calif.

CIRCLE NO. 332

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A Terminal Specifying Aid, a four-page brochure, is designed as an aid in determining the physical and functional characteristics for the company's tailor-made CRT terminals. Approximately 200 characteristics are listed under the headings of general, display, character codes, cursor, keyboard layout, editing functions, tabulator format, communications functions and peripherals. The aid includes diagrams of three sample keyboard layouts plus a blank master diagram for the customer to use in specifying his requirements. SYS Computer Corp., Hackensack, N.J.

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Electronic Design 2, January 18, 1973

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A Varian Subsidiary
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92112
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TWX 910335-1527

Information Retrieval Number 75

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Best of all, it’s available in quantity right now in the following configurations:

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*These three types are also available in formed-lead TO-5 for dual-in-line socket configuration, as CA3094S, CA3094AS, and CA3094BS.

Interested? Let us send you a Data Sheet and Application Note (ICAN-6048). Write: RCA Solid State, Section, 57A 18 Box 3200 Somerville, N.J. Phone: (201) 722-3200

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